

Toxicology Knowledge and Information: the Impact of New Information and Communication Technologies

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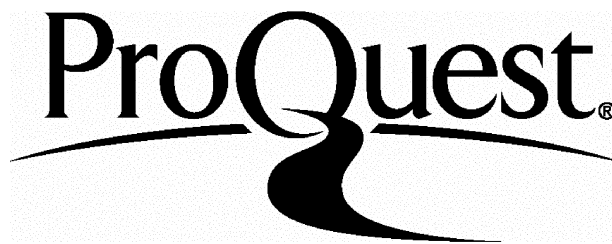
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Abstract

This thesis examines the communication of scientific knowledge. Specifically, it considers the effect of new information and communication technologies (ICTs) on this process. It focuses on the discipline of toxicology, although the findings should be applicable to related subject areas.

Toxicology was chosen because it is a rapidly developing, multifaceted subject area, with a rich history of information resources.

New ICTs are defined as those computer and telecommunication technologies which have permeated our society from around 1980 onwards.

The aim is to define toxicology information at the turn of the millennium, and to predict how its communication processes will progress over the next 5 - 10 years. This is achieved by examining facets of the discipline, and by researching the changes which have occurred from the inception of the subject, to the present day. Emphasis is on those changes taking place over the past 20 years, as these parallel the contemporary phenomenon of rapid technological advancement in western society.

No analysis of this kind has previously been undertaken for toxicology information. The methodology also presents a novel, composite, mechanism for the study and understanding of communication within a discipline.

Specific outcomes:

- A systematic way to identify toxicology resources is defined
- A model for toxicology communication in 2002, is derived
- Toxicology is found to have changed from being a sub-discipline, to a field in its own right, which exports ideas in addition to importing them
- Ways of overcoming deficiencies in retrieval from existing information systems and services are suggested
- The effectiveness of available tools for organising and describing toxicology information is assessed, and a three layer model for representation of a toxicology statement is proposed
- An understanding of the impact of new ICTs on toxicology communication is gained, which gives insight into possible changes in the near future

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Chapter One: An Approach to Scientific Communication

1.1 Introduction

This thesis considers the influence of new information and communication technologies (ICTs) on the information and communication systems of the scientific discipline of toxicology.

It is a study of scientific communication; specifically, a study carried out from the perspective of library and information science (LIS), as will be discussed below. It is not a study of the science of toxicology *per se*, nor of toxicological knowledge for its own sake; nor is it a study focusing on technical aspects, nor on specific systems.

Its primary purpose is threefold:

- to provide an understanding of information and communication in one particular scientific discipline at the turn of the millennium
- to provide insights into the influence of new ICTs on the communication processes within toxicology
- to provide a methodology for understanding the communication processes within any discipline from an LIS perspective

This leads to three principal research questions:

- what is the nature, qualitative and quantitative, of toxicology information and knowledge, and of the information systems which support its communication?
- what is the influence of new ICTs on these systems?
- can a method be suggested for determining these factors, which would also be applicable to other disciplines ?

In the process of answering these questions, it may be possible to provide some practical guidance for LIS specialists, particularly within toxicology, on issues such as useful resources, and searching strategies; but these are not the primary focus of the study.

Toxicology was chosen as the discipline to be studied for four main reasons:

- the author of this thesis was familiar with the subject, and its information resources
- it is an 'information rich' subject, due to its scientific, practical, legal and moral importance, with a diverse range of information resources and ICT applications
- it is a subject for which resource listings, discussions of information provision and evaluations of information resources, etc. already exist, allowing the possibility of comparisons to check the validity of the results obtained, and to assess changes over time
- it overlaps with other disciplines, e.g. medicine, pharmacology, environmental science, yet is a coherent subject in its own right

1.2 Scientific Communication

The communication processes within science have been studied, both generally and for specific topics or disciplines, by numerous researchers. This extensive body of work will not be described here: see, for example, Meadows (1974, 1998) and Vickery (1999) for overviews, Garvey (1979), Line (1998), Meadows (1996), Meadows and Buckle (1992), Rolinson, Al-Shanbari and Meadows (1996), Royal Society (1993), and Tenopir and King (2000) for more specific studies, and Hurd (2000) for a view of future possibilities. Other relevant studies are noted at appropriate points in this thesis.

Two particular issues should be clarified.

One is what should be included in the definition of 'science'; and how far back in time concepts and resources should be regarded as 'scientific', and hence appropriate for inclusion in a study of scientific communication. If toxicology is regarded as the systematic study of poisons, which is its usual definition, then it has a very long history; far pre-dating the beginnings of what is usually regarded as modern science in the seventeenth century. In this thesis, the whole of this long history is regarded as worthy of consideration for the light it sheds on the development of toxicology as a science; although, obviously, most attention will be given to more recent times.

The second is what counts as 'information'. It is conventional to make a distinction between 'informal' and 'formal' information, or communication. Formal information is regarded here as all communications which are recorded, and therefore capable of being transmitted, stored and retrieved. Informal information is that information which is known by a person or persons, but which is not recorded: 'personal contacts, special interest groups, seminars, conferences, and related activities' (Meadows and Buckle 1992, p 280). This study focuses on formal information, although informal activities of the kind noted above are increasingly becoming accessible, and hence 'formalised', through the medium of the World Wide Web. In general, ICTs are tending to blur and change the boundaries between formal and informal information (Meadows 1998), as will be seen later in this thesis in the case of toxicology.

No rigid distinction will be made between 'information' and 'knowledge', but 'information' will be regarded as embodied in specific records and documents, reserving the term 'knowledge' for the conceptual basis of the discipline.

1.3 Information and Communication Technologies

There seems little need to justify a focus on the effect of new ICTs. Studies of scientific communication generally emphasise the point that 'the impact of information technology on scientific communication [is] indeed one of the most important ... automated information-handling is affecting scientists' work, both in their contacts with each other and in their use of information facilities' (Meadows and Buckle, 1992, p 289).

But what should be counted as ICTs is a moot point; still more what should be counted as 'new' ICTs. In their time, writing instruments, the printing press, the punched card tabulator, and the digital computer may all have reasonably been regarded as 'new ICTs', leading to the idea of a series of 'information revolutions', each powered by the development of one or more new technologies (see, for example, Bawden and Robinson 2000).

For the purposes of this thesis, 'new ICTs' are regarded as those stemming from the integration of the information processing power of the personal computer with the communications capabilities of networks, especially the Internet. This choice was made on the basis that it is these technologies, rather than those which are either old-established or still in the development stage, which appear to be having the greatest effect on scientific and scholarly communication, and whose influence deserves investigation.

This provides an interesting perspective. Given that the bulk of the work reported in this thesis was carried out, or earlier findings re-checked, during 2001, it reports the situation on the 10th, 20th and 30th anniversaries of significant developments:

- 30 the first email messages were sent over the US ARPANET network, the forerunner of the Internet, in autumn 1971 (Hafner and Lyon 1996)
- 20 the IBM PC was first supplied in autumn 1981 (Palfreman and Swade 1991)
- 10 the World Wide Web was released for public use in summer 1991 (Berners-Lee 1999)

On this basis, the studies reported in this thesis take a 20 to 25 year time frame as a basis for comparison of the effects of these technologies over time.

1.4 The LIS perspective

The study of a scientific discipline and its information resources and communication patterns are closely connected; information and communication processes are dictated in large measure by the nature of the discipline, which is itself defined by its knowledge base, and associated information processes and products. Specific examples of this general principle will be seen, for the case of toxicology, later in this thesis.

Most studies of scientific disciplines appear to have taken one of two forms. There is the 'insider' approach, in which an expert in the field reflects on its nature and development, focusing on the concepts of the subject and its increasing knowledge base; examples of this will be seen later in this thesis for the sub-disciplines of toxicology. Then there is the 'sociological' approach, in which the development of the subject is examined as a social phenomenon; this involves the usual social research methods of interviews, questionnaires and so on, augmented more recently by bibliometric and scientometric analyses. For examples of these kinds of disciplinary study, see Garvey (1979), Borgman (1990) and Becher and Trowler (2001).

Both of these approaches take note of information and communication processes, but do not focus on them. The approach of this thesis is somewhat different. Taking an LIS perspective, it analyses toxicology primarily in terms of its recorded information products and systems, examined in a number of ways. Some aspects of the other general methods are included; some bibliometric analyses are carried out, and the published views of experts are evaluated and compared. But there is no attempt, to interview a sample of toxicologists about their use of new ICTs; instead usage is assessed by an examination of information products; the number of toxicological web sites, for example, and the extent to which these cited in the journal literature.

It also focuses closely on ICTs for the communication of information. As Meadows (1996) points out, IT affects both the process of research itself, and the process of communicating research; although some relevant aspects of the former are mentioned, it is the latter which is the primary interest here.

This approach should yield information complementary to that which may be found from the others. It is not entirely novel, in that many studies have looked at particular aspects of scientific communication in particular disciplines: citation rates and half-

lives, terminology, nature of article titles, principal information resources, core journal lists, and so on. But the examination of a variety of such aspects in conjunction, to build up a picture of a discipline from an LIS perspective appears to be novel.

1.5 Components of this thesis

To gain valid insight to a discipline, and to understand how its communication patterns are being changed by new ICTs, from a LIS perspective, a multi-faceted approach must be taken, since no single aspect could provide a whole picture.

Initially, the nature of toxicology as a science, its historical development, and that of its information services, are reviewed. This allows an understanding of what toxicology is, and what it does. Further insight can be gained from the consideration that a discipline comprises its information and communication systems. Thus, a detailed examination is made of current information resources for toxicology. From this, a model of contemporary communication can be derived, and the impact of new ICTs can be assessed. The resulting, primarily qualitative viewpoint, is then enhanced by a series of bibliometric analyses, which offer some quantitative measures. To be more specific, an analysis of the many evaluations of toxicology information resources and services which have been performed in the past leads to a detailed comparative evaluation of the performance of current state-of-the-art resources. The nature of toxicology knowledge, as seen through the variety of knowledge organisation tools available is then examined. Insight into how toxicology information systems can be improved is obtained.

Finally, the findings of these analyses are drawn together, to describe toxicology information in the year 2002, and to give an overall assessment of the impact of new ICTs on communication within the discipline. A new model of the scientific communication of toxicology at the beginning of the third millennium is derived; with the proviso that for a changing information environment 'making generalisations about current trends [is] an uncertain process' (Meadows and Buckle 1992, p 289).

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Chapter Two: Toxicology as a Discipline

2.1 Introduction

This chapter considers the nature of toxicology itself, and the consequences of this nature for its information and communication systems; as Wexler (1990) points out, understanding the 'information framework' of a field of science can offer an insight into the organisation and activities of the field itself. The reverse is also certainly true; the nature of the field determines the kind of information and communication 'support services' which are required. The material in this chapter deals with the synergy between these two factors. It is based partly on an analysis of the published literature, and partly on empirical data generated as part of this study.

The chapter is divided into three main sections, dealing with toxicology, toxicologists, and the information 'support systems' of the discipline respectively.

2.2 Toxicology

2.2.1 Definitions

The term 'toxicology' is derived from the Greek τοξικός (toxikos), the adjective of τοξον (bow). The link is the term τοξίκου (toxikon) a term originally used by the Greek historian Herodotus to mean 'poisoned arrow', (Niesink, de Vries and Hollinger 1996B, p i), though it later took the more general meaning of 'poison'.

The usual non-specialist definition is simply that toxicology is 'the science of poisons', as given, for example, by Chambers English Dictionary (1993) where poison is defined as 'any substance which, taken into the body, destroys life or impairs health'.

Although toxicology is almost invariably concerned with the effects of chemical substances, the term is sometimes used for the harmful effects of other agents, e.g. radiation toxicology, referring to harm caused to mammals, including humans, by ionising radiations (Adams and Wilson 1993); though such radiations are, of course, produced by particular chemical substances.

Information on the web site from the University of Western Ontario, department of pharmacology and toxicology, suggests that there are two classes of agents that toxicologists study:

- Chemical agents (synthetic or naturally-occurring) that include 64,000 compounds used in commerce (5,000 million tons per year or more); 5,000 food additives; 4,000 medicinal drugs; 1,200 household products (at least!); substances produced by bacteria, fungi, molds, spores, plants and animals and approximately 700 new chemicals that are identified or introduced each year.
- Physical agents such as radiation (e.g. UV, electromagnetic), noise, pressure and dust.

(http://www.pharmtox.med.uwo.ca/career/tox_frm.html, last visited 14/2/02)

Ottoboni (1991) gives a more restrictive definition of toxicology, defining it as 'the science that investigates the adverse systemic effects of chemicals'. By 'systemic' is implied a consistent and specific action upon particular organs or systems.

In order to decide upon a sensible working definition of toxicology for this study, it is helpful to begin with this restrictive definition; a consistently observed harmful effect, due to a particular form of exposure to a given chemical in a particular species. It is usually taken to include effects such as carcinogenicity, mutagenicity, and teratogenicity.

A somewhat wider definition includes harmful effects of substances due to contact with living tissues which are not 'toxic' in this sense, because they do not exert a specific effect on organs or systems, but which rather destroy or damage whatever tissues they come in contact with. Examples are corrosiveness - the destruction of tissues which the chemical contacts - and irritation - a milder effect, producing symptoms such as blistering and itching. Examples of corrosive chemicals are concentrated acids and alkalis; dilute solutions of corrosives are irritants, as are many other substances, including some spices and natural oils. These effects, though not 'toxicity' in the strictest definition, will be included, as it is often difficult to distinguish between them in practice, and most information sources make no sharp distinction. The term 'poison' is used for corrosives, as for toxic substances, since in both cases a small dose can cause serious harm.

Allergy, or hypersensitivity - the appearance of symptoms following exposure to a previously encountered substance (an allergen) which would normally be regarded as harmless - is another adverse effect which does not fall within the strictest definition of toxicology, because the allergen does not exert its harmful effect on all similarly exposed members of the species affected. However, pragmatically it is often included within the scope of toxicology, and indeed forms part of the specialism of immunotoxicology. It is therefore included as an aspect of toxicology for this study.

A wider definition still would include all 'harmful' or 'hazardous' effects of chemicals, including an explosive or flammable nature. This is too wide to come within the definition of toxicology, and these effects are not specifically considered. It should be noted, however, that information sources often class them together, under the heading of 'toxic and hazardous properties'.

Though it now has a clear status as a scientific discipline (though the exact nature of this is somewhat unclear, as will be discussed later), toxicology is also very much an area of professional practice: 'the ultimate objective of the discipline of toxicology is the protection of life - in particular, that of man - against external harmful factors'

(Niesink de Vries and Hollinger 1996B, p i). Koeman (1996, p3) defines the main practical objectives of toxicology as:

- to elucidate the poisonous (toxic) properties of chemicals
- to carry out scientific research in order to increase knowledge regarding the toxic properties of chemicals
- to evaluate the hazards of chemicals to organisms in relation to the concentrations in which these substances are present in the environment (risk estimation)
- to advise society on measures to control or prevent the harmful effects of chemicals (hazard control)

Zbinden (1992) reminds us that 'experimental toxicology has a dual purpose; it is both a scientific discipline, and a tightly regulated function designed to protect consumers against the adverse effects of newly developed and marketed chemicals'.

It is also a subject with strong legal and ethical ramifications. This is particularly so for the whole area of toxicity testing, by which the potential harmful effects of chemical substances are identified. Toxicology is 'a profession with wide-ranging social implications... [in which] interpretation and application of knowledge gained in the toxicology laboratory may be overshadowed by political, commercial, regulatory and technological issues and pressures' (Ballantyne, Marrs and Turner 1993B p xi).

Ethical issues also impinge heavily upon toxicology, from several perspectives (Vere 1993). One is the necessity to balance risks and benefits in using potentially hazardous substances for many purposes. A second is the issue of animal experimentation, particular for toxicity tests prescribed by regulation, which are seen by many as unnecessary and unscientific. A third is the use of toxic chemicals for warfare.

Finally, as will be made clear in the following section on the history of the discipline, toxicology is very much an evolving subject. In moving from art to science, and from simple observation and description of effects to an experimental approach, and a study of mechanisms, it parallels other scientific disciplines. It is, perhaps, unique in its change of emphasis; while the earliest 'applied toxicologists' were concerned with the deliberate poisoning of human beings with a small range of toxic agents, and with protection against this, the modern science is concerned with protection against the harmful effects of a wide range of substances, encountered in a variety of circumstances.

2.2.2 History of toxicology

A fuller version of this section may be found in the Appendix, part 2.2.a.

'Toxicology is considered by many to be a very recently developed scientific discipline. On the contrary, observation of harmful effects of chemical substances on living organisms is rooted in prehistory' (Decker 1987, p 1)

'Modern toxicology is a multi-disciplinary science and as such had to await the development of many of the natural sciences before it could become a quantitative study. Although many descriptions regarding the actions of poisons and antidotes were published prior to the nineteenth century, little of this information was based upon scientific studies' (Loomis 1978, p 3)

'Toxicology... is a borrowing science that has evolved from ancient poisoners' (Gallo 1996, p 3)

Toxicology is somewhat unusual in its historical development, in that it has a very long history as a collection of pragmatic knowledge of poisons, but a rather short history as a scientific discipline (Tansey 1993). Despite advances, noted below, from the sixteenth century onwards, it was only during the mid-nineteenth century that developments in chemical analysis made possible the reliable detection and identification of poisons, providing the basis for the modern science.

The historical development of toxicology has been reviewed in detail by Borzelleca (1994), Decker (1987), Gallo (1996), Koeman (1996), Oser (1987), Goulding (1987), and Ottoboni (1991) with an emphasis on public health aspects, and, with respect to more recent developments, by Zbinden (1992). Thompson's classic work of 1931 deals with the application of toxicology to criminal poisoning. The historical development of sub-disciplines has also received attention: Oser (1987) emphasises regulatory toxicology in his account, Niyogi (1980) deals with forensic toxicology, while Hänninen (1985) gives a personalised account of the development of behavioural toxicology. Holmstedt and Liljestrand (1981) give an account of the history of pharmacology, but including much toxicological material, based on reprints from historical sources.

Here, only a summary outline will be given, with emphasis on those aspects affecting, and reflecting, developments in information and communications.

Ballantyne, Marrs and Turner (1993B p xi) note that 'some fifty years ago [i.e. about 1940 from their timepoint], toxicology was barely recognized as a discipline and had few active participants, although some experimental pathologists at that time would now be regarded as within the sphere of toxicology.' They date the rise in interest in the subject, and its recognition as a discipline, to the decades since then. However, as with most intellectual topics, the roots of the discipline go much further back in time. Borzelleca (1994) identifies three main phases through which toxicology has passed in maturing to a scientific discipline, and with slight modification, these are used as the basis for the discussion below:

- *observation*; phenomenology, listing of poisons and antidotes
- *experimentation*; analytical, forensic, mechanistic
- *application*; risk assessment, safety factors

Observation

Prehistoric societies would have been well aware of the harmful effects of natural substances; plants, fruits, insect and reptile venoms, etc., and these are still used to the present day by tribal peoples in Africa and Asia for hunting, and warfare (Decker 1987). Archaeologists have found poisoned tips of arrows and spears, among other artefacts, (Tansey 1993).

The medicinal properties of plants were well known to the ancient Egyptians (Manniche 1989). Aspects of their knowledge are revealed in a number of 'medical papyri' of varied nature (Nunn 1996, chapter 2). Among these is the Ebers Papyrus, dating from between 1550 and 1500BC, and purchased in Luxor (ancient Thebes) in 1872 by the German Egyptologist Georg Moritz Ebers (1837-1898), having been discovered in the area a decade earlier by the American adventurer Edwin Smith. More than 20 metres long, the papyrus identifies more than 700 active substances, in about 900 formulae or recipes, with 47 'case histories', and is described by Dawson (1929), as 'not a book in the proper sense of the word; it is a miscellaneous collection of extracts and jottings from at least forty different sources', and by Nunn (1996) as 'a collection of different medical texts which have been run together in a rather haphazard order'. It seems clear, nonetheless, that the papyrus indicates knowledge of the toxic properties of various natural materials, including opium, aconite, hellebore, hemlock, hyoscyamus, lead, copper and antimony, as well as insect and animal venoms. Antidotes are described, commonly a mixture of chemical and physical measures, plus incantations, typical of the merging of rational observation and treatment with magic in Egyptian medicine.

By contrast with the multi-faceted, and confused, Ebers papyrus, the Brooklyn papyrus is concerned exclusively with snake bites. It has been dated to the late period of ancient Egyptian history, around 300BC, but is written in the style of the Middle Kingdom, either because it is a copy of a much older text, or because the writer chose an archaic style to lend authority. It is essentially a manual for the treatment of snake bite, and includes a guide to snake identification, with an accompanying prognosis and advice on treatment; the latter is largely rational, with some magical elements (Nunn 1996).

The second known list of poisons and antidotes, after the papyrus, comes from the civilisation of Ancient China. The *Pen Ts'ao* or *Pun Tsao*, the Great Herbal attributed to Shen Nung, the second of China's mythical emperor's, was written about 2700BC, although the earliest extant version dates from around 200AD, at the beginning of the Han dynasty. It contains lists of poisonous plants and other substances, with antidotes.

[Borzelleca (1994) noting that both the Ebers papyrus and the *Pen Ts'ao* present useful drugs and harmful substances together, sees in this the earliest evidence for the joint development of toxicology and pharmacology.]

Other Ancient Near East civilisations had similar listings of toxic substances. The dangers of medicinal products, particularly when adulterated, were well known to the Babylonians. There is no list of poisons in the Bible, although the book of Deuteronomy contains proscriptions on foodstuffs in considerable detail, but numerous references indicate an awareness of naturally-occurring poisons and their effects, e.g.: 'their wine is the poison of dragons and the cruel venom of asps' Deuteronomy 32:33; 'He shall suck the poison of asps, the viper's tongue shall slay him' Job 20:16 (Authorised Version). Borzelleca (1994) has further examples.

In the Hindu world, early Sanskrit medical writings including the Rig-Veda of 1500 -1200 BC, and the Ayur Veda, of 700-900 BC, describe the effects of various poisons, mineral, vegetable and animal, as well as the effects of the bites of venomous insects and reptiles, but give only vague suggestions for prevention or treatment. The Shastras, commentaries on these early Sanskrit writings, produced about 300 years later, deal more extensively with antidotes.

Many Greek and Latin texts deal with matters of toxicological interest, and they are referred to in much classical literature, particularly with respect to arrow poisons Decker (1987); hence the roots of the term noted at the start of this chapter.

The Greeks, not surprisingly in view of their seminal role in the development of the concepts upon which Western science would later be grounded, were foremost in the development of the study of poisons, moving beyond simple listings to detailed descriptions of the effects of various poisons, antidotes, and management.

The Hellenic world produced the first written works dealing specifically with poisons (Decker 1987). These include two poems by Nikander of Colophon (185-135 BC), who was physician to Attalus, King of Bithynia, and who was said to have been allowed to experiment with the effect of poisons on condemned criminals. The first poem, the 'Theriaca' of about 1000 lines, deals with poisonous plants and animals, including aconite, hemlock, henbane, opium, and snake venoms; the second poem, the 'Alexipharmaca' of about 600 lines, deals with antidotes to these. While much of their content is fable, Decker (1987) suggests that they contain a considerable body of valid information which must have been gleaned by careful observation.

The 5-volume 'Materia Medica' of Pedanius Dioscorides (40-90AD), written around 77-78AD, and largely devoted to herbal medicines, contains information on poisons and their antidotes, in which well-known poisons were classified, for the first time, according to their origins. These included animal sources (serpents, toads, crustaceans, etc.), plants (aconite, colchicum, hemlock, opium, etc.), and minerals (arsenic, lead, cinnebar, and so on). Much of this is clearly based on empirical observation, though the work also included 'fabulous' poisons, such as the blood of wild bulls. Dioscorides' work remained the standard for some 1500 years, with many commentaries written on it, but no major advances or additions made. It was translated into English by the herbalist John Goodyer in 1655.

Borzelleca (1994) discusses these and other Greek contributions in detail, seeing in them the first evidence of the experimental approach to toxicology. Their school lasted for many centuries.

The Roman civilisation, though they derived much of their medical knowledge from the Greeks, had a strong interest in poisons. Aurelius Cornelius Celsus, described as the 'Hippocrates of the Romans', authored a number of medical texts, as well as a general encyclopedia: his classic text *De Medicis* (which survived to be one of the first medical books published after the introduction of printing in the 15th century) included a section on toxicology, largely drawing from Greek sources.

Both Greek and Roman physicians noted the poorer health of persons working in certain trades, or undertaking certain kinds of manual labour (Ottoboni 1991); in this can be seen the genesis of occupational medicine, and occupational toxicology.

In the Arab world, science and medicine flourished after the collapse of Roman civilisation, with most of the important Greek works being translated. Pharmacy, in particular, was developed beyond that known in the classical world, with some remarkably modern-looking information resources: the scholar al-Biruni (Abu al-Rayhan Mohammed ibn Ahmed a-Biruni 973-1048), at the age of 80, produced a guide to the properties of 720 medicines, listing each according to its name in five languages (Duncan 1998).

Maimonides (Rabbi Moses ben Maimon, 1130-1204), a Jewish philosopher and physician, was another writer, whose works on poisons were remarkably long-lived. His book *Poisons and Antidotes/Upon Poisoning and its Treatment*, was translated into Latin in 1305, into French in 1865, and into German in 1873 (Borzelleca 1994). Like some of the earlier Greek writers, he described the phenomenon of bioavailability, noting that milk, butter and cream could delay intestinal absorption.

Pietro de Abano (1250-1316), a teacher and physician in Padua, Italy, attempted to reconcile the Greek and Arabic traditions of medicine, including the treatment of poisoning, in his book *Conciliator Differentiarum*. Another work of his, *De venemis*, dealt with poisons under the, by now traditional, headings on animal, vegetable and mineral, and for the first time noted routes of administration other than oral: by inhalation, and through the skin. His book was published in 14 editions.

Poisons, usually of plant origin, were carefully and knowingly used in classical societies for murder, suicide, execution, hunting, and similar purposes, and the poisoner became, in a sense, the first applied toxicologist. As Decker (1987 p 2) puts it 'the focus of early toxicology quickly became the murder of fellow beings'. Indeed, much of the earliest impetus for the development of toxicology, apart from its value as a tool for the poisoner, was primarily forensic, as a response to the widespread use of poisons for murder over many centuries (Thompson 1931, Ballantyne, Marrs and Turner 1993C, Goulding 1987).

Experimental

The experimental phase of toxicology is generally held to date from the 16th century, though, some experiments (generally of a highly unethical kind) had been carried out

from the earliest days, and some writers had speculated about mechanisms of toxicity. After this date, of course, the observation/descriptive tradition continued. European literature from the Renaissance onwards includes many examples of descriptive writings on natural toxins, often included in herbals: one well-known example is the Dutch 'Herbarium of Kruidtboeck', by Petrus Nylandt, of 1673.

The sixteenth century Swiss physician and alchemist Philippus Theophrastus Aureolus Bombastus von Hohenheim, commonly known as Paracelsus, (1493-1541) is often taken as one of the founders of the discipline of toxicology, writing what may be regarded as the precursors of toxicology textbooks (Deschamps and Morgan 1993), and introducing on a scientific basis, the concepts of an experimental and mechanistic approach to toxicology. In particular, he drew attention to the dose-dependency of toxic effects, and to the fact that every substance, in large enough quantity, will do harm, while 'toxic' substances, in appropriate doses, may be beneficial.

Paracelsus' other contributions to toxicology included the use of animals to test the effects of chemicals, the introduction of the concept of target organ toxicity, and further elaboration of the chemical hazards faced by miners, which, as noted above, had been recognised since ancient times, in his *Treatise on the Diseases of Miners* of 1567.

In addition, Paracelsus also introduced inorganic medicine for internal use.

Paracelsus' ideas were taken up by later scholars, including the French physician Jacques Grevin (1538-1570), who further developed the concept of chemical-biological interactions, earning the title 'father of modern biotoxicology' (Borzelleca 1994), and who published what became a classic work *Deux Livres des Venins* in 1568.

With the beginnings of science-based medicine in the eighteenth century, the careful study of adverse reactions to medicinal preparations became another foundation for the discipline, an early example being the description of the toxicity of digitalis by William Withering in 1785. At about the same time, Samuel Hahnemann, best known as the founder of homeopathy, carried out toxicological studies on healthy human subjects, including himself, using current therapeutic agents, such as mercury, belladonna, and aconite.

As Oser (1987) points out, the most pertinent science underlying toxicology is chemistry, since without reliable analysis of toxic agents, no science of toxicology would be possible. This appears to have been first recognised explicitly by Joseph Plenck, an early, and arguably the first forensic toxicologist, who wrote in his 1781 treatise 'Elementa Medicinae et Chirurgiae Forensis': 'the only certain sign of poisoning is the chemical identification of the poison in the organs of the body'.

The founder of modern toxicology, particularly in its analytical and forensic aspects, is considered to be the Spanish chemist and physician Mathieu Joseph Bonaventura Orfila (1787-1853), born on Minorca, who studied chemistry and medicine in Paris, and applied the combination of these disciplines to the new science, finally becoming dean of legal medicine at the University of Paris (Beeson 1930). His two volume *Traité de Toxicologie: Traité des poisons tirés des règnes minéral, végétal et animal ou toxicologie générale considérée sous les rapports de la physiologie, de la pathologie et de la médecine légale*, commonly known as the *Traité des Poisons*, written in 1814-15, and published in English in 1817, is probably the first book devoted entirely to toxicology, and is regarded as certainly the first standard text on the subject, which was thereby established as an experimental science distinct from pharmacology.

The nineteenth century saw much experimental work, following the example of Orfila, in the investigation of toxic effects and mechanisms. The development of toxicology paralleled, and drew from, that of organic and analytical chemistry, and went along with - indeed intertwined with - that of pharmacology and physiology. At the beginning of the century, toxicology was being recognised as a scientific discipline, with an extensive knowledge base of observed effects of, and antidotes to, many poisons, and with some limited experimental and analytical basis; but little had been done in providing any systematic answer to the basic mechanistic question 'how do poisons kill?' (Borzelleca 1994). These questions could only now be answered, as the 'mechanistic' era of toxicology began, with the classic work of two physiologists, Magendie and Bernard (see appendix 2.2.a).

Another founder of modern toxicology is Frederick Accum (1776-1838). His best known work was a *Treatise on Adulterations of Food and Culinary Poisons* (1820), and he may reasonably be regarded as the founder of the 'public safety' aspect of toxicological research.

Accum's work was followed up by other analysts, and, in the UK, culminated in the publication in 1855 of Dr Arthur Hill Hassell's book 'Food and its adulterations'. This led

to the passing of the first British Food and Drug Adulteration Act in 1860, with stronger laws following in 1875. A similar process of scientific advances and public pressure led to the passing of the first Food and Drug Act in the USA in 1906.

Medical toxicology continued to develop throughout the nineteenth century, the most celebrated example being the enquiries into deaths due to chloroform anaesthesia. The advances led to the recognition of toxicology as a distinct entity, though still closely bound up with pharmacology and physiology, drawing from a range of chemical, biological and medical sciences for its development. This feature of the development of toxicological science has continued to the present day, with Gallo (1996) noting that from 1900 the subject has developed and expanded by assimilating knowledge and techniques from most branches of biology, chemistry, mathematics and physics.

Application

The need for toxicologists to consider the 'incidental' exposure of individuals and populations to harmful substances, became increasingly recognised in the nineteenth century. At this time came the initial development of occupational toxicology, as a result of the industrial revolution, which involved large working populations exposed to potentially hazardous chemicals. This was given impetus by the passing of workers' insurance laws, initially in Germany (1883), later in Britain (1897) and the USA (1910).

By the end of the nineteenth century, the UK had passed seven Factories Acts, including reforms on chemical safety.

The early development of industrial toxicology in the USA is described in detail in the autobiography of Alice Hamilton (1943), the leading occupational physician of her time who researched and published widely on the topic, most notably in her text *Industrial Toxicology* (1934). One of the most interesting points repeatedly made by Hamilton, in her account of what she starkly terms the 'poisonous trades', is the national differences in access to, and understanding of, this aspect of toxicological knowledge. Ironically, in view of the predominant role played by the USA in regulatory toxicology in more recent years, in the early years of the twentieth century that country was far behind Europe in this respect. Thus, Hamilton writes 'American medical authorities had never taken industrial diseases seriously, the American Medical Association had never held a meeting on the subject, and while European journals were full of articles on industrial poisoning, the number in American medical

journals up to 1910 could be counted on one's fingers' (Hamilton 1943, p1). She also refers to the 'strange silence' on the subject of industrial toxicology in American medical magazines and textbooks, by comparison with those of Europe, and suggests that it may have been due to a national perception that the subject was 'tainted with Socialism or with feminine sentimentality for the poor' (Hamilton 1943, p115); a striking example of the influence of socio-political factors on the knowledge base of a supposedly objective science. One specific example which she gives is that of 'phossy jaw', a disfigurement brought on by breathing phosphorus fumes. This was first described in Austria in 1845, with cases treated in the USA during the following decade. But, Hamilton notes, 'while all over continental Europe and England there was eager discussion of this new disease, many cases were reported and all sorts of preventive measures proposed, practically nothing was published in American medical journals from 1851 to 1909' (Hamilton 1943, p117). Further examples are those of benzol poisoning in rubber workers, described at an international medical congress in Moscow in 1897, but not reported in any American publication until 1910, and of carbon disulphide poisoning in rayon manufacture, for which 'the medical journals were full of reports, from Italy especially, and from all over Europe [but] for over ten years, during which time the viscose industry in [the USA] grew enormously, no American report of damage from this poison appeared ... foreign literature was full of detailed descriptions, but I doubt if any American medical student ever heard a word on the subject' (Hamilton 1943, p388). This neglect of toxicological knowledge extended into the record keeping of American doctors, as Hamilton notes with respect to the treatment of victims of lead poisoning: '... no hospital interne [sic] ever noted where the victim of plumbism had acquired the lead. Hospital history sheets noted carefully all the facts about tobacco, alcohol, and even coffee consumed by the leaded man, though obviously he was not suffering from those poisons; but curiosity as to how he became poisoned with lead was not in the interne's mental make-up' (Hamilton 1943, p10).

The rise of the chemical and pharmaceutical industries, in the nineteenth and particularly the twentieth centuries, has led to a change from a concentration on the toxic effects of natural, usually plant, compounds, to those of the products of chemical manufacture (generally termed xenobiotics). The sheer number of different compounds, all with potential toxic effects, is a major challenge for industrial and regulatory toxicology; for example, Hamilton (1943) notes that the only poisonous substances used or encountered industrially in the state of Illinois around 1910 were lead, arsenic, brass, carbon monoxide, the cyanides and turpentine; by the 1940s, the list of chemicals used in even a single trade was many times as long. She also refers to

the problems caused by the replacement of the small number of industrial solvents - petroleum distillates, wood alcohol, turpentine - used around the turn of the century by the wide variety of synthetic solvents following the 1914-18 war.

The vast number of compounds has also led to the origin of regulatory toxicology, the requirement for assessment of the potential harmful effects, which now accounts for the great majority of expenditure on toxicological research (Ballantyne, Marrs and Turner 1993C). This was hastened by the legislation on foodstuffs enacted in several countries at the turn of the century, which led to the development of standardised toxicity testing, to assess the numerous new preservatives and food colorants being introduced (Borzelleca 1994). One response to this was the establishment of internal toxicology research laboratories by a number of major chemical companies in the USA, including Dow, Union Carbide and Du Pont; laboratories of this sort, intended to help guide decisions on workers' health and on product safety have been major contributors to the knowledge base of toxicology since that time; see, for example, Scribner and Weiler (1995). Some of these laboratories have developed significant toxicology information resources in their own right; examples are the Central Toxicology Laboratory (formerly ICI but now part of Syngenta, Cheshire, UK) and TNO BIBRA, Surrey, UK, formerly the British Industrial Biological Research Association. The former has taken a lead in the development of systems and services for handling toxicology information, for example ARTEMIS, an early example of a comprehensive computerised toxicology data-handling system (Clapp and McNamee 1985). The latter was founded in 1960, as a joint venture of the British government and the UK food industry, with the aim of promoting research into chemical toxicology, with particular reference to foodstuffs. A later diversification into wider application areas of toxicology saw its name change to BIBRA Toxicology International; under its current title, its areas of interest are chemical toxicology, nutrition and ecotoxicology.

Governmental involvement with toxicology became more explicit at the beginning of the 20th century, a Division of Industrial Hygiene being established by the US Public Health Service in 1914. 1930 saw the foundation of the US National Institutes of Health, which has subsequently been the foremost exemplar of governmental involvement in toxicological research and information provision. Forensic science, including toxicology, advancing in capabilities with developments in analytical chemistry, was given greater importance by law enforcement agencies; one well-known example being Alexander Gettler, who served at the toxicology laboratory of the New York Medical Examiner for many years, and testified in hundreds of trials (Niyogi 1980).

One particularly significant event was the poisoning of a large number of persons in the USA in 1937, by a medical product containing the solvent diethylene glycol, which resulted in 107 deaths. This led to US legislation, the 1938 Amendment to the Food and Drug Act, forbidding the marketing of any new product until it had been assessed for safety by the Food and Drug Administration, setting the standard for the dramatic increase in regulatory toxicology which has followed. This can be traced to the influence of the 1939-45 war, with its very marked increase in the production of drugs, pesticides, munitions, synthetic fibres and industrial chemicals, which was the starting point for what Gallo (1996) describes as the exponential growth of toxicology, particularly in its regulatory aspect, since that time. Indeed, Doull (1984) argued that the development and evolution of toxicology in the 1980s was being driven by pressure from the regulatory arena. This resulted in the formalization of an experimental programme of toxicity testing for all drugs, foods and cosmetics in the USA in 1955, later revised by the FDA in 1982.

In the UK, following the thalidomide tragedy, the Committee on Safety of Drugs was established in 1964, and the Medicines Act was passed in 1968.

Another stimulus to toxicological work came with the first systematic use of poisonous chemicals in warfare, during the 1914-18 War, and thereafter defence considerations have played a major part in stimulating toxicological research, particularly in the initial investigations of the mechanisms of toxicity, and in the development of clinical toxicology.

Concerns for the health of consumers, patients and workers, and for environmental protection have, of course, increased greatly during the last 50 years, fuelling the growth of toxicology; both basic research and regulatory requirements. Gallo (1996) argues, as a 'working hypothesis', that toxicology has expanded in response to legislation, itself passed in response to real or perceived tragedies. Highly publicised disasters such as thalidomide, Seveso and Bhopal, and the recognition of the environmental damage caused by organochlorine pesticides publicised by Rachel Carson's influential book 'Silent Spring' (1962), have added particular emphasis. A review of a number of 'disasters' is given by Illing (1993), and the wider context of these issues discussed in detail by Gallo (1996).

One immediate consequence of this was the further strengthening of governmental involvement in toxicology, particularly environmental toxicology, and especially in the USA, during the 1960s: this included the expansion of the role of the Food and Drug

Administration, and the establishment of the Environmental Protection Agency, the National Institute of Environmental Health Sciences, and the National Center for Toxicologic Research (Gallo 1996). During the 1970s, concerns about hazardous chemical wastes, following the publicity surrounding the dangerous materials at the Love Canal site in the USA, led to the passing of the Toxic Substances Control Act and 'right to know' legislation, which in turn have led to great activity in creation of information resources in their support.

The UK Health and Safety at Work Act was passed in 1974, as a framework for modern chemical safety legislation. More recently, regulations for the control of substances hazardous to health (COSHH) have come into being.

Over time, toxicology in general has moved away from its origins in acute, particularly human, toxicology, towards long-term and non-target species studies, to studies of carcinogenicity, mutagenicity and teratogenicity, and to in-depth examination of mechanisms. This has been fuelled by developments in the other sciences on which toxicology depends, and Gallo (1996) regards modern (i.e. 20th century) toxicology as a continuation of the development of the biological and physical sciences in the late 19th and the 20th centuries.

Zbinden (1992) describes the momentum of the development of toxicology in terms of 'three eras' of experimental toxicology, since about 1920. In the first era, that of discovery, the basic foundations of this approach were laid, with the realisation of the many ways in which adverse effects of chemicals could manifest themselves, and the development of experimental means for assessing and quantifying these. In the second era, that of 'biomechanistic investigations', beginning in the 1940s, experimental toxicology evolved from a 'descriptive and tightly regulated routine procedure' to a truly scientific and rational investigation, appealing to academic investigators who would not wish to be involved in simple safety-testing procedures. This has led to deeper understanding of toxic responses, and provides explanations such as species differences, organ affinities and chemical interactions. Even so, as Zbinden cautions, there are still relatively few chemical compounds whose toxic effects are fully understood. Finally, stemming from the 1980s, there is the era of 'individual expression', in which the influence of a variety of factors, but particularly genetics, in determining the response of individuals to potentially toxic substances may be understood.

This advance in scientific understanding has created something of a tension, in that it takes a considerable time for the insights and methods developed by toxicological research to be adopted in the safety testing procedures required by law. The latter must, to a degree, stand aloof from the rapidity of research, in order to provide the stability necessary for the practical operations of regulatory authorities and manufacturers of chemical products. Nonetheless, the slowness of adoption of newer findings and techniques has led to accusations that industrial toxicity testing is wasteful of money and resources, unethical in its excessive reliance of testing with large numbers of animals, and can lead to undue delay in the introduction of useful new products. Zbinden (1992) expresses this tension in measured tones: 'if the methods and the concepts of evaluation of toxicological studies were adapted continuously to the newest findings generated in research laboratories, a valid documentation of safety studies for regulatory approval could never be assembled. On the other hand, it is frustrating to see how slowly well-established, scientifically-based facts and concepts are incorporated into the industrial safety testing routine and the regulatory practice of risk assessment.... As in every other discipline of natural sciences, the speed with which new knowledge is accumulated in experimental toxicology is phenomenal. The task of identifying the relevant discoveries and their incorporation into the practice of industrial safety testing and risk evaluation is extremely difficult'. More tersely, Stitzel (1998) comments 'we are about to begin the 21st century using many toxicology methods that were originally developed in the 1940s. I can think of few other fields where acceptance of scientific progress has been so effectively blocked'.

At the same time as experimental (scientific) toxicology has been developing in these ways, clinical toxicology, the treatment of acute poisoning, hitherto carried out by general physicians, has developed into a specialist branch of medicine, supported, from the 1950s, by the specialist support of poisons information centres, responding to the greatly increased range of chemical substances available to the public (see, for example, Vale and Meredith 1993).

Since the 1970s, the use of computers has had a dramatic impact upon the practice of toxicology, as on other areas of science and medicine. Of particular importance has been the development of computerised methods for predicting toxic effects (see, for example, Coombes and Judson 1995, Benigni and Richard 1998, McKinney et. al. 2000). Wider use of these methods will have major impact upon the practice of toxicology, particularly the regulatory and risk assessment aspects.

2.2.3 Nature of the discipline

The exact nature of the discipline is hard to describe exactly. It has roots in both science and medicine, (Ballantyne, Marrs and Turner 1993C, p 3) referring to it as 'a recognized scientific *and* medical discipline' [my italics].

However, while its scientific qualities are not in doubt, it is clear that, particularly in the aspect of toxicity testing and hazard assessment, that scope still exists for professional judgement, based on expertise and experience: 'That toxicology is not an exact science has become a cliché among its practitioners. Notwithstanding the detailed descriptions of experimental conditions and procedures promulgated under the heading of "guidelines", the options and leeways open to the investigator are so numerous that no two studies of a given substance in laboratories of "equal competence" turn out to be exactly the same' (Oser 1987). This has led to the assertion that modern toxicology may still be said to be both an art and a science (Gallo 1996), by contrast with some other disciplines, for example chemistry (Knight 1992), which have progressed steadily over time away from qualitative art and towards quantitative science. For comparison, contrasting views exist about the nature of medicine, which is seen by some to be both an art and a science (Morrell 2000), and by others to have largely moved from art to science (Azzone 1998).

Like many other contemporary sciences, toxicology is continually changing and developing in terms of techniques and concepts; Weiss and Cory-Slechta (1994) suggest that some components of contemporary toxicology are undergoing almost continuous change.

Toxicology clearly has both pure and applied aspects, and overlaps with many other disciplines, 'encompassing a very large number of basic and applied issues' (Ballantyne, Marrs and Turner 1993C, p3). There are two clear, albeit inter-related 'strands' within toxicology: the 'pure' research aspect, aimed at elucidating toxic mechanisms and similar factors, and the 'toxicity testing' aspect, aimed at producing realistic estimates of potential harm.

Freiss (1995) argues that toxicological research, aiming at protection of human health from adverse effects of chemicals (arguably an over-restrictive definition of the subject), has a logical sequence of five stages:

- gathering of a toxicological database from animal experimentation

- projection or extrapolation of animal data to prediction of effect on exposed human populations
- validation of prediction of human effects by epidemiological studies of exposed human populations
- for validated effects, development of quantitative measures of potency via important routes of human exposure
- development of quantitative measures of the risks of specific toxic effects in humans under specified exposure conditions

Freiss goes on to argue that these steps involve two major, and different, forms of scientific and technical effort:

- scientific, encompassing the experimental generation of the database, followed by extrapolation or prediction of impact on humans
- methodological, estimating intrinsic potency and human intake dosage, to yield estimates of risk

Freiss refers to these two steps as toxicological evaluation and risk assessment, respectively, and notes that they are typically carried out by two communities of technical specialists who differ markedly in their training, experience, mandate and priorities. He denotes these two kinds of toxicologist as research specialists and risk assessment/management specialists, and argues that a more successful interaction between them is essential in generating the most useful toxicological data, and making best use of it.

Gallo (1996 p 6) sees these aspects as defining some unique characteristics of toxicology: 'The history of many sciences represents an orderly transition based on theory, hypothesis testing, and synthesis of new ideas. Toxicology, as a gathering and an applied science, has, by contrast, developed in fits and starts. Toxicology calls on almost all the basic sciences to test its hypotheses. This fact, coupled with the health and occupational regulations that have driven toxicology research since 1900, has made this discipline exceptional in the history of science.' He also suggests that toxicology may be unique in 'pointing' to both basic sciences and direct applications at the same time.

Forensic science is a more extreme example than toxicology, involving a very broad base of scientific and technical disciplines. It is 'essentially the application of scientific methods and techniques to matters involving the public: that covers a lot of ground.

Every science from chemistry to medicine, from biology to statistics, from dentistry to anthropology, can be a forensic science, if it has some application to the law or public matter' (Siegel, Saukko and Knupfe, 2000). Lee (2000) emphasises this diversity: 'Forensic science is always a diverse field, built on the principles of chemistry, biology and physics, and incorporating countless other specialities. Today, the service offered under the guise of "forensic science" includes specialities from virtually all aspects of modern science, medicine, engineering, mathematics and technology. For those working within some area [of forensics] it is nearly impossible to maintain even a cursory level of knowledge regarding all available subcomponents within forensic science.' In addition to these scientific and technical aspects, legal and procedural matters, such as documentation of evidence, are of great importance (Eckert 1997).

This science is therefore much more multi-disciplinary than toxicology, which rests upon a more limited base of chemical and biomedical science, albeit with a regulatory and legal dimension. To a greater extent than toxicology, forensic science can best be understood, in Hirst's terms, as a field of study (see later section).

Virtually all writers note that toxicology is multi-disciplinary - 'a major multidisciplinary science' (Oser 1987), 'a multi-disciplinary science .. a multi-disciplinary field' (Loomis 1978), but the exact nature of the disciplinary mixing is subtle. Koeman (1996, p 7) carefully defines that:

'Toxicology is typically a *multidisciplinary* field of science, which, to an increasing extent, assumes the character of an *interdiscipline*. This implies that the integration of various disciplines in toxicology not only means that the various sciences are applied simultaneously, but also that integration poses its own specific problems' [author's italics].

A similar view is expressed in the 1998 information pack for the graduate toxicology programme of the University of Rochester (New York): 'By its nature, toxicology is highly interdisciplinary. It combines the knowledge base and approaches of such fields as physiology, pharmacology, psychology, biochemistry and molecular biology, to address fundamental questions regarding the mechanistic effects of chemicals on living organisms.'

The editors of a major monograph (Sipes, McQueen and Gandolfi 1997) suggest that toxicology 'is the scientific discipline that combines the elements of chemistry and biology. It not only addresses how chemicals affect biological systems, but how

biological systems affect chemicals. Due to this broad definition, toxicology has always been an interdisciplinary science. It uses advances made in other disciplines to better describe a toxic event or to elucidate the mechanism of a toxic event.'

(This seems to suggest that as a combination of chemistry and biology, toxicology equates to biochemistry; this is not the case, as is clarified later in this section. Toxicology encompasses many more disciplines than merely biochemistry).

We can take this to mean that there is a single interdisciplinary subject called toxicology; this will have its own knowledge base, and its own set of concepts and methods. However, we must also recognise that much of toxicology makes direct use of knowledge, concepts and methods from other disciplines. These considerations will have considerable implications for information and communication, as will be discussed later.

It is worth going a little further along this line, to enquire into the nature of toxicology. To do so, it will be helpful to use the idea of Paul Hirst, the philosopher of education, on the 'forms of knowledge (Hirst 1974, Walsh 1993). Drawing ultimately on the ideas of the Greek philosophers, particular Aristotle, Hirst proposes that all knowledge and understanding may be logically locatable within a finite number of domains. These domains, or categories, are to be distinguished by four criteria:

- central concepts peculiar in character to that form (e.g. "number" in mathematics, "mass" in physical sciences, "sin" in theology)
- a distinctive logical structure (mathematical concepts and symbols are related in very different way to statements of religious belief)
- distinctive forms of expressions, testable by distinctive criteria (tests of validity are very different in physical science from those in literary criticism, and the logical deduction of mathematics is different from the empirical verification of physical science)
- a collection of particular skills and techniques, developed for the particular form of knowledge to be handled (although he regards this criterion as less important than the other three).

Where these criteria are violated, what results is not a new domain, but nonsense; the statements that "magnetic fields are angry" or that "cardinal numbers are holy" can have no meaning, beyond [perhaps] the metaphorical.

Hirst proposes that there are seven such domains, or "*forms of knowledge*". These are: mathematics; physical sciences; human sciences; literature and the fine arts; morality; religion; philosophy. They are sometimes stated equivalently as: logico-mathematical; empirical; interpersonal; aesthetic; moral; religious; philosophical. In earlier versions of his theory, history and social sciences were also treated as independent forms, but are not generally so regarded.

Academic subjects may then be mapped onto these forms. Sometimes they will correspond exactly; mathematics and philosophy, for example, are forms directly identifiable with subject areas and academic courses. These same forms may also be basic to other discrete subject areas, of course: mathematics for theoretical physics and econometrics, for example. More commonly, a discrete subject area falls, along with many others, as an example of a form. Hirst's formalism gives no help in deciding the boundaries and scope of a subject; we may agree that physics and chemistry are both examples of the physical science form, but this does not help us to decide where the areas overlap, nor what is chemical physics and what physical chemistry. Hirst sees these forms of knowledge as equating to disciplines concerned with validating one logically distinct form of expression of knowledge, by developing one particular way of structuring experience.

- In proposing such forms, Hirst regards knowledge as falling into three types; propositional knowledge, "knowing that"
- procedural knowledge, "knowing how"
- knowledge by acquaintance, "direct knowledge"

Whilst his theory was originally propounded on the basis of the supremacy of propositional knowledge (Hirst 1974), Hirst subsequently revised his views to take account of the extent to which propositional knowledge is, in fact, based on procedure, theory relates to "know how", and the forms may be seen as a rarefied description of practice (Walsh 1993).

Nonetheless the forms and associated disciplines, as stated, appear as entirely "pure" theoretically-oriented topics. Hirst recognises a second concept; a "practical discipline" based on one of the forms, but oriented towards solving practical problems. Engineering, and its various sub-branches, for example, is clearly a practical discipline based upon the form of physical science.

Beyond this, Hirst recognises that there are some academic subjects, pure and applied, which do not fit neatly into one of these forms. The reason is simply that such subjects do not share the concerns of the disciplines noted above; rather they are focused on their subject matter, drawing on all forms of knowledge which contribute to them. Hirst refers to these as "fields of study"; multi-disciplinary in nature, and given coherence, not by adherence to a single form of knowledge and mode of discourse, but by a focus on a common central topic. By contrast with the forms of knowledge, which Hirst considers finite in number, these fields, composite second-order constructions, may be formed as convenient, and are not limited in number; they expand as knowledge itself expands. The main example which Hirst gives in introducing this concept is geography, where the central focus of humanity in the environment is studied using the methods and languages associated with several forms.

Considering toxicology in the light of these ideas, it seems that there are two ways in which toxicology may be viewed. Most practising toxicologists would presumably regard the subject as falling within the 'physical sciences / empirical' form. Since, as we have seen, toxicology has a strong practical aspect, it should be viewed as a 'practical discipline'. An alternative view could be taken, based on the impact of social, political and ethical issues on the science. If these are accepted as a part of toxicology, then it could be argued that the subject would be better treated as a 'field of study', whose focus of interest is the harmful effects of substances on organisms and ways of dealing with them. This inclusive definition would certainly incorporate all forms of studies, views and writings dealing with all aspects of toxicology, and from all perspectives. However, it is probably more realistic, considering the nature of most toxicology literature, and the concerns of most toxicologists, to prefer the scientific 'practical discipline' definition.

We can therefore conclude that toxicology is a practical discipline, within the form of the empirical natural sciences, while showing some of the characteristics of a more general 'field of study'.

2.2.4 Inter-relations between toxicology and other disciplines

It is clear that toxicology is among the most multidisciplinary of sciences, with strong implications for its information and knowledge base: 'it is a discipline that requires the integration of many areas of knowledge: basic biochemistry, chemistry (analytical

and organic), pathology, and physiology' (Niesink, de Vries and Hollinger 1996B, p i). Koeman (1996, p6) goes further: 'to obtain insight into the mechanisms and processes underlying the effects of poisons, in principle *all* basic medical-biological and chemical sciences should be integrated in toxicological research' [my italics]. Gallo (1996) notes that toxicology assimilates knowledge and techniques from 'most branches of biology, chemistry, mathematics and physics', and that it 'calls upon almost all the basic sciences to test its hypotheses. It is, in short, in Gallo's phrase, a 'borrowing science', which has drawn its strength and diversity from its proclivity to borrowing. While this may mean that it has suffered from the absence of a single goal, its diversification has allowed the creative intermingling of ideas and concepts from academia, industry and government.

Ottoboni (1991) points out that 'there are many scientists from a host of scientific disciplines who, along with toxicologists, expound on the toxic properties of chemicals'; she notes that these include molecular biologists, microbiologists, biochemists, plant pathologists, environmental scientists, pharmacologists, physicians, and veterinarians. Conversely, toxicologists need to access knowledge from these other disciplines in order to fully understand the nature of the toxicity of particular chemicals, and its implications. She suggests that pronouncements on toxicological matters by specialists from these related disciplines may lead to misunderstanding, particularly in the minds of the public, about the nature and seriousness of toxic hazards.

Borzelleca (1994) notes that toxicology is 'an important scientific discipline that derives its uniqueness and strengths from the integration of many chemical and biological sciences and supporting disciplines' and also that it is 'one of the few sciences in which academic, industrial, and regulatory scientists can interact effectively'.

Blood (1969) suggests that the 'science of toxicology' is 'one that interrelates information derived from such disciplines as biochemistry, physiology (plant and animal), pharmacology, pathology, microbiology, entomology, forensic medicine, industrial medicine, and food technology'. He noted that (in the late 1960s) there was a 'wealth of information related to toxicology' to be found in 'monographs, symposia, and journals in these many speciality areas', but that there was dearth of general texts, and little material for students, or those needing toxicology information but not active in the field.

The nature of the inter-relations between toxicology and other disciplines will now be considered. It is helpful to follow Koeman (1996) in distinguishing between two forms of inter-relation:

- 'vertical' integration, by which toxicology adopts the methods, and uses the knowledge base of other basic disciplines of biomedicine and chemistry, e.g. pathology, cell biology, organic chemistry
- 'horizontal' integration, by which toxicology integrates with applied disciplines, mainly in the health and environmental areas, e.g. clinical medicine, nutrition, environmental science, and occupational medicine.

In either case, it appears from the analysis carried out for this study, that a three level integration process may be seen:

- the methods and knowledge base of the discipline are used by the toxicologist
- there is an overlap, forming a sub-discipline of toxicology, e.g. the overlap with analytical chemistry forming analytical toxicology, that with immunology forming immunotoxicology, and that with occupational medicine giving occupational toxicology
- the integration is so complete that the methods and concepts of the other discipline are simply absorbed into toxicology *per se*

This third stage is what leads to the emergence of Koeman's 'interdiscipline' of toxicology; at present, this is far from complete, and the first two stages predominate, with results for information and communication which will be discussed later.

The linking between toxicology and other disciplines is far from simple, has been viewed differently with time, and may vary from country to country. In particular, the basic 'roots' of toxicology are viewed differently; as noted above, it is not entirely clear whether it should be regarded as a scientific or as a medical discipline.

Most commonly, it is viewed as an off-spring of pharmacology (and, as noted below, this link shows itself clearly in a number of journals covering the joint topic). The closeness of the relationship is also shown by the inclusion of the two topics in the title of many academic chairs (Holnstedt and Liljestrand 1981). This is due to the fact that many studies of the effect of drugs (pharmacology) are, in fact, measuring a selective toxicity, and that the methods and techniques of the two sciences

necessarily have much in common. Also, no beneficial drug is without side-effects, i.e. toxic manifestations, and the study of the two naturally go together. Pragmatic support to this linkage has been given by the 'emphasis on the unity of pharmacology and toxicology' by the highly influential National Institutes of Health in the USA (Weiss and Laties 1969). Smyth (1960) emphasised this link by commenting '.. our toxicology is an infant, barely emerged from the womb of pharmacology. We do not fully know how to utilise our strengths and talents'.

However, Mello (1975) notes distinct differences between the subjects: while pharmacology is typically interested in the 'transient' and immediate effects of a dose of an active substance, toxicology also needs to consider the harmful effects of substances accumulating over considerable periods of time. Also, while pharmacology deals with deliberately administered substances, this is often not the case for toxicology, where the substances may be 'encountered incidentally' in a wide variety of ways. Hesse-Callaway and Greim (1996) suggest that toxicology before the 1970s was largely carried out by those with a pharmacological, or other medical, background, but that its new status as a multidisciplinary specialism requires toxicologists with backgrounds in a broad spectrum of the natural sciences, and a familiarity with the latest techniques in relevant disciplines such as molecular biology, analytical chemistry and immunology.

In some countries, including Britain, the safety evaluation aspect of toxicology has a close link with pathology (Ballantyne, Marrs and Turner 1993C). Indeed Mello (1975) suggests that 'traditionally toxicology has been a sub-speciality of pathology'; the rationale being that toxic effects can usually be defined in terms of tissue changes which can be observed and described by gross (i.e. naked eye) or microscopic examination. Gallo (1996) notes that experimental pathology, though not traditionally thought of as toxicology, evolved during the 1940s, largely from toxicological investigations.

Koeman (1996) suggests that it is based primarily on physiology and pathology, though with links to many other disciplines. Oser (1987) suggests that the most pertinent science in the development of modern toxicology is chemistry, while Freiss (1995) argues that the development of recent quantitative research in toxicology since the 1930s has resulted from the adoption of 'the most advanced techniques and concepts from many evolving areas of the biological sciences'. Frazer (1968) argued that toxicological work was based on biochemistry and experimental pathology. Eesa and Cutkomp (1984), for the specific case of pesticide toxicology,

suggested that it could be regarded as a branch of physiology, though closely allied to pharmacology.

Loomis (1978) suggests that 'toxicology is a multi-disciplinary field, and as such it borrows freely from several of the basic sciences. A knowledge of, and an ability to study, the interactions between chemicals and biologic mechanisms is predicated upon a background in *all* of the basic physical, chemical, and biologic subjects [my italics]. Toxicology borrows freely from chemistry, and more particularly biochemistry. It is dependent upon the knowledge and understanding of physiology. Knowledge of statistics and public health is fundamental to the study of toxicology. Pathology is said to be a part of toxicology, for a harmful effect from a chemical on a cell, tissue, or organism must necessarily manifest itself in the form of gross, microscopic, or sub-microscopic deviations from the normal. The field most closely related to toxicology is pharmacology, for the pharmacologist must understand not only the beneficial effects of chemicals, but also the harmful effects of those chemicals that may be put to therapeutic use.'

An interesting change in views of the nature of the discipline over recent years is shown by two academic departments. The University of Surrey toxicology prospectus [available from www.surrey.ac.uk/SBS/pg_taught_courses/toxicology.htm] suggested in 1999 that toxicology is 'a multidisciplinary subject encompassing pathology, physiology, biochemistry and pharmacology'. In early 2002, this had been modified to 'a science that encompasses a wide variety of biological and chemical disciplines. These include biochemistry, pharmacology, physiology, molecular biology, pathology, immunology and epidemiology'. The brochure for the toxicology programmes of the University of Guelph, Canada, [available from www.chembio.uoguelph.ca/tox] stated in 1999 that it is 'a fairly new discipline, with roots in biology, biochemistry, chemical analysis and statistics. Genetics and nutrition also play important roles.' By 2002, the reference to it being a new science has been dropped, the brochure stating simply that toxicology 'has its roots in ..' the same sciences. These changes of phraseology indicate both the emergence of toxicology as a well-established science in its own right, and the broadening of the scope of disciplines on which it draws.

Ottoboni (1991) states that toxicology was 'born of pharmacology and, until relatively recent years, was considered a subdivision within the science of pharmacology. Pharmacology, of necessity, embraced toxicology because it is neither possible nor practical to study the therapeutic effects to the exclusion of toxic effects.' She

suggests that the 'therapeutic index', an important medical concept being the ratio of the toxic dose to the dose giving the desired therapeutic effect - a larger value indicating, all other things being equal, a safer drug - is an instance of the close relation between the two subjects.

Table 2.1 shows some of the disciplines with which toxicology has been suggested to have links and strong relationships. This is an indicative, rather than a complete list; nor could it be complete, short of a complete enumeration of scientific disciplines bearing in mind the suggestion above that there should be links with all biomedical and chemical science. They are categorised roughly into basic sciences and application areas:

Table 2.1 Disciplines linked with toxicology

basic sciences

epidemiology
pathology
psychology
biochemistry
immunology
pharmacology
physiology
organic chemistry
analytical chemistry
pharmacy
immunology
cell biology
molecular sciences/ molecular biology
genetics
clinical medicine
veterinary science
computer science
statistics

application areas

environmental science / ecology
clinical medicine
occupational health / medicine
industrial hygiene
nutrition / food science

Influence of toxicology on other disciplines

It is evident, as shown above, that a variety of scientific disciplines have affected, and contributed to, the development of toxicology. It is equally true, though perhaps less obvious, that toxicological studies have influenced the development of other disciplines; though, of course, in the case of older work, these studies may not have been regarded as 'toxicology' *per se*. McIntyre (1969), for examples, argues that toxicology studies have had a considerable influence on pharmacology and physiology; two disciplines which, as noted above, have close associations with

toxicology, but usually in the sense of influencing, rather than being influenced, pharmacology often being regarded as its 'parent'. In the case of pharmacology, McIntyre suggests that 'most of the potent life-saving drugs now in use arose as a consequence of the study of toxicology'; for physiology, he argues that 'progress in physiology was slow until forensic toxicology entered the modern era'.

This, he suggests happens in one of two ways. 'Pure' toxicology studies may lead directly to physiological and pharmacological discoveries, while observation of 'toxic side-effects' of new drugs under test may lead to compounds with valuable properties. He gives numerous examples of both of these occurrences. The former includes such examples as:

- Crum-Brown's classic studies of the structure-activity relationships of alkaloids related to curare
- the equally well-known studies of Dale on toxic 'ptomaines', resulting from the putrefaction of meat, which led ultimately to the elucidation of the action of acetylcholine
- the investigation of deaths among cattle fed on sweet clover, which led to the isolation of the pharmacologically interesting dicumerols
- Fleming's discovery of penicillin, initially a toxicological problem

The latter category includes:

- the toxic action of *Brassica* compounds, being tested as antiluetic agents, which led to treatments for goitre
- investigation of side-effects in antihistamine compounds led to development of tranquilizers
- hypoglycaemic effects of antibiotics led to a treatment for some forms of diabetes

McIntyre uses these examples, and others including the early work of Bernard and Magendie, to argue for a careful scientific approach to toxicology testing, by 'teams of highest training in every branch of medical science, all imbued with eagle-eyed vigilance' rather than 'unimaginative and cumbersome regulations'; a clear example of the continuing tensions between the 'scientific' and 'regulatory' approaches to toxicology.

Borzelleca (1994) makes the same points, emphasising the work of Claude Bernard, whom Borzelleca describes as 'an outstanding early physiologist/toxicologist', in the use of curare to study the physiology of the neuromuscular junction. Similarly, Pond (1996) notes that 'since antiquity, the study of toxicology has underpinned and illuminated therapeutics', since the beneficial and harmful effects of a substance lie along a continuum of dose-response action; hence even the most potent toxins, such as botulinum and ricin, may be used in appropriate doses for therapeutic purposes.

Referring to more recent times, Sipes, McQueen and Gandolfi (1997) note that toxicology uses the advances of other disciplines, but also 'toxicology contributes to the advancement of other disciplines by providing chemicals with selective or specific mechanisms of action. These can be utilised to modify biochemical and physiological processes that advance our understanding of biology and the treatment of disease.'

More generally, Gallo (1996) suggests that toxicology is evolving from a 'borrowing science' to a 'seminal discipline seeding the growth and development of several related fields of science and science policy'.

2.2.5 Divisions and sub-disciplines of toxicology

As Eaton and Klaasen (1996) note, the variety of potential adverse effects and the diversity of chemicals in the environment make toxicology a very broad science, and toxicologists are therefore usually specialised to work in one area of toxicology. As a result, toxicology is frequently observed to be divided into a number of divisions, or sub-disciplines. The nature of these divisions vary between authors, and over time. However it is usually based, directly or indirectly, on some classification of toxic agents, or their properties. No single classification is applicable to the whole spectrum of toxic agents, and the variety of the subject matter dictates that a variety of classifications are needed, used singly or in combination. These are discussed by several authors, with Eaton and Klaasen (1996) dealing with it in most detail. Classifications may be based on the role or purpose of toxicologists, on the nature of the toxic substance, or on the characteristics of exposure. These will now be outlined and exemplified.

Boyland and Goulding (1968), noting that 'the word toxicology is of different import according to the context in which it is used - forensic, industrial, clinical, experimental, biochemical, and so on', regarded the subject as divided into four main aspects:

- **analytical toxicology**
- **legal aspects** of poisoning, a part of **medical jurisprudence**
- **clinical poisoning**, including acute overdosage and side-effects of drugs
- **experimental toxicology**, assessing possible hazards from substances in the environment

Loomis (1978) recognised three, rather different, 'principal divisions' within toxicology:

- **environmental**: concerned with the harmful effects of chemicals encountered incidentally, or as a result of environmental contamination, and hence including occupational health, food toxicology, and environmental pollution
- **economic**: concerned with the harmful effects of substances intentionally administered, and including side-effects of drugs,
- **forensic**: dealing with medical and legal aspects, and including clinical toxicology or poisoning

Eaton and Klaasen (1996) recognise three main categories, and three specialist areas, within toxicology. The main categories are:

- **descriptive**: concerned with toxicity testing, providing information for safety evaluation and regulation
- **mechanistic**: concerned with identifying and understanding the mechanisms by which chemicals exert toxic effects
- **regulatory**: deciding, on the basis of information provided by the other two categories, on the risk posed by a substance, and the appropriate legal response

The three specialist areas are:

forensic: a hybrid of analytical chemistry and fundamental toxicological principles, concerned principally with the medicolegal aspects of harmful effects of chemicals

clinical: part of medical science dealing with disease caused by toxic substances, emergency medicine and management of poisoning

environmental: focuses on the impact of chemical pollutants in the environment, particularly on non-human organisms.

ecotoxicology is a specialised aspect, dealing with the impact of toxic substances on population dynamics in an ecosystem.

Some of these sub-divisions amount to specialisms within toxicology, often stemming from the integration of toxicology with other disciplines, as noted above. The most important of these sort of sub-divisions, as assessed from the literature of the field, and from general descriptions, are:

- **general:** dealing with generally applicable concepts and models
- **experimental** or **laboratory:** design and conduct of toxicology research and testing procedures, *in vivo* and *in vitro*
- **clinical** or **medical:** concerned with human poisoning, usually acute - its causes, diagnosis and management
- **occupational:** concerned with adverse effects of chemicals encountered in the workplace
- **industrial:** specific form of occupational toxicology, in the industrial workplace
- **environmental** or **eco:** concerned with effects of toxic pollutants, usually at low level, on all flora and fauna in the environment, as well as on humans
- **aquatic:** specific form of environmental toxicology, dealing with adverse effects of aquatic biosystems from chemicals in water
- **forensic:** concerned with establishing cause of death or injury due to poisoning in humans (or possibly animals), often with reference to legal processes
- **veterinary:** concerned with poisoning of wild or domestic animals
- **product:** concerned with potential harm from chemical substances in any commercial product - assessment of potential harm, and protective measures
- **pharmacological:** specific form of product toxicology, where the product is a therapeutical agent
- **regulatory:** construction and operation of regulations (national, continental, or worldwide) for toxicology assessment for products, particularly mandatory toxicology testing programmes
- **chemical** or **analytical:** dealing with methods of analysis of toxins
- **nutritional** or **food:** harmful effects of foods and food additives / preservatives

Toxicology may also be divided in other ways, which are sometimes also regarded as sub-disciplines or specialisms. Most commonly this is by target organ toxicity, e.g.:

- nephrotoxicology (kidney)
- neurotoxicology (nervous system)
- ototoxicology (ears)
- pulmonary toxicology (lungs)
- cytotoxicology (cells)
- dermatotoxicology (skin)
- hepatotoxicology (liver)
- gastrointestinal toxicology
- cardiovascular toxicology
- immunotoxicology (immune system)
- endocrinotoxicology (endocrine system)
- haematotoxicology (blood)

or by the form of harm caused, e.g.:

- reproductive toxicology
- developmental toxicology
- neonatal toxicology
- embryotoxicology
- teratogenicity
- carcinogenicity
- mutagenicity
- behavioural toxicology

There is some overlap between these, e.g. reproductive toxicology, referring to some harm caused to the reproductive function, might alternatively be regarded as toxicity having the reproductive system as the target organ, while behavioural toxicology may be regarded as the gross result of neurotoxicity.

In some cases, this breakdown may also reflect an overlap between toxicology and another discipline, as in the case of behavioural toxicology, where the overlap is with psychology. Indeed, Hänninen (1985) prefers the term 'toxicopsychology', indicating her belief that psychology is the 'mother discipline' of this area. By contrast, Niesink (1996) describes behavioural toxicology as a 'branch of toxicology'; that which measures, describes, elucidates and predicts neurotoxic effects by using techniques developed in the behavioural sciences. Similarly, Ballantyne, Marrs and Turner (1993C) describe neurological and behavioural toxicology as exemplifying a specific form of

toxicity testing process. (This particular sub-discipline will be discussed in more detail later, as an example of the development of such specialities.)

Other classifications of toxicology may be used, though these are not usually regarded as sub-disciplines. These include:

the route of administration, e.g.:

- peroral toxicity (by mouth)
- percutaneous toxicity (by skin)
- inhalation toxicity (via the lungs)
- parenteral toxicology (other than through the alimentary system)

the type of toxic substance, e.g.:

- pesticide toxicity
- solvent toxicity
- metals toxicity
- animal and plant poisons

the physical state of the toxic substance, e.g.:

- toxicity of gases
- toxicity of dusts

chemical nature of the toxic substance: e.g.:

- toxicity of aromatic amines
- toxicology of halogenated hydrocarbons

mechanism of action, e.g.:

- suhydryl inhibitor
- methemoglobin producer

poisoning potential, e.g.:

- extremely toxic
- very toxic
- slightly toxic

duration of exposure, e.g.:

- acute
- sub-acute

- sub-chronic
- chronic

'type' of toxicity, e.g.:

immediate / delayed

reversible / irreversible

local / systemic

'general' classifications: e.g.:

- irritants and corrosives
- air pollutants
- occupation-related agents
- naturally-occurring toxins

Other subject fields related to toxicology may be noted which do not achieve the status of sub-disciplines. One such is the study of mycotoxins, toxic compounds produced by fungal contamination of foods, whose literature, which extends into agricultural, veterinary, chemical, microbiological and medical journals, has been studied by Datta (1987). This field began as an agricultural problem in 1911, due to contamination of agricultural products, and led to chemical and microbiological investigations. It later established itself as a serious veterinary and medical problem, after poultry fed on groundnut diets began to die in large numbers in the 1960s, and fears for human health were expressed. It finally became regarded as primarily a food science issue. In this case, a subject of study which was originally located firmly within an established field (agriculture) became specialised in its own right, and finally became a heterogeneous field of study in nature, rather than forming a sub-discipline in its own right.

Another example is combustion toxicology, or fire toxicology, the study of the toxic effects caused by substances generated in fires (Hartzell 1996). These are usually constituents of smoke, such as hydrogen cyanide and carbon monoxide. Initial concerns about fatalities caused by inhalation of toxic smoke had been expressed in the 1930s, but the field of fire toxicology is generally considered to have been pioneered by the medical-physiological investigations of JA Zapp, of the US Army Chemical Corps, around 1950 (Zapp 1951). The problem came more to the fore in the 1970s, with much greater use being made of synthetic materials, with unknown and potentially greater toxicity when burnt, in buildings and furnishings. This led to several investigations of the subject by various official bodies, and to legislation, as well as to

a rapid increase in publication, with 65 papers on the topic published in the *Journal of Fire Sciences* alone, between 1983 and 1995 (Hartzell 1996). One of the difficulties of the area, as Hartzell points out, is that fire scientists have often lacked an understanding of the principles of toxicology, while toxicologists have failed to appreciate the physics and engineering principles involved in the study of fires. Despite the efforts and resources put into it, this remains an area between disciplines, with no journals or societies of its own.

2.3 Toxicologists

2.3.1 Toxicology as a profession

Just as toxicology was slow to develop as a scientific discipline, so it is only in recent years that 'toxicologist' has become a recognised profession, or disciplinary label.

Hesse-Callaway and Greim (1996) suggest that the profession of 'toxicologist' stems from the 1970s, when sufficient recruits for toxicology could no longer be found from among candidates with medical, particularly pharmacological, backgrounds. Toxicology had become a specialised discipline, its multidisciplinary nature requiring individuals with a background in a broad spectrum of the natural sciences, and a familiarity with the latest techniques in disciplines such as molecular biology, analytical chemistry and immunology. This situation led to the need for formal training courses in the subject, leading to certification as a toxicologist.

Even so, there still appears to be some reluctance to use the term as the sole indication of professional interests, and disciplinary affiliation. Frazer, writing in 1968, noted that his use of the term 'toxicologist' denoted 'a person who is trained and experienced in the techniques of biochemistry and experimental pathology, who aims to discover whether substances have any toxic potential and to express this in quantitative terms, and who endeavours to explain the mechanism of toxic effects in terms of modern biochemistry'. He contrasts this with what he regards as the 'classical' toxicologist of earlier decades, who was primarily an analyst. Pond (1996) regarded herself 'not .. solely as a toxicologist, rather as a pharmacologist, toxicologist and physiologist.'

2.3.2 Toxicology qualifications

In order to assess the requirements for work as a toxicologist, the job advertisements in the magazine *New Scientist* were examined for the years 1980, 1990 and 2000. Full results for this analysis are included as appendix 2.3.a.

New Scientist is the leading UK weekly printed science magazine, and, over the period covered, has been the single major forum for the advertising of scientific jobs (Universities Advertising Group 2003). Another important source is the journal *Nature*,

but this focuses mainly on academic posts, while *New Scientist* also includes industrial positions (Society for General Microbiology 2002). Due to time constraints, only *New Scientist* was considered in this investigation.

Examining these advertisements gives, so far as is possible, a consistent picture of recruitment to toxicology-related work. The results cannot be exact - they will, for example, be affected by the recruitment practices of organisations, which may change over time - but they should serve to bring out any major changes.

Advertisements which related to toxicology were identified. A focused approach was taken, to keep the study within bounds; advertisements were only included if they used 'toxicology', 'toxicologist' or an equivalent wording in a prominent place in the advertisement. Repeat advertisements were ignored. For each advertisement identified, the organisation, position and requirements of qualification and experience, were noted.

The number of advertisements in each year was as follows:

1980	38
1990	69
2000	63

Results of the changes are presented in table 2.2, as percentages to show comparisons over time more readily. Table 2.3 shows the toxicology sub-fields mentioned, whilst table 2.4 shows changes in the other disciplines mentioned in the advertisements over time.

Table 2.2 Changes in qualifications needed for toxicology jobs over time (%)

	1980	1990	2000
Mentioning toxicology qualifications	0	7	26
Mentioning a sub-field of toxicology	32	36	56
Requiring P/G or medical qualifications	11	12	38
Not requiring degree-level qualifications	26	17	3

Table 2.3 Toxicology sub-fields mentioned in job advertisements over time:

	1980	1990	2000
acute	/	/	/
analytical	/	-	/
biochemical	-	/	/
cellular	-	/	-
chronic	-	/	-
clinical	/	-	/
developmental ¹	/	/	-
eco- ²	-	/	/
forensic	-	/	/
general	/	/	/
genetic ³	/	/	/
immuno-	-	-	/
inhalation	-	/	/
neuro-	-	/	/
regulatory	-	/	/
reproductive	/	/	/
species-specific ⁴	/	/	/
veterinary	-	/	/

(/ present, - absent)

¹ including teratology

² including environmental

³ including mutagenicity

⁴ mammalian, rodent, avian, fish, invertebrate

Table 2.4 Disciplines, other than toxicology, specified in job adverts over time (%s)

	1980	1990	2000
biochemistry	13	17	5
biological sciences ¹	29	36	29
biomedicine ²	8	6	14
chemistry ³	8	13	14
environmental science	-	2	3
pathology	-	2	6
pharmacy	3	4	5
pharmacology	5	9	14
physiology	-	3	-
veterinary medicine	-	2	6
<i>toxicology</i>	0	7	26

¹ including biology, applied biology

² including medical laboratory sciences, haematology, histology

³ including applied chemistry, analytical chemistry

Specification of toxicology as a required qualification has come from nil in 1980 to over 25%, second only to the requirement for very generic 'biosciences'; evidence of the emergence of toxicology as a discipline in its own right. The continued specification of a very broad range of other disciplines (see table 2.4) attests to the

continuing multidisciplinary nature of toxicology. We see toxicology in 1980 as a field of study populated by workers with qualifications, often of sub-degree standard, from a variety of contributory disciplines, and with limited recognition of sub-disciplines within it. By 2000, it has become a virtually all-graduate profession, with a large demand for post-graduate qualifications and for formal training and qualification in toxicology, and with a majority of posts specifying a sub-discipline.

The main trends over time are:

- increase in specification of toxicology qualifications/formal training, from nil to over 25%
- increase in requirement for P/G qualifications, and virtual disappearance on non-degree posts
- increase in specification of sub-fields

2.3.3 Education for toxicology

Formal education in toxicology as a subject in its own right is a relatively recent phenomenon. Loomis (1978) noted that (in the late 1970s) 'in America and Western Europe, the teaching of toxicology as a science is accomplished only in a fragmented fashion'. In medical schools, the topic was taught as part of pharmacology, focusing on harmful effects of therapeutic agents in humans, and possibly including the treatment of accidental poisoning; effects of chemicals on tissues might be covered in pathology courses. Courses in public health and preventive medicine usually included some aspects of pollution, and occupational exposure. 'A few' schools of pharmacy taught the detection and identification of xenobiotics. Veterinary schools usually dealt with harmful effects of chemicals on pets and livestock, while departments of oceanography and fisheries might include study of toxicity to marine life.

The major change, contemporaneously with other developments in the disciplinary structure of toxicology, stems largely from the 1960s. Borzelleca (1994) and Gallo (1996) review the establishment of toxicology training programmes in US academic institutions during the 1960s and 1970s, most notably at the University of Kansas Medical Centre and at the University of Rochester NY.

Describing the situation in the USA in the 1990s, Gallo (1996) remarks that toxicology graduate programmes may be found in medical schools, schools of public health, and of pharmacy, as well as in environmental sciences and engineering.

Undergraduate programmes in toxicology are now being offered, and toxicology features in the curricula of 'liberal arts' undergraduate schools. Wexler (1990) comments that over 100 US universities offered graduate programmes in toxicology.

In the clinical toxicology area, Wolf and Hamilton (1994) describe a toxicology component in the training of physicians specialising in emergency medicine. This one-month course includes experience in a poisons control centre, laboratory experience in toxicology screening, work with patients, case discussions, and literature discussions. There is a supplementary course of guided reading, offering a rapid overview of some general principles, followed by a survey of the toxicity of a wide range of drugs, household products, naturally occurring substances, and venomous creatures, with general and specific treatments.

Vale and Meredith (1993) recommend medical toxicologists should have a broad training in either internal medicine, paediatrics or emergency medicine, combined with a specialist training in medical toxicology. They emphasise the importance of a knowledge of pathology and of forensic and analytical techniques for the medical toxicologist, as well as an understanding occupational and environmental aspects, and an appreciation of the biochemical and toxicokinetic background. In addition to postgraduate degrees and diplomas in toxicology they see the need for short-term 'refresher' programmes, for physicians and poison centre staff.

In some areas of toxicology, accreditation following training is of the essence; particularly, as noted earlier, in forensic toxicology, with its legal implications. Niyogi (1980) describes the programme of training and certification set up by the American Board of Forensic Toxicology during the 1970s, and compares it with certification by boards in other areas, including clinical and veterinary toxicology, and industrial hygiene. Wolf and Hamilton (1994) suggest that toxicology training for physicians be supervised by a 'board certified toxicologist'. Hesse-Callaway and Greim (1996) comment on the internationally recognised diploma of the American Board of Toxicology, and describe the steps being taken by various European countries during the 1990s to move towards similar formal accreditation.

Toxicology courses in the UK: Undergraduate

The 1999 official course listing for UK undergraduate admissions (UCAS 1999) lists just 4 courses including 'toxicology' in their title. All are listed in the 'pharmacy and pharmacology' section:

BSc	Toxicology	Napier University (Edinburgh)
BSc	Environmental toxicology	Anglia Polytechnic University
BSc	Applied biology (toxicology) (Leicester/Milton Keynes)	De Montford University
BSc	Pharmacology with toxicology	Kings College London

For comparison, an equivalent publication of 30 years earlier, Cornmarket's *Which University* (Labovitch 1967), lists no UK undergraduate course mentioning toxicology in its title. Indeed, the only mention of the subject at all is of 'selective toxicity' as an option in the pharmacology course of Chelsea College, London University.

The equivalent figures for other subject areas in 1999, are as follows:

Biochemistry	69
Pathology	8
Pharmacology	25
Physiology	28

All mentions of 'pathology' in course titles were included, but the other subjects were restricted to single subjects: if combinations of subjects had been included, the numbers would have been considerably higher.

It is clear that toxicology has not gained status as a subject for undergraduate study in the UK, by comparison with similar subjects, such as biochemistry, pharmacology and physiology. It seems similar in this respect to pathology.

Toxicology courses in the UK: Postgraduate

Hobson's Guide to Graduate Studies (Hobson 1999) lists 10 taught postgraduate courses in some aspect of toxicology. Most are in the 'pharmacy and pharmacology' section, but some are in genetics, medical sciences, and environmental sciences. Other courses, e.g. occupational health and medical chemistry, are noted as including some toxicology. The 10 specifically toxicology courses are:

MSc	Ecotoxicology	Ulster University
MSc	Toxicology	Ulster University
PgDip	Genetic toxicology	Swansea University
MSc	Molecular pathology and toxicology	Leicester University
MSc	Toxicology	Birmingham University
MSc	Pharmacology and toxicology	Hertfordshire University
MSc	Toxicology	Hertfordshire University
MSc	Toxicology	Imperial College London
MSc	Toxicology / Applied toxicology	Surrey University
MSc	Applied Toxicology	Portsmouth University

For comparison, the numbers of taught postgraduate courses in the similar subjects which were more popular as undergraduate courses are:

biochemistry	9
pharmacology	5
physiology	13

These include all variants of the name, but not necessarily all specialised aspects, and certainly not all interdisciplinary courses including some aspect of these subjects. By comparison, toxicology seems a much more 'popular' topic for teaching at postgraduate level.

Although it not possible to carry out a similar process of comparing numbers of courses worldwide, examination of printed listings and of web-based information suggests a generally similar picture. Toxicology is not generally taught as an undergraduate level subject, though toxicology material may appear in a variety of other courses: postgraduate level teaching in toxicology, building on an undergraduate education in one of the relevant biological sciences, is a popular option worldwide.

Summary of toxicology education

Information on a number of courses and training programmes worldwide, which were considered to typify toxicology education at present, were obtained from the institutions' web sites and their syllabi analysed. Full copies of the syllabi are available as appendix 2.3.b.

- Napier University, BSc Toxicology

[www.napier.ac.uk, visited 7/1/2002]

- King's College London, BSc Pharmacology with Toxicology
[www.kcl.ac.uk/depsta/biomedical/pharmacology/index.html, visited 7/1/2002]

Examples of UK undergraduate courses in toxicology, alone and in combination with another subject.

- Surrey University, MSc Toxicology and MSc Applied Toxicology
[www.surrey.ac.uk/SBS/pg_taught_courses, visited 7/1/2002]

An example of a UK postgraduate toxicology course.

- University of Rochester, New York
[www2.envmed.rochester.edu/envmed/tox, visited 7/1/2002]
- North Carolina State University
[www.cals.ncsu.edu/toxicology/Graduate_study.htm, visited 7/1/2002]

US examples of postgraduate study in toxicology.

- University of Guelph
[www.chembio.uoguelph.ca/tox, visited 7/1/2002]
- University of Western Ontario
[www.pharmtox.med.uwo.ca/Grad, visited 7/1/2002]

Canadian examples of toxicology courses at both undergraduate and postgraduate level.

- Swiss Postgraduate toxicology education
[www.chtox.ch/modules-all.htm, visited 7/1/2002]

An example of a European in-service training course in toxicology at postgraduate level.

From this survey, several comments may be made. The educational system which has developed for toxicology reflects some of the basic features of the science, discussed earlier. Its development also runs parallel to the development of the discipline's information and communication systems.

Toxicology, as a discipline in itself, is taught exclusively at the level of higher education. More than this, it is clear that at undergraduate level it is very much a minority subject, compared with subjects such as biochemistry. At postgraduate level, the subject comes into its own, and the number of courses available compare more

closely with similar disciplines. It is taught in different sorts of departments - rarely one of toxicology alone - and from different perspectives, reflecting the multi-faceted and pervasive nature of the subject. Graduate study, in particular, shows in its curricula the wide variety of material which comes under the heading of 'toxicology'. Conversely, its appearance in liberal arts programmes in the USA reflects its significance outside the scientific specialisms. The legal implications of toxicology are seen in the various formal accreditation schemes, which accompany or parallel study for academic qualifications.

The nature of toxicology as a 'borrowing science' is seen clearly in its curricula. At undergraduate level, students are required to study extensively across the basic biological science, usually with a concentration on toxicology's 'parent' disciplines - pharmacology, physiology and pathology. At postgraduate level, the same is not the case, concentration being on toxicology-specific material, but a knowledge of the basic sciences is required for admission to graduate study in toxicology. The reverse side of this aspect, the contribution of toxicology to other disciplines, can be seen in various joint programmes of study, and in toxicology modules contributing to other subject degrees.

Education in this subject is a recent phenomenon, appearing only in the 1960s and becoming extensive in the following decade. In this respect, it closely parallels the emergence of toxicology-specific information services, described later. As an academic discipline emerges, education and information systems develop side-by-side, as part of the intellectual support systems; this is seen particularly clearly for toxicology.

2.3.4 Learned societies for toxicology

In this section, the role of learned societies and professional associations in toxicology will be examined, with particular reference to information and communication. The role of societies in the development of sub-disciplines and specialisms will be considered later in this chapter.

Societies as journal publisher/sponsors

The most conspicuous role for learned societies in the information chain has been as publishers on journals.

The list of 236 'active' periodicals related to toxicology, identified in Ulrich's International Periodicals Directory (1999), was examined, to find information on the publisher (PY field) and sponsor (SP field). Publishers were categorised, crudely, since only the name was available, as:

commercial	177
society	21
other	38

where 'other' includes government agency, academic institute, and research institute. The predominance of commercial publishers is clear. However, 41 of the periodicals published by commercial organisations had a society named as a sponsor. This is likely to be a minimum value, since some sponsorship may be less formal, and hence not indicated by a directory such as Ulrich's. Therefore, at least 25% of toxicology-related periodicals have some input from a society, as publisher or sponsor; the sponsor role now being more significant than that of publisher *per se*.

Examples of publication by a society are:

Journal of Toxicologic Pathology
Japanese Society of Toxicologic Pathology

Archives of Toxicology, Kinetics and Xenobiotic Metabolism
Serbian Medical Society; Toxicology Section

Environmental Toxicology and Chemistry
Society of Environmental Toxicology and Chemistry

and of sponsorship by a society:

Human & Experimental Toxicology; an international journal
Published by Stockton Press
Sponsored by the British Toxicology Society

Cell Biology and Toxicology
Published by Kluwer Academic Publishers
Sponsored by the Genetic Toxicology Association

Mutagenesis

Published by Oxford University Press

Sponsored by the UK Environmental Mutagen Society

Japanese Journal of Toxicology

Published by Yakugyo Jiho Co., Ltd.

Sponsored by the Japanese Association of Clinical Toxicology

Other examples are given later, in the sections dealing with activities of specific societies.

This follows the general trends in scientific publishing over the past 50 years. Meadows (1974, p 87) notes 'the most obvious change in the mode of publication of scientific journals since the Second World War has been the sudden growth in importance of commercial (as distinct from society) journals', which he sees as paralleling the change from largely personal to largely library subscription. Grogan (1970, p 106), writing of essentially the same period, suggests that '.. societies have lacked the financial resources (and possibly the commercial enterprise) to initiate further titles, despite the vast increase in the amount of research work in need of a literary outlet. Into the breach have stepped scientific and technical publishing houses [and] we now have the phenomenon of several hundred primary research journals, a significant sector of the pattern of scientific communication, appearing apparently successfully as a commercial undertaking'.

A decade later, Singleton (1981) found, in a survey of 625 British learned societies in all subject areas, for which information was obtained on 495 societies, that only 18% had no journal, 72% had one, and 10% more than one. 30% of the societies with journals co-operated with publishers (usually commercial publishers), the proportion being higher for science: although Singleton does not give the proportion in his paper, it can be calculated as approximately 47%. The equivalent figure for the toxicology journals above is 66%. This, taken, alongside the fact that only 25% of journals can be identified in any way with society, may be taken as (admittedly crude) evidence for the continuation of the trend towards publication being undertaken by organisations other than societies, and the societies' role being more that of a sponsor.

Nonetheless, the fact that at least a quarter of periodicals, including some of the most highly regarded and best known, are associated with a society or association,

suggests that these organisations are still playing a significant role in this aspect of the communication of toxicology information.

Overview of toxicology societies

The activities of some exemplar societies were analysed. The examples were chosen to represent different aspects of toxicology, and are not comprehensive. Full details of the societies, taken from their web sites, are included as appendix 2.3.c.

Toxicology generally

- International Union of Toxicology
- Society of Toxicology
- American College of Toxicology
- British Toxicology Society

Sub-disciplines of toxicology

- Teratology (looking at a range of societies)
- Society of Forensic Toxicology
- In vitro toxicology

Note that societies in sub-disciplines are also discussed later, in the section 2.4.3, dealing with behavioural toxicology, and its comparison with other specialisms.

Toxicology in a wider context

- Society of Environmental Toxicology and Chemistry (SETAC)

It is clear that the development of the communication and information systems of toxicology is closely linked to the development of the discipline itself. Toxicology societies and associations are an integral part of this process, since they contribute both to the development of toxicology, and toxicologists, and to the information transfer process. This is emphasised by the involvement of many societies in educational activities, and in public awareness campaigns, reflecting the other important stimuli to information system development.

All of the societies considered here were founded between 1960 and 1980, with the one exception founded in 1994, after a long period of informal collaboration. In this, they are typical of the whole societal structure of toxicology, which came into being largely during the 1960s and 1970s, contemporaneously with the development of the

educational programmes and information systems and services discussed in other sections.

All the societies considered here, and no doubt all others, have information and communication as a central part of their purpose. All have some form of 'information product': usually traditional, and mixing both formal and informal communication - journals, newsletter, bulletins, membership lists, conference proceedings, monographs, etc. - but some using new technology, and mainly for informal communication - electronic discussion groups, links to members' web pages, interactive membership lists, etc.

Societies and associations within toxicology operate at all geographical levels - international, national and regional - and enthusiastically join together creating still more diverse groupings for meetings and events. The use of new communications technology, while clearly simplifying the making of links across large distances and national boundaries, does not seem to be diminishing the desire for face-to-face contact between toxicologists in a geographically defined region. On the contrary, some of the initiatives noted above suggest that a major use for new ICTs will be facilitating such contacts. Similarly, training activities are supported by several societies, and these are very much 'hands on' events; a reminder that the practice of toxicology is still an activity requiring tacit 'know how', and not to be conducted entirely in cyberspace.

The continuing perceived importance of face-to-face contact is shown by the tenacity with which all societies continue to hold conferences, symposia, workshops, and other forms of meeting. Again, new ICTs seem, for the present at least, to be used in support of, rather than as an alternative to, such 'traditional' styles of meeting.

In a manner analogous to their geographical diversity, the societies operate across a range of specificity of interest, from the very general to the highly specific, mimicking, and helping to establish, the network of sub-disciplines and inter-disciplines which exists under the general heading 'toxicology'. This diversity is complemented by the way in which the societies bring together toxicologists from the spectrum of working environments; principally academic, governmental and commercial concerns.

For the purpose of this study, the most interesting aspect of the societies' activities is the way in which their information and communication activities, which are evidently central to their existence, are affected by new ICTs, with respect to both formal and

informal communication.

2.4 Information 'support systems' for toxicology

The previous sections have shown how the development of the science itself has been accompanied by publications, emerging educational systems, and professional societies and institutions. This section examines the synergistic growth of toxicology information and communication in parallel with the discipline and its infrastructural agents.

2.4.1 Evidence of disciplinary growth

The growth and development of toxicology as a scientific discipline has been accompanied by the usual intellectual support systems. Ballantyne, Marrs and Turner (1993B, p xi, 1993C p 5) identify the changes as:

- an expansion of the population calling themselves professional toxicologists
- an increase in the number of units and establishments devoted to toxicological investigations
- establishment of a private industry devoted to toxicology testing and consultation
- provision of courses at undergraduate and graduate levels dealing with general and special areas of toxicology
- the formation of many learned societies, professional organisations, and certification boards devoted to general and specialist aspects of toxicology
- a proliferation of publications on toxicology and its sub-specializations
- the appearance of a number of journals devoted to general, special and applied toxicology
- a proliferation of abstracting services related to toxicology information
- a dramatic increase in the number of textbooks and monographs devoted to general and special aspects of toxicology

Clearly, most of these have some relevance, direct or indirect, to information and communication systems. The first three points indicate a growth in the number of individual and organisational producers and users of information. The educational institutions, as well as supporting the first three points, produce a good deal of information directly, in the form of teaching material, and published research, as well as libraries and similar facilities: the impact of education institutions has become

greater in recent years, due to the impact of the Internet . The societies and organisations are themselves often active in publishing, library provision and other information-related activities. The final four points refer directly to information products.

A specific example of the synergy between the development of a discipline and the development of its information and communication systems, is given by Niyogi (1980), in his survey of the development of forensic toxicology in the USA. He shows how the early progress of the discipline was fostered, first by monographs and treatises brought in from abroad, then, from the mid-19th century by similar works written by American scientists; and how the establishment of the discipline was directed by the launching, or re-focusing, of journals, by the birth of training and accreditation programmes, and by the setting up of national and international societies.

Similarly, Hamilton (1943) notes that the establishment of industrial medicine as a recognised branch of medicine in European countries, led to the creation of an extensive literature on toxicological dangers to industrial workers and methods of protection; lacking such a speciality in the USA, that country's literature contained little mention of the topic.

2.4.2 Historical perspectives

This section is divided into three parts, taking a date of 1949, fifty years prior to writing, as a convenient divider. Initially, some significant aspects of the development of toxicology information systems prior to that date are considered; then the literature of that time is analysed. Finally, more recent developments are reviewed.

The discussion is selective rather than comprehensive, and does not attempt to repeat all points made in earlier sections, nor in other writings on the topics; see, for example, Kissman and Wexler (1985), and Wexler (1990).

Toxicology information systems pre-1949

The early development of toxicology information is distinguished by the long standing interest in the 'art of poisoning'. The early written descriptions of poisons and antidotes, from ancient cultures, have been exemplified earlier in this chapter.

From the beginnings of the science of toxicology in the sixteenth century to well into the nineteenth century, the only significant means for the communication of information was the monograph, and precursors to the modern textbook, such as those of Grevin, Fontana, Orfila, Bernard.

As stated earlier, the first recognisable toxicology text, Orfila's '*Traité des Poisons*', was published in 1814-15. Although toxicological work featured in the communication system for medical information which developed during the nineteenth century, it was not until the end of the century that a substantial toxicology literature developed, largely in the form of manuals describing both experimental methods and the effects of large numbers of substances, and published mainly in German (Koeman 1996). Holmstedt and Liljestrand (1981) point out the importance of the textbooks written during the late 19th century by authors such as Lewin and Kobert, which encapsulated most of the data then known to the science.

'The erudition of these men encompassed so much that nobody living today can hope to achieve a similar profound knowledge of all aspects of toxicology' (Holmstedt and Liljestrand 1981, p 354).

The first journal devoted to toxicology, the German *Fuehner-Wieland's Sammlung von Vergiftungsfaellen* (later *Archiv für Toxicologie*), was launched in 1930. Early journals devoted largely, though not wholly, to toxicology were the Russian *Farmakologiya i Toksikologiya* in 1938 (Mashkovski 1988), and the Danish *Acta Pharmacologica et Toxicologica* in 1945, the latter being the first English language journal of the subject; the continuing close link between pharmacology and toxicology is evident. Prior to the introduction of these specialist resources, toxicological work was published in general scientific or medical journals, or in journals relating to the application of toxicology, such as the *Journal of Industrial Hygiene*, which commenced publication in 1918.

Scientific conferences, which became a regular feature of professional life during the late nineteenth century, were an important stimulus to the developing field. Hamilton (1943), for example, notes the importance of the International Congress on Occupational Accidents and Diseases in communicating information on industrial toxicology in the early years of the twentieth century. However, there were no learned or professional societies devoted to toxicology *per se*, nor any formal educational courses specialising in the subject.

1949; the toxicology literature of fifty years ago

An interesting insight into the literature of toxicology in the mid-twentieth century is given by an examination of the Catalogue of H.K. Lewis's Medical, Scientific and Technical Lending Library, The edition examined was 'revised to December 31st 1949' and published in 1950.

Lewis's Library, founded in 1848, was one of the most significant libraries for medicine and allied subjects for users in Britain and its Empire. It provided a reading room at its Bloomsbury premises, and lent books to its subscribers, who are noted in the catalogue as 'individuals, book clubs, medical and scientific societies, research departments of industrial firms, etc., in all parts of the world'.

The Library, and hence its catalogue, included 'all works of any importance, English, American and Foreign (when translated), in Medicine and Science generally, as well as a wide range of technical works'. Every book in the Library was 'the latest revised edition. On publication of a new edition (with revisions) all copies of the previous edition on the shelves are immediately withdrawn, and copies coming back from subscribers are not returned to the shelves ... books for which there is no demand, and text-books which have passed out of date, are withdrawn from time to time.' Historical works were not included, but 'many monographs and standard works now out of print', were provided.

The catalogue at this date included approximately 27,000 titles. Four periodicals - *British Medical Journal*, *Lancet*, *Nature* and *Clinical Journal* - were taken, as were 51 annual reports and yearbooks, but none specifically devoted to toxicology.

This catalogue gives a good snap-shot of the monograph literature of the time, which seems likely, from the criteria quoted above, to be reasonably comprehensive, and to have included all aspects of toxicology.

In order to identify toxicological works, the index to the catalogue was consulted. This has a set of subject headings devised by Lewis's, and gave very brief details of the items listed under the heading. The catalogue itself was then consulted, and relevance judged from the title. Although this was not an exact process, because of the use of idiosyncratic subject headings, with very limited cross-referencing, and because of the difficulty is deciding content of books from a title, it still gives a reasonable assessment of the extent and nature of the coverage of toxicology.

'Toxicology' itself did not have a subject heading in Lewis's scheme. The main subject headings giving access to toxicology material were:

- Forensic Medicine and Toxicology
- Poisons and Poisoning
- Toxins

The items found fall into several general categories, accepting that there is overlap between them; they are shown in table 2.5:

Table 2.5 Toxicology items from Lewis's catalogue 1950

General Toxicology and Poisons

Toxicology, WD McNally, 1937
 Toxicology, WA Pearson, 1932
 Toxicology, or the effects of poisons (3rd edn.), FP Underhill, 1936
 Manual of toxicology (15th edn.), AH Brundage, 1926
 Manual of toxicology (2nd edn.), RA Witthaus, 1911
 Poisons: their effects and detection (5th ed.), AW Blyth and MW Blyth, 1920
 Poisons parade, WF Boos, 1940
 Poisons, their properties, chemical identification, symptoms and emergency treatments, VJ Brookes and HN Alyen, 1946
 Malay poisons and charm cures, JD Gimlette, 1929
 Poison, the history, constitution use and abuses of poisonous substances, H Glaser (trans. M Wolff), 1937
 Poison mysteries in history, romance and crime, CJS Thompson, 1923
 Poison mysteries unsolved, CJS Thompson, 1937
 Poisons and poisoners, CJS Thompson, 1931

Forensic Toxicology

Legal medicine and toxicology (2nd edn.), F Peterson, WS Haines and RW Webster, 1923
 Manual of medical jurisprudence and toxicology (5th edn.), WGA Robertson, 1925
 Aids to forensic medicine and toxicology (12th edn.), JH Ryffel (ed.), 1949
 Synopsis of forensic medicine and toxicology (2nd edn.), EWC Thomas, 1945
 London Hospital lectures in forensic medicine and toxicology (3rd edn.), FJ Smith and G Jones
 Legal medicine and toxicology, RW Webster, 1930
 Handbook of medical jurisprudence and toxicology (8th edn.), WA Brend, 1941
 Medical jurisprudence and toxicology, WD McNally, 1939
 Forensic medicine and toxicology (6th edn.), JD Mann and WA Brend, 1922
 Textbook of medical jurisprudence and toxicology (10th edn.), JP Modi, 1949
 Legal medicine and toxicology, RL Emerson, 1909
 Legal medicine and toxicology (2nd edn.), TA Gonzales, M Vance and M Helpen, 1940
 Buchanan's textbook of forensic medicine and toxicology (9th edn.), JEW MacFall, 1925
 Medical jurisprudence and toxicology (8th edn.), J Glaister, 1945

Toxicology in warfare

Lethal war gases, physiology and experimental treatment, FP Underhill, 1920
 Medical aspects of mustard gas poisoning, AS Warthin and CV Weller, 1919

Clinical and drug toxicology

Clinical toxicology (2nd edn.), CH Thienes and TJ Haley, 1948
 Clinical toxicology, E Leschke, 1934
 Treatment of acute poisoning, HL Marriott, 1935
 What to do in cases of poisoning (15th edn.), W Murrell and HG Broadbridge, 1944
 Manual of pharmacology and its applications to therapeutics and toxicology (7th edn.), T Sollmann, 1948
 Handbook of materia medica, toxicology and pharmacology (4th edn.), FR Davison, 1949

Analytical toxicology

Laboratory manual for the detection of powerful and poisonous drugs (6th edn.), W Autenreith, 1928
 Poisons, their isolation and identification (2nd edn.), F Bamford, 1947

Analytical chemistry of industrial poisons, hazards and solvents (2nd edn.), MB Jacobs, 1949

Industrial toxicology

Industrial toxicology, LT Fairhall, 1949

Gas poisoning in mining and other industries, J Glaister and DD Logan, 1914

Industrial toxicology, A Hamilton, 1934

Industrial toxicology, A Hamilton, RT Johnson and HA Christian, 1945

Industrial poisons in the United States, A Hamilton, 1925

Industrial toxicology, D Hunter, 1944

Toxicology and hygiene of industrial solvents, KB Lehmann and F Flury (eds.), (trans. E King and HF Smyth), 1943

Toxicity of industrial organic solvents, E Browning, 1937

Food toxicology

Food poisoning (2nd edn.), GM Dack, 1949

Food poisoning (2nd edn.), EB Dewberry, 1947

Food poisoning and food-borne infection (2nd edn.), EO Jordan, 1931

Food poisoning and food infection, WG Savage, 1920

Toxicology of specific substances

Lead poisoning, JC Aub et. al., 1926

Lead poisoning, A Cantarow, 1944

Lead poisoning and lead absorption, TM Legge and KW Goadby, 1912

Chronic nephritis and lead poisoning, LJJ Nye, 1933

Carbon monoxide asphyxia, CK Drinker, 1938

Fluorine intoxication, K Roholn, 1937

Toxicology of plants on South Africa, together with a consideration of poisonous foodstuffs and fungi, DG Steyn, 1934

Pharmacology and Toxicology of Uranium Compounds, C Voegtlin and HC Hodge (eds.), 1949

Toxins and Venoms

Ergot and ergotism, G Barger, 1931

Venoms, venomous animals and antivenomous serum treatment, A Calmette, 1908

Toxins, and venoms and their antibodies, E Pozzi-Escot (trans. AI Cohn), 1907

Toxins and antitoxins, C Oppenheimer (trans. CA Mitchell), 1906

Legal aspects

Pharmacy and Poisons Act (1933) Explained, H Glyn-Jones, 1933

The predominance of clinical treatment of acute poisoning, and the forensic applications of toxicology, are evident from the items listed. Missing are the environmental and drug safety aspects of the subject, and the specialisms and sub-disciplines, all of which play a large part in more recent publication patterns.

The field of industrial toxicology was clearly emerging with its own specialised literature at this time. It is interesting to note Browning's text on toxicity of industrial solvents. By the late 1980s, this remained a standard work, though by then expanded to four volumes, no doubt costing considerably more than the 7s6d (0.375 pounds sterling) quoted in 1949.

There is an evident reliance on standard texts, many running into numerous editions, which is still a feature of medical publication today. Older works are still included, and in view of the introductory comments in the catalogue, quoted above, this indicates that older material was still regarded as valuable. Several works are translated

(though from which language can only be guessed), indicating an interest in non-English material.

Beyond the monograph literature, there was, at this date, still only a handful of journals specialising in toxicology, and these largely linked with pharmacology, as noted above. The first American journal dedicated to toxicology, *Toxicology and Applied Pharmacology*, which Gallo (1996) refers to as the 'flagship journal of toxicology' was not launched until 1959. The Society of Toxicology was founded shortly afterwards, in 1961, and adopted the journal as its official publication.

Toxicological material would have been covered by the major disciplinary secondary services, particularly Index Medicus and Chemical Abstracts, but no specialised secondary services were then in existence. Nor were there any equivalents of the modern data compilations or extensive technical report series. This situation, in fact, lasted until the late 1960s (Kissman and Wexler 1985).

No specialised educational curricula devoted to toxicology were in existence, and none of the toxicology societies of the present day had been founded.

Toxicology information systems post-1949

The driving forces behind the growth and development of toxicology in the past 50 years may be summarised as:

- exponential increase in the number of synthetically produced industrial chemicals
- large increase in the number and variety of new drugs and other medicinal preparations and devices
- mandatory testing and associated regulations for chemicals used commercially, domestically and medicinally
- enhanced public awareness of potential chemical hazards to humans, animals and environment
- greater extent of litigation, relating to occupational exposure, environmental damage, and product safety concerns
- enhanced scientific knowledge and technical capabilities, making possible new forms of research and testing

These factors have led to an increase in the growth rate of toxicology knowledge, and a corresponding increase in the number of information products designed to communicate that knowledge.

Kissman and Wexler (1985) summarise this well: 'the sheer volume of toxicological literature and data, generated because of research, testing, legislation or otherwise, is the immediate motivating factor for new information systems design'.

The expansion in toxicology information is described by Deschamps and Morgan (1993) as an 'information explosion', a 'plethora of information', and an 'avalanche of toxicology literature', in terms both of raw data and of evaluated concepts and knowledge. This, in turn, has contributed to the development of specialisms within toxicology. It has also contributed to a tension between the academic development of toxicology as a science, and the practices of toxicity testing, risk assessment and regulation.

All of these factors have placed strong and unusual demands on the information systems supporting the communication of toxicology knowledge.

The most evident result has been the expansion in the number of journals devoted to the topic. Wexler (1990) commented on the 'steep rise in the number of journals devoted to toxicology in general and to specialized areas within the subject' during the 1960s, 70s and 80s. This, in fact, seems to be so.

In order to get a rough indication of the rate of increase over time of toxicology periodicals, the 236 active toxicology-related periodicals identified from Ulrich's International Periodicals Directory in the previous section, (societies as journal publisher/sponsors), were RANKed (Dialog command) by year of first publication; this information was available for only 205 of the records. Taken together with the fact that this ranking will not include periodicals which have ceased publication (rather than simply changing name etc.) this means that the results are indicative, rather than comprehensive. The ranking is shown in table 2.6. A similar RANKing by decade is shown in table 2.7.

Table 2.6 RANKing of toxicology periodicals by year of first publication:

No	Year
1	1998
2	1997
5	1996
4	1995
3	1994
7	1993
11	1992
9	1991
2	1990
6	1989
11	1988
8	1987
8	1986
6	1985
7	1984
4	1983
7	1982
11	1981
8	1980
7	1979
5	1978
6	1977
4	1976
5	1975
3	1973
5	1972
4	1971
2	1970
1	1969
1	1968
3	1967
1	1966
2	1965
2	1964
1	1963
4	1962
1	1961
4	1959
3	1958
3	1957
2	1955
1	1954
4	1950
1	1948
3	1947
1	1944
1	1938
1	1930
1	1926
1	1922
1	1907
1	1873

Table 2.7 Ranking by the numbers of new periodicals in each decade:

1990s (to date)	44
1980s	76
1970s	41
1960s	16
1950s	17
pre-1950	11

The earliest toxicology journals were published in the 1930s. The earlier journals shown in table 2.6 are those not devoted to toxicology specifically, but containing some toxicology material, e.g. Naunyn-Schmiedebergs Archiv fuer Pharmakologie und Experimentelle Pathologie (1873), and Pharmaceutica Acta Helvetiae (1926). Examination of the records from Ulrich's International Periodicals Directory suggests that up to the end of the 1960s, the growth was almost entirely in 'conventional' scientific journals, dealing either with toxicology *per se*, or with the subject as part of a wider remit. From then on, the nature of the material becomes more diverse, as exemplified by the 11 new periodicals introduced in 1981. These are a mix of several kinds of periodical:

journals of toxicology, general and specific

- Journal of Applied Toxicology
- Human Toxicology
- Aquatic Toxicology
- Courtroom Toxicology

journals of broader scope, including toxicology

- Progress in Pesticide Biochemistry and Toxicology
- Regulatory Toxicology and Pharmacology
- Journal of Environmental Pathology, Toxicology and Oncology

journals of other disciplines, including some toxicology

- Drug Development Research
- Trends in Analytical Chemistry

information from regulatory agencies

- Toxic Substances Control Act - Test Submission Database

information from other institutes

- CIIT Activities (Chemical Industry Institute of Toxicology)

The smaller numbers for 1997 and 1998 may reflect the time lag in the appearance of new periodicals in the directory.

Table 2.7 shows a steady growth through the 1950s and 1960s, which doubles in each of the next two decades, then an indication of a slowing during the 1990s. However, predictions for the number of 'toxicology journals' around 1990 has been estimated at 'more than 100' (Kissman and Wexler 1985), 125 (Wexler 1990), and 'over 120' (Gallo 1996). These estimates will be examined in chapter four of this thesis.

As well as scientific and academic journals, other periodical sources became of importance for toxicology during this period (Wexler 1990), because of the increasing economic and social importance of the subject: these include trade journals, scientific and general magazines, newsletters and newspapers.

Secondary services developed to match the increased volume of primary material. A major impetus to this was a 1966 report of the US President's Science Advisory Committee on toxicological information, which led to the establishment of the Toxicology Information Program at the National Library of Medicine (Kissman and Wexler 1985). This program has developed a number of widely used secondary services, including the Toxline bibliographic database (1972) and Toxicology Data Bank factual/numeric database (1978). Other data compilations produced at the same period were those of the Environmental Mutagen and Teratogen Information Centres, EMIC and ETIC respectively. Data compilations produced by the US Environmental Protection Agency, National Institute for Occupational Health and Safety, and other agencies, continue to be valuable resources for toxicology information. Most of these were set up in response to environmental and safety legislation, the best known example being the Toxic Substances List, the predecessor of the Registry of Toxic Effects of Chemical Substances (RTECS), which was established in 1971, as a response to the US Occupational Safety and Health Act of 1970.

Other developments in secondary services in this period included the establishment of new and specialised bibliographic services, e.g. Toxicology Abstracts, (Cambridge Scientific Abstracts), and the creation of separate toxicology sections within existing sources, such as Chemical Abstracts. CAB Abstracts, (Commonwealth Agricultural Bureau) was set up in 1972, and included a toxicology section. In 1977, the UK Health and Safety Executive (set up in 1974) launched HSELine, a database covering aspects of health and safety at work.

The 1966 report referred to above, also raised concerns that are still of relevance today, and discussed in chapters 6 and 7 of this thesis; particularly the need for computerised files of toxicology information, as widely accessible as possible, and the problem of accessing information in unpublished reports and the internal files of commercial organisations.

Monograph and textbook publication also increased during this period. As toxicology became established as an academic subject, initially as a part of a course or department with wider subject scope, a larger number of specialist books were

produced. Examples of these are Albert's *Selective Toxicity* (1951), which presented for the first time a concise documentation of site-specific toxicity, and which has subsequently appeared in several editions. DuBois and Geiling's *Textbook of Toxicology* (1959), and Loomis' *Essentials of Toxicology* (1968), which has also appeared in several editions. Wexler (1990) lists other examples.

Borzelleca (1994) suggests that toxicology became firmly established as a discipline in its own right about 1970, with a consequent need for textbooks covering the whole of the subject, several texts being available, but none entirely adequate. He identifies Casarett and Doull's 1975 text *Toxicology, the Science of Poisons* as the first to meet the need, further suggesting that the first text to include both the principles of toxicology and the techniques and tools of other disciplines - biology, pathology, mathematics, physics, chemistry and engineering - necessary to understand these principles, was Hayes' *Principles and Methods of Toxicology* (1984). Both these texts have stood the test of time and have now reached their 6th edition (2001) and 4th edition (2000) respectively. Wexler (1990) describes Casarett and Doull's text as the 'pre-eminent textbook in the field'.

The most comprehensive monograph produced to date is the 13 volume work of Sipes et al. (1997). According to the editors' preface (Sipes, McQueen and Gandolfi 1997), this was written in response to the need for 'an extensive and authoritative work', due to the 'explosion of information' in toxicology since about 1950. The result is a multi-authored 'in-depth state-of-the-art review', aiming to encompass information from the molecular level to the intact organism, across the various disciplines of toxicology. This is the most ambitious work of its kind thus far, but the preface gives interesting insights into some aspects of this sort of publication:

- time lag - the concept was developed by the publisher during 1989-90, but the work was not published until 1997
- comprehensiveness - despite the title, the editors note that the work 'does not meet the literal definition of comprehensive'. Certain topics, such as the toxicology of the skin, and of the ear, are omitted, 'due to space limitations'.
- currency - 'the time it takes to receive, edit and print the various chapters limits inclusion of the latest information. Our goal was to provide a strong foundation'
- references - 'while exhaustive referencing was not performed, sufficient references were used to support the statements and provide the reader with adequate sources for finding additional information'

- indexing - external standards were used; the EMTREE thesaurus for subject terms, and IUPAC nomenclature for chemical substances
- scope - the material extends beyond toxicology, to encompass 'key physiological and biochemical processes in a variety of tissues'
- audience -the potential audience (even allowing for a publisher's enthusiasm for a large market) is diverse, including students, academic scientists (not just toxicologists), industrial scientists and occupational health professionals, government scientists and regulators, consultants, and lawyers

Until the 1950s, textbooks of medicine devoted little space to adverse drug reactions, and that to only the ill-effects due to a very small numbers of substances (Davies 1985). In 1952, Myler's *Side Effects of Drugs* appeared, the first book devoted entirely to adverse reactions.

In general, the expansion of publications up to the 1960s was slow; the pace quickened during that decade, Gallo (1996) commenting on the launch of several new journals; during the 1970s and 80s growth was 'exponential' (Borzelleca 1994) or, in the context of one aspect of toxicology, 'almost exponential' (Weiss and Cory Slechta 1994).

Gallo (1996), linking the growth of disciplinary 'support systems' with legislation on toxic substances, notes that 'the expansion of legislation, journals and new societies involved with toxicology was exponential during the 1970s and 1980s and shows no signs of slowing down. Currently, in the United States there are dozens of professional, governmental, and other scientific organisations with thousands of members and over 120 journals dedicated to toxicology and related disciplines.' This is confirmed and exemplified by the discussions in earlier sections, pointing to the origins of the present 'support systems' for toxicology to around 1960 (the year in which the Society of Teratology was founded, followed by the Society of Toxicology in the following year), and to emergence of the system in essentially its present form by 1980 (in which year the International Union of Toxicology was established); although increases in quantity in all parts of the support systems have continued through the 1980s and 1990s.

An increase in the number of those employed as toxicologists would also be expected to accompany and reflect the growth in disciplinary support systems, however, there is no single source of information on the worldwide toxicology workforce. International, national or local, annual estimates of manpower, even from

the 1960's onward, are hard to locate, and possibly non-existent. Figures would need to summarise the numbers of all those employed as toxicologists in government, industry and research, and in any other organisations, such as consultancies. One problem in estimating manpower is that the definition of a toxicologist varies over time; some of those working in a toxicological field refer to themselves as professionals of a different discipline. It is probable that individual organisations have some record of the numbers within their workforce over time.

The increase in the toxicology workforce can be roughly assessed from the growth of the leading professional association for the discipline, the US-based Society for Toxicology. From 9 founding members in 1961, the society grew to 183 in the following year, and to 827 in the next decade. Ten years later, in 1982, it had 1,600 members, and 'nearly 2,500' in 1986, 25 years after its founding. Latest figures (2002) are double this, at 'approximately 5,200'. [Data from the history of the Society, at <http://www.toxicology.org/MemberServices/history.pdf>]

A 1996 Society of Toxicology (US) survey suggested that there were 'at least 9,000 employed toxicologists in North America' with degree level or higher qualifications, about 50% at doctoral level. The membership of the society at that time was 5,500, not all in the US.
(<http://www.toxicology.org/PublicOutreach/CareerResources/jobmarketsurvey.html>)

A National Science Foundation survey in 1999 showed 3, 540,800 persons engaged in scientific and engineering occupations, with 955,300 being biological sciences. Taking the Society of Toxicology figure of 9,000 toxicologists, this is 0.25% of the total scientific and engineering workforce, and 0.9% of the biological scientists.
(<http://www.nsf.gov/sbe/srs>).

The International Union of Toxicology Societies website gives membership figures for the 43 national and international societies affiliated. These give a total of 20,988. Some will be members of more than one society, inflating the figures, but others will not have joined any. If these factors roughly cancel out, then there are about 21,000 active professional toxicologists at the beginning of 2003.
(<http://www.toxicology.org/iutox/iutoxms/memsoc.html>)

If the 1996 Society of Toxicology survey mentioned above is representative, then about one third of active toxicologists would not be members of a main, national society. The total figure then would be nearer 30,000.

Accurate figures for the main UK toxicology society in late 2002 may be contrasted with leading societies for other disciplines in this country:

British Toxicology Society (http://www.thebts.org)	950
British Medical Association (http://www.bma.org.uk)	126,000
Royal Society of Chemistry (http://www.rsc.org)	46,000
Biochemical Society (http://www.biochemistry.org)	8,500
Physiology Society (http://www.physoc.org)	'over 1,800'

Toxicologists are only 1% of the number of doctors, and 2% the number of chemists, and less than 50% of the smaller life science disciplines.

To take this a stage further, one could attempt to estimate the growth of the entire economy for toxicology. As with manpower, any published figures on the amount of money spent on toxicology are difficult to locate, although it would seem likely that individual drug or chemical companies would have some idea of the amount of their own spending on toxicity research and activities per year. It would first be necessary to define the scale on which such an estimate was to be made, i.e. worldwide, international, national or local, and also the type of activities to be included – as we have already seen that toxicology covers a wide and multidisciplinary area.

In relation to other areas, it may be reasonable to suggest that toxicology consumes similar resources to other biomedical fields such as pharmacology and biochemistry. Whilst more resources may be devoted to toxicology than less commercial fields such as history, areas of more practical application such as computing and engineering would be expected to attract larger funding.

International links, including formal congresses and conferences, developed alongside national organisations: the broadest representation of toxicologists worldwide is included within the International Congress of Toxicology, made up of toxicology societies from all continents. International co-operation has led directly to the creation of information interchange programmes and information products: examples are the International Programme on Chemical Safety (IPCS), which was

begun as a co-operative venture of the World Health Organisation, International Labour Organisation, and United Nations Environment Programme in 1978, and International Register of Potentially Toxic Chemicals (IRPTC), which stemmed from a United Nations-sponsored conference in 1972. Such meetings were also on occasion the catalyst for changes in perception of the discipline; for example, a 1960 meeting on 'problems in toxicology' which focused attention on the relevance of toxicology to environmental and social problems (Coon and Maynard 1960, Kissman and Wexler 1985).

Other conferences and professional meetings played an important role in information transfer: Kissman and Wexler (1985) suggest that these meetings, and other informal communications, were particularly important prior to about 1965, as the field became established. An annual conference on toxicology and safety evaluation in the prestigious Gordon Research Conferences series was established in the mid-1950s, and proved very influential in the development of toxicology as a discipline, later changing its title to the more specific Mechanisms of Toxicity. Several other conferences related to special areas of toxicology are now in existence (Gallo 1996). General societies, such as the Society of Toxicology, have formed speciality sections and regional chapters to deal with the greater number of scientists involved in the subject; some of these are exemplified in an earlier section.

One particular point of note is that the division referred to above between 'basic' toxicological research, and its applications in toxicity testing, risk assessment and regulation, means that the knowledge base of toxicology may be primarily generated by one group of toxicologists and primarily used by another, with a resulting less than optimal use pattern. Freiss (1995) argues that basic researchers should have a greater say on the nature of the information generated, and the way it is used. Zbinden (1992) urges that an important challenge for the future will be the oversight and coordination of continuous updating of methods of toxicological testing and of the concepts of data evaluation and risk assessment. This plainly requires full and efficient access to data, information and knowledge, and expert evaluation of them.

Ethical considerations also have an influence on information and communication systems in toxicology. For example, FRAME (Fund for the Replacement of Animals in Medical Experimentation) is a UK-based organisation campaigning, on scientific as well as ethical grounds, for the reduction and eventual replacement of all animal experimentation. FRAME has taken an interest in toxicology, and toxicity testing, in

particular. A 1983 report of its Toxicity Committee (FRAME 1983) contained two particular recommendations of direct relevance to information provision:

- unnecessary duplication of animal experimentation should be avoided by the wider dissemination of data. A time limit should be set on the confidentiality of results obtained. The results of all toxicological investigations should be published or otherwise be made available, e.g. in a central register of toxic effects. [paragraph 37]
- care must be taken to ensure that the information stored in databases for general use is both reliable and relevant to the user [paragraph 98]

A revision of the UK Animals (Scientific Procedures) Act, which came into effect in September 1998, (1998, number SI 1974), requires that anyone applying for a project licence to carry out animal experimentation must demonstrate awareness of the possibilities of reducing and replacing animals in the research; this may require documentation of literature searches carried out.

Use of computer systems for modelling of toxic effects, and prediction of toxicity has a two-fold impact upon the information and knowledge base of the subject (Menzel 1995). Since the validity of the results obtained by these methods is entirely dependent on the quality of the information used as input to them, effective use relies upon an information base which is adequate, both in quantity and quality. There then arises the status of toxicity 'data' predicted by computer rather than measured experimentally. Whether such data should be allowed to be entered into publicly available databanks, and under what conditions, remains an open question. Similarly the need for archiving the software by which the predictions were made, by analogy with the careful recording of the conditions and procedures of laboratory experimentation, which is taken for granted, must be considered.

The information systems of toxicology are greatly influenced by its multidisciplinary nature. This has three principal consequences:

- information required by the toxicologist (which itself may be very varied, according to the nature of the toxicologist's work) may be found across a wide range of disciplines, and their information sources
- toxicology information is published in, and abstracted and indexed by, a wide variety of publications in various fields of science

- much information appears in publications devoted to the specialisms of toxicology

With respect to this last point, Ballantyne, Marrs and Turner (1993B, p xi) note that most of the dramatically increased number of textbooks devoted to toxicology in recent years are, in fact, largely concerned with specialist areas or sub-disciplines. They suggest that the few general texts which exist are often brief, of limited scope, and may be directed to audiences more general than toxicologist specialists, whether practitioners or students. These remarks echo those of Blood (1969), over 25 years earlier, and may be contrasted with Gallo's (1996) more general statement that 'texts and reference books for toxicology students and scientists abound'.

A survey of currently available material, [see chapter three], suggests that there is only a small number of authoritative 'general toxicology' monographs available, and recently published leading examples are: Ballantyne, Marrs and Syversen (2000), Hayes (2000), Klaasen (2001), and Niesink, de Vries and Hollinger (1996). This gives a further indication of the extent to which toxicology remains a multidisciplinary area, rather than an established discipline.

In order to gain a feel for this issue, a small-scale test was carried out, using the 'British Books in Print' file, on the Dialog host system. Items with the word 'toxicology' in the title published during 1996, 1997 or 1998 were identified, and assigned, on the basis of title to one of three categories:

general - including textbooks and monographs, and also dictionaries and databooks, encyclopaedias, annual reviews, etc.

subdiscipline - covering an area of toxicology, as exemplified above

specialist - covering a topic more specialist than these

To identify change over a short time period, this was later repeated for the years 1999-2001:

	96-98	99-01
general	25	19
subdiscipline	41	28
specialist	5	14

Accepting the limitations of this approach, and particularly the assignment by title, this confirms the view that book publishing in toxicology is concentrated on the sub-disciplines. The highly specialist topics are more likely to be published in the form of journal articles than monographs, although their number is increasing with time. The figures for general books are conflated by the rather diverse collection of material grouped here. A maximum of 20 - the exact figure depending on definition - were 'general texts', in the sense of the comments quoted above, i.e. about 15% of the total.

One rationale for the prevalence of the more specialist monograph may be the point, noted in an earlier section, that graduate courses in toxicology largely comprise specialised modules, and will require correspondingly specialised texts. Also, given the relatively few educational programmes in toxicology, it may be unreasonable to imagine that the field can support a large number of general texts.

For comparison with other subject areas, this exercise was repeated for engineering and for chemistry. The same simple approach was used, identifying books with 'engineering' and with 'chemistry' in the title. In the first case, this led to retrieval of some titles that were not to do with engineering disciplines, due to the more general meanings of the term: these are noted as 'not relevant' below. Because of the larger number of books on these topics, the years 1997, and 2000 - in the middle of the range used for toxicology - were used.

engineering

	1997	2000
general	112	110
sub-discipline	160	138
specialist	78	58
not relevant	30	44

chemistry

	1997	2000
general	94	72
sub-discipline	152	112
specialist	40	38

Similar patterns are seen in both cases to that for toxicology, with books on sub-disciplines predominating over general works, while specialities receive least publication in this form.

Taking percentages over all the samples - and ignoring the irrelevant engineering examples - gives the following summary.

	toxicology	engineering	chemistry
general	33	34	33
sub-disciplines	52	45	52
specialist	15	21	15

This shows that, in this aspect of its publication pattern, toxicology seems to be typical of science and engineering disciplines.

An analogous phenomenon is the number of journals devoted to the sub-disciplines. Some examples are:

Aquatic Toxicology	(Elsevier)
Clinical Toxicology	(Marcel Dekker)
Neurotoxicology	(Intox Press)
Drug and Chemical Toxicology	(Marcel Dekker)
Food and Chemical Toxicology	(Elsevier)
Bulletin of Environmental Contamination and Toxicology	(Springer Verlag)
Carcinogenesis	(IRL Press)
Teratogenesis, Carcinogenesis and Mutagenesis	(Wiley)

It might be expected that the links between toxicology and other disciplines would be demonstrated by the existence of journals covering the 'overlap area'. In fact, this is seen particularly clearly for pharmacology, e.g.:

Annual Review of Pharmacology and Toxicology	(Annual Reviews Inc.)
Journal of Pharmacological and Toxicological Methods	(Elsevier)
Pharmacology and Toxicology (Copenhagen)	(Munksgaard)
Toxicology and Applied Pharmacology	(Academic Press)

There remains scope for disagreement as to the extent to which toxicology information is still scattered throughout the literature of other disciplines, as was the case before about 1960. Hard and Neal (1988) suggest that this is no longer the case,

and that the increase in toxicology-specific journals has largely eliminated this scatter. Conversely, Wexler (1990) argues that important toxicological findings still appear in journals of pharmacology, epidemiology, and cancer research, to name but three examples. A study of the Toxline database suggested that toxicology remains a 'diffuse field', with its primary literature spread through a variety of disciplinary journals (Small 1987); among the more significant of these journals were *Cancer Research*, *Lancet*, *Journal of Chromatography*, and *Proceedings of the National Academy of Sciences*. This aspect will be considered further in chapter four.

2.4.3 Information in sub-disciplines

In this section, the relation between the development of sub-disciplines within toxicology and their accompanying information systems is examined. The main example is behavioural toxicology, since this is an area particularly rich in historical accounts. Shorter descriptions are given for three other areas: neonatal toxicology, *in vitro* toxicology, and mycotoxins.

Behavioural toxicology

Behavioural toxicology is a particularly suitable example for examining sub-disciplines of toxicology, since several authors have given accounts of its development, with reference to communication and sharing of information.

Hänninen (1985) and Russell and Singer (1982) both give examples of the difficulties of information access within this emerging sub-discipline of toxicology, which involves the psychological assessment of changes in behaviour due to exposure to chemical substances with neurotoxic effects. These changes may affect, for example, memory, learning ability, reflexes, mood etc.; these are, of course, very different from the factors generally studied by toxicologists. The initial impetus came from the work of occupational health physicians, such as Hänninen, examining individual patients. It was later realised that psychological and behavioural tests were valuable complements to other clinical and chemical tests for toxicity, and could indeed provide warning of toxic exposure before any other symptoms were manifested. The trend now is to work with standardised tests, in a computerised 'battery' for this purpose, (see Niesink 1996 and Weiss and Cory-Slechta 1994 for recent overviews of the topic.)

Hänninen notes that at the outset of her work, when these effects were first recognised, the standard textbooks of occupational medicine gave some insight into neurotoxicity, but that the lack of systematised data, or underlying disciplinary concepts, gave an 'unstable base' for practical applications in occupational medicine. She describes, from a personal viewpoint, the development of this speciality, noting the importance of papers presented at 'general' toxicological congresses in sparking interest, and bringing together those with an interest in the subject. However, she notes feeling 'like a curiosity rather than a scientist to be taken seriously', when presenting results to such general audiences. She emphasises the impetus given to the emerging sub-field by the organisation of specialist workshops, noting the first of these, in 1972, as marking 'the formal debut of behavioural toxicology', these having been preceded by informal and occasional meetings. Some years later, workshops convened by the World Health Organization marked a 'second landmark of progress in the area': these workshops were aimed at co-ordinating research efforts, and achieving consensus as to research methods and data monitoring, necessary steps as the new research area matures. (These led to a series of larger international symposia on neurobehavioural methods in occupational and environmental health, jointly organised by the WHO and the Commission of the European Communities, the second being held in Copenhagen in 1985, the proceedings edited by P Grandjean). Meetings and symposia were also important in establishing the new discipline in various areas of the world; Russell and Singer (1982), for example, refer to a significant conference held in Australia in 1980 in identifying the emergence of 'behavioural toxicology' as a new discipline in Australia; they place it firmly within the ambit of psychology.

It is worth noting that, although both these authors place the 'formal' beginnings of behavioural toxicology in the 1970s, the term had been used, with the implication of description of a coherent subject, considerably earlier. For example, Brimblecombe (1968) describes a considerable body of literature on the subject dating back to the 1950s, Bignami (1976) noted that, while behavioural toxicology had 'only recently gained status as a semi-autonomous discipline', several lines of research in the area had been firmly established for fairly long periods of time. Ruffin (1963), commenting on work being carried out in this area in the USA in the early 1960s, made the suggestions that:

- behaviour was 'a proper object for the attention of the experimental industrial toxicologist'

- behavioural toxicity should be accorded as status close to the top of the hierarchy of toxicity study criteria
- some environmental toxicologists should evolve into behavioural toxicologists, or 'psychotoxicologists', as Ruffin termed them, by analogy with the successful transformation of some psychologists into psychopharmacologists
- studies of behavioural toxicity should be carried out by integrated teams of psychologists and those with 'traditional' experience

These may be taken as an indication of the way in which a specialism and its knowledge base may develop well ahead of formal structures.

Beard (1974) suggests that interest in the subject in the USA began in the latter part of the 1950s, largely because of surprise engendered by the realisation that much stricter standards for occupational air pollution prevailed in Russia than in any Western country, and were based partly on behavioural considerations. Beard describes the reaction of American toxicologists and industrial hygienists as 'passion' and 'cries of outrage'. He notes that 'none of us who were concerned about industrial health appeared to be aware that the study of the influence of toxic agents upon the behaviour of animals was already well established in the United States ... in the pharmacology laboratories.' However, only drugs had been tested in this way, not industrial substances. Beard dates the first behavioural testing of an industrial material in the USA to studies carried out with mercury vapour about 1960 at the University of Rochester, and reported to a meeting of the American Hygiene Association in 1961.

An interesting example of the diverse views which may be held as to the status of a subject by its practitioners is given by contributors to the proceedings of the formative 1972 conference. The editors of the proceedings describe behavioural toxicology as 'a young discipline' (Weiss and Laties 1975), while other contributors suggest that it is 'no more than embryonic so far as being a science is concerned, with few generalisations or theory' (Dews 1975), and on the other hand that 'we perceive the maturing of the new branch of science called behavioural toxicology... brought about by understanding both its utilities and limitations' (Ts'O, Leong and Chenoweth 1975).

An alternative sign of the formation of a new sub-discipline (though not specifically discussed by Hänninen or by Russell and Singer, though the latter give some references) is the appearance of review articles, textbooks or monographs, or (especially for toxicology) governmental reports. Mello (1975), for example, states that

behavioural toxicology first received 'formal recognition' with the publication of Weiss and Laties' 1969 review. For behavioural toxicology, early examples of each of these, dating from the late 1960s and early 1970s, are:

Weiss B and Laties VG, Behavioural pharmacology and toxicology, Annual Review of Pharmacology, 1969, 9, 297-326

This article was the fourth in a series devoted to behavioural pharmacology, but was the first to make specific reference to behavioural toxicology, which was identified as one of four main themes in the review. The authors' rationale for doing so (Weiss and Laties 1969) was 'to recognize explicitly that such a discipline is coming into existence', apparently prompted by two main factors: a new concern of society ('the cries of society for help in solving environmental problems'), and a recognition that much of what was termed behavioural pharmacology was, in fact, selective toxicology. Emphasising the close link between pharmacology and toxicology, they noted 'many studies of the behavioural effects of drugs can be conceived as attempts to determine selective toxicity as a direct aim'. They criticised most experiments in the area as seeking 'to demonstrate rather gross, generalised toxic effects, rather than adopting the more precise methods of behavioural pharmacology; an apparent criticism of the 'psychological' approach to the subject. 15 years later, concern was still being expressed about the problem of lack of rigour in behavioural toxicology research (Weiss and Cory-Slechta 1994). They also suggested that European toxicologists had been more aware of the contribution that behavioural techniques can make. [It is worth noting, as an example of the rapidity of literature growth, that, writing an equivalent review with literature up to 1975, Bignami (1976) was forced to limit discussion to just two lines of work, noting that anything else would be an extensive treatise rather than a review.]

Porter R and Birch J (eds.) (1970), Chemical influences on behaviour, Churchill, London

This book consists of the proceedings of a Ciba Foundation study group, with the same title, held in London in early 1970, with 22 participants. The term 'behavioural toxicology' is not used anywhere in the text, though 'behavioural toxicity' is referred to by two speakers. It is by no means clear from any of the papers, or the reported discussions, that a new field of study is emerging; on the contrary, one speaker urged the need for the replacement of behavioural tests as soon as possible by biochemical or pharmacological methods, which would be simple and more reproducible. The statement that 'the toxicologists and pharmacologists are at cross-purposes' (Silverman 1970) seems to sum up much of the tone of this meeting, and book.

Weiss B and Laties VG (1975), *Behavioural toxicology*, Plenum, New York

Although it has a publication date of 1975, this book is, in fact, the proceedings of a conference held in 1972; the one noted by Hänninen as marking the formal debut of behavioural toxicology. The editors, rather more modestly, refer to it simply as the first formal meeting devoted to the subject held in the USA (Weiss and Laties 1975). As an example of the 'mingling' and overlap of sub-disciplines, the meeting was the 5th in a series devoted to environmental toxicology. The editors state that at that stage behavioural toxicology was a 'young discipline in the United States' and that this was 'one of its first books'. They noted that its contributors had interests spanning a wide variety of problem areas, but were largely focused on issues of methodology, representing the most immediate concern of the new subject.

Xintaris C, Johnson BL and de Groat I (eds.) (1974), *Behavioral toxicology*, US Department of Health, Education and Welfare, Washington DC, NIOSH Publ. No. 74-126

This report, sub-titled 'Early detection of occupational hazards', is the proceedings of a workshop held under the auspices of NIOSH (the US National Institute for Occupational Safety and Health) in 1973, with the aim of exchanging information on testing methods, and their application to setting standards for worker protection; this is the meeting denoted by Hänninen as the first international meeting devoted solely to the subject. Specifically, it was held in response to a legislative requirement, under the US Occupational Safety and Health Act of 1970, to include behavioural factors in assessing occupational safety issues; an interesting example of the influence of legislation on the science of toxicology.

A conference proceedings of a few years later, reporting a meeting held by the Southwest (USA) Psychological Association in 1976 (Zenick and Reiter 1977), still shows a variety of views as to the status of the field. The title of the meeting refers to it as an 'emerging discipline', while contributors refer to it as 'in a relatively early developmental stage, having received little formal recognition', 'a concept which, as yet, has not been fully developed', 'our evolutionary process has only recently begun', but conversely '.. a feeling that we are well past puberty and represent a mature field of endeavour'. This diversity of views may reflect the fact that the meeting, although organised under the auspices of psychology, also drew participants from a variety of other disciplines, including toxicology, pharmacology, physiology and veterinary medicine.

It is noteworthy that Hänninen categorises the first two formal meetings devoted to the topic as stemming from two rather different perspectives - behavioural pharmacology and industrial medicine respectively - and that these were followed shortly by European meetings examining the subject from a psychological perspective; thereby showing that even this sub-field within a multidisciplinary subject is itself multi-disciplinary. This is amplified by her contention that advances in this area were related to developments in occupational toxicology, epidemiology, neurotoxicology, and psychology, and that the major challenge for behavioural toxicology in its first decade was finding a place and role within these older-established subjects.

Similarly, van Gelder (1975) noted that behavioural toxicology was 'a new field with a relatively small group of full-time dedicated workers', with few toxicologists trained, well-read, or even acquainted with behaviour, so that there was 'a real problem of acceptance by the more traditional areas of toxicology'. [Nearly two decades later, Weiss and Cory-Slechta (1994) commented that the expansion of the range of techniques applied to such problems had extended over a broader spectrum of behavioural and neurosciences.] Buck et al. (1977) suggested that the problem of defining behavioural toxicology, a concept not fully developed, led to an 'identity problem', among workers in the field and in the eyes of colleagues in other disciplines.

Van Gelder also suggested that experimental psychologists viewed the subject very differently from toxicologists, regarding it as 'applied research', with a rather negative connotation of 'uncreative'. Spyker (1974) also saw it as very much an applied discipline, regarding it as 'a fascinating new field of job health research', but noted that she had been 'confused by the definition of behavioural toxicology... all week' of the 1973 NIOSH conference. She also, as early as 1972, saw the emergence of a sub-specialism of this new field: behavioural teratology, the overlap of teratology with behavioural toxicology (Spyker 1974, 1975).

By contrast, Weiss and Laties (1969), as noted above, saw the subject as firmly within the ambit of behavioural pharmacology, and similarly Dews (1975) suggested that 'it is becoming clear that behavioural toxicology is recognised as a branch of pharmacology'. Dews also regarded it as a drawback that 'most behavioural toxicologists have come into the subject directly from psychology or from some other branch of toxicology - very few through behavioural pharmacology. It is sad to see behavioural toxicology having to relearn painfully lessons that behavioural

pharmacology already knew 15 years ago'. Mello (1975), however, while acknowledging the 'several commonalities' between behavioural pharmacology and toxicology, noted major differences dictating differences in methodology: particularly the distinction between the pharmacological need to identify the immediate effect on behaviour of a dose of a substance, and the toxicological need to identify the effect of an agent which may accumulate slowly over time, but also the pragmatic fact that many substances of concern to the toxicologist are not deliberately administered.

Hänninen notes the particular value of informal contact, in particular visits to institutes and laboratories, in information exchange. This may be expected to be of particular importance in an emerging area, with few formal communication channels. She notes the example of her visit to a colleague who 'never published a line in any international scientific journal', but who was able to provide valuable information informally.

Both Hänninen (1985) and Russell and Singer (1982) discuss the state of behavioural toxicology in the early 1980s, about 10 years after the formal emergence of the field. Russell and Singer note that it was still divided into three distinct aspects: problem-oriented basic research, using experimental models; field research, assaying and monitoring toxic manifestations; and clinical work with affected individuals. They note that these three sectors do not provide as much support for each other as might be wished, and that the discipline is not a coherent whole. It is tempting to suggest that we see here, in miniature, aspects of toxicology as a whole. They see the field as having a clear overlap with traditional clinical psychology, more specifically with the 'newly developing profession of "neuropsychology"', the major difference being a need for knowledge about the basic concepts and techniques of neurochemistry and neuropharmacology. They do not mention those of toxicology *per se*, and further ignore toxicology in their list of initial competences from which scientists have entered behavioural toxicology: pharmacology, biochemistry, psychology and the social sciences. Their suggestion for a postgraduate qualification in behavioural toxicology builds specialised aspects on top of a programme for core knowledge in physiology, biochemistry and pharmacology-toxicology [sic].

Russell and Singer note that it would be a 'very unusual person' who could claim to be expert in all three aspects of the field: although there are concepts common to both, the interests, attitudes, depth of knowledge and skills of those specialising in each aspect will differ. This echoes Hänninen's view of this new specialism as being

itself sub-divided. Similarly, Buck et al. (1977) argued that it was unlikely that any single researcher would possess the 'many and varied' skills needed to conduct behavioural toxicology studies, and multi-disciplinary teams efforts would be required, providing the strength of a diversity of disciplines. They note the disciplines required as:

- psychology
- toxicology
- veterinary and/or human medicine
- chemistry
- physiology
- pathology
- biophysics
- biomedical engineering
- computer science
- statistics

Hänninen makes much the same points, emphasising the significance of formal and informal information systems in providing coherence, or lack of it:

'Notwithstanding increased international contacts, behavioural toxicology is still a rather inconsistent discipline. It is comprised of the contributions of numerous small research groups spread around the world, each applying their own methodology. The research is conducted in different scientific environments and in varied multidisciplinary settings, and the reports are disseminated to various scientific journals - more to journals of occupational medicine or neurotoxicology than to psychological ones. And those doing research in this field are still very poorly informed about what others are doing and what they are thinking about the essential issues of behavioural toxicology.'

She concludes that efforts to augment communication between different groups, and thereby provide coordination and coherence to the field are essential.

Russell and Singer (1982) make much the same point, suggesting that the development of a systematic body of knowledge in support of behavioural toxicology as a 'comprehensive discipline' is essential, and recommending the establishment of an 'information bank', or 'information exchange centre', for

behavioural toxicology in the Australian situation. (This does not, in fact, appear to have been established.)

In point of fact, although neither Hänninen nor Russell and Singer mention it in their accounts, a journal devoted to this new subdiscipline was launched by Elsevier in 1979: *Neurobehavioral Toxicology*. Subsequently, this was renamed: first, more generally, as *Neurobehavioral Toxicology and Teratology*, then, even more generally, as *Neurotoxicology and Teratology*. Another, separate journal, *Neurotoxicology*, was also launched in 1979, published by Intox Press, and has remained with the same title to the present day.

This indicates that the new sub-discipline of (neuro)behavioural toxicology may not have been large enough, or coherent enough, to support a journal of its own, though the growth of its literature has been described as 'almost exponential' (Weiss and Cory-Slechta 1994). It also suggests that the field has become recognised as one within toxicology - as indicated by Niesink (1996), by Weiss and Cory-Slechta (1994), and by Ballantyne, Marrs and Turner (1993C) - , rather than within psychology or the other behavioural sciences, which seems to have been Hänninen's view.

It is also interesting to note the professional associations which have become established in this area. These are the Behavioural Toxicology Society and the, more specialised, Neurobehavioural Teratology Society.

The first of these, the Behavioural Toxicology Society, was founded in 1982, as an 'off-shoot' from the more general Behavioural Pharmacology Society, following several years of interactions and presentations at that society's meetings (a recent example of the 'emergence' of toxicology from pharmacology). It is 'an organisation of scientists who employ behavioural methods to identify and characterise the neurotoxic effects of chemical exposures'. Its purposes are to 'promote good scientific research into the effects of toxic agents on behaviour and the nervous system, to provide a forum for the presentation and discussion of relevant research, and to educate persons interested in the field'. Meetings are held each year.

The Neurobehavioural Teratology Society (<http://nbts.bsbe.umn.edu/nbtshonf.html>) was established in 1977. It holds regular meetings for its members, but otherwise its emphasis appears to be on promoting interactions with other organisations, and within its membership. To the latter end, it provides an interactive membership list

from its website, and encourages members to set up personal home pages, linked via the Society's site.

These two societies have, since 1988, co-sponsored the Elsevier journal *Neurotoxicology and Teratology*, noted above, the membership of the Societies providing the editors and editorial board. It is, however, worth noting that the intended audience for this journal, according to the publisher's website (<http://www.elsevier.com>), comprises 'neurotoxicologists, neurochemists, teratologists, and clinical epidemiologists'. Even allowing for the desire of a publisher to attract a large, and hence general, readership, this suggests that the behavioural toxicologist, or teratologist, is still not a recognised professional entity.

It is clear from the above that these societies play a significant part in communication of information within these sub-disciplines, both by journal sponsorship, and, as will be seen below, by meeting presentations.

There is also at least one professional body with a somewhat wider remit. The International Neurotoxicology Association was founded in 1978 (to judge from the dates of its annual meetings), and also has a significant part to play in the transmission of behavioural toxicology information, as will be seen below.

In order to investigate these matters further, the current literature of the topic was examined, and its publication patterns elucidated.

Initially, a search was carried out on Toxline and Embase, via Dialog, since this pair of databases has a good combined coverage of relevant literature. The specific concept of behavioural toxicology was identified by searching for the terms BEHAV? and TOXIC? or BEHAV? and NEUROTOX?, with up to two words intervening between the two wordstems. This gave 378 items published in 1996, 97 and 98, after duplicates had been eliminated. These were then ranked according to publication, with the following results, (table 2.8), showing those publications with 5 or more items, after correcting for different forms of journal citation:

Table 2.8 Behavioural toxicology articles ranked by publication (Toxline/Embase) 1996,1997,1998. Publications with 5 or more items.

1	31	(ANNUAL) SCIENTIFIC MEETING OF THE RESEARCH SOCIETY ON ALCOHOLISM
2	24	NEUROTOXICOLOGY AND TERATOLOGY
3	14	FEDRIP DATABASE
4	11	HUMAN PSYCHOPHARMACOLOGY
6	10	PHARMACOLOGY BIOCHEMISTRY AND BEHAVIOR
7	7	NINTH CONGRESS OF THE INTERNATIONAL SOCIETY FOR BIOMEDICAL RESEARCH ON ALCOHOLISM
8	7	TWENTY-FIRST ANNUAL MEETING OF THE NEUROBEHAVIORAL TERATOLOGY SOCIETY
9	5	ALCOHOLISM CLINICAL AND EXPERIMENTAL RESEARCH
10	5	ENVIRONMENTAL HEALTH PERSPECTIVES
11	5	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
12	5	FUNDAMENTAL AND APPLIED TOXICOLOGY
13	5	GOVT REPORTS ANNOUNCEMENTS & INDEX (GRA&I)
14	5	OBSTETRICS AND GYNECOLOGY CLINICS OF NORTH AME
15	5	SIXTH MEETING OF THE INTERNATIONAL NEUROTOXICOLOGY ASSOCIATION

First place in the ranking goes to meeting papers, and indeed four of the fifteen sources are meetings and congresses, suggesting that the significance of this form of information transmission is still important for this area. Two of the societies are those noted above, the other two are devoted to the study of the effect of alcohol.

One of the two journals of the specialism, Neurotoxicology and Teratology, comes in second place with 24 items. The second journal of the specialism, Neurotoxicology, contributes 4 items, and is therefore not included in the ranking.

The mixing of specialised sources, general toxicology sources, and general medical sources is notable, suggesting that information transfer in this field is still very varied.

In order to select a different sample of literature, and to use different RANKing options, a similar search was carried out on Scisearch.

An initial search collected a set of roughly relevant material; this sought any occurrence in title/abstract/author's keywords of the terms TOXIC? or NEUROTOXIC?, together with BEHAVIOUR?, BEHAVIOR?, PSYCHOLOG?, or PSCHIATR? (these latter terms were added as the controlled indexing available with Toxline and Embase is not used in SciSearch, so we need to cover a wider range of possible terms.)This gave 2414 items published in the years 1996, 1997 or 1998.

These search results were examined more closely, by adding a requirement for combinations of these terms to be present in the title. Three searches were carried out:

- with the 'toxicity' terms in the title giving 368 items
- with the 'behavioural' terms in the title giving 403 items
- with either 'toxicity' or 'behavioural' terms in the title giving 701 items

These were then RANKed by source name (listing those sources providing 5 or more items), and by ISI subject code (listing those codes providing 15 or more items). The latter is a rough ranking of sources by subject, where any source may have more than one subject code. The results are shown in tables 2.9, 2.10 and 2.11.

Table 2.9 Behavioural toxicology items from SciSearch, with 'toxicity' terms in the title, ranked by source and ISI subject code, 1996,1997,1998:

Source

1	19	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
2	17	NEUROTOXICOLOGY
3	12	ENVIRONMENTAL HEALTH PERSPECTIVES
4	10	BRAIN RESEARCH
5	8	JOURNAL OF ECONOMIC ENTOMOLOGY
6	8	NEUROTOXICOLOGY AND TERATOLOGY
7	7	FUNDAMENTAL AND APPLIED TOXICOLOGY
8	6	CHEMOSPHERE
9	6	TOXICOLOGY AND APPLIED PHARMACOLOGY
10	6	TOXICOLOGY AND INDUSTRIAL HEALTH
11	5	HUMAN & EXPERIMENTAL TOXICOLOGY
12	5	TOXICOLOGY

Subject code

1	115	TOXICOLOGY
2	78	PHARMACOLOGY & PHARMACY
3	74	ENVIRONMENTAL SCIENCES
4	64	NEUROSCIENCES
5	29	CHEMISTRY
6	19	BIOCHEMISTRY & MOLECULAR BIOLOGY
7	19	PUBLIC HEALTH
8	18	PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH
9	15	MARINE & FRESHWATER BIOLOGY

Apart from Brain Research and Journal of Economic Entomology (which contributes papers on effects of pesticides), journals are all of toxicology or environmental sciences.

Toxicology, and the closely related pharmacology codes, are predominant, with environmental sciences third, and neurosciences - the most representative of the 'behavioural' subject groupings, only fourth.

Table 2.10 Behavioural toxicology items from SciSearch with 'behavioural' terms in the title, ranked by source and ISI subject code, 1996,1997,1998:

Source		
1	23	PHARMACOLOGY BIOCHEMISTRY AND BEHAVIOR
2	21	NEUROTOXICOLOGY AND TERATOLOGY
3	14	BRAIN RESEARCH
4	10	ENVIRONMENTAL HEALTH PERSPECTIVES
5	9	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
6	9	NEUROTOXICOLOGY
7	6	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
8	6	ENVIRONMENTAL TOXICOLOGY AND PHARMACOLOGY
9	6	JOURNAL OF PHARMACOLOGY AND EXPERIMENTAL THERAPEUTICS
10	6	PHYSIOLOGY & BEHAVIOR
11	6	TOXICOLOGY AND APPLIED PHARMACOLOGY
12	5	FUNDAMENTAL AND APPLIED TOXICOLOGY
13	5	JOURNAL OF ECONOMIC ENTOMOLOGY

Subject code		
1	93	NEUROSCIENCES
2	88	TOXICOLOGY
3	85	PHARMACOLOGY & PHARMACY
4	66	ENVIRONMENTAL SCIENCES
5	25	PSYCHIATRY
6	22	BEHAVIORAL SCIENCES
7	19	CLINICAL NEUROLOGY
8	15	MARINE & FRESHWATER BIOLOGY

The journal list looks rather different from the previous source list; its 'top' journal did not figure earlier.

The subject code listing clearly shows the changed emphasis, with NEUROSCIENCES exceeding TOXICOLOGY, and PSYCHIATRY, BEHAVIOURAL SCIENCES, and CLINICAL NEUROLOGY entering the list.

Table 2.11 Behavioural toxicology items from SciSearch with both 'toxicity' and 'behavioural' terms in the title, ranked by source and by ISI subject code, 1996.1997,1998:

Source		
1	26	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
2	25	NEUROTOXICOLOGY AND TERATOLOGY
3	24	PHARMACOLOGY BIOCHEMISTRY AND BEHAVIOR
4	22	BRAIN RESEARCH
5	21	NEUROTOXICOLOGY
6	19	ENVIRONMENTAL HEALTH PERSPECTIVES
7	12	TOXICOLOGY AND APPLIED PHARMACOLOGY
8	11	FUNDAMENTAL AND APPLIED TOXICOLOGY
9	10	CHEMOSPHERE
10	9	JOURNAL OF ECONOMIC ENTOMOLOGY
11	9	JOURNAL OF PHARMACOLOGY AND EXPERIMENTAL THERA
12	8	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
13	8	ENVIRONMENTAL TOXICOLOGY AND PHARMACOLOGY
14	7	JOURNAL OF NEUROSCIENCE
15	7	TOXICOLOGY
16	7	TOXICOLOGY AND INDUSTRIAL HEALTH
17	6	BEHAVIOURAL BRAIN RESEARCH
18	6	ENVIRONMENTAL RESEARCH
19	6	HUMAN & EXPERIMENTAL TOXICOLOGY

20	6	PHYSIOLOGY & BEHAVIOR
21	5	EUROPEAN JOURNAL OF PHARMACOLOGY
22	5	HYDROBIOLOGIA
23	5	JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION
24	5	JOURNAL OF APPLIED TOXICOLOGY
25	5	MARINE ENVIRONMENTAL RESEARCH
26	5	PHARMACOLOGY & TOXICOLOGY
27	5	WATER RESEARCH

Subject codes

1	180	TOXICOLOGY
2	144	PHARMACOLOGY & PHARMACY
3	139	NEUROSCIENCES
4	130	ENVIRONMENTAL SCIENCES
5	37	CHEMISTRY
6	30	BIOCHEMISTRY & MOLECULAR BIOLOGY
7	30	PSYCHIATRY
8	28	PUBLIC HEALTH
9	27	MARINE & FRESHWATER BIOLOGY
10	24	PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH
11	23	BEHAVIORAL SCIENCES
12	22	CLINICAL NEUROLOGY
13	20	AGRICULTURE
14	16	ENTOMOLOGY

(Note that some sources appear in the 'combined' list when they were not present in either of the previous two lists. This is because they were present in both the previous lists but below 5 occurrences; combining the two sets has put them above the limit of 5.)

The combined list clearly shows a mix of sources, reflecting the diverse publication patterns within this discipline.

The source code list in table 2.11 again shows the diverse nature of this specialism, though the 'toxicology' subject appears dominant. It is reasonable to regard this as further evidence that this specialism is, in information transfer terms, largely within toxicology. However, the rankings of the items with 'behavioural' terms in the titles show that there is a strong corpus of psychologically-oriented material being published within the sub-discipline, identified by choice of terms in titles and publication in journals from that subject grouping, rather than from toxicology.

This is also a good indication of the care that must be taken in using RANKing of this sort, since the way in which the set of material to be RANKed is chosen may have a significant effect on the results.

Other sub-disciplines

The example of behavioural toxicology sheds light on the relation between the development of a specialism and its 'intellectual support services', which in turn are information resources, or are closely associated with them.

A further example, noted earlier, was that of forensic toxicology [described in detail by Niyogi (1980)], for which the publication of monographs and texts, launching of journals, and formation of societies were all instrumental in the development of the specialism. Two strong contrasts between this case, and that of behavioural toxicology are the much longer time period over which forensic toxicology has developed, and the emphasis placed on formal training and accreditation by various boards; essential for those who will present evidence to courts of law. In these respects, behavioural toxicology seems much more typical of current specialisms within toxicology.

To gain an insight into the variety of publication patterns in toxicology specialisms, three other examples were studied, and compared with behavioural toxicology. They were:

- neonatal toxicology
- in vitro toxicology
- mycotoxins

In each case, the same procedure was followed, i.e. fairly simple searching to identify, so far as possible, unambiguously relevant material, followed by RANKing to assess publication patterns.

Neonatal toxicology: Searching for this concept on Scisearch, by combining the terms TOXIC? with NEONTAL, NEONATE? or NEW(w)BORN, gives 870 items published in 1996, 97 or 98. Ranking these by source, down to sources containing 10 items and by subject code gives the results in table 2.12.

Table 2.12 Neonatal toxicology items from SciSearch, ranked by source and by ISI subject codes, 1996,1997,1998:

Source

1	26	BRAIN RESEARCH
2	15	TOXICOLOGY AND APPLIED PHARMACOLOGY
3	13	EUROPEAN JOURNAL OF PHARMACOLOGY
4	13	PEDIATRIC RESEARCH
5	12	NEUROTOXICOLOGY
6	11	PEDIATRICS
7	10	JOURNAL OF ECONOMIC ENTOMOLOGY
8	10	JOURNAL OF NEUROSCIENCE
9	10	NEUROSCIENCE
10	10	REPRODUCTIVE TOXICOLOGY

Subject code

1	199	NEUROSCIENCES
2	141	PHARMACOLOGY & PHARMACY
3	129	TOXICOLOGY
4	86	PEDIATRICS
5	79	BIOCHEMISTRY & MOLECULAR BIOLOGY
6	42	CLINICAL NEUROLOGY
7	38	ENVIRONMENTAL SCIENCES
8	26	MEDICINE, GENERAL & INTERNAL

Repeating the rankings with more specific 'core' items based on restriction to terms in the title shows little change.

A combined search on Toxline and Embase, for the same time period, yields table 2.13.

Table 2.13 Neonatal toxicology items from Embase/Toxline search, ranked by source, 1996,1997,1998:

1	31	NEUROTOXICOLOGY AND TERATOLOGY
2	28	TERATOLOGY
3	28	BRAIN RESEARCH
4	25	PEDIATRICS
5	19	ALCOHOLISM CLINICAL AND EXPERIMENTAL RESEARCH
6	17	ANNUAL SCIENTIFIC MEETING OF THE RESEARCH SOCIETY ON ALCOHOLISM
7	12	TOXICOLOGIST
8	10	ASHP MIDYEAR CLINICAL MEETING
9	10	BRITISH MEDICAL JOURNAL
10	10	LIFE SCIENCES
11	9	TOXICOLOGY AND APPLIED PHARMACOLOGY
12	8	JOURNAL OF ECONOMIC ENTOMOLOGY
13	8	NEUROSCIENCE LETTERS

Restricting the search to more specific items defined by title terms causes little change to this ranking.

Note that in this ranking the most significant two journals are published under the auspices of the societies discussed earlier (Behavioural Toxicology

Society/Neurobehavioural and Teratology Society and the Teratology Society). The scatter of material across rather diverse publications, and the importance of conference proceedings are again evident.

In vitro toxicology: Searching for this concept on Scisearch, by simply combining the terms TOXIC? and IN(w)VITRO or INVITRO, gives 247 items published in 1996, 97 or 98. Ranking these by source, down to sources containing 5 items, and by subject code gives table 2.14.

Table 2.14 In vitro toxicology items from SciSearch, ranked by source and subject codes, 1996,1997,1998:

Source		
1	22	ATLA-ALTERNATIVES TO LABORATORY ANIMALS
2	11	TOXICOLOGY IN VITRO
3	6	BRAIN RESEARCH
4	6	NAUNYN-SCHMIEDEBERGS ARCHIVES OF PHARMACOLOGY
5	6	TOXICOLOGY AND APPLIED PHARMACOLOGY
6	5	FASEB JOURNAL
Subject codes		
1	81	TOXICOLOGY
2	52	PHARMACOLOGY & PHARMACY
3	23	VETERINARY SCIENCES
4	21	BIOCHEMISTRY & MOLECULAR BIOLOGY
5	21	ENVIRONMENTAL SCIENCES
6	18	NEUROSCIENCES
7	14	ONCOLOGY
8	12	CELL BIOLOGY

The predominance of two specialist journals, ATLA and Toxicology In Vitro, is notable.

Equivalent rankings were produced from a combined search on Toxline and Embase, which yielded a total of 1798 items, with the same time period restriction. The ranking of journals, after equivalencing variant forms of journal title, is shown in table 2.15.

Table 2.15 In vitro toxicology items from Embase/Toxline search, ranked by source, 1996,1997,1998:

1	126	TOXICOLOGY IN VITRO
2	108	TOXICOLOGY AND APPLIED PHARMACOLOGY
3	60	MUTATION RESEARCH
4	50	IN VITRO TOXICOLOGY
5	49	TOXICOLOGY
6	45	TOXICOLOGY LETTERS
7	39	CHEMICAL RESEARCH IN TOXICOLOGY
8	37	ARCHIVES OF TOXICOLOGY
9	31	TOXICOLOGICAL SCIENCES (ex. FUND. APP. TOX.)
10	26	FOOD AND CHEMICAL TOXICOLOGY
11	26	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH
12	23	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
13	22	CARCINOGENESIS (OXFORD)
14	22	ENVIRONMENTAL HEALTH PERSPECTIVES

ATLA, the journal which headed the Scisearch rankings, is not currently covered by either of these databases. Conversely, another specialist journal, In Vitro Toxicology (subtitled Journal of Molecular and Cellular Toxicology), appears here.

In this case, the scatter of the literature across sources is less than in the previous two examples. Specialist journals head the ranking, while toxicology-specific sources are predominant.

Mycotoxins: This example of the behavioural toxicology sub-discipline may be contrasted with the study of mycotoxins, mentioned earlier, the literature of which is analysed by Datta (1987). This is an example of a field of study with a common focus, contamination by fungal toxins, which has been studied with the methods of, and reported in the literatures of, a number of disciplines: agriculture, food science, human medicine, veterinary medicine, chemistry, microbiology, etc. The extent of interest in the topic in the various subject literatures varies over time, as the focus of interest changed from an academic study grounded in agriculture and studied by the methods of chemistry and microbiology, to be regarded later as a veterinary and food science problem. While it is clearly multidisciplinary in nature, there is no indication that this was ever regarded by those involved in the work as a sub-discipline in its own right, nor that the sort of intellectual coherence desired by Hänninen for behavioural toxicology was ever envisaged as necessary.

Searching for this concept on SciSearch, using the terms MYCOTOXIN?, MYCO(W)TOXIN? And FUNGAL(W)TOXIN?, initially without date restriction (i.e. 1990 to date), gives 1138 items. Ranking these by source, down to sources containing 10 items, and by subject code gives table 2.16.

Table 2.16 Mycotoxins items from SciSearch ranked by source and by subject code, 1990 onwards:

Source

1	50	CEREAL RESEARCH COMMUNICATIONS
2	46	FOOD ADDITIVES AND CONTAMINANTS
3	44	JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
4	40	MYCOPATHOLOGIA
5	33	JOURNAL OF FOOD PROTECTION
6	31	JOURNAL OF CHROMATOGRAPHY A
7	24	APPLIED AND ENVIRONMENTAL MICROBIOLOGY
8	21	FOOD AND CHEMICAL TOXICOLOGY
9	21	JOURNAL OF AOAC INTERNATIONAL
10	21	PLANT DISEASE
11	20	REVUE DE MEDECINE VETERINAIRE
12	16	PHYTOPATHOLOGY
13	14	TOXICOLOGY AND APPLIED PHARMACOLOGY
14	11	ACS SYMPOSIUM SERIES
15	11	POULTRY SCIENCE

Subject code (those covering more than 10 items)

1	245	FOOD SCIENCE & TECHNOLOGY
2	146	AGRICULTURE
3	129	TOXICOLOGY
4	118	BIOTECHNOLOGY & APPLIED MICROBIOLOGY
5	117	PLANT SCIENCES
6	109	CHEMISTRY, APPLIED
7	89	CHEMISTRY, ANALYTICAL
8	82	BIOCHEMISTRY & MOLECULAR BIOLOGY
9	81	VETERINARY SCIENCES
10	69	MICROBIOLOGY
11	67	MYCOLOGY
12	67	PHARMACOLOGY & PHARMACY
13	45	PATHOLOGY
14	44	AGRICULTURE, DAIRY & ANIMAL SCIENCE
15	42	PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH
16	38	CHEMISTRY
17	33	BIOCHEMICAL RESEARCH METHODS
18	31	PUBLIC HEALTH
19	30	ENVIRONMENTAL SCIENCES
20	22	IMMUNOLOGY
21	20	ONCOLOGY
22	17	CELL BIOLOGY
23	17	MULTIDISCIPLINARY SCIENCES
24	15	CHEMISTRY, ORGANIC
25	13	BIOMETHODS
26	13	NUTRITION & DIETETICS
27	12	GENETICS & HEREDITY
28	11	BIOPHYSICS
29	10	BIOLOGY

Restricting the search to the most specific items by using title terms gave very similar rankings, shown in table 2.17.

Table 2.17 Mycotoxins title term items from SciSearch ranked by source and by subject code, 1990 onwards:

Source

1	40	FOOD ADDITIVES AND CONTAMINANTS
2	36	MYCOPATHOLOGIA
3	27	JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
4	23	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY
5	15	APPLIED AND ENVIRONMENTAL MICROBIOLOGY
6	15	JOURNAL OF CHROMATOGRAPHY A
7	14	REVUE DE MEDECINE VETERINAIRE
8	13	CEREAL RESEARCH COMMUNICATIONS
9	12	JOURNAL OF AOAC INTERNATIONAL
10	11	FOOD AND CHEMICAL TOXICOLOGY
11	11	TOXICON

Subject codes

1	147	FOOD SCIENCE & TECHNOLOGY
2	87	TOXICOLOGY
3	64	CHEMISTRY, ANALYTICAL
4	59	AGRICULTURE
5	58	CHEMISTRY, APPLIED
6	54	MYCOLOGY
7	51	PHARMACOLOGY & PHARMACY
8	46	BIOTECHNOLOGY & APPLIED MICROBIOLOGY
9	46	VETERINARY SCIENCES
10	43	CHEMISTRY
11	41	BIOCHEMISTRY & MOLECULAR BIOLOGY
12	40	MICROBIOLOGY
13	33	PLANT SCIENCES
14	33	PUBLIC HEALTH
15	30	AGRICULTURE, DAIRY & ANIMAL SCIENCE
16	30	ENVIRONMENTAL SCIENCES
17	26	PATHOLOGY
18	20	VETERINARY MEDICINE

In order to assess the change over time in publication patterns, the rankings above, which reflect a long time period, were compared with those resulting from a restriction to items published in 1996, 97 or 98 and shown in table 2.18.

Table 2.18 Mycotoxins title term items from SciSearch ranked by source and by subject code, 1996,1997, 1998:

Source

1	14	REVUE DE MEDECINE VETERINAIRE
2	13	FOOD ADDITIVES AND CONTAMINANTS
3	12	CEREAL RESEARCH COMMUNICATIONS
4	12	JOURNAL OF CHROMATOGRAPHY A
5	8	JOURNAL OF AOAC INTERNATIONAL
6	7	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL S
7	6	JOURNAL OF FOOD PROTECTION
8	5	MYCOPATHOLOGIA

Subject codes

1	46	FOOD SCIENCE & TECHNOLOGY
2	33	CHEMISTRY, ANALYTICAL
3	28	VETERINARY SCIENCES
4	25	TOXICOLOGY
5	23	BIOTECHNOLOGY & APPLIED MICROBIOLOGY

- 6 22 CHEMISTRY, APPLIED
- 7 21 BIOCHEMISTRY & MOLECULAR BIOLOGY
- 8 20 AGRICULTURE

For comparison, the search with mycotoxin terms anywhere in the record was repeated on a combination of Toxline and Embase, for items published in 1996, 97 and 98 and also for those published in 1986, 87, and 88, and order to see any evident change over time. The ranking for 1996-98 is:

Table 2.19 Mycotoxins title term items from Toxline/Embase, ranked by source, 1996,1997,1998:

- 1 118 FOOD ADDITIVES AND CONTAMINANTS
- 2 73 FEDRIP DATABASE
- 3 65 ADVANCES IN EXPERIMENTAL MEDICINE AND BIOLOGY
- 4 56 JOURNAL OF CHROMATOGRAPHY A
- 5 54 NATURAL TOXINS
- 6 39 CEREAL RESEARCH COMMUNICATIONS
- 7 36 TOXICOLOGY AND APPLIED PHARMACOLOGY
- 8 34 FOOD AND CHEMICAL TOXICOLOGY
- 9 31 MYCOPATHOLOGIA
- 10 29 APPLIED AND ENVIRONMENTAL MICROBIOLOGY
- 11 22 JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
- 15 18 ARCHIVES OF TOXICOLOGY
- 16 18 INTERNATIONAL JOURNAL OF FOOD MICROBIOLOGY
- 12 17 JOURNAL OF FOOD PROTECTION
- 13 16 JOURNAL OF BIOLOGICAL CHEMISTRY
- 14 14 ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGIC
- 17 10 BEIER

Table 2.20 Mycotoxins title term items from Toxline/Embase, ranked by source, 1986,1987,1988:

- 1 60 GOVT REPORTS ANNOUNCEMENTS & INDEX (GRA&I)
- 2 56 APPLIED AND ENVIRONMENTAL MICROBIOLOGY
- 3 34 JOURNAL OF CHROMATOGRAPHY
- 4 34 TETRAHEDRON LETTERS
- 5 33 JOURNAL OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS
- 6 25 MYCOPATHOLOGIA
- 7 25 TOXICON
- 8 13 POULTRY SCIENCE
- 9 10 AMERICAN JOURNAL OF VETERINARY RESEARCH
- 10 29 FOOD AND CHEMICAL TOXICOLOGY
- 11 10 JOURNAL OF ORGANIC CHEMISTRY
- 12 18 TOXICOLOGY AND APPLIED PHARMACOLOGY

The FEDRIP database, which appears high in the 1996-98 rankings, is a database of US government supported research in progress, and is a subfile within Toxline.

Although some change in publication patterns over time is evident, the general impression is again of a rather scattered literature, with no principal journals, and little concentration around toxicology *per se*. Conference proceedings again appear as significant, though in this case less so than governmental reports.

Summary for sub-disciplines

In most respects, this study of several sub-disciplines of toxicology shows that the same general points as have emerged for the discipline as a whole.

The multidisciplinary nature of the field is strikingly evident here, with no clear hierarchy apparent in the way in which toxicology and other disciplines overlap and divide. Indeed, particularly striking is the lack of any definition of quite what constitutes a sub-discipline, or inter-discipline, with very differing views voiced by practitioners in the behavioural example as to what the nature of their own speciality was.

The importance of specific publications - books, conference proceedings and journals - in establishing and defining sub-disciplines is clear. The formation of societies is also a defining point, though in some cases the existence of several societies with overlapping interests may be a cause of confusion. The role of societies as publishers and sponsors of journals, and as organisers of conferences and meetings, is shown up as particularly important here, with society-sponsored journals being in some cases the core publications of the speciality.

Conversely, accepting the importance of these formal publications, the significance of informal interaction, at conferences and meetings and also via laboratory visits etc., in establishing new specialisms is shown clearly. The effect of new ICTs in this respect cannot be shown by a historical perspective such as this, and will be discussed later in this thesis.

In three out of the four cases exemplified, a wide scatter of publication across sources and subject areas was evident, less so for the fourth case (*in vitro* toxicology).

Conference proceedings were an importance source of information in all the examples, though in one case (mycotoxins), governmental reports were more important. These findings re-emphasise the diversity of the toxicology information system, and the difficulty of identifying general patterns within the communication of this complex subject.

2.5 Conclusions

We have seen in this chapter, that the definition of toxicology itself is a matter for debate and interpretation, and have taken, as a working definition of toxicology for this study, the idea that it is 'a consistently observed harmful effect, due to a particular form of exposure to a given chemical in a particular species'. The differences in definition of the subject, in particular when very broad definitions are adopted, have clear and practical consequences for information provision, when it has to be decided what information falls within the realm of toxicology.

It has been shown that toxicology, on the one hand, has a very long history, dating back to ancient times, but also that it is a very modern science, with its intellectual support systems (educational, informational and social) stemming only from about 1960. This paradox has also influenced the nature of the discipline, and hence of its information and communication systems.

We have concluded that toxicology is 'a practical discipline, within the form of the empirical natural sciences', while showing some of the characteristics of a more general field of study. This definition caters for the considerable debate about quite what the nature of toxicology is, and specifically allows for the fact that it is, at the same time, both a pure and an applied discipline. Indeed, it is unique among disciplines in having the characteristics of a pure science, and a strong academic base, while also having an important applied, regulatory, aspect, which has, to a large extent, driven its recent development. More than other sciences, it carries a weight of legal and ethical considerations about its practices and conclusions. These factors also strongly influence the kind of information systems which have developed to communicate toxicology information.

Toxicology is highly multidisciplinary, arguably an 'interdiscipline', which draws on most of the basic biological and chemical sciences for its methodology. One of the consequences of this is that there is some uncertainty among practitioners as to what constitutes a 'toxicologist'; certainly the qualifications required for employment in the field do not suggest that there is a unique disciplinary standing. Recently, however, toxicology has begun to create its own concepts and methods, and 'return' them for the use of other disciplines. This transformation of a 'borrowing science' into a contributor has interesting implications for the communication of relevant knowledge, which are considered in chapter four. In the not-so-distant past, toxicology has been

entwined with three other disciplines in particular: pharmacology, physiology, and pathology. In some of its aspects, analytical chemistry can be added. These linkages still show themselves in its information transfer.

A variety of sub-disciplines exists within toxicology, and on the boundaries between toxicology and other disciplines. These in their turn generate new information needs and information products.

The growth of the information systems of toxicology has happened in parallel with, and in synergy with, three other factors of disciplinary growth: educational programmes; the founding and subsequent activities of learned and professional societies and associations; and legislative and regulatory requirements. In order to understand the current state of the information systems of toxicology, and their likely future developments, it is necessary to appreciate the current and future state of these other factors.

The analyses reported in this chapter have confirmed some general aspects of the information systems of toxicology. The formal literature is large, diverse and, often, scattered, including monographs, journals, conference proceedings, and government reports. Informal interactions, including conferences and meetings, have played, and continue to play, an important part. Societies and associations play an important role in the information transfer process.

New ICTs are used to a varied extent. Toxicology was one of the first subject areas to benefit from technologies such as online databases and databanks; internet-based resources are now being adopted by several societies. The nature and extent of their influence will be discussed in later chapters.

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Chapter Three: Information Resources in Toxicology

3.1 Introduction

This chapter considers contemporary information resources in toxicology. In so doing, it follows on from the development of information and communication systems outlined in the last chapter. Its purpose is to show how today's resources fit into the overall system for communication within the discipline, and to examine changes brought about by new ICTs.

The following research questions are addressed:

- How can toxicology information resources be identified?
- What kind of information resources are currently used for toxicology communication?
- How have new ICTs affected the nature of these resources?

To answer these questions, a selective, categorised listing of resources is produced. In order to do this, the nature of subject resource listings is considered, with an analysis of the way in which they have changed over time, particularly with the influence of the Internet. Ways to produce them are discussed and a general methodology for creating resource listings is proposed, and then used to draw up a toxicology resource list.

To assess the impact of new ICTs, the final list is compared with equivalent listings from the past.

3.2 Subject Guides and Resource Listings

The terms 'subject guide' and 'resource listing' are used here, synonymously, to mean any collection of descriptions of information resources in a particular subject area,

3.2.1 The nature of subject guides

Such tools have a long history; Hill, McIlwaine and Williamson (1997) refer to a literature guide for engineers written in 1891. Terminology may be inconsistent; for example, Wexler (1988) notes that the second edition of his guide to toxicology resources may be described by a librarian as an annotated bibliography and directory, while he prefers to think of it as a sourcebook. A well-known glossary of library terminology, Prytherch (1995) prefers the term 'subject bibliography' ('a list of material about a particular subject or individual'), reserving 'subject guide' to mean a guide to the shelves of the library. Internet resource listings may be termed 'virtual libraries' or 'subject gateways'.

Listings and guides of this sort can take varied forms. Most well known ones are printed products: books and directories; chapters or sections in monographs; journal articles; reports; and conference presentations. Guides in digital form are now increasingly available, predominantly as HTML files, with links to the resources if these are also in HTML form.

Apart from the obvious characteristics of subject topic and physical format, resource listings may be distinguished by three principal characteristics:

- comprehensiveness: to what extent does the list aim to cover, and succeed in covering, *all* significant items within its field of interest; as is noted below, this aspect seems to have changed significantly over time
- currency: how often is the guide updated; clearly the Internet subject gateway, typically updated monthly or more frequently, has the advantage over the traditional printed tool, updated annually at best
- annotation: what degree of description and evaluation is applied to the resources listed

With regard to comprehensiveness, although this has often differed greatly between guides of roughly the same date, a general trend over time can be discerned. Earlier guides, roughly those dating from before 1980, usually made some claim to comprehensiveness; later guides have emphasised selectivity, understood in different ways.

Typical of the claims of earlier guides is that of Yescombe's guide to sources of information on rubber and plastics, compiled in 1966-67:

'No guide of this kind can hope to be exhaustive, but every effort has been made to include all important sources and to describe them accurately up to the end of January 1967' (Yescombe 1968, p ix)

A particularly telling, and relevant, example is given by the guide to medical sources edited by LT Morton and collaborators. The first edition, dating from 1974, makes an unambiguous claim to complete coverage:

'This book attempts to provide a comprehensive guide to the general and specialised literature covering the medical sciences .. Limitations of space have not permitted a separate chapter for every branch of medicine, but readers will find that several of the contributors have covered their subjects very broadly' (Morton 1974, preface)

By the fourth edition of 1992, the claim was very different:

'This book is intended to serve as an evaluative guide to the most important sources of information that each contributor has recommended from experience of the subject, rather than as a directory of sources' (Morton and Godbolt 1992, preface)

Guides and listings of the 1980s and 90s have emphasised selectivity. Some have focused on illustrating principles, as in Vernon's 1984 guide to management and business literature:

'This book .. makes no attempt to cover all aspects of an ever-broadening subject area. It concentrates instead on trying to help people to understand what the literature has to offer, the various forms in which it is published and how to find information by using libraries and other sources' (Vernon 1984, p x)

Grogan's 1970 guide to the literature of science and technology, primarily written for students, shows this at its logical conclusion, by describing types of resource, giving one or more examples for each:

'.. attention is concentrated on types of literature, and individual titles are normally listed merely as manifestations of those types... where a guide such as this has to be comprehensive is in demonstrating all the types of scientific literature.' (Grogan 1970, p 9)

Others, recognising the difficulty of compiling guides and lists against a background of rapid change in resources, have combined a focus on basic principles with an attempt to list the most important, or most enduring, tools. Maizell's 1979 guide to chemical information is an early exemplar of this trend:

'One of the basic premises on which this book is written is that of change .. New and improved information tools are constantly being introduced, and, concurrently, older tools become less valuable, become obsolete, or are discontinued. Accordingly, this book presents the most important and enduring of the classical tools of chemical information: the more significant newer tools; and, most importantly, the underlying methods, principles, and keys .. Because this book emphasises the more enduring principles that lead to the most effective use of chemical information, the coverage of sources, methods and tools is selective.' (Maizell 1979, preface p vii)

Still others, faced with a plethora of potentially relevant resources, have tried to emphasise less well-known sources, for example Welch and King's 1985 guide to medical sources:

'What we have attempted is to describe services and publications which we feel should be better known. With some rare exceptions familiar features and works are not covered. In some sections we have been very selective in order to keep the text to a manageable size. The wish to draw attention to less familiar material has been the criteria of selection.' (Welch and King 1985, preface p x)

A general trend has been to emphasise selectivity by personal judgement of the 'best' resources, an idea clearly described by Wexler:

'This remains a selective list with no attempt made to cover exhaustively all available materials. A selective list always assumes a certain presumptuousness on the author's part in judging some books more deserving than others. I have further risked charges of audacity by highlighting the books that I deem especially noteworthy with an asterisk. I have no concrete criteria for these judgements other than my personal opinion in examining the texts.' (Wexler 1988, preface p xv)

'The goal of this revised third edition is to provide an up-to-date selective guide to sources of information in all aspects of toxicology and ancillary fields, such as environmental and occupational health and risk analysis.' (Wexler 2000, preface p xix)

Other listings have attempted to list the 'best' or 'quality' resources, using detailed and clearly stated quality criteria. This has become particularly important with the advent of the world wide web, and the OMNI biomedical resources guide (<http://www.omni.ac.uk>) is a good example.

Finally, there is the recent trend to produce subject guides of a highly specific nature. Fitzpatrick (2000) describes resources produced by the US Toxicology and Environmental Health Information Program. Narrowing this approach slightly, Wexler (2001), and Fonger et al. (2000) both describe in detail, resources comprising just the TOXNET service. Kehrer and Mirsalis (2001) concentrate on web sites for professional toxicology societies, whilst Brinkhuis (2001) describes toxicology information from US government agencies. More specifically, Poore, King and Stefanik (2001) refer to toxicology information resources from the US Environmental Protection Agency (EPA).

A further issue is the method of structuring the guide, and of categorising the resources. Virtually all guides, other than the most limited, are categorised in some way; indeed, they must be so, if they are to be usable, but the criteria for structuring are quite varied. Many listings have adopted some form of structuring by primary, secondary, tertiary source, though this is often differently defined. Others use a structuring by subject speciality, by national origin of resources, or by physical format. Any of these may form a primary division, and some guides have a complex system of sub-division.

The problem is clearly enunciated by Wexler, who points out that the organisation of such a list is critical in providing efficient access, but that there is no perfect way to achieve this.

'It has become considerably more difficult to know how to categorise items.'
(Wexler 2000, preface p xix)

He also points out the inherent advantages of a computerised over a printed resource listing, in allowing access according to various criteria, and expresses the hope that his book will one day be joined by an electronic version.

3.2.2 Methods of production

The production of resource listings appears to have been an art rather than a science, at least until more systematic procedures were introduced to deal with Internet resources. In an attempt to identify any standard methodologies for producing such listings, searches were carried out on relevant bibliographic databases and on the Internet, textbooks of librarianship and information science were scanned, and the introductions to a variety of subject guides were examined. No indication was found of any generally accepted procedure, or even of any individually adopted systematic method, for producing such guides; this appears to a rather idiosyncratic procedure, based on the knowledge, experience and preferences of the compiler.

This view is expressed clearly by Foskett and Hill in their foreword to a series of subject guides:

'Individual chapters are written by experts .. [who] give a view based on experience of finding and using the most appropriate sources' (Foskett and Hill 1992, foreword)

This view is echoed by the more recent editorial team for this series:

'[these guides] aim to bring you the knowledge and experience of specialists in the field. Each author regularly uses the information sources and services described and any tricks of the trade that the author has learnt are passed on.' (Hill, McIlwaine and Williamson 1997, foreword)

This reliance on individual experience is seen in the OMNI procedure, by which volunteer subject experts select the Internet sites for inclusion.

The only frequently used alternative appears to be a widening of this 'expert knowledge' approach, by soliciting the views of subject experts, or information providers, by some form of questionnaire. This was done in the construction of an early guide to US-based general toxicology information resources, NRCST (1969). A questionnaire was sent to a list of providers of potentially useful resources, based on an existing register of information resources in the area; it was noted that this approach gave a directory which was representative, though not exhaustive. Separate listings were provided for poison control centres, which could be listed comprehensively, and for journals and professional organisations, for which a representative listing is given.

3.2.3 Toxicology subject guides and resource listings

The toxicology subject area has seen a variety of subject guides and resource listings, exemplifying many of the points made above. These will be discussed in the context of qualitative evaluation of resources in chapter five, and only a few salient examples will be given here.

The printed book listing is exemplified by Wexler's monograph, a new edition of which was published in 2000. As noted above, this provides a selective listing, with indications of particularly significant items, based on personal experience. It is structured primarily by format: following an initial chapter on the history of toxicology, chapters 2-21 describe US-based resources, according to publication medium. Chapters are further sub-divided in a variety of ways, including subject and origin. Chapters 22-24 consider international toxicology resources, whilst chapter 25 covers resources from different countries. There is a mixture of annotated entries and directory style un-annotated listings. The book was first published in 1983, and a second edition appeared in 1988. It is still regarded as the single best resource listing for the subject.

The monograph chapter is exemplified by Deschamps and Morgan's (1993) article in a two-volume monograph on general and applied toxicology. Structured into three main sections by type of resource - printed, computerised, and personal/organisational - this provides a mix of annotated descriptions of some

individual resources, with additional directory listings. The intention of the authors is given as showing the range of possible sources with limited numbers of specific examples. A section in a monograph, in this case on medical information resources, is exemplified by Morton and Godbolt (1992), who provide annotated descriptions of a small number of sources. Monographs of this sort are typically updated every few years, Morton and Godbolt being in its 4th edition.

The journal article format has several exemplifications, of which only two are mentioned here. The article by Liverman et al. (1997) gives a discursive description of a number of online databases, for which brief details are then displayed in a tabular format; there is no other structuring. Halton (1986) gives annotated descriptions of databases within a structure dividing by database category - dictionary, bibliographic and information - giving examples of databases within each category. Like most journal articles, these have not been updated.

An example of a report format is Hargreaves' (1980) British Library report on toxicology information sources; this gave an extensively annotated description of a set of resources aiming at comprehensiveness, and structured by form: bibliographic databases, factual databanks, printed/card/microform products, institutions and research centres, and national / international toxicology information programmes. Another example is the guide to sources in chemical toxicology, jointly produced by the Association of Information Officers in the Pharmaceutical Industry (AIOPI) and the UK Online User Group, AIOPI (1980). This is categorised by type of resource, with unannotated listings of printed textbooks and handbooks (sub-divided by specific subject), and of printed abstracting and indexing services, and annotated listings of computerised sources. Like most reports, these were a single publication (though the AIOPI report describes itself as a first edition), and have not been updated.

Conference proceedings are exemplified by Robinson (1989), who gives a selective and annotated list of computerised information resources, categorised by format: online bibliographic databases, online factual databanks, and CD-ROM sources.

Of several Internet sites offering lists of toxicology resources, a typical example is the toxicology section of MedPharm, offered by the Italian Università degli Studi di Torino (<http://www.medfarm.unito.it/toxicol/toxicol1.html>). This offers an unannotated list of exclusively world wide web resources, categorised by subject speciality: general toxicology, poisons, clinical toxicology, drug and alcohol abuse, and toxicology education. OMNI, the UK based, biomedical subject gateway, offers a highly

selective list of web resources without categorisation other than subject access by NLM classification and MeSH thesaurus terms. The sites are selected according to strict quality criteria, fully annotated, and checked for correctness and possible change on a monthly basis.

It is clear from these examples that the toxicology discipline already offers an array of diverse resource listings. Whilst none of these, even Wexler's most recent, and arguably, definitive, resource guide, claims to be comprehensive, it is not the intention of this chapter to produce a complete, contemporary listing. Indeed, this is rather an impossible task, as even were it feasible to identify every single resource relevant to toxicology, the rate at which new resources can be produced anywhere in the world far exceeds any current ability to track them.

The purpose of the listing is to provide a contextual framework for toxicology information, which can serve as a tool for understanding of the range and relative significance of information resources. The list specifically includes newer, network based resources, and can be compared with similar listings from the past, in order to assess the impact of new ICTs.

3.3 Methodology for Creating Resource Listings

The perfect or complete resource list for any discipline is an unattainable goal at the time of writing. There is no procedure by which one can create such a universal resource. Nor is there a definitive method for creation of a more limited resource list. If we wish to examine communication of information within a discipline, we should first be able to identify and evaluate the resources which form the discipline, being confident that we have addressed a representative sample of all types of information resource. A strategic approach to the creation of resource lists would therefore be useful at this stage.

Creating a resource list must involve some searching to identify resources. Because of the proliferation of sources, particularly where the Internet is concerned, the problem will almost certainly lie in the selection and organisation of a large amount of material, rather than a difficulty in finding anything at all. This will necessitate an evaluation step, in which resources which have been identified as relevant to the subject are assessed against a pre-defined set of criteria, to decide whether they are appropriate for inclusion in the resource list.

A further, initial, stage is also required; the construction of an intellectual framework within which to fit the material found, and thereby to make sense of it. Creating such a framework is equivalent to setting a context for the resources found, and is a part of the 'critical thinking' approach, often proposed as an essential skill in making effective use of information resources in general, and the Internet in particular. Gibson and Meade express this idea clearly:

'Context mysteries for Internet information and searching will continue to be a problem. The critical thinker will have to develop a site orientation to Internet resources in order to invest them with meaning. Retrievals in cyberspace have to be placed in some kind of mental framework created by the searcher. Various kinds of mental frameworks can be created, including classifying Internet resources by origin or provenance, type of data, need for special manipulation or file management, or even an intellectual seriousness scale that would presumably locate certain Usenet groups at the low end of the scale while placing the Oxford Text Archives or the Coombspapers Archive at the high end of that same scale. Critical thinkers will invent frameworks that help

create context in what often seems like a context-free environment.' (Gibson and Meade 1996, p 144)

This reference to a context-free environment reminds us that the Internet poses particular problems in this respect, precisely because of the consistent presentation, by a Web browser, of information from a variety of origins. The visual and tactile, as well as intellectual, context clues present in the examination, for example, of books and journals in a paper-based library are entirely lacking in the digital environment.

Similar arguments are made by the OMNI group:

'Establishing the context of a resource can be a challenging task. By context we refer to aspects such as scope, audience, authority and provenance. Networked information resources tend not to have a common set of features such as statement of responsibility, introduction or preface from which to draw such information. The policy of pointing directly to individual resources places a greater responsibility on [list compilers] to examine sources of information about a resource (eg. home pages, parent documents and help files), in order to place a candidate resource in context.' (OMNI 1999)

The creation of a resource list may therefore be regarded as a three stage process:

- choose/create a framework
- identify resources
- evaluate resources

Each of these will now be examined in more detail, and a specific methodology outlined for the creation of a toxicology resource listing.

3.3.1 Creating a framework

As noted in the previous section, existing subject guides and resource listings, for toxicology, as well as for other subject areas, make use of a variety of schemes and frameworks for categorising resources, and thereby giving structure to the list.

Since the list is to be created and maintained in digital form, it might be argued that choice of a framework is not so crucial, since the electronic format means that

multiple frameworks could be maintained, and resources selected *post hoc*, by whatever criteria seemed appropriate. However, this would be to miss the main point of the establishment and use of such a framework. It acts as an intellectual aid to the creator of the listing, in helping to impose structure and context on the mass of material likely to be encountered during the compilation of the list, thereby helping to ensure consistency, elimination of duplicates, balance and common sense in the choice of material. As will be seen, if a framework based on type of material is chosen, it acts as an aid to the compiler, in enabling a 'cascade' style of resource identification. Subsequently, a suitable framework should also serve as an aid to the user of the list, acting as a guide to the nature, and inter-relations, of what is provided. This is not to say that supplementary access points to the main framework cannot be provided for convenience, but this does not detract from the necessity of the main context-setting framework.

There are four forms of general framework categorisation, excepting those, exemplified above by Gibson and Meade, which are Internet specific, which appear feasible for the toxicology list to be used in this thesis:

- by subject
- by format
- by location
- by type of material

The first of these, a subject categorisation, in this case dividing material by specific type of toxicology, is commonly used for subject guides, including some in the toxicology area. Indication of subject is obviously essential, but this form of categorisation is not suitable as a main framework for this list. For one thing, many resources cover multiple subjects, leading to duplication in listing, and possible confusion. More importantly, a primary breakdown by subject would bring together very diverse forms of information, and would be less than helpful to the user of a list of this sort, while it might well be appropriate for a list involving only a single format of information, e.g. online databases, or printed journals.

The second form of framework is one based on format of information: printed book, online bibliographic database, web page etc. While this is a useful element of information to have in the description of each resource, it is not suitable as the primary framework. For one thing, some resources exist in several forms - e.g. Index Medicus / Medline exists in print, online, and CD-ROM, leading to duplication. For

another, it would be rare for a user to look for specific formats, unqualified by other considerations.

The third form of categorisation divides resources in the list according to country, or place of origin. This is done, to some extent, in Wexler's 1988 listing of toxicology resources, and also features in his more recent edition of the book. There is some justification for this in the case of legislative and regulatory aspects of toxicology, which may well differ from country to country. Overall, however, categorisation of resources by location does not help us understand the context of resources within the discipline.

This leaves the fourth type of framework, in which resources are initially categorised according to their type. This seems plausible for a list which is intended to serve as a snapshot of the toxicology discipline, since it promotes an understanding of the communication process, and indicates what sort of information items may be available. It leaves open the question of exactly how the categories will be defined.

An adaptation of a 'traditional' library/information framework, based on structure of literature, particularly scientific literature, is derived for the toxicology listing in this case. Resources are divided into primary, secondary, tertiary, and quaternary categories, essentially according to their distance along the communication chain from the original 'raw' information. A particularly clear and full description of this sort of categorisation is given by Grogan (1970). Adaptation is necessary because this model was intended for a system of publication based purely on printed products. Limited modification coped with the inclusion of computerised sources, e.g. machine-readable abstracting and indexing services, but the arrival of the new forms of information product require the model to be extended further. Nonetheless it is noteworthy that this relatively elderly model still serves very well in helping to clarify the allegedly chaotic system of (largely networked) information of the present time. Under the adaptation of this system, resources may be categorised as shown in table 3.1. It must be noted that the categorisation is not intended to be absolute; rather it is derived from consideration of communication within toxicology.

Table 3.1 Framework for resource categorisation

Primary: the original information, in whatever form it takes

case reports
company reports, financial data
course notes, interactive training materials, syllabi
conference proceedings
data tabulations
diaries, web diaries
journal articles
media reports
memoranda, letters, e-mail messages, postings to newsgroups, text messages
notebooks
organisations' and individuals' websites (n.b. organisations per se are classed as 3^o resources)
patents
preprints
regulations and legislation
reports
standards
technical manuals
theses, dissertations
trade and product information

Secondary: 'worked over' knowledge, which organises the primary material in some way

classification schemes
data compilations, reference works, handbooks, encyclopaedias
dictionaries, glossaries, thesauri
faqs (frequently asked questions)
indexing and abstracting services, online databases, databanks
monographs, textbooks, treatises
pharmacopias, formularies
reviews and summaries of progress

Tertiary: rather diverse sources, which aid the use of information resources at all levels; typically they do not carry 'subject' information at all, and may not be subject specific

- academic and research departments
- associations and societies
- bibliographies and reading lists (generally refer to printed matter)
- course listings
- directories
- Internet directories, subject gateways, virtual libraries (all are categorised)
- Internet search engines
- library catalogues
- libraries and information services
- lists of abstracting and indexing services
- lists of mailing lists
- lists of newsgroups
- lists of research in progress
- lists of expertise
- literature guides (annotated descriptions of printed and network resources)
- online hosts, lists of databases and searchable sites
- periodical location lists
- portals (offer a mix of subject related services)
- resource lists, recommended or core resources (list any subject related resources, not just articles)
- webliographies (list of web resources)
- webrings
- yearbooks

Quaternary: list other listings, may also list other 'lists of lists'. Can be both subject specific and of a general nature.

- bibliographies of bibliographies
- guides to libraries/catalogues
- lists of lists
- lists of organisations

N.B. There is a further, zeroth order, of information; the 'raw' data which comes from laboratory instruments: however, although this can now be readily captured, stored and transmitted elsewhere, it is not truly an information resource until it has been organised and described so as to be understandable in 'public, or formal use', at which stage it can be regarded as primary information.

3.3.2 Identifying the resources

Identifying the resources to be put into a list of this sort will inevitably be, to some extent, a subjective process, depending on the subject knowledge and experience of the compiler. However, if the framework suggested above is used, this will provide an outline to be followed, as an aid to making the procedure systematic.

The basic principle is to begin with the higher level resources, and use them sequentially, following listings, references, hypertext links etc., to find those at lower levels. Thus, quaternary resources are used to find tertiary, tertiary to find secondary (in practice all levels), secondary to find primary. In an ideal information world, where every resource occupied its assigned place in the hierarchy, this approach could be followed in its 'pure' form, starting with a comprehensive quaternary source, and then following references down through the hierarchy without any return from lower levels to higher. This situation does not exist for any subject domain. The comprehensive quaternary resource does not exist in any field. In all cases, some resources will not be found via a higher level tool; these may be identified by serendipitous searches. Likewise, it is probable that more than one quaternary resource will exist within a domain, and the search process will comprise a network of pathways, rather than a straightforward cascade. References to higher as well as lower resources should be expected. For example, a reference from a journal article (primary) to a review article (secondary), is a possibility. When one is dealing with resources in hypertext form, links 'upwards' will frequently be encountered, so that the compiler must expect some iterations to higher levels. Even so, the general principle of starting with resources at higher levels and using them to find those at lower levels is still a useful means of attaining a systematic procedure.

There is then the question of *how* resources are identified at each level. There are, again in general terms, three ways:

- personal knowledge
- expert advice
- searching

Personal knowledge: under normal circumstances, the compiler of a resource list will have some subject expertise, and this will therefore normally be the first source of entries to the list at every level.

Expert advice: the second stage, use of expert advice, implies advice of subject experts above and beyond that of the compiler. As noted previously, at least one toxicology resource listing was produced using this method alone, by asking a panel of experts for their favoured resources, and consolidating the results. However, though arguably preferable to accepting the views of a single compiler, it is not a method which can be used alone. It is likely to be used in conjunction with other methods, as either the initial or the final step in the procedure. It would be appropriate for it to be the initial step in the case where the compiler had no personal expert knowledge, and this was used in its stead; the 'reference interview' carried out by an information specialist before carrying out a search on behalf of a client is an analogy. If this method is followed, caution must be exercised with regard to bias of any kind.

More usually, and certainly in this study, this step comes late in the procedure; expert advice is sought as a check on, and a means of seeking additions to, an initial list compiled on the basis of steps one (personal knowledge) and three (searching).

Searching: the third means of identifying items for the list is searching. This rather general term covers a variety of processes, which will vary according to the subject area of the list, and also to the type of material which will be included in it. There will generally be specific searching options for different levels of material, and also for material in different formats. However, there will be some overlap in the latter: Internet search engines, for example, will usually return web pages, but some of these may contain information on printed books and journals, or on means of accessing online databases.

Search Tools

Searches will therefore be carried out using tools appropriate for the subject matter and the type, or level, of material being sought. In general, this will mean using bibliographic databases and Internet search tools to identify material at each of the four levels. In addition, level specific tools, designed to retrieve a particular resource type will be consulted as needed. When searching for secondary resources, for example, the documentation of providers of online and CD-ROM services enables identification of relevant databases and databanks. Library catalogues may be consulted to identify books. It may also be appropriate to examine physical collections of material, or items describing them, e.g. collections of books and journals in specialist libraries.

Searching requires that the compiler be able to identify suitable search tools. Such tools are also resources to be included on the list. For example, subject specific, bibliographic databases like Toxline, are secondary resources for toxicology information, and are thus included in the resource list, but they are also sources to be searched for further resources. Search tools may be known to the list compiler. If this is not the case, then the search tools must first be identified by searching generally, in databases such as Library and Information Science Abstracts. The construction of a resource list is thus a cyclical event, rather than strictly hierarchical.

Three kinds of bibliographic (or full text) database were useful for identifying resources for the toxicology list:

- subject specific databases, which may include items on information resources in their area. For toxicology, examples include Toxline, Medline, and Biosis.
- databases covering library/information literature, which would be likely to include items describing subject resources: e.g. Library and Information Science Abstracts (LISA), Social SciSearch.
- 'general' databases, covering material in a particular form: e.g. Books in Print, Dissertation Abstracts, National Technical Information Service (NTIS, for governmental reports, particularly from the USA).

Internet search tools include search engines and directories. Since the number of these is high, and their nature changes so rapidly, it is inappropriate to be too specific as to which to use at any one time, but selection should be based on coverage of Internet material and frequency of update Sullivan (1999), as well as any which may cover the relevant subject particularly well, for example, the environmental organisation directory (<http://www.webdirectory.com>). This is again a circular argument, since subject specific search engines would be useful resources in themselves, to be identified and added to the list. General directories emphasising 'professional' material, such as BUBL, (<http://www.bubl.ac.uk>) would also be favoured.

Search Terms

It will also be necessary to construct search strategies in order to find relevant material. This will require the combination of terms reflecting the subject, in this case 'toxicology', with those reflecting the concept of the type of information resource. More precise terms may be used to search for a specific toxicology sub-discipline, (e.g. teratology), or for a specific type of resource (e.g. mailing list).

Very simple searching, perhaps just the subject indication, can be used in general or library and information science databases, when the number of hits will be limited, or where the concept of an information resource is implicit in the purpose of the database. Simple searching may also suffice to query level specific search tools, such as directories of databases, where the subject term alone will retrieve relevant entities.

When searching subject specific resources such as online databases, more detailed search specification will usually be needed, because of the larger amount of potentially relevant material which is likely to be retrieved. General Internet search tools will also demand more complex strategies due to the very large amounts of material they cover.

3.3.3 Evaluating and selecting resources

The identification process can generate large amounts of potentially relevant material. There is thus a need for the list compiler to make choices from the material identified, or at least to ratify its appropriateness for inclusion in the resource list. While there will inevitably be some element of subjective judgement in this selection / ratification, and different list compilers might be expected to make some different decisions, an element of consistency can be imposed by the use of selection guidelines, if not rigid criteria.

Guidelines for selection of material have always existed in library and information work, originally under the heading of 'book selection'. The topic has been given impetus recently in the context of evaluation of Internet information, in particular by the establishment of 'quality gateways' such as OMNI (Organising Medical Networked Information) and SOSIG (Social Science Information Gateway), Anagnostelis (1997), Tate and Alexander (1996). While the precise sets of criteria used for these gateways, which only list Internet sites, are too restrictive for the toxicology list, which aims to cover relevant items in all formats, they are a good basis for derivation of a more general set of criteria.

The most relevant set of criteria for initial consideration is the set of criteria used by OMNI, since these have been designed specifically to deal with biomedical material. These are set out below in brief: a full version can be found at OMNI (1999).

- Scope (subject area, breadth, depth, time period and format or type of information)
- Intended audience
- Authority (who are the providers)
- Provenance (where does it come from? How long has a resource been available, either in print or as an electronic version)? How is it maintained ?
- Coverage
- Accuracy of information content
- Currency / frequency and regularity of updating
- Uniqueness / comparison with other sources
- Accessibility and usability
- Charging policy
- Special requirements (hardware and software)
- Software reliability
- Copyright
- Language
- Design and layout / user interface
- User support / documentation

The criteria used in selecting material for the list of toxicology resources were a generalised and modified version of this list:

- authority: who produces the resource; what qualification have they to do so
- provenance: in essence the stability and longevity of the resource
- objectivity, evaluation; is the information evaluated and balanced; or does it present a single point of view
- currency: how up-to-date is the resource; how often is it up-dated
- accuracy: how valid is the information; what is the 'quality control'; how are errors corrected
- coverage, completeness: how complete, within its stated area of coverage
- relevance: how useful would the resource be, and to what sort of users

These are, in fact, quite similar to the five 'classic' criteria (accuracy, authority, objectivity, currency, coverage) which Tate and Alexander (1996) remind us were traditionally used to evaluate print resources. Provenance has been added to reflect the more dynamic networked environment, and relevance because of the subject specialist nature of this resource evaluation.

The criteria were applied in a context sensitive way. If many similar resources were found, then any one would be judged more strictly, largely by authority and provenance, than one where few others of its kind existed. In the latter case, the criteria would simply be 'how representative is this of material of this kind?' In those cases where the resource is the only exemplar of its kind, then that was sufficient criterion for inclusion.

Since the listing is intended to provide an illustration and exemplification of the kinds of toxicological resources available at the present time, rather than to give a set of 'quality assured' resources, some of the restrictions applied by OMNI are not relevant here. For example:

'Resources are included only if they contain substantive information... Personal pages or simply collections of pointers to other resources do not meet this requirement and are de facto excluded.... Ephemeral material, such as advertisements and e-mail messages or newsgroup postings, is also normally excluded' (OMNI 1999).

3.3.4 Procedure for construction of resource list

In summary, the procedure for creating a resource list is shown in table 3.2, developed from Robinson (2000), assuming that:

- the scope of the subject is understood
- the list compiler has some subject expertise
- the compiler has an initial knowledge of some sources

A more specific interpretation for the toxicology listing is given in table 3.3.

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Table 3.2 Procedure for construction of an information resource list

1. establish a contextual framework for 1° 2° 3° 4° materials
2. create an initial list from known resources at each level
3. identify search tools: bibliographic/full text databases, Internet search engines and directories, level specific tools
4. consider search terms
5. search for further resources at each of the four levels in turn, starting at the highest, using appropriate search tools, terms and strategies
6. use resources found at each level to identify more at lower levels
7. where a resource gives a reference (in printed or bibliographic files) or a link (in HTML files) to a previously unidentified resource at a higher level, check it to see if any more resources can be found
8. evaluate all resources against appropriate criteria, select those for inclusion
9. if appropriate, submit final list for checking by independent subject experts
10. present listing in sensible format

Table 3.3: Procedure for construction of an information resource list in toxicology

- 1. establish contextual framework of 1° 2° 3° 4° materials**
- 2. identify a set of bibliographic or full text databases to be used**
- 3. identify Internet search tools to be used**
- 4. identify level specific resources to be used**
- 5. decide on search terms and strategies to be used**
- 6. identify quaternary sources**
 - from personal knowledge
 - search internet search tools
 - search bibliographic databases
 - search level specific tools as needed to identify specific quaternaries
e.g. *printed lists of lists (from library catalogues)*
- 7. identify tertiary sources**
 - from personal knowledge
 - from quaternary sources already found
 - search internet search tools
 - search bibliographic databases
 - search level specific sources as needed to identify specific tertiaries:
e.g. *library and information services (from directories)*
toxicology organisations and societies (from directories)
online host systems (from guides)
 - if new quaternary sources are found, check for new tertiary sources in them
- 8. identify secondary sources**
 - from personal knowledge
 - from references/links in tertiary sources already found
 - search internet search tools
 - search bibliographic databases
 - search level specific entities for each type of secondary resource:
e.g. *books (from catalogues and book lists)*
bibliographic databases (from host's documentation)
full text databases
CD-ROMs (from directories and publishers' listings)
 - if new tertiary sources are found, check for new secondary sources in them
- 9. identify primary sources**
 - from personal knowledge
 - from references/links in tertiary sources already found
 - from references/links in secondary sources already found
 - search internet search tools
 - search level specific tools to identify types of primary resources:
e.g. *mailing lists and newsgroups (from listings)*
journals (from periodicals databases, and specialist libraries)
 - if new tertiary sources are found, check for new primary or secondary sources
 - if new secondary sources are found, check for new primary sources in them
- 10. Recheck all entries against evaluation criteria**
- 11. Submit to independent subject experts for checking**
- 12. Check final list for overall balance and sensible presentation**

3.4 Creating a List of Information Resources in Toxicology

The methodology described in the previous section was followed to create a listing of current information resources in toxicology, which is presented in the next section, 3.5. The list does not aim to be comprehensive, but serves to exemplify the types of resources available, and to illustrate how toxicology communication has developed in the wake of new ICTs. The list has a UK perspective, in that it lists primarily English language resources, and concentrates on sources likely to be relevant to someone based in the UK.

3.4.1 Identifying quaternary resources

Search Notes

Printed quaternary resources are not usually subject specific, but electronic examples exist, such as Esmerel's *List of lists of disability resources* (<http://www.esmerel.org/lists>).

Ideally, individual lists of lists devoted to one or more aspect of toxicology would be identified for the final resource listing. In practice, however, due to the complex nature of toxicology as a discipline, it seemed necessary to anticipate that any such lists would be contained within resources covering a broader subject base.

As no toxicology specific quaternary resources were known to begin with, some general electronic (web based) and printed examples were examined for sections pointing to lists of toxicology resources. The examination was carried out by a combination of keyword searching and browsing through the subject headings. Where keyword searching was used, the term 'toxicology' was entered, although it is acknowledged that this could limit the search by overlooking lists in more specific areas of toxicology such as mutagenesis, carcinogenesis, teratology, health and safety or pollution.

The WorldWideWeb virtual library, (<http://vlib.org.uk>) offered Science as a top level heading, from which the choices of either *Health* or *Biosciences* seemed possible leads. Neither category offered a toxicology subcategory, however. Searching the virtual library by keyword for *toxicology* generated 75 matches, none of which were lists of resources.

Although BUBL (<http://www.bubl.ac.uk>) is intended to be a selected catalogue of Internet resources rather than a list of lists, the site was examined due to its emphasis on the inclusion of library and information related resources. It was considered that the tertiary BUBL list of resources may have included some lists of toxicology lists, thus forming an example of a tertiary resource yielding higher, quaternary ones. Searching for *toxicology* within the subject field of the catalogue generated a list of 16 entries, some of which, such as the list of Toxicology Internet Resources at the University of Pittsburgh (<http://www.hsls.pitt.edu/intres/index.html?page=29>), were lists of lists.

The NISS gateway (<http://www.niss.ac.uk>) was included in this section for similar reasons. The *medical sciences* category yielded a list of 9 resources under the subheading *pharmacology, therapeutics and toxicology*, but as none of these were toxicology specific, this could not be considered as a list of lists, even though two of the links were in fact to library catalogues.

The classic, printed quaternary resource is Besterman's World Bibliography of Bibliographies, first published in 1939 and issued in revised editions in 1947, 1955 and 1965. In including abstracting and indexing services, it somewhat overlaps with what are regarded here as tertiary sources.

In the fourth (1965) edition, the only relevant subject heading is 'toxicology', and six references are listed, all of which are list of lists, or bibliographies. The retention of rather aged works, and the importance of German language material, is noticeable. The book was not included in the final listing due to age, but it should be stressed that older works may be of some value, as they may be the only existing record of an aspect of toxicology.

Internet search tools were used to locate other quaternary resources either wholly devoted to, or at least containing sections of, links to toxicology resource listings.

Identifying search terms to represent the concept of quaternary resources in toxicology proved interesting, as there is no standard way for resource listings in any subject to be titled or indexed.

The word *toxicology* was chosen to represent the concept of the subject sought, as any listing of resources should contain the term itself within the title, heading or main body text of the web page. Again, it is possible that use of this broad term missed more specific listings in sub-disciplines such as poisoning or health and safety, but an

examination of the results revealed sites representative of various areas of toxicology, so this was not considered to be a major drawback.

The concept of *quaternary resource* was harder to define exactly. Initial searches, attempting to identify the concept of quaternary resource alone, without any subject specification, proved too general.

Searching for either: list of lists or
lists of lists

returned a variety of resources containing lists of some sort, but not necessarily of tertiary, or even subject specific resources. Most notably, these phrases proved suitable for identifying lists of email lists.

Searching for: quaternary resource or
quaternary resources

returned some extremely specific resource listings referring to the quaternary period in time. It was therefore decided not to use the term *quaternary*.

The terms *list toxicology resource resources lists* were used to attempt to combine the concepts of toxicology and list of lists. This seemed to work well, as several of the highest ranking hits pointed to a list of toxicology resource lists.

Sites returned from each search were considered in descending order of ranking, until they were consistently found to be irrelevant. Usually much fewer than 100 sites were viewed. Of those remaining, only those containing links to lists of resources which were relevant to toxicology were included in the final listing. Some of these however, also contained links to actual resources, as well as to further lists.

Finally, Medline, LISA, Social Science Index, Books in Print (UK and US) were searched via Dialog for relevant material. No new lists of lists were found.

Selecting and presenting the resources

As the number of quaternary resources found was fairly small, the selection process was straightforward; sites were included if at least some reference to toxicology resource listings was evident. It would be expected that some further degree of selection would be necessary when searching for lower levels of resources, due to the

larger numbers of relevant items which exist. Most of the quaternary resources included listings of a more general nature than just toxicology, and all included links to primary and secondary resources as well.

When presenting the quaternary resources in a sensible order, it was apparent that division by subject would be inappropriate as most of the lists covered toxicology at a general level. As noted earlier however, this may have been due to the use of the broad term *toxicology*. Division was therefore made by type of quaternary resource, as listed in table 3.1.

Comments on quaternary resources

The lists of lists identified are, with one exception, web pages, and most offer links to web-based listings. One, from the University of Washington, (<http://www.staff.washington.edu/ehlib/outlinks/bibliog2.html>) offers a list of printed bibliographies. Most point to lists of resources in a variety of subjects, but specialised listings within the field of toxicology do exist, and the number of these may increase with time. An example is the American College of Medical Toxicology Resource Listing - Key Sites Providing Links to Multiple Sources of Information (<http://www.acmt.net/toxresor.htm#anchor311101>).

Most list creators do not undertake to create purely quaternary resources, and links to primary and secondary resources are present in most quaternary lists.

The number of web page listings reflects the ease with which these items can be produced and published. The provenance of these network items may be less than their printed counterparts however, as often pages disappear without trace. Printed volumes may go out of print, but at least some hard copy and bibliographic reference may remain.

Printed lists of lists are relatively few in number, even in broader subjects such as medicine, so it is not surprising that none were found devoted to toxicology. Existing works such as Bestermann (1965) are really too outdated to be of significance, although it might be argued that some older toxicology information is still useful either for historical interest or even because no newer data exists. The only printed work included in the current list is part of a series on hazardous chemicals and pollutants. This was found from a web based tertiary listing of printed resources, and its existence suggests the possibility that other more specific quaternary resources could be located by searching with narrower terms than toxicology.

The number of web based quaternary resources found no doubt reflects the ease and relatively low costs involved in publishing this type of work, and the number of toxicology resource lists which can now be found on the web.

The listing at Novosibirsk State University (<http://www.nsu.ru/biology/courses/internet/loflists.html>) contains links to other quaternary resources and so may even be considered to be a 'super list'.

Lists of associations, societies and organisations were found, and these were also regarded as quaternary resources, following the decision to regard an organisation *per se* as a tertiary information resource. Some prominent examples are therefore included in the final listing of quaternary resources.

Finally, of the 19 web lists identified, 6 were from academic institutions, 3 were part of a commercial web site, and the remainder were provided by government or professional associations.

3.4.2 Identifying tertiary resources

Search Notes

An initial list of printed and electronic tertiary resources was created from personal knowledge. Further resources were found by searching the quaternary resources identified in the last section.

Well known, general reference works by Lea and Day (1996) and Murray and Schlicke (1999) were checked for their coverage of toxicology resources, but these were considered limited with regard to the wealth of subject specific lists available.

Internet search engines and directories were then used to look for more tertiary resources. Tertiary resources on the initial list were examined to identify terms used to describe them; specifically words and phrases forming titles, headings and metadata. As with the quaternary resources, there was no standard way for the resources to be described, although all contained a reference to the subject term 'toxicology' and to the nature of the resource. The subject of the resource listing was usually simply 'toxicology' but narrower terms such as 'environmental', 'chemical safety' and 'hazard' were also present, indicating that it would be possible to be more precise in searching if a more focused approach was desired. However, the term toxicology

was usually present somewhere in the text, and thus use of the broader term could be relied on to identify tertiary resources within a sub discipline.

The following terms were used as appropriate to search for the tertiary entities:

Toxicolog*, resource*, list*, links, directory, directories, guide*, bibliography, bibliographies, webliography, webliographies, catalogue*, database*, search engine*, gateway, portal, mailing lists, newsgroups, research, expert*, information service*, organisation*, department*, course*, webring*

(The asterisk denotes truncation)

Books in Print (UK and US), Medline, LISA and Social Science Index were queried for any further lists of toxicology resources. A combination of terms representing toxicology was used in addition to terms referring to information resources, services or systems.

Finally, level specific resources were used to identify particular tertiary resources including:

Library/information services: (appendix 3.4.a) Standard UK guides were consulted to identify library/information services indexed as covering toxicology:

- The Aslib Directory of Information Sources, 1998 edition
- Three volumes published by the British Library
 - McBurney V, 1995, Guide to Libraries in London
 - Dale P, 2001, Guide to Libraries and Information Sources in Medicine and Health Care (3rd edn.)
 - Dale P, 1992, Guide to Libraries and Information Units in Government Departments and Other Organisations (10th ed.)
- The Library Association's Directory of Medical and Health Care Libraries in the United Kingdom and the Republic of Ireland, 10th ed., 1998

All of these have some limitations in their compilation, which is based on the return of questionnaires, but taken together should identify the most significant services, with an indication of examples of others.

Each guide was used in the same way. The indexing was consulted for 'toxicology' and similar terms, and the items found there listed. Using more general terms, such as 'medicine' or 'pollution' was not found to be helpful. Then the guide was scanned cover to cover to identify other possibilities. This was necessary because of the limitations of the subject indexing, particularly with regard to large and general collections, which are not indexed with every topic covered. The Library Association's Directory was not found to be of use in this study, as libraries are not indexed by subject at all.

One evident problem with all directories, particularly the older British Library volumes, is that they are rapidly outdated, by changes in government departments, industrial mergers, etc. The entries found all had to be checked individually for currency before inclusion in the resource listing. Internet searches were carried out to identify web sites relevant to new library/information services located in this section. It is worth noting that as many organisations now have web sites, it is possible to use Internet search engines as 'level specific tools' to identify this particular type of tertiary entity. This is especially useful if a world wide, rather than simply UK, perspective is needed.

Toxicology societies/organisations: (appendix 3.4.b) Learned societies and professional associations in the toxicology area have already been discussed in chapter two, the emphasis there being on their role in the development and definition of the discipline/s of toxicology. However, it is clear from the discussion given in the earlier section that such organisations continue to play an important role in the information transfer process. Here, these organisations are considered as information resources, by virtue of their activities in publishing and sponsoring journals and newsletters, sponsorship of meetings, conferences and workshops, and direct providers of advice and information. Many toxicology societies and organisations make use of new ICTs. Invariably, this includes a presence on the Internet as a web page, and some were already found from the Internet searches. For completeness, the Internet Scholarly Societies Project (<http://www.lib.uwaterloo.ca/society/overview.htm>), and two printed directories, Fischer CA and Schwartz CA (1995) and the Yearbook of International Associations (1994/95), were also consulted. Any new entities found were searched for using Internet search tools, in order to check for an additional Internet presence.

Three points are immediately clear from this incomplete analysis of rather dated reference works:

- toxicology societies are extant at international, continental, and country level (these works do not include the regional societies which also exist), and for general and specific aspects of toxicology (though these tools do not include many specialised societies)
- a variety of access points will be necessary; these tools focus on national, international and 'general' societies, and even with this remit omit some well-known societies, the British Toxicology Society being an obvious example.
- most organisations and societies now have an Internet presence in the form of a web page, which offers a more contemporary and reliable method of identification than printed directories.

Online host systems: The collections of databases and databanks offered by various online host systems form a significant tertiary resource for toxicology information. The most well known and specific for this subject area is TOXNET (<http://toxnet.nlm.nih.gov/>), a collection of toxicology related databases searchable via a single interface, overseen by the US National Library of Medicine. The databases were originally accessed via data networks, as for any other online system, but recently have become available to search via a web interface, which also allows use of the usual command language.

The two 'general' host systems which offer extensive collections of information relevant to science and technology are those of the Dialog Corporation and of STN. Dialog offers toxicology-related files among a very wide selection of information across the subject spectrum; STN focuses on files of relevance to science and technology. Both STN and Dialog host systems are now searchable via the Internet.

Other host systems offer smaller numbers of files, or concentrate on other areas. Questel/Orbit, for example, concentrates on intellectual property databases, and offers a relatively small number of toxicology-related files - Chemical Abstracts, Enviroline, HSEline, Merck Index, and the Derwent files - none uniquely. German host DIMDI offers some toxicological databases with a customised graphical user interface via the web. Although not English language, this host is very well known and therefore mentioned here. The English language sources are not unique; there are also two German language files, Siemens Gefährstoff-Datenbank (SIGEDA) and Internationale Chemische Sicherheitsdatenblätter (ICSC) which are not covered by the other hosts.

German search terms must be used for the latter databases, and it is recommended that both languages are used when searching several databases simultaneously.

A separate Internet search was carried out to find any lists of internet search tools dedicated to toxicology.

Selecting and presenting the resources

In contrast to the limited number of quaternary listings identified, too many tertiary entities were found during the searches to include everything in the final list of resources. Resources were therefore selected from the search results using the criteria described in section 3.3.

In order to present the resources in a useful way, they were divided by sub-type. The section of resource lists was further divided, by subject, because specific resource listings were available, and contrasted clearly with those containing links to more general resources.

Comments on tertiary resources

As expected, far more tertiary resources were identified, than quaternary. Approximately 150 were included in the final listing. Examples of most of the sub-types of tertiary resource listed in table 3.1 could be found for toxicology.

Most tertiary resources contain links or references to material at any of the four levels, including other tertiary resources. Links or references to lists of organisations and societies, were also evident. These were classed as quaternary resources and some examples were added to the quaternary section of the final listing. Some web pages linked only to other web sites, e.g.

- NIOSH listing
<http://www.cdc.gov/niosh/toxicol.html>

whereas others listed material in all formats, e.g.

- MedWebPlus
<http://www.medwebplus.com/subject/Toxicology.html>

The most readily identified tertiaries were web sites for organisations, associations and societies, or indeed academic departments and research institutes. It is tempting to

feel that all organisations have a web presence these days, and that consequently, Internet search engines can be relied upon, as level specific tools, to locate them. This is not entirely true however. Search tools do not include every web site within their indexes, and not every organisation has a web presence. For the moment, printed directories and specific listings (may be Internet based) must be consulted if complete information is required. An example is the African Toxicology Society, which is listed in the Yearbook of International Associations (1994/95), but which as yet does not have an Internet presence. It can also be found listed in the Union of International Associations Yearbook of International Organisations (<http://www.uia.org/uialists/ndx/org/org4.htm>), which clearly refers to the existence of the organisation, but notes that there is no accompanying web page. Lack of a web site may be for a variety of reasons, including limitations of technological infrastructure, cost, or that the entity is too small or private to warrant a public portrayal.

Many organisations with a web site existed before web technology arrived. Their web presence was established as a means of communicating with their members and others interested in their specialisation. An example here would be the British Toxicology Society (<http://www.thebts.org>).

Some organisations have taken advantage of the communication facilities offered by Internet technology to enhance the features and services provided to their members and other interested parties. An example here includes TIAFTnet, website of The International Association of Forensic Toxicologists (<http://apf.cbft.unipd.it/tiaft/info/tiaftnet.html>). Features include a mailing list for members only, where the archive can be accessed from the web page, a web forum for discussion open to all, ftp service for download of larger files, and a members area with access to bulletins, case-notes, on-line reviews and the therapeutic-toxic drug concentrations list. Such entities tend to include the word *network*, *net* or *web* as part of their title.

A solely web based, or virtual, organisation, may also be postulated, in contrast to those which have a physical presence (office/staff/paper publications) in addition to their digital products. This virtual entity would act as a focal point for communication between those interested in the subject matter, and may be exemplified in the phenomenon of web rings. This relatively new terminology refers to a collection of web sites pertaining to a particular subject. The site authors link their sites together using software which supports features such as listing member sites, moving on to the

next site, selecting a random site, and listing of membership rules. Web rings provide a way for those with even idiosyncratic interests to find each other, and to communicate globally, in a way which before the web would probably have been impossible. The use of the English language as a common communication language cannot be ignored in this case.

Web rings are extremely popular in recreational areas such as fan fiction, rather than professional disciplines. Nevertheless, a web ring for Forensic Entomologists (<http://nav.webring.yahoo.com/hub?ring=forent&list>) was found, which suggests that in time other toxicology and sub-discipline sites may link together to create web rings. Web rings in broader areas such as medicine and medical libraries also exist. See for example:

- International Medical Libraries on the Web Ring
<http://www.glenlib.demon.co.uk/medlib/>
- The Medical Student and MD Webring
<http://victorian.fortunecity.com/literary/463/md/medstu2.htm>

Most of the toxicology organisations' web sites include lists of resources, with varying degrees of annotation and subject coverage. Some lists were long and of a general nature, including seemingly every resource known to the author. Other lists were much more specific, listing resources within a sub discipline, such as the Human Genome and Toxicology Group (<http://www.hsrdo.ornl.gov/taraweb/hgt.htm>).

Also found were personal resource lists, composed by people involved in some way with the profession, for example, Alan Barbour's Forensic Toxicology Page (<http://userzweb.lightspeed.net/~abarbour>).

Subject gateways, offering categorised resource lists, are also present on the Internet, although not as numerous as straightforward listings. Gateways specific to toxicology include the Toxicology Online Resource Directory (<http://www.toxicologyonline.com/directory/xcdirectory.asp>), but toxicology resources can also be retrieved from broader subject gateways such as the medically orientated OMNI, and multidisciplinary directories such as Yahoo! (www.yahoo.com). The issue of quality is clearly of importance, and is to some extent addressed by gateways such as OMNI, in the evaluation of sites by subject experts. To some extent, this also happens with the more general directories such as Yahoo! and

the Open Directory Project (<http://www.dmoz.org>). Understandably, the site review process takes time and money, and consequently fewer sites are found listed in 'quality' gateways. Simple listings of 'favourite' or 'known' resources are easier to produce, and so more abundant. Often these bear a disclaimer, with regard to the value of the listed sites.

Web based lists of resources, and subject gateways may perhaps be regarded as networked versions of printed guides to the literature. Although in these cases, the 'literature' is often other information residing on the network, and the amount of accompanying annotation or evaluation may be limited. Printed guides to the literature in toxicology are also available. These are defined here as works describing all types of resources, in contrast to those detailing, or evaluating a single or certain type of resource. Well known examples of literature guides are given in the final listing. Literature guides are found as journal articles, book chapters and books, and given that publications of this type are reviewed, it may be that the information about toxicology literature within such items is more 'valuable' or of a higher 'quality' than the information contained in un-reviewed items such as web based resource lists.

Whilst no electronic example of a printed guide to the toxicology literature was found, it may be worth noting that the author of the most significant printed guide to date, Philip Wexler, expresses the hope that his printed work will be joined by an electronic counterpart in the near future.

The two toxicology portals found seem to be subject gateways, although the term portal does suggest the presence of more interactive options and services. It may be that true portals for toxicology have yet to develop, and that in time more complex resources may emerge.

Lists of abstracting and indexing services can be found (from SilverPlatter and the National Library of Medicine), but these usually refer to the electronic versions of what were originally printed tools. More common are lists of electronic databases from the web pages of host companies, and collections of links to searchable toxicology databases over the Internet as a whole. The issue here is one of coverage, as no listing includes all data bases. The best known collective of databases for Toxicology is probably Toxnet, a service offered by the National Library of Medicine. This set of toxicology databases was only available to search via a host system network and command language, but has recently become available to search via a web interface.

Searching for lists of newsgroups and mailing lists can be successful using major search engines. Clearly, such communication and discussion forums exist within the toxicology discipline, although they are not as numerous as those for broader subjects such as medicine, law and business.

Only one list of mailing lists for Toxicology was found, and this was part of a broader collection of medical mailing lists. Two lists of newsgroups were found, dealing with environmental and forensic toxicology respectively. This suggests that at the level of direct communication (that is between individuals), specific areas of the discipline become important.

Finally, to identify people as information resources, it is possible to find lists of experts in many subjects, and toxicology is included in this, probably mostly because of listings of expert witnesses, whose services could be rendered in legal cases. It is likely that most toxicology related organisations have lists of members, but it does not appear that personal names are readily available from organisational sites. The exceptions are academic institutions, and some commercial research organisations, where staff are named, and a professional contact published. Lists of expert witnesses are commercial, and the people on the list would hope to gain employment this way.

This tertiary section of the resource listing was started in 1999, and it is interesting to note the changes which occurred during the years 2000 and 2001. Several web based resource lists ceased to exist, and many sites changed their web addresses. It is worth noting that unlike printed publications, it is not easy to follow up on subsequent editions of network resources. In many cases, keywords from the titles of resources identified in 1999 were used to track down the addresses of their current counterparts, by entering them into the major search engines.

Specifically, changes include academic work, which can move to another institution, along with its authors; the clinical teratology web site moved from Weber University to Washington University (<http://depts.washington.edu/~terisweb>). It is also evident that funding of any given project will dictate whether it keeps its point of origin in academic realms, or moves on to a commercial environment. An example in this last case would be MedWeb, which began in academia at Emory University, Atlanta, Georgia, but is now only found as commercial entity MedWebPlus (see above).

Examples of sites which completely disappeared include the list of Poisonous Plant Databases at the University of Maryland. In contrast, more organisations created a

web presence over the two years, and those whose web sites were rather limited, such as that of the British Toxicology Society (see above), improved their design and content.

Notably, Philip Wexler's new edition of *Information Resources in Toxicology* was published (2000), reflecting the increasing number of resources relevant to the discipline in its new, much larger size.

With regard to guides to the literature, relatively few new printed works were apparent, with the most recent papers detailing only single resources such as TOXNET, or specific types of resource such as web pages of toxicology societies.

Tertiary entities are well represented within the toxicology discipline, but finding and monitoring them requires understanding of the terminology used to describe them, and ingenuity in following the networked sources should they relocate.

3.4.3 Identifying secondary resources

Search notes

An initial list of secondary information items was created from personal knowledge, and from sources revealed by the tertiary entities. Internet search engines, online databases and level specific tools were then used to identify further examples of each sub-type of secondary resource.

Search terms included the word stem toxic*, combined with words or phrases to describe the type of resource being sought. The latter included:

classification, reference work, handbook, encyclopaedia, dictionary, glossary, thesaurus, abstracting/indexing service, database, databank, monograph, textbook, book, treatise, pharmacopia, review, summary

(truncation was used when appropriate)

Findings from searching level specific tools are outlined below.

Classification schemes: no special classification scheme for toxicology *per se*, or for subjects closely connected to it has been produced.

The most specific scheme, the National Library of Medicine classification, closely resembling the Library of Congress Classification, includes toxicology, but only a coarse level of specificity. The other widely used enumerative schemes, Dewey Decimal Classification and Universal Decimal Classification, also include places for toxicology and related concepts, but neither deals with the subject in sufficient degree of detail as to be regarded as a useful resource for analysing and understanding the subject in any depth. The treatment of toxicology by these and other classifications is analysed in chapter seven.

Data compilations, reference works, handbooks and encyclopaedias: (appendix 3.4.c) The Hazardous Substances Data Bank (HSDB) includes extracts and summaries of toxicological evaluation from 'a core set of standard texts and monographs'. The frequent use of a source from this set indicates that HSDB's expert compilers, from the National Library of Medicine's Toxicology Information Program, regard it as a reliable source, and, by implication, that it may be included in any listing of 'significant' toxicology resources.

The HSDB records generated during the databank evaluation described in chapter five were reviewed, and those sources which were referred to on more than three occasions were listed. While this is far from an exact analysis, it gives a list of widely referenced material of this type, and 16 resources were found.

Dictionaries, glossaries, thesauri: (appendix 3.4.d) In addition to using online databases and internet search engines, thesauri were also identified from the documentation provided by database producers, and by examination of the main British collection of thesauri in the ASLIB library.

Databases and databanks: (appendix 3.4.e) Although it is possible to use Internet search engines to identify some relevant databases and databanks, it is still necessary for completeness to examine the resources offered by major host systems, to identify all their useful material. As noted in the section on tertiary sources, the two host systems which offer extensive collections of information relevant to science and technology are those of the Dialog Corporation and of STN. The TOXNET service, accessible via the National Library of Medicine, offers a collection of toxicology specific databases.

The sources offered by the Dialog Corporation are the most wide ranging. Three means were used to identify useful resources from among these:

Dialog and Datastar subject groupings

Both the Dialog and Datastar online host systems allow several files to be searched simultaneously. A set of pre-defined subject groupings are provided for this purpose; 'toxicology' is a grouping on both systems. The resources in these groups are chosen by Dialog Corporation subject experts.

39 files were included in Dialog's TOXICOLOGY OneSearch category, and 13 resources included in Datastar's TOXICOLOGY CROS group.

Dialog Bluesheets

The Dialog Bluesheets offer descriptions of each of the databases hosted by the Dialog Corporation, and are made available as a searchable file. Searching this file for subject terms offers a rapid, if crude, way of identifying the files which will offer this sort of material.

The Bluesheets file was therefore searched for the term 'toxicology'. The documentation for 18 databases, including the major bibliographic files, referred to this term (treating different time periods, and training and alerting variants, as a single database).

In order to widen the search, so as to ensure that the term 'toxicology' was not too restrictive, the search was repeated using a set of truncated terms:

toxic? or carcinogen? or mutagen? or teratogen? or poison?

This identified an additional 15 databases, largely databanks or full-text sources:

Dialindex

The Dialindex database, which searches sets of Dialog databases to determine which contain a particular index term, was then searched for the term 'toxicology', against all available databases. A total of 383 out of 454 files had some reference to the term.

This set, which demonstrates the variety of sources providing some mention of toxicology, was then reduced to those having larger numbers of occurrences. This is a somewhat arbitrary process, process since the files are of very different nature, sizes and time period.

Restricting the set to those files showing more than 5,000 occurrences of the term, and simplifying by showing only one database name when several files may be mentioned, gave 17 databases, from which CA Search was a notable omission. If the criteria were relaxed to 2,000 occurrences, then a further 16 databases were added to the list. These included Magazine database, Marquis Who's Who and Canadian Newspapers, all of which may not be thought of immediately as toxicology resources.

The Dialindex search was then repeated, using the more general term 'toxic?'. In this case, 434 out of the 454 files had some mention of the term; a clear indication of the ubiquity of toxicology information.

Other host systems do not offer similar aids to identifying resources, and relevant files had to be judged from their descriptions in the host's documentation.

STN, a host system which aims to provide access to the sources primarily required for science and technology, Ridley (1996), offers a variety of files with some apparent relevance to toxicology. Some are searchable by chemical substructure. They include both bibliographic databases, and numeric databanks.

Orbit/Questel offers a relatively small number of toxicology-related files - Chemical Abstracts, Enviroline, HSEline, Merck Index, and the Derwent files - none uniquely.

OCLC's First Search offers no files of toxicological relevance, other than Medline.

TOXNET is a service offered by the US National Library of Medicine (NLM) Special Information Service. It consists of a collection of databases and databanks which may be queried via a common web-based interface. Although the TOXNET service is not a host system per se, it does act as one in that it provides access to a series of databases, which are located at (<http://toxnet.nlm.nih.gov>).

CD-ROM resources: (appendix 3.4.f) CD-ROMs in Print (1998) was consulted.

The only relevant subject heading in the index was 'toxicology', and 29 items are listed under this heading. They vary in nature, and not all fall within the category of secondary sources as defined for this project.

The emphasis is clearly on the 'health and safety' aspects of toxicology, rather than on the scientific or medical. The CD-ROM format is used largely as a convenient way

of packaging single resources, as an alternative to online versions, (e.g. Registry of Toxic Effects of Chemical Substances (RTECS)) or print (e.g. Sax's Dangerous Properties of Industrial Materials), or packaging several complementary sources. Few of these resources offer unique information or search facilities, Poisindex being the exception.

Monographs, textbooks, treatise: (appendix 3.4.g) For medical libraries, there are standard recommended 'core collections': the US Brandon and Hill (1997) recommendations, and the equivalent for the UK compiled by Hague (1994/1995). These are general guides, recommended for 'a small or medium-sized library in a hospital or comparable medical institution' (Hague 1994/95).

Hague's list does not have toxicology as a subject section, and includes only a few toxicology-related items, in sections on accident and emergency medicine, and pharmacology.

The US Brandon and Hill lists are provided for three settings:

- for small medical libraries
- for nursing
- for allied health professions

These are published biannually, with interim updates. These lists of books and journals are aimed at providing a balanced list of resources, and are chosen purely on the basis of the expert opinion of their compilers. They favour US-published and -oriented material, where it is available. A small amount of toxicology material is listed.

Other level specific tools were also used to identify textbooks, including library catalogues and book shop collections.

Reviews and summaries of progress: (appendix 3.4.h) Reviews and summaries of progress may appear in multiple formats; as books, electronic texts, or as journal articles for example. Whilst journal articles reporting the first occurrence of an event are undoubtedly primary material, a review article, or even a whole edition of a journal devoted to summarising a topic, may be regarded as secondary resources, having added some value to the original first report. It was therefore decided to include journal based reviews with secondary resources. The number of review articles in toxicology is vast, but no level specific tools exist for the specific

identification of material in this category. In order to identify the more important periodicals in which reviews of toxicology appear, two approaches were followed:

- searching Ulrich's periodical directory (via Dialog), and assessing the results
- searching for review articles in bibliographic databases, and ranking the sources

Identifying review articles from Ulrich

Ulrich's periodicals directory was searched for

REVIEW or REVIEWS

and

TOXIC? or CARCINOGEN? or MUTAGEN? or TERATOGEN? or POISON?

the terms being allowed to occur anywhere in the basic index, i.e. including notes and publisher information as well as title, to ensure comprehensiveness. There were 39 items found, of which 37 were rated 'active'.

On inspection, it seemed clear that some of these were medical or scientific journals with toxicology or toxicity as a small component of their scope. Others were local or ephemeral in nature. Removal of these suggested a core set of 17 periodicals carrying toxicology reviews.

Identifying reviews sources from bibliographic databases

This was done initially in SciSearch and then in a combination of other bibliographic databases. This ensured that alternative journal selection policies by the database producers were allowed for, and also allowed the alternatives of SciSearch's 'document type' category and a search on titles and abstracts.

In each case a selection of review articles, defined as noted above, was selected, duplicates were removed, and the resulting set ranked by journal name, using the automatic Dialog procedures. The resulting lists were edited manually, to allow for idiosyncrasies in the duplicate removal, journal names changes over time, equivalencing of journals and their supplements, etc.

SciSearch was searched, for the time period from 1990, for items with

TOXIC, TOXICITY, TOXICOLOGY or TOXICOLOGICAL in the title, and with the document type REVIEW assigned. There were 979 such items. RANKing by source name, down to those with 10 or more items, gave 17 journals.

In order to widen this very specific title word search, the title terms:

CARCINOGEN? OR MUTAGEN? OR TERATOGEN? OR POISON?

were combined with the REVIEW document type. The resulting set of journals, again RANKing by source name down to those with 10 or more items, was actually quite similar to the first, with 6 sources occurring in the 'top 10' of each.

When the two sets of title terms are combined, giving 1817 unique items, after duplicate removal, the overall sources ranking shows the six titles already noted, plus those strongly featuring in one of the lists:

- Adverse Drug Reactions and Toxicological Reviews
- Reviews of Environmental Contamination and Toxicology
- Reproductive Toxicology
- Drug Safety
- Methods in Enzymology
- Environmental Carcinogenesis and Ecotoxicology Reviews
- Pharmacology and Therapeutics
- Chemical Research in Toxicology

In order to widen the scope of this investigation, four other bibliographic databases - CA Search, Medline, Embase and Biosis - were searched together; these were chosen so as to cover all perspectives on toxicology, and hence obtain a good overview of its review literature. These databases were searched for the years 1996, 1997 and 1998, using the same subject specification as in SciSearch, but explicitly searching for the term REVIEW in the records, rather than using a document type indicator.

A search for TOXIC, TOXICITY, TOXICOLOGY and TOXICOLOGICAL in the title, together with REVIEW anywhere in the basic index, gave 2204 items, reducing to 1692 after removal of duplicates. When they were source ranked as before, several of the journals noted in the equivalent SciSearch ranking featured highly,

plus some others which are not included in the ISI database, including: Microscale Testing for Aquatic Toxicology, and the BIBRA toxicity report series.

An equivalent search with

CARCINOGEN?, MUTAGEN?, TERATOGEN? or POISON?

in the title gave 1761 items, reducing to 1272 after duplicate removal. Source ranking showed a large number of items in Mutation Research, and the importance of two 'general biology' methods journals, for molecular biology and enzymology.

Finally, the two search results were combined, giving a total of 2906 records. After duplicate removal, the source ranking was compared with that obtained in SciSearch. Five journals appeared with 20 or more items (roughly the 'top 10') in each:

- Mutation Research
- Annual Review of Pharmacology and Toxicology
- Environmental Health Perspectives
- Critical Reviews in Toxicology
- Food and Chemical Toxicology

These could reasonably be thought of as the 'central core' from this study, and were included in the final resource listing.

Selecting and presenting the resources

The nature of the resources at this level leads to the identification of large numbers of resources very quickly. For this reason, a higher degree of selectivity was employed in choosing items to be included in the list. Highest weighting was given to currency, and to the author's perception of the usefulness and provenance of an item. Resources were organised, as in other sections, as sub-types of the four main categories.

Comments on secondary resources

Unlike the items in other categories, the secondary resource types are all traditional formats; none of them are Internet specific. With the exception of a classification scheme, examples of each of the sub-types could readily be found for the toxicology

discipline. Additionally, the nature of the materials in this category, including well known books, reviews and databases, resulted in large numbers of items being retrieved. The selection of items for the final listing was therefore made by favouring currency and provenance. It is notable that resources used by the author 20 years ago persist in the same format in the present time.

Whilst none of the secondary resource formats are new, electronic examples from each subtype can be found, and these can usually be accessed via the Internet. For some items, such as databases, this is clearly useful. For those items containing large amounts of text which is intended to be read sequentially, the usefulness of an Internet version may be less.

It is worth noting that secondary publications are increasingly used as a substitute for primary information, and ready access to electronic versions may increase this tendency, resulting in changes in the use of primary publications.

3.4.4 Identifying primary resources

Search notes

Primary resources were listed from personal knowledge, and from the secondary and tertiary resources already identified.

This category includes resources in both traditional and Internet specific formats. There are clearly many longstanding toxicology journals, which exist in both printed and electronic format. Few academic examples exist of resources such as web diaries however, and none could be found which were relevant to toxicology. There are also more usual network formats, such as mailing lists, newsgroups and web pages. Some of this material is only available on private networks, and therefore not retrievable by the procedures used in this dissertation. Other types of primary resource, including letters, notes, memoranda, diaries and reports may also be difficult, if not impossible to trace, due to their personal, private or commercial nature. Not all primary material is recorded in print, and/or electronic format, and certainly not all of it is made available via network technologies such as the Internet.

To complete the listing, searches in bibliographic databases were carried out to identify articles referring to primary literature, and any relevant level specific tools,

such as directories of periodicals and lists of mailing lists and newsgroups were examined.

Search terms included the word stem toxic*, combined with words or phrases representing the type of resource being sought. The latter included:

primary literature, mailing list, newsgroup, journal, ejournal, report, thesis, dissertation, abstract, course, teaching/training material, syllabus, proceedings, diary, web diary, regulation, legislation

(truncation was used where appropriate)

It would be more comprehensive to include more specific terms than the broad stem toxic, but this was avoided, as before, in order to keep the number of resources to a manageable size.

Some notes on the level specific tools used are given below:

Journals: (appendix 3.4.i) There are many ways to identify core journals within a discipline. This depends on the reason for the core listing, and the definition of the term 'core'. For the toxicology resource listing, the objective was to identify a selection of prominent and authoritative publications, to illustrate significant examples of the information type. Three ways were used to identify toxicology journal sets:

- Identifying toxicology periodicals from Ulrich's International Periodicals Directory
- Identifying toxicology journals from secondary service coverage
- Identifying key toxicology journals by RANKing

Identifying toxicology periodicals from Ulrich's International Periodicals Directory

This directory of periodicals was searched to identify toxicology related journals (August 1999). The directory is sub-divided into subject groupings, but none of these overlap exactly with toxicology. A search for the term 'toxicology' retrieves records for 294 periodicals. 114 of these have 'toxicology' in the title, and 198 have it in subject descriptors; the 63 records which have neither of these have the term in either a 'notes' field, or in the name of the publisher or sponsor.

236 out of the 294 periodicals indexed in some way with 'toxicology' are 'active' in Ulrich's list, as are 87 out of the 114 with 'toxicology' in the title.

As a check on the subject headings used by Ulrich's, those assigned to the list of 294 periodicals were identified, using the Dialog RANK command. The results were as follows:

Rank	Number	Heading
1	209	ENVIRONMENTAL STUDIES
2	198	TOXICOLOGY AND ENVIRONMENTAL SAFETY
3	112	PHARMACY AND PHARMACOLOGY
4	63	MEDICAL SCIENCES
5	41	BIOLOGY
6	27	PUBLIC HEALTH AND SAFETY
7	18	ABSTRACTING, BIBLIOGRAPHIES, STATISTICS
8	17	ABSTRACTING AND INDEXING SERVICES

This shows that most journals fall into the categories of toxicology/environmental subjects, but that a number occur in more peripheral areas such as pharmacy, pharmacology, medical sciences, biology and public health and safety.

Particularly notable are the periodicals devoted to specialisms within toxicology e.g.:

- Advances in Combustion Toxicology
- Ecotoxicology
- Toxicology in Vitro
- Reproductive Toxicology
- Inhalation Toxicology

and those indicating the overlap with other disciplines, e.g.:

- Journal of Toxicologic Pathology
- Annual Review of Pharmacology and Toxicology
- Cell Biology and Toxicology ; an international journal devoted to research at the cellular level

Sometimes, these two effects may be seen simultaneously, e.g.:

- Focus on Pulmonary Pharmacology and Toxicology
- Environmental Toxicology and Pharmacology.
- Regulatory Toxicology and Pharmacology

Identifying toxicology journals from secondary service coverage

The Science Citation Index, and its online implementation, SciSearch, produced by the Institute of Scientific Information, is a multidisciplinary bibliographic database, based on coverage of a set of journals regarded as the 'most significant' in all fields of science. Selection of these journals, and assignment to subject groups, is carried out on the basis of expert judgement of ISI editors plus subject specialist advisors, backed up by extensive citation analysis as a measure of 'impact'. Presence of a journal in the toxicology section of this database's coverage is therefore a *de facto* indication of probable significance as a primary source for the subject.

The 1998 ISI journal listing includes over 5,300 periodical titles, assigned to 164 subject categories: a journal may be assigned to more than one subject category. One of the sections is 'toxicology'. Other sections might be expected to contain some toxicology-related material, e.g. 'allergy', and 'public, environmental and occupational health', but their scope is too wide to be useful for this purpose, and the 'overlap' facilities suggest that any journals with strong toxicology leanings will be included in this section. 71 journals are listed in the 'toxicology' section, and these were entered into the final toxicology resource listing.

Identifying key toxicology journals by RANKing

A third approach to the identification of key journals in a subject area is to search for a set of items clearly reflective of that subject in a database, and identify the journals from which they come.

This was tested for toxicology by searching individually on a series of databases on the Dialog host, which might be expected to have reasonable coverage of toxicology literature. 'Core' toxicology material was selected by specifying that the items must have the term 'toxicology' in the title. This also ensured that the analysis was not affected by the indexing policies of each database. Time periods were chosen so as to analyse roughly equivalent numbers of items from each database. The journals, or other sources, from which these items were taken were then listed by the Dialog RANK command, down to journals containing 10 or more items, with the results corrected to allow for cases of journal name changes (identified from Ulrich). Correction was also necessary to allow for differences in journal name citations within the various files, which are due to variant editorial practice over time or in various sub-files.

The results cannot be taken as exact, due to these problems, but they give an adequate guide to the situation. Use of International Standard Serial Numbers (ISSN) would have avoided some of these problems, but these are not present in all files, and present their own problems with journal merges etc.

Databases searched were:

Scisearch	1990-current	1603 items
Medline	1985-current	1978 items
CAB Abstracts	1972-current	1180 items
Biosis	1993-current	2453 items
Embase	1985-current	2103 items
Life Science Collection	1982-current	2830 items
CA Search	1990-current	1804 items
Toxline	1990-current	2671 items

Toxline is, of course, a special case, being a composite file; the search initially generated 3562 items, which were reduced to 2671 by the Dialog duplicate removal procedure. Life Science Collection also comprises sub-files, but it was thought unlikely to have sufficient overlap to make duplicate removal necessary or sensible.

Combining ranked lists from bibliographic databases

In order to find a crude estimate of the most significant set of journals, those occurring in 3 or more of the above lists were ranked, according to the number of databases in which they appear, as shown below. This is not an accurate, or strictly quantitative procedure, but it does give an indication of the most 'visible' journals, as indicated by the appearance of numerous abstracts in several secondary services.

It is debatable whether Toxline should be included in such a process, since it reproduces subfiles from other sources, and items may thereby be 'counted twice'. Given that the purpose of this list is assessment of 'perceived significance' or 'visibility', rather than bibliometric analysis, it is justified.

8	FOOD AND CHEMICAL TOXICOLOGY /FOOD AND COSMETIC TOX
7	TOXICOLOGY LETTERS
7	VETERINARY AND HUMAN TOXICOLOGY
7	REGULATORY TOXICOLOGY AND PHARMACOLOGY

7	ENVIRONMENTAL HEALTH PERSPECTIVES
7	FUNDAMENTAL AND APPLIED TOXICOLOGY / J TOXICOL SCI
7	MUTATION RESEARCH
7	TOXICOLOGY
7	ARCHIVES OF TOXICOLOGY (including supplements)
6	HUMAN & EXPERIMENTAL TOXICOLOGY / HUMAN TOXICOLOGY
6	TOXICOLOGY IN VITRO
6	JOURNAL OF TOXICOLOGY-CLINICAL TOXICOLOGY
6	ENVIRONMENTAL AND MOLECULAR MUTAGENESIS
6	JOURNAL OF APPLIED TOXICOLOGY
5	MUTAGENESIS
5	JOURNAL OF ANALYTICAL TOXICOLOGY
5	TOXICOLOGY AND APPLIED PHARMACOLOGY
5	TOXICOLOGIC PATHOLOGY
4	NEUROTOXICOLOGY AND TERATOLOGY
4	REPRODUCTIVE TOXICOLOGY
4	CLINICAL CHEMISTRY
4	JOURNAL OF THE AMERICAN COLLEGE OF TOXICOLOGY / INT. J. TOXICOLOGY
4	ADVERSE DRUG REACTIONS AND TOXICOLOGICAL REVIEWS
4	PHARMACOLOGY & TOXICOLOGY
3	THERAPEUTIC DRUG MONITORING
3	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
3	NAUNYN-SCHMIEDEBERG'S ARCHIVES OF PHARMACOLOGY
3	CRITICAL REVIEWS IN TOXICOLOGY
3	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
3	JOURNAL OF FORENSIC SCIENCES

Although this is an informal means of ranking journals, the resulting set of 30 journals seems to be a reasonably good compilation of 'core' toxicology material. All but 5 of these journals were included in the 71 titles covered by the SciSearch service, as described above.

Mailing lists and newsgroups: In order to identify resources of this kind, searches were carried out in the following level specific tools:

- JISCMail (<http://www.jiscmail.ac.uk>), the UK mailing list server for the academic community
- Liszt (<http://www.liszt.com>), a directory of public mailing list servers
- Google Groups (<http://groups.google.com>), a search engine for newsgroups

using the terms 'toxicity', 'toxicology', 'poison'.

Whilst some mailing lists were found from the Liszt directory, Google Groups only indicated one newsgroup of relevance, bionet.toxicology. A more fruitful source of discussion groups was the web pages of toxicology related societies and organisations, which listed other resources. Some organisations, such as the Society of

Forensic Toxicologists, and the American College of Medical Toxicology have their own discussion groups.

Regulations and legislation: although not scientific information in the strict sense, this sort of information is of relevance to, and uses data from, regulatory toxicology, and health and safety aspects. Sources available include the text of legislation, detailed regulations and guidelines deriving from it, and information about specific products, substances, industrial plants, and locations. A complicating factor is that legislation and regulation of toxic substances is, in virtually all countries, fragmented according to the use of substances: medicines, pesticides, foodstuffs, industrial raw materials, etc.

Such information comes almost exclusively from local, national and supra-national government bodies. It is multifarious, voluminous, and no single resource offers access to all that is available. Wexler's (2000) guide to toxicology resources suggests some country specific sources, but to be current, it is necessary to search for documentation from the relevant government and regulatory bodies of the region of interest.

Reports: much toxicology information, particularly the results of 'routine' tests carried out for regulatory or Health and Safety reasons, never appears in the scientific literature, but is publicised in technical report series.

These were identified by searching subject-specific bibliographic databases, particularly Chemical Abstracts which claims good coverage of the report literature, by combining the term TOXIC? in the title with the TECHNICAL REPORT document type, and RANKing the results, to identify the most common sources.

These include one toxicology-specific report series

- US National Toxicology Program Technical Report Series

one series with a high toxicology component

- US Environmental Protection Agency R&D Report Series

and two sets of series where toxicology reports are in a minority, though still numerous in real terms

- PB and AD report series from the US National Technical Information Service (NTIS)
- various report series from the European Commission

Also, significant for reasons of quality rather than quantity, are report series which provide evaluations and assessments of toxicity, of which the best known example is the BIBRA Toxicity Profiles.

Selecting and presenting the resources

Resources were grouped according to the sub-types listed in the primary literature category. Journals were selected more rigorously than newer types of resource such as newsgroups and web diaries.

Comments on primary resources

Traditional examples of primary literature in toxicology are readily retrieved, and the issue is one of selection rather than identification. Journal articles, conference proceedings, meetings reports, and technical reports may all be found by searching online databases, and to some extent by using Internet search engines. Most of these primary resources are published in printed format, although examples of each could be found as web pages; consequently, searching bibliographic or online databases proved more useful than querying Internet search tools. The retention of the printed format reflects the preference most readers feel for paper rather than screen based reading material. Almost all of the printed and electronic journals are of the traditional 'refereed' variety. Certainly those included by the Science Citation Index are of this type, indicating the continued importance of this core communication method in toxicology.

Journal names were listed, rather than individual articles, although it could be argued that it is the articles *per se*, rather than the journal, which contain the primary information. While there would undoubtedly be some value in compiling lists of key journal articles, this level of specificity was not warranted for the current listing.

Media reports were also included as primary resources, although in some cases reporting may be considered to summarise existing facts, or review the current status of an issue, and these latter forms may be regarded as secondary sources.

The ease of publishing information on a web page, coupled to the fact that most text is prepared in electronic format anyway, allow the traditional primary resources to be

made available as electronic documents, in addition to their printed counterparts. Electronic versions of printed journals, proceedings and reports are now quite common, although further study would be needed to gain some measure of how much they are used as an alternative to, or in conjunction with, printed copy. The question of cost is another issue. Some articles can be found freely, whereas others require some form of payment.

Electronic journals without a printed counterpart can be found, although there are only two examples, from India and the US, in this instance. In both cases, the amount of material available is rather sparse, but this may be due to the fact that the publications only commenced in 1998 and 2000 respectively. Both journals state that articles are only published after they have been reviewed. One of these journals is published by the American College of Toxicology, and sent to readers via email. It is interesting to consider how these journals are regarded by the profession.

New ICTs have clearly increased the amount of formal information which can be readily accessed, whether this is by making articles available as web pages, or by facilitating document delivery. It is another question to consider whether the amount of formal information *per se* has increased as a result of new technologies.

Much primary information may be regarded as informal, however. That is, the information which is communicated amongst individuals, groups of individuals or organisations, but which remains outside the realm of published information. New ICTs can be seen to have changed the amount of informal information which can be accessed, in the guise of web pages, email lists, discussion forums and network based diaries. Examples of these communication methods can be seen in the area of toxicology, although as may be expected, mailing lists are the most readily identified.

Information such as course notes, outlines and syllabi may also be regarded as informal information, to the extent that they were only readily available to those within a given organisation. Several examples of toxicology related educational material can now be found on web pages. The drawbacks to this new availability is that often the material is published for the attention of a specific class or group, so that the exact context, level, authority and even date are missing for a more public audience. This problem could readily be improved if the authors of such material included more descriptive information about the nature of the work.

Some outstanding examples of course web sites can be found in areas related to toxicology. The Oxford University Clinical Laboratory Sciences site for example,

(<http://www.ndcb.ox.ac.uk/LMC>) provides a portal type interface to relevant services and materials for those studying laboratory medicine. The site offers different levels of access to students and non-students. Students can access core materials including: exam instructions, timetable, lecture slides, handouts, learning objectives, reading lists and exam techniques. There are also links to lists and reviews of course books, self-assessment resources, learning zones, tutor areas, a virtual reality pathology pots museum, multiple choice questions bank, links to public databases such as PubMed, and to university library databases. There is also a link to a chatzone, interestingly accompanied by a warning that this could be a 'barren wasteland of emptiness'. Clearly, such applications are not so readily embraced by course members in this field, regardless of the popularity of such communication means in less academic areas. Finally of interest is the section on access to the resources via handheld devices and WAP 'phones. The indication here is perhaps that other devices than a PC will soon be commonplace for access to information.

The accessibility of grey literature such as reports, recommendations and legislation is improved with the advent of new ICTs. Internet search engines and directories locate web pages containing full text versions of many examples in the field of toxicology. The issue here is that there is no guarantee that the information sought will be available, and there is no single place to look to see the context of resources of this type. Again the need for resources to be dated is evident. Choosing correct keywords is problematic because often the titles and headings of these documents are obscure.

Finally, some primary information may remain unavailable, whether formal or informal. This includes information which is classed as confidential for some reason, resources which may not be networked, and even personal or group opinions and knowledge, which may not be recorded electronically.

It may be envisaged that this sort of information would be available to those with a right to retrieve it. Issues such as the privacy of electronic mail, personal data recording devices, telephone conversations and text messages may change according to who needs to know and why, but no examples of this sort of information retrieval were considered for this study.

Increasingly, raw data may be found, for example the Toxic Release Inventory, published by the US Environmental Protection Agency, shows toxic emission data, and this is available in several formats. In this case, however, the data has been

worked into a publishable format, and so it does not equate to the zeroth order of data proposed earlier in this chapter. This level is used to describe data as it is first encountered, without any interpretation.

3.5 Toxicology Information Resource List

This list is given in the appendix, section 3.5.a.

3.6 Comments on contemporary toxicology resources: the impact of new ICTs

Perhaps the most obvious comment to make is that more toxicology resources exist now than 20 years ago. This increase in the volume of the literature would be expected, simply as a result of the passage of time. Using Toxline as a measure, Kissman et al. (1982) estimated the growth rate of toxicology journal articles at 107,000 per year. Nevertheless, it may be that an additional increase has occurred, consequent to the increasing prevalence of electronic communication in our lives, and particularly, the emergence of the world wide web. It is difficult to derive a method by which to measure this exactly.

Certainly the tendency to store information in electronic format, and the ready availability of a world wide publishing mechanism, have led to the perception of global rather than local information retrieval. This in itself increases the amount of information to be dealt within any one discipline. For the example of toxicology, resources may be identified from places such as Russia and China. 20 years ago, such information would be virtually impossible to retrieve, and quite hard to even know about. This change is, of course, not solely due to new ICTs; clearly political, social and economic issues have played a part. A significant factor is the use of English language in network based communications. It can, however, be stated that the amount of information available to those interested in toxicology has increased because international resources can be more readily located, and that this is because of new ICTs.

The same argument may also apply for local resources. It may now be possible to find more home produced information, because it is easier for the authors to publish it. The example of 'grey' literature, described by Kissman and Wexler (1983) as including technical reports, government documents and dissertations, may be relevant here. Much US government and international regulatory bodies information is now available in full text from web pages, Everitt (2000).

There is still then the question of whether new ICTs have resulted in the generation of novel information, which would not exist without them, or whether the increase is only due to enhanced publishing and access mechanisms, and to copies of information being produced in additional, electronic formats.

New, raw toxicology data, referred to earlier in this chapter as a zeroth category of information, have undoubtedly been generated over the past 20 years. Kissman and Wexler (1983) refer to the following areas of toxicology testing and research: carcinogenesis, mutagenesis, reproductive toxicology and teratogenesis, target organ toxicology, structure activity relationships and risk assessment. Today there are additional areas such as genomics, proteomics and genetically modified animals (Fry and George 2001). Whether any of the new data are due solely to new ICTs is beyond the limits of the current study, which focuses on information communication, rather than data generation. It is, however, possible to suggest here that new ideas/work/techniques may have been facilitated by new ICTs, in that information communication between toxicologists is now easier, and this may generate increased research and consequently increased raw data.

The extent to which raw data is collected in electronic form allows data to be archived alongside any electronic publication which refers to it; this makes it possible for a reader to check, or re-analyse the data to their own satisfaction (Meadows 1998), in a way which is rarely possible in print.

Torasson et al. (2002), discuss how data from genomics and proteomics can be linked to analyses for risk assessment.

For information in the main four resource categories, it is likely that new ICTs have played an 'encouraging' role, rather than having been directly responsible for the existence of novel information. This role envisages information at any of the four levels, which enters the communication process only in a form which is derived from new ICTs. Examples of types of encouraged information include:

- postings to mailing lists and discussion groups
- web pages containing unpublished personal or organisational information
- web diaries
- lists of resources or bibliographies
- portals
- multimedia course sites
- webrings
- lists of lists

From the above examples, it can be seen that an amount of primary, tertiary and even quaternary information, which may previously have remained 'informal', (ie.

difficult/impossible to retrieve) now has an opportunity to become part of the 'formal' information communication process. The lack of effect on secondary resources reflects that fact that secondary communication is by nature part of the formal communication process. Bibliographic services have been accessible via networks for longer than 20 years, and therefore the impact of new ICTs is rather less than for other types of information. With regard to printed works, these do not readily transfer to an electronic environment, although examples can be found, and so here again the impact of new ICTs is minimal.

The concept of encouraged information thus reveals a second impact of new ICTs; an increase in the number of forms which information resources can take. Specific ICT based information forms can be seen on the resource categorisation listing, shown earlier in this chapter.

The current range of forms of toxicology information can be compared with those described around 20 years ago in the Proceedings of the Symposium on Information Transfer in Toxicology, held at the US National Library of Medicine in September 1981 (Kissman et al. 1982). This report refers to primary, secondary and tertiary literature, but within the confines of traditional forms including preprints, journal articles, conference proceedings, technical reports, abstracting and indexing systems (and their computerised counterparts), databanks, books and monographs. The resource categorisation listing proposed in this study re-defines the sort of information assigned to each category, adds a quaternary level of resource, and extends the number of forms available to encompass new ICTs.

Whilst the web may have boosted the availability of formal primary material such as journal articles, conference proceedings and report literature, it is in the area of informal 'pre-primary' information that the new forms have had their greatest impact.

Kissman et al. (1982) detailed the communication of toxicology information from generation to primary publication, referring to a pre-publication phase involving the invisible college, the semi-formal mechanism of ongoing research information collation, and the distribution of preprints. They point out that these forms are by no means reliable, and that much information is 'lost' between the stages of data generation and the primary publication of results and conclusions. Conversations between members of an invisible college are untraceable, as are preprints, and ongoing research listings do not include everything and may not be kept up-to-date.

Communication still takes place between workers before, during and after the acquisition of raw data, or zeroth level information, but before the work is ready for publication. The difference now is that it is possible to 'capture' and subsequently 'retrieve' this informal information to some extent, as some of it may enter the formal communication arena via forms resulting from new ICTs. Examples would be the archives of discussion or mailing list postings, and these could be regarded as an extension of the invisible college idea. Personal web pages and web diaries can be used to publish preprint text, initial thoughts and summaries of ongoing research information. Again though, some informal information will still remain unrecorded, or may be kept solely on private systems. There is also the issue of durability, in that archives of mailing lists may not be kept forever, and personal web pages are maintained at the discretion of the author.

The hyperlinked nature of the web clearly lends itself to the publication of web based lists of resources, services, and even other lists. Many toxicological examples of these forms can be found, and although printed variants still exist, these newer forms are clearly of increasing importance.

The listing of toxicology resources given in the appendix, section 3.5.a can be used to construct a model of information communication for toxicology at the time of writing. This is shown in figure 3.1.

This model can be compared with earlier ones, such as that derived by Garvey and Griffith (1972) and the Royal Society (1981). Information chain models are also discussed by Duff (1997). Several differences can be noted. Firstly, a pre-primary phase can be discerned, in which information can now enter the formal communication process before the primary publication of an idea or concept. The core communication, between primary and secondary services, remains largely unchanged, although the allocation of printed works such as books and monographs to this section is different from other communication models (Kissman 1982) which regard these as tertiary entities.

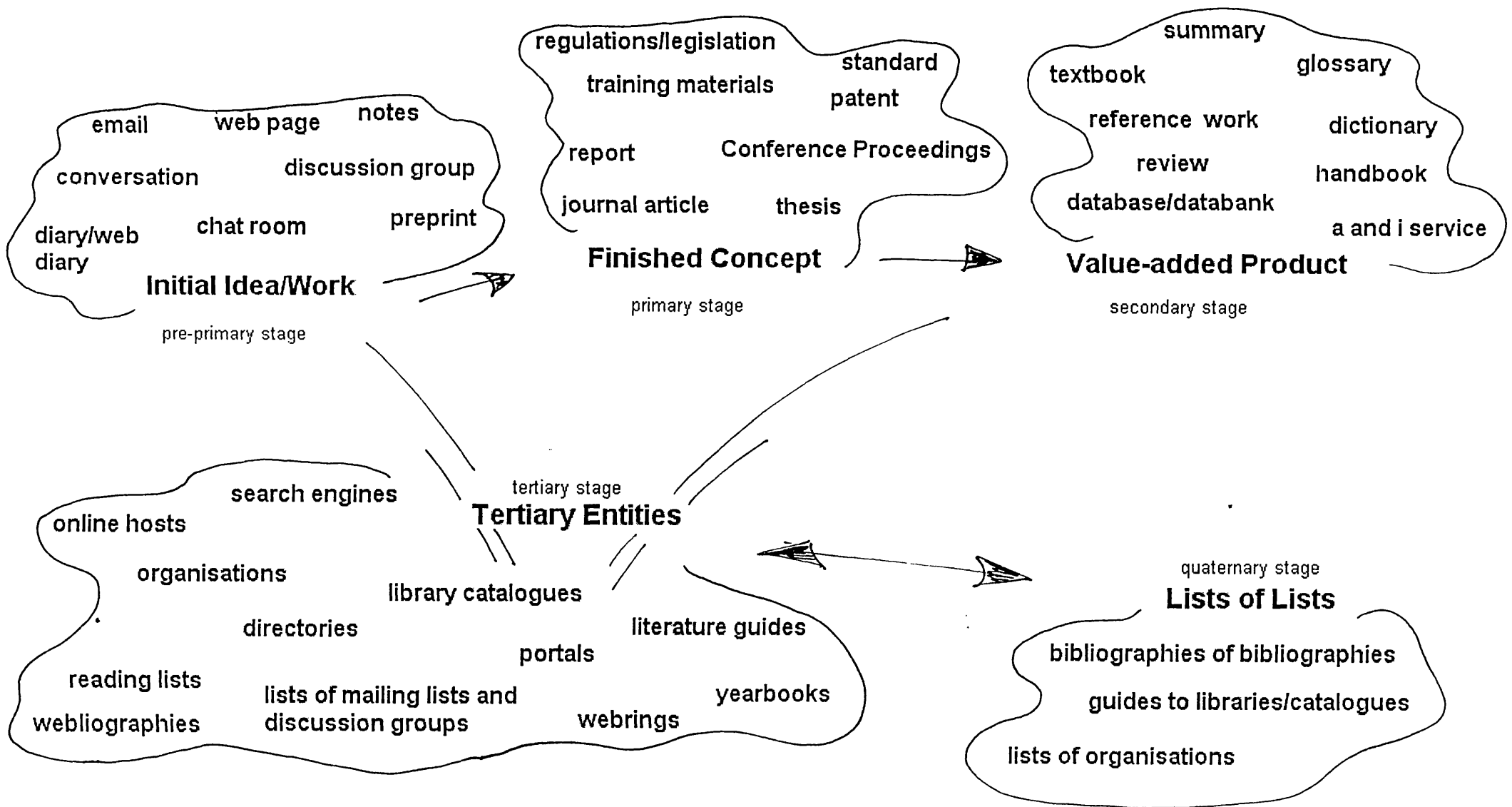
The pre-primary, primary and secondary resources all feed into the tertiary resources. In reality, tertiary listings sometimes point also to quaternaries, so it may be considered that these too, contribute to resources at this level.

Finally, the tertiary entities feed into the quaternaries, although again here it is possible to find pointers to other levels of information.

Nevertheless, this model provides an approach to information communication which is Z-shaped, in comparison to the linear models previously described.

Whilst compilation of the list of resources has given an insight into the qualitative impact of new ICTs on toxicology communication, it is not possible to draw any quantitative conclusions as to the actual amount of impact in any one area. Chapter four, considers how this may be achieved.

Figure 3.1 Information Communication Model



3.7 References

[Note: Editions listed are those used during this study; more recent versions may be available at the time of reading.]

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Chapter Four: Bibliometrics

4.1 Introduction

These bibliometric studies are aimed at providing answers to some specific questions related to the topic of this thesis. They are not aimed at providing 'mappings' of the discipline, in terms of individuals, schools of thought, and institutions, as has been done, for example, for information policy (Rowlands 1999), chemical engineering (Shama, Hellgardt and Oppenheim 2000), developmental dyslexia (Perry and Rice 1998), information science (White and McCain 1998) and women's studies (Cronin, Davenport and Martinson 1997).

They are largely based on the analysis of datasets derived from online databases. Though undeniably useful, the results of such analyses must be used with care, because of some intrinsic difficulties in their application, such as the various ways in which 'relevant' material may be defined, the limitations in the size of sets which may be ranked or 'de-duplicated', and the imprecision of the procedures for duplicate removal, Ingwersen and Christansen (1997), Wormell (1998). These analyses were supplemented, when appropriate, by use of ISI Journal Citation Reports data, by the use of web search engines, and by scanning of printed publications.

The work reported in this chapter examines the following issues:

- the size and growth of the toxicology literature over the past 25 years
- the globalisation of toxicology
- the impact of digital information in the formal literature
- aspects of the communication of toxicology information, with respect to other disciplines

In each case, the aim is to use the insights gained to assess the influence of new ICTs.

This material builds upon the initial analysis of toxicology communication described in chapter two, and the resources exemplified in chapter three.

4.2 Estimating the size and growth of the toxicology literature.

Three aspects are considered separately: scientific journals, leading to consideration of a 'core list'; books and monographs; and web resources. Individual reports, toxic substance assessments, etc. were not considered separately, since, in as much as these are available as individual public documents, they are likely to be available in the form of a web resource.

4.2.1 Journals

First, the SciSearch database was used, which includes all items from a 'core' set of high impact academic journals, but which is limited to title words for identifying subjects - abstracts are included in later years, and there are 'research fronts' and cited references, but no indexing. A search for title words TOXICOLOG? or TOXIC or TOXICITY or POISON? was used, to identify inarguably toxicological material and the number of articles found for each year is shown in table 4.1, together with the % change in the number published from year to year.

Table 4.1 Toxicology articles published each year, showing % change from 1975

Year	total <i>per yr</i>	tox titles	% change
1975	427825	1536	-
1976	449458	1756	14%
1977	532208	2313	32%
1978	537342	2488	8%
1979	555543	2489	0%
1980	564694	3393	36%
1981	587485	3779	11%
1982	612361	4207	11%
1983	660171	4234	1%
1984	674821	4120	-3%
1985	694036	4262	3%
1986	703984	4462	5%
1987	716621	4616	3%
1988	698594	4288	-7%
1989	658685	3798	-11%
1990	686428	2868	-25%
1991	706087	2658	-7%
1992	720440	2703	2%
1993	761459	2742	1%
1994	799838	2787	2%
1995	858970	3039	9%
1996	900486	2908	-4%
1997	939113	2931	1%
1998	945948	2997	2%

1999	976230	3197	7%
2000	984246	3074	-4%

These SciSearch figures show a growth from 1536 items in 1975 to 4616 in 1987, then a decline to 2658 by 1991, then a re-growth to over 3000 by 1999, after which the figure of 3074 in 2000 indicates a tailing off, which would be confirmed by results for later years. The explanation may lie partly in the nature of the ISI database (which itself does not grow steadily in size), partly in a change in the nature of toxicological research, and hence publication, and partly in a change in the nature of titles of articles, on which this analysis depends.

Journal coverage within the SciSearch database obviously varies over time, as may be assessed from the annual ISI journal listings. Generally the trend is to increase the numbers of journals in all subject categories: the toxicology category increased from 6 journals in 1975, through 20 in 1980, to 55 in 1995. Increase is not automatic - a drop from 22 to 19 is seen, for example, from 1978 to 1979, and from 56 to 55 in 1996 to 1995. The monitoring and adjustment of journal coverage, by both quantitative impact factors and by expert opinion, is intended to ensure that this database includes at any time the most significant journal articles. Use of this database is therefore likely to give a reliable measure of the size of the core toxicology literature.

To check the effect of any changes in title words, two journals with a large amount of toxicology material - *Toxicology and Applied Pharmacology*, and *Fundamental and Applied Toxicology* (later *Toxicological Sciences*) - were chosen, and the proportion of articles having the title terms listed previously were examined. Results were as follows:

Table 4.2 Proportion of articles containing toxicity terms in the title

Toxicology and Applied Pharmacology			
year	total	with title words	percentage
1980	286	67	23
1985	274	47	17
1990	252	29	12
1995	222	20	9
2000	235	16	7

Fundamental and Applied Toxicology			
year	total	with title words	percentage
1985	149	38	26
1990	161	52	32
1995	160	54	34
2000	308	40	13

Both show quite a low percentage of articles with 'toxicity words' in the title, dropping off dramatically in recent years. Inspection of titles shows the reason for this. Articles increasingly describe the detailed mechanisms of specific toxic effects in particular target organs, rather than overall toxicity; a change due to the increasing sophistication of the science of toxicology itself. Hence, reliance on title words is not adequate for identification of the size of the toxicology literature, although it will identify a sub-set of undoubted toxicological relevance. This tendency, for developing scientific literatures to use more specific title terms, was noted over twenty years ago by Buxton and Meadows (1977).

If we take the toxicology material in the journals covered by ISI as being the academic core of the discipline, then if it is defined by title words, it is seen to vary between 2,500 and 4,500 items per year over the period 1980-2000. Taking into account the low proportion of material having such title terms, a more realistic estimate would be at least 5,000 to 10,000.

The effect of the database producer's journal selection policy, can be tested by repeating the analysis on a database, with a different selection policy. This was done with Medline, first using the same keyword search of the title field as before. The exercise was then repeated, searching for the terms TOXICOLOGY or POISONING anywhere in the record; this is dominated by intellectually assigned index terms (controlled vocabulary) giving a more realistic definition of the toxicology literature. Results are shown in table 4.3.

Table 4.3 Toxicology articles published each year, in Medline, identified by title terms and by controlled indexing

year	total	tox titles	index terms
1975	242143	1660	2376
1976	246385	1692	2297
1977	252146	1804	2430
1978	261977	1906	2480
1979	270772	1905	2553
1980	268812	1877	2271
1981	270721	2115	2399
1982	281637	2066	2454
1983	295309	2275	2593
1984	304163	2196	2612
1985	314180	2195	2524
1986	327032	2326	2418
1987	343948	2385	2452
1988	361088	2279	2255
1989	376797	2478	2713
1990	384421	2476	2585
1991	385044	2323	2512

1992	357048	2156	2352
1993	393021	2169	2418
1994	401200	2182	2349
1995	410294	2288	2325
1996	415258	2163	2332
1997	425178	2213	2674
1998	437332	2077	2498
1999	444034	2152	2462
2000	457123	2163	2355

Here, the toxicology title term items grow from a starting point of 1660 in 1975 to a maximum of nearly 2500 in 1989-90, then settling to a roughly steady number of about 2150. The index term items stay largely consistent over time, suggesting that this may reflect indexing policies as much as literature size.

To obtain a more rounded measure of the size of the literature, not reliant on a single database, would be straightforward in principle. Toxicology material could be identified by a search on title words and descriptors in the four major disciplinary sources likely to cover the bulk of toxicology material: Medline, Embase, CA Search and Biosis. Duplicate records would be removed, and the distribution over time of the remainder assessed. Unfortunately, this straightforward process is not feasible, because of the limited size of record sets which can be de-duplicated and ranked in the Dialog service (5,000), the only host system to allow this sort of analysis on these databases.

An alternative procedure was therefore adopted. Toxicology material was identified in each of the databases separately, and the distribution by year of publication determined. The total numbers of records for each year were found by summing the four individual figures. A correction to the size of the literature was made, by assessing the extent of duplication between the databases for toxicology material estimated by title word/descriptor searching in several different years. Although rather crude, this is the only practical method in view of the set size limits for Dialog analysis. It should be adequate for providing an approximate indication of the size of the toxicology literature.

This analysis suggests that the extent of duplication over the four databases for toxicology material varies considerably over the period and is dependant on the title words/descriptors. The lowest value of overlap of any set in any one year was 12%, the highest 39%. The mean is 27%, with some indication of increasing overlap with time. As an approximation, overlap was taken as 30% for the period.

The counts for the four databases, using the search

toxicolog?/ti,de or toxic/ti,de or toxicity/ti,de or poison?/ti,de

to define toxicology material, are given in table 4.4.

Table 4.4 Number of toxicology articles per year summed from Medline, Embase, CA Search and Biosis, corrected for duplicates.

Year	count	corrected for overlap	%change
1975	20622	14435	-
1976	21166	14816	3%
1977	23281	16296	10%
1978	24172	16920	4%
1979	25059	17541	4%
1980	26255	18378	5%
1981	28363	19854	8%
1982	31258	21881	10%
1983	32581	22808	0%
1984	34307	24015	5%
1985	33041	23129	-4%
1986	35599	24919	8%
1987	32276	22593	-9%
1988	33521	23465	4%
1989	34381	24067	3%
1990	40178	28125	17%
1991	48880	34216	22%
1992	62011	43408	27%
1993	86160	60312	39%
1994	87568	61298	2%
1995	87195	61036	0%
1996	82275	57592	-6%
1997	66786	46750	-19%
1998	53769	37638	-19%
1999	56804	39763	6%
2000	63111	44178	11%

The picture emerging from this analysis of the toxicology literature as assessed by coverage in secondary services is not a simple one. Starting from a figure of about 15,000 items per year in the mid 1970s, the literature increases by up to 10% per year, reaching about 25,000 items per year by the mid 1980s. The growth does not appear steady, and declines are seen in some years. Dramatic increases around 1990, peaking at almost at 40% increase in 1993, take the total to over 60,000 in the mid-1990s, from when it declines to under 40,000 just a few years later, before increasing again at the end of the decade.

While the figures may be distorted by changing practices of the database producers, in terms of indexing and journal selection, the use of four distinct databases, and the combination of title words and indexing terms, should overcome this to a large extent. It seems likely that the toxicology literature does indeed demonstrate volatility, responding to changes in scientific practice and regulatory requirements.

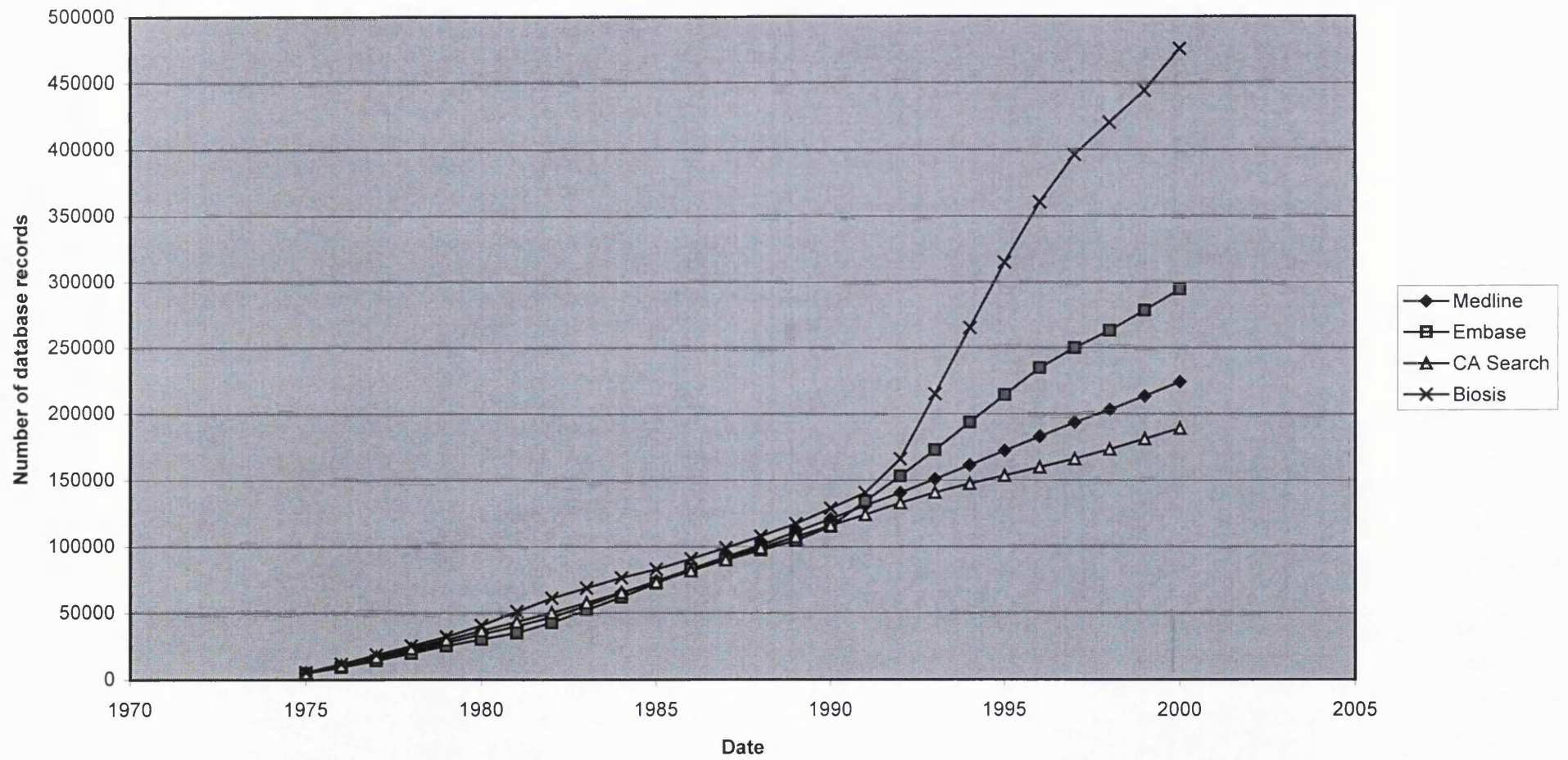
Figure 4.1 shows the cumulative growth of the toxicology literature in these four databases, using the search strategy as above and ignoring overlap. It is clear that

there is a steady growth, very similar in all four databases, between 1975 and 1990. In the 1990s a more rapid growth is seen in Biosis and Embase, which Medline and CA Search continue to grow linearly.

The marked growth in Biosis records since the early 1990s is likely to be due partly to a change in the Biosis indexing system at that time, which means that the definition of toxicology will be less precise than in the other services (Gretz and Thomas 1991).

In very rough terms, we can say that this form of analysis shows the toxicology literature to vary in size from about 20,000 to 60,000 items per year through the period, with a 'core' (as assessed by the ISI analysis on p 192) of 5,000 to 10,000 items per year.

Figure 4.1 Cumulative growth of toxicology literature



An alternative means of assessing the changing size of the toxicology literature is by examining *Toxline*, the predominant secondary service of the area. Although material in *Toxline* is not exclusively toxicological, nor is it comprehensive in its coverage of the subject, it has often been used as the single best measure for this purpose, for example by Kissman. The number of records in *Toxline* varies with time as shown in table 4.5.

Table 4.5 Number of articles in Toxline over time

Year	Items	Annual growth (%)
1980	32447	-
1981	32969	1.6
1982	35352	7.2
1983	37657	5.7
1984	40544	7.7
1985	41733	2.9
1986	43037	3.1
1987	43608	1.3
1988	44954	3.1
1989	48657	8.2
1990	50932	4.7
1991	51479	1.1
1992	51850	0.7
1993	55223	6.5
1994	57297	3.8
1995	58017	1.3
1996	59473	2.5
1997	59518	0.1
1998	61314	3.0
1999	63033	2.8
2000	65622	4.1

Although the file size increases annually, the increase varies between 0.1% and 8.2%, showing something of the same volatility as the earlier analysis. The literature size, increasing from 32,000 to 65,000 items per year, is in reasonably close accordance with that previous analysis, of Medline, Embase, CAsEarch and Biosis, above.

That the increase in toxicology publication is primarily due to an increase in the number of sources (i.e. journals), rather than the number of items in each source is clear from an examination of the numbers of items in particular sources over time; for example *Toxicological Sciences* and *Archives of Toxicology*, leading journals in the USA and Europe respectively, table 4.6.

Table 4.6 Number of articles in Archives of Toxicology and Toxicological Sciences over time.

	Toxicological Sciences	Archives of Toxicology
1985	149	114
1986	156	195
1987	147	252
1988	148	140
1989	156	88
1990	161	115
1991	157	116
1992	152	120
1993	123	121
1994	142	106
1995	160	115
1996	192	117
1997	128	123
1998	164	110
1999	220	73
2000	308	115

To attain further insight into the growth in number of journals, Ulrich's International Periodicals Directory (Dialog 2001 file) was used to rank all journals categorised in any way as 'toxicology' by their year of first publication, up to and including 2000. The results are shown in table 4.7.

Table 4.7 Toxicology journals listed in Ulrich's International Periodicals Directory (2001) over time

Year	New journals
1873	1
1907	1
1922	1
1926	1
1930	1
1937	1
1938	1
1942	1
1944	1
1947	3
1948	1
1949	1
1950	5
1952	1
1953	1
1954	1
1955	2
1957	3
1958	3
1959	5
1961	4
1962	3
1963	3
1965	1

1966	3
1967	5
1968	3
1969	2
1970	2
1971	4
1972	9
1973	4
1974	3
1975	6
1976	6
1977	9
1978	7
1980	9
1981	14
1982	11
1983	10
1984	8
1985	7
1986	10
1987	9
1988	11
1990	4
1991	8
1992	17
1993	12
1994	6
1995	6
1996	7
1997	5
1998	4
1999	5
2000	2

This shows a slow build-up in toxicology journal titles through the first half of the twentieth century, then a more rapid growth from the 1960s, reaching a maximum in the 1980s and early 1990s, and reducing at the end of the century. This confirms the picture given by Wexler (1990) of a steep growth in the number of journals from the 1960s to the 1980s; his prediction of a similar increase through the 1990s has not been fulfilled.

This drop in growth after 1995 may indicate saturation - there are enough journals to publish toxicology material - or may reflect the influence of new ICTs - there are now other ways to make the information available than in a conventional journal.

The figures from Ulrich and ISI suggest that there are currently about 300 journals carrying a substantial amount of toxicology material, though there are many more which include some toxicology content. This may be compared with Wexler's 1988 estimate of 125 journals largely devoted to toxicology, with hundreds more carrying

significant toxicology material frequently, as an indication that the toxicology journal literature has grown in scale but retained its general 'shape'.

4.2.2 Core list of journals for toxicology

A number of methods for identifying lists of 'core' journals in particular subject areas have been described. They include:

1. subjective assessments, often by surveys of staff at an institution or of a professional association (Wilder 2000)
2. examination of holdings at relevant specialist libraries, the core list being those taken by several libraries, or library statistics, the core being those relevant journals which are used most (Wilder 2000)
3. choose a small set of 'source journals', and look at what journals are cited by articles in these; the top ranked are the core (Gross and Gross 1927). A variant on this is to use 'Annual Reviews in ..' review journals as the source (Sengupta 1990)
4. choose an appropriate abstracting and indexing service, and rank the number of items included from each journal; the top ranked are the core (see Sengupta 1990 for examples). Kushkowski, Gerhard and Dobson (1998) extend this to include several relevant secondary sources, searching each and consolidating the results: the core list includes those journals contributing most items in the total set of sources. Sittig (1996) proposes a more sophisticated variant: identifying relevant material by subject searching, then identifying the number of relevant articles from each journal, and also the proportion of that journal's content which this constitutes - the core is then those journals with both a high total number and high proportion of relevant articles
5. a variety of citation-based methods may be used, defining core lists as those journals having the highest rank by total number of citations or by various impact factors (see, for example, Hirst 1978, Borgman 1990). Wilder (2000) proposes an elaboration on this: core journals are those having a high value for the Estimated Annual Citation Rate, value which adjust 'raw' citation figures by the 'half-life' for that journal, the time taken for articles to be cited which differs between subject area.

Note: The meaning of 'core' journals, as the term is used in the literature, may include both quantitative and qualitative aspects. Quantitative usually predominates, in that core journals are usually taken to be those which include the

largest number of articles in the subject area, or of articles assessed as 'good' by some quantitative measure, such as citation impact factor. However, qualitative factors, usually the judgement of a subject expert as to the most significant journals in a field, may be used in addition to, or instead of, quantitative factors, in deciding on core journals.

There is an obvious correlation between these methods - journals may be chosen for library collections, for example, on the basis of the opinions of library users, who will tend to cite articles from those which they then read - and Wilder (2000) points out that similar results are often obtained from different methods, at least in academic settings.

The only example of comparison of methods for creating core lists in toxicology is given by Kuch (1976), who used three methods for producing an 'initial candidate core list':

1. lists of core journals were taken from authors of monographs and similar secondary information products; these lists were consolidated by choosing items appearing on several lists, using a formula to give emphasis to items on short lists
2. journals cited in literature reviews and analyses were consolidated
3. expert practitioners (toxicologists) were asked to choose from journal list

The three lists were tabulated, and the core chosen as the overlap between the three

For this study, a core list of journals for toxicology was produced. In keeping with this thesis's emphasis on examination of recorded information, no attempt was made to use subjective methods - asking experts, examining library holdings (since these must, ultimately, be chosen subjectively by someone), etc. Two objective methods were used; one based on contribution to secondary sources as a measure of 'visibility', and one based on citations, as a measure of 'impact'. For comparison, subsequent reference is made to a published recent 'subjective' core list.

The first list, based on secondary services, is that already derived in chapter three, based on the occurrence of a journal high in the ranking of 3 or more secondary services. This leads to a list of 30 journals (see page 172).

The second, citation-based, list is derived from the 1998 Journal Citation Reports from ISI, which ranks the 71 journals in the toxicology category by impact factor (the ratio of citations to recent articles to the number of such articles). For comparison with the first list, the top 30 journals of this list are taken.

The 'visibility' core list is given first, with the equivalent position in the citation-based rankings shown in table 4.8.

Table 4.8 'Visibility' core list of journals, with the equivalent position in the citation-based rankings. (Journals listed in order of 'visibility')

Secondary service core list	Position in JCR ranking
1. Food and Chemical Toxicology	21
2. Toxicology Letters	27
3. Veterinary and Human Toxicology	51
4. Regulatory Toxicology and Pharmacology	38
5. Environmental Health Perspectives	-
6. Journal of Toxicological Sciences	8
7. Mutation Research	9
8. Toxicology	23
9. Archives of Toxicology	19
10. Human and Experimental Toxicology	40
11. Toxicology in vitro	46
12. Journal of Toxicology	32
13. Environmental and Molecular Mutagenesis	6
14. Journal of Applied Toxicology	48
15. Mutagenesis	-
16. Journal of Analytical Toxicology	12
17. Toxicology and Applied Pharmacology	5
18. Toxicologic Pathology	33
19. Neurotoxicity and Teratology	25
20. Reproductive Toxicology	37
21. Clinical Chemistry	-
22. International Journal of Toxicology	67
23. Adverse Drug Reactions and Toxicological Reviews	-
24. Pharmacology and Toxicology	34
25. Therapeutic Drug Monitoring	18
26. Annual Review of Pharmacology and Toxicology	1
27. Naunyn-Schmiedberg's Archives of Pharmacology	-
28. Critical Reviews in Toxicology	2
29. Environmental Toxicology and Chemistry	7
30. Journal of Forensic Sciences	-

Next, the top 30 journals in the impact factor ranking are shown. Their presence in the secondary service list is shown by 'S', table 4.9.

Table 4.9 Top 30 journals in the ISI impact factor ranking, indicating presence in the secondary service list (S)

1. Annual Review of Pharmacology and Toxicology	S
2. Critical Reviews in Toxicology	S

3. Chemical Research in Toxicology	-
4. Drugs	-
5. Toxicology and Applied Pharmacology	S
6. Environmental and Molecular Mutagenesis	S
7. Environmental Toxicology and Chemistry	S
8. Journal of Toxicological Sciences	S
9. Mutation Research	S
10. Aquatic Toxicology	-
11. Marine and Environmental Research	-
12. Journal of Analytical Toxicology	S
13. Drug Safety	-
14. Teratology	-
15. Journal of Toxicology and Environmental Health	-
16. Food Additives and Contaminants	-
17. Biomarkers	-
18. Therapeutic Drug Monitoring	S
19. Archives of Toxicology	S
20. Xenobiotica	-
21. Food and Chemical Toxicology	S
22. Annals of Occupational Hygiene	-
23. Toxicology	S
24. Toxicon	-
25. Alcohol	-
26. Neurotoxicology and Teratology	S
27. Toxicology Letters	S
28. Ecotoxicology	-
29. Inhalation Toxicology	-
30. Neurotoxicology	-

A total of 46 journals appear on the two lists, with 14 in common. These 14 may reasonably be regarded as a 'tight' core of toxicology journals, table 4.10:

Table 4.10 'Tight' core of toxicology journals. (in order of impact factor ranking)

Annual Review of Pharmacology and Toxicology
Critical Reviews in Toxicology
Toxicology and Applied Pharmacology
Environmental and Molecular Mutagenesis
Environmental Toxicology and Chemistry
Journal of Toxicological Sciences
Mutation Research
Journal of Analytical Toxicology
Therapeutic Drug Monitoring
Archives of Toxicology
Food and Chemical Toxicology
Toxicology
Neurotoxicology and Teratology
Toxicology Letters

To these might be added a further 10 journals from the 'visibility' list, which are also in the ISI toxicology category (impact factor ranking), but not in the top 30 initially selected, table 4.11.

Table 4.11 Additional journals for 'tight' core list, from ISI toxicology category

Veterinary and Human Toxicology
Regulatory Toxicology and Pharmacology
Human and Experimental Toxicology
Toxicology in vitro
Journal of Toxicology
Journal of Applied Toxicology
Toxicologic Pathology
Reproductive Toxicology
International Journal of Toxicology
Pharmacology and Toxicology

This set of 24 journals (table 4.10 and table 4.11) is certainly in close accordance with what would have been produced by the author of this dissertation, subjectively, but based on knowledge of toxicology and its literature.

In order to make a comparison with the 'subjective' approach, a recent, published core list of journals produced by a UK expert in toxicology information (Copestake 2000) was examined. This includes 27 journals, in alphabetical order, table 4.12.

Table 4.12 Core toxicology journals (Copestake 2000)

Archives of Environmental Contamination and Toxicology
Archives of Toxicology
Bulletin of Environmental Contamination and Toxicology
Carcinogenesis
Critical Reviews in Toxicology
Drug and Chemical Toxicology
Ecotoxicology and Environmental Safety
Environmental Toxicology and Chemistry
Food and Chemical Toxicology
Journal of Toxicological Sciences
Human and Experimental Toxicology
Journal of the American College of Toxicology
Journal of Applied Toxicology
Journal of Environmental Pathology, Toxicology and Oncology
Journal of Toxicology and Environmental Health
Mutagenesis
Mutation Research
Neurotoxicology and Teratology
Pharmacology and Toxicology
Regulatory Toxicology and Pharmacology
Reproductive Toxicology
Toxicology
Toxicology and Applied Pharmacology
Toxicology and Industrial Health
Toxicology in vitro
Toxicology Letters
Veterinary and Human Toxicology

17 of these are in the 30 journals on the 'visibility' list, 11 in the top 30 from the ISI impact factor ranking, and a further 7 in the additional 10 added from the full list of 71 ISI journals. This shows good agreement between the three ways for generating core lists.

A set of 10 journals present in all three lists of approximately 30 journals might be seen as forming the 'core of the core' of toxicology literature, table 4.13, as an alternative to the 'tight' core list shown in table 4.10. All of the journals in table 4.13 are also present in table 4.10, indicating that the different approaches to core journal definition give similar results.

Table 4.13 'Core of the core' toxicology literature

Critical Reviews in Toxicology
 Toxicology and Applied Pharmacology
 Environmental Toxicology and Chemistry
 Journal of Toxicological Sciences
 Mutation Research
 Archives of Toxicology
 Food and Chemical Toxicology
 Toxicology
 Neurotoxicology and Teratology
 Toxicology Letters

[Another seven journals could be added as being lower than the top 30 in the impact factor rankings, but which are present in the other two lists:

Veterinary and Human Toxicology
 Regulatory Toxicology and Pharmacology
 Human and Experimental Toxicology
 Toxicology in vitro
 Journal of Applied Toxicology
 Reproductive Toxicology
 Pharmacology and Toxicology

It is therefore clear that it is possible to define a core set of toxicology literature in a much 'tighter' fashion than for other interdisciplinary areas (Kushkowski, Gerhard and Dobson 1998). This indicates that, although journals from related fields - such as pharmacology, environmental sciences, clinical chemistry and forensic science - appear in both lists, toxicology *per se* has developed its own core literature.

The derivation of a core listing based on the number of quality (*or relevant*) articles present in a journal will neglect general journals which may offer relevant papers on a more limited basis. Both sources used for the construction of core listings above,

identify journals with the highest quantity of relevant articles, and it should be noted that general journals carrying fewer 'quality' papers are thus underrated.

To get some insight into changes over time, the lists derived in this study were compared with those produced by Kuch (1976). He produced a list of 30 journals with high ratings on all three of his approaches, of which only two (denoted by X) are in the any of the core lists above:

Table 4.14 Kuch (1976) list of 30 core journals, showing those in core lists derived for this study

Journal of Pharmacology and Experimental Therapeutics	
Biochemical Pharmacology	
Food and Cosmetic Toxicology (now Food and Chemical Toxicology)	X
Toxicology and Applied Pharmacology	X
Acta Phamacologica Toxicologica	
Journal of Pharmacy and Pharmacology	
Science	
Nature	
Proceedings of the Society for Experimental Biology and Medicine	
Analytical Chemistry	
Journal of Agricultural and Food Chemistry	
American Industrial Hygiene Association Journal	
Annals of Occupational Hygiene	
British Journal of Industrial Medicine	
Industrial Medicine and Surgery	
Journal of Occupational Medicine	
Archives of Industrial Hygiene and Occupational Medicine	
Archives of Industrial Health	
Biochemical Journal	
Journal of Biological Chemistry	
British Medical Journal	
Journal of the American Medical Association	
New England Journal of Medicine	
American Journal of Public Health	
Cancer	
Journal of the National Cancer Institute	
Cancer Research	
International Journal of Cancer	
Archives of Environmental Health	
Environmental Research	

In a second list of 23 journals, with high ratings on two of his approaches, only eight (denoted by X) are in any core list above, table 4.15.

Table 4.15 Kuch (1976) list of 23 core journals, showing those appearing in any core list derived in this study

Archives of Toxicology	X
Clinical Toxicology (now Journal of Toxicology)	X
Critical Reviews in Toxicology	X

Drug Metabolism and Disposition	
Life Sciences	
Teratology	
Pharmacology and Toxicology	X
Toxicology	X
Comptes Rendus	
Journal of Applied Physiology	
British Journal of Cancer	
Annals of the New York Academy of Sciences	
Mutation Research	X
Analytical Biochemistry	
Archives of Biochemistry and Biophysics	
Biochimica Biophysica Acta	
Clinical Chemistry	X
Lancet	
Public Health Reports	
American Journal of Clinical Pathology	
Environmental Health Perspectives	X
Journal of Industrial Hygiene and Toxicology	
Journal of Pharmaceutical Sciences	

Only 10 out of Kuch's 53 core journals are still in the core, by any of the measures defined above. What is particularly noticeable is the extent to which Kuch's listing of the mid-1970s was largely comprised of material from associated sciences - medicine, biochemistry, pharmacology, etc. - which has now largely been supplanted in the core by a much wider range of specifically toxicology publications.

4.2.3 Books and monographs

In order to assess the size and growth of the toxicology monograph literature, the British and American Books in Print files were searched for items with toxicology and poisoning terms in titles or subject descriptors, and duplicates removed. These files contain out-of-print items dating back to the 1970s, so that a ranking by publication year gives a good assessment of the literature. A total of 4281 items was identified, published in years up to and including 2001. Although this includes out of print books, these are still likely to be available in libraries, and should be included in the 'current' toxicology literature. The results are shown in table 4.16.

After the small number of elderly, but obviously still relevant, items, the picture is much the same as for journals: a growth through the 1960s and 70s, increasing dramatically through the 1980s and 90s, with some indication of a slowing in growth at the end of the century.

By way of comparison, the monographs listed in the most recent edition of Wexler's comprehensive listing of toxicology were examined. These are noted as emphasising recent books of value to the practising toxicologist, and a proportion deal not with toxicology *per se*, but with other subjects of importance to toxicologists.

Approximately 1,000 toxicology items are listed here, and may be taken as giving an indication of the size of the 'core' of currently useful monographs.

Table 4.16 Toxicology publications from UK and US Books in Print, ranked by year

Year	Books published
1905	1
1919	1
1920	1
1937	1
1950	1
1951	1
1953	1
1955	1
1957	1
1959	1
1960	2
1961	5
1962	4
1963	6
1964	5
1965	4
1966	4
1967	6
1968	4
1969	11
1970	9
1971	10
1972	23
1973	24
1974	29
1975	21
1976	23
1977	45
1978	51
1979	71
1980	67
1981	64
1982	63
1984	78
1985	104
1986	131
1987	170
1988	172
1989	181
1990	215
1991	288
1992	265
1993	255
1994	329
1995	332
1996	322
1997	323
1998	301

1999	301
2000	279
2001	266

4.2.4 Web resources

Assessing the size of the Internet, and the number of web resources in any subject area is notoriously difficult (Molyneux and Williams 2001), and the best which will be attempted here is a very rough estimate. It is not generally possible to identify growth rates because of the difficulty in identifying the first 'publication' of web resources, but the extent of updating can be assessed. The Google search engine was used for these studies, as it has the most comprehensive index of web material (Sullivan 2001).

The general assumption is that there is a very large amount of information available on the web on almost any subject, and this appears to be borne out by a simple search for toxicology. Searching for:

toxicology OR toxicity OR toxic OR poison OR poisons OR poisoning

in the text of any web page updated in the last 3 months on Google returns over one million hits. However, more discriminating searches show a different picture.

Using the Google engine, searches were carried out for various terms in the titles of web pages; this should be more discriminating in identifying resources dealing primarily with these subjects rather than the simple occurrence of a term on a page. To assess the currency of information, these searches were restricted to material updated in the last year, and the last 3 months (searches performed in February 2002).

Table 4.17 Toxicology items found from Google search engine restricting results to terms in the title field and material updated in the last year and the last 3 months

Terms in title field	Resources updated		
	any time	last year	last 3 mths
toxicology OR toxicity OR toxic	63,800	56,600	40,200
poison OR poisons OR poisoning	61,900	59,900	58,200
toxicology OR toxicity OR toxic OR poison or poisons or poisoning	89,700	87,800	71,400
toxicology	19,400	15,200	10,800

acute toxicity	319	178	85
regulatory toxicology	33	23	17
inhalation toxicology	120	82	63
neurotoxicity or neurotoxicology	1020	768	455
toxicity testing	326	229	159

Restricting to terms in the titles of resources considerably reduces the extent of resources available, while the use of quite precise terms brings a further dramatic reduction. This suggests that the amount of web resources providing significant information - as indicated by the use of terms in titles - for specific toxicology topics is, in fact, very limited.

This very rough analysis suggests that the number of significant toxicology resources on the web being updated each year is around 70-80,000, with a 'core' - denoted by the more specific term 'toxicology' in the title - of around 10-20,000. Intriguingly, this is very similar to the extent of formal toxicology publication noted earlier. Resources dealing in a substantive way with specific areas of toxicology are to be numbered in hundreds rather than thousands. Typically, a little more than half seem to be kept regularly updated.

One important question is whether these new web resources duplicate traditional primary or secondary resources, or provide a different form of information. Some light has been shed on this by the survey of resources in chapter three. This was extended here to provide a more quantitative indication. 500 of the 10,500 toxicology resources identified from Google were chosen randomly - by examining records in the same numbered place on randomly chosen search results pages - examined, and placed into general categories. In particular, when any resource appeared likely to provide 'substantive information', it was always put in that category. Results, expressed as percentages, are shown in table 4.18.

Table 4.18 Categorisation of search results from table 4.17

Academic institutions	24%
Publishers/libraries	20%
Toxicology organisations	19%
Lists of sources	9%
Learned societies	8%
Substantive toxicology information	7%
News items	6%
'General' information	3%
Conferences	2%
Regulations/legislation	2%

The main content is typical of web-based material, as exemplified in chapter three. Even taking the generous interpretation used here, substantive toxicology information is present in less than 10% of these web resources; which, it should be noted, are chosen so as to form of the 'core' of toxicology on the web.

It therefore seems reasonable to conclude that the web is providing a largely different form of information from that in the traditional sources, rather than duplicating it.

4.2.5 Size and growth of the toxicology literature: summary

The analyses described above suggested that the toxicology literature at the end of the twentieth century consisted of:

- ~60,000 journal articles, with a core of ~10,000 particularly significant articles
- ~300 journals, with a tightly defined core of 10-25 journals in total
- ~4,000 books and monographs, with a core of up to 1,000 items in total
- ~70-80,000 web resources, with a core of ~10-20,000 significant items updated per year

The growth patterns of the printed resources has followed the same general pattern, with some fluctuations: a slow growth up to the 1960s, and more sustained growth for the next decade or so, a dramatic growth in the 1980s and early 1990s, and a flattening off of growth towards the end of the 1990s. The growth has been due to the creation of new resources, particularly scientific journals and report series.

The web resources have clearly come into being from the mid-1990s onwards. It is intriguing to note that the printed and web resources are now roughly equal in magnitude, and to speculate that the slowing of growth in 'traditional' resources is associated with the increase in the newer formats. This, however, does not appear to be so from the limited analysis shown here. Primary and secondary 'substantive' information is relatively sparse on the net.

From the 'Z'-shaped model derived in chapter three, it may be argued that the increasing number of web resources is likely to be in the pre-primary category, and in the tertiary and quaternary resources.

4.3 Globalisation of toxicology

In this section, two aspects of the global nature of toxicology are examined: the languages in which it is written, and the geographic areas in which it is done.

4.3.1 The languages of toxicology

This aspect of the study had the aim of assessing the languages in which toxicology information is published, and how this may have changed over time.

Initially, the SciSearch database, covering core academic journals, was used, to identify material by a search for toxicology, toxicity, toxic and poison (truncated) in titles, as before, and RANKING by language for items published in 1980, 1990 and 2000. The results are shown in table 4.19.

Table 4.19 Toxicology items from SciSearch ranked by language for 1980, 1990 and 2000

1980	(total 3393)
English	90%
French	3%
German	3%
Russian	1%
Japanese	1%
less than 1%:	Spanish, Dutch, Italian, Czech, Hungarian, Swedish, Polish, Rumanian
1990	(total 2853)
English	92%
Russian	2%
French	2%
German	2%
Japanese	1%
Spanish	1%
less than 1%:	Czech, Portuguese, Hungarian, Chinese, Dutch, Italian, Polish, Serbo-Croatian, Swedish
2000	(total 3074)
English	96%
French	1%
German	1%
Japanese	1%
less than 1%:	Spanish, Russian, Portuguese, Czech, Chinese, Hungarian, Polish, Dutch, Rumanian, Turkish

The predominance of English in this set of literature is clearly increasing.

This was then compared with Medline, a database with a wider selection of journals; particular 'local' medical journals, in which toxicology issues might be expected to appear in local languages, using the same search and analysis process. The results are shown in table 4.20.

Table 4.20 Toxicology items from Medline ranked by language for 1980, 1990 and 2000

1980	(total 1877)
English	70%
Russian	8%
German	5%
French	4%
Polish	3%
Japanese	2%
Italian	2%
Spanish	1%
Chinese	1%
Danish	1%
less than 1%:	Serbo-Croatian, Romanian, Bulgarian, Dutch, Swedish, Czech, Slovak, Hebrew, Hungarian, Norwegian, Portuguese, Afrikaans, Ukrainian
1990	(total 2476)
English	79%
Russian	6%
French	4%
German	3%
Japanese	2%
Spanish	2%
Polish	1%
Chinese	1%
Italian	1%
less than 1%:	Dutch, Bulgarian, Danish, Norwegian, Swedish, Czech, Portuguese, Serbo-Croatian, Hungarian, Romanian, Korean, Slovak,
2000	(total 2163)
English	89%
French	2%
Russian	2%
Spanish	2%
Japanese	1%
German	1%
Polish	1%
less than 1%:	Chinese, Italian, Portuguese, Czech, Danish, Hebrew, Hungarian, Serbo-Croatian, Slovak, Swedish, Dutch, Norwegian, Ukrainian

Although Medline starts with English less dominant (70% compared with 90%), increasing dominance over 20 years parallels Scisearch. All other languages decline, that of Russian being particularly noticeable.

The 16 languages in SciSearch are all present in Medline, which has an additional 8 languages, all in the 'tail' of less than 1% occurrence.

To check that the language distribution in Medline was not an artefact of the selection of toxicology items by title terms, the exercise was repeated, using the occurrence of the terms TOXICOLOGY or POISONING anywhere in the record (principally in the intellectually assigned indexing terms). The language distribution obtained was virtually identical.

The process was repeated in Excerpta Medica (Embase), as this database is likely to have a wider coverage of 'minor' European language material, and the results are in table 4.21.

Table 4.21 Toxicology items from Embase ranked by language for 1980, 1990 and 2000

1980 (total 2179)

English	71%
German	6%
French	5%
Japanese	5%
Italian	3%
Russian	2%
Polish	2%
Dutch	1%
Spanish	1%
Czech	1%
Less than 1%:	Bulgarian, Danish, Hungarian, Romanian, Serbo-Croatian, Hebrew, Norwegian, Portuguese, Swedish, Korean, Slovak, Chinese, Afrikaans, Greek

1990 (total 2770)

English	85%
Japanese	4%
German	3%
French	3%
Spanish	1%
Russian	1%
Italian	1%
less than 1%:	Bulgarian, Dutch, Chinese, Polish, Czech, Norwegian, Serbo-Croatian, Danish, Korean, Portuguese, Romanian, Swedish, Turkish

2000 (total 2543)

English	91%
French	2%
German	2%
Spanish	2%
Japanese	1%
less than 1%:	Chinese, Polish, Dutch, Portuguese, Italian, Korean, Czech, Turkish, Russian, Bulgarian, Danish, Hebrew, Slovak

These results parallel Medline, with the increasing pre-dominance of English and decline of 'minor' languages even more marked.

This process could be repeated in other databases, but the results already seem clear. Although the primary literature of toxicology is published in a variety of languages, English has been predominant since 1980, especially in the 'core' of leading scientific literature, and is now overwhelmingly so. All other languages have declined, the decline of Russian being particularly marked. Only French, German and Spanish consistently contribute more than 1% of this literature.

Nonetheless, it should be remembered that even the 'less than 1%' may contribute several papers a year. Although not significant numerically, if they deal with some aspect of toxicity or poisoning not covered elsewhere, overlooking them may be a serious matter of individual sufferers. An actual example in the field of toxicology is that described by Chan (1977), in which recognition of a successful treatment for potentially fatal mushroom poisoning was delayed for several years, because it was originally published only in languages other than English.

4.3.2 Location of toxicology research

This part of the study examines the countries from which the toxicology literature originates, to assess how global is the science, and how this may have changed over time.

The only way this can be done conveniently is via SciSearch Geographic Location field, taken automatically from the author address, and 'cleaned up' for the purposes of this study, for consistency across the time period, thus:

bring England, Scotland, Wales, NI as United Kingdom

bring East and West Germany as Germany

bring all countries of former USSR together as 'former USSR'

bring countries for former Yugoslavia as 'former Yugoslavia'

bring Czechoslovakia and Czech and Slovak Republics as Czech/Slovak

The same search process, based on title words, as for the language study was used: the total number of records differs, because not all records have an identifiable geographical origin. The results were rounded to whole percentages to emphasise the 'overview' nature of this study: the percentages may add up to more than 100%, since some papers have authors from more than one country.

Table 4.22 Toxicology items from SciSearch ranked by geographical location for 1980, 1990 and 2000

1980	(total 3222)
USA	50%
United Kingdom	8%
Germany	6%
France	5%
Japan	4%
Canada	4%
India	4%
Former USSR	2%
Australia	2%
Sweden	2%
Italy	2%
Israel	1%
Belgium	1%
Netherlands	1%
Switzerland	1%
Denmark	1%
Finland	1%
Norway	1%
Poland	1%
Czech/Slovak	1%
South Africa	1%
countries contributing less than 1%:	Hungary, New Zealand, former Yugoslavia, Spain, Nigeria, Austria, Brazil, Egypt, Taiwan, Ireland, Argentina, Chile, Greece, Romania, French Polynesia, Iraq, Mexico, Turkey, Venezuela, Bulgaria, Kenya, Peoples' Republic of China, Portugal, Saudi Arabia, Sri Lanka, Costa Rica, Gambia, Ghana, Hong Kong, Iran, Jamaica, Morocco, Papua New Guinea, Paraguay, Senegal, Singapore, South Korea, Sudan, Tanzania, Thailand, Zimbabwe
1990	(total 2742)
USA	46%
United Kingdom	10%
Canada	5%
France	5%
Japan	5%
Germany	4%
India	4%
Former USSR	3%
Australia	2%
Italy	2%
Netherlands	2%
Spain	2%
Sweden	2%
Belgium	1%
Switzerland	1%
Denmark	1%
Peoples' Republic of China	1%

South Africa	1%
Brazil	1%
Israel	1%
Czech/Slovak	1%
Finland	1%
Norway	1%
Former Yugoslavia	1%
Countries with less than 1%:	Hungary, Ireland, Nigeria, Austria, Argentina, New Zealand, Egypt, Mexico, Saudi Arabia, Greece, Kuwait, Pakistan, Poland, Bulgaria, Chile, Ethiopia, Portugal, Sudan, Turkey, Indonesia, Iraq, Jamaica, Malaysia, South Korea, Taiwan, Tunisia, Colombia, Costa Rica, Ghana, Hong Kong, Iceland, Luxembourg, Morocco, Singapore, Sri Lanka, Thailand, Bangladesh, Bhutan, Cuba, Guatemala, Kenya, Mozambique, Nicaragua, Panama, Papua New Guinea, Peru, Philippines, Reunion, Trinidad and Tobago, Uganda, United Arab Emirates, Venezuela, Vietnam, West Indies Associated States, Zimbabwe

2000	(total 2891)
USA	40%
United Kingdom	10%
Japan	6%
Germany	6%
France	6%
Canada	5%
Italy	4%
India	4%
Spain	3%
Australia	3%
Netherlands	3%
Sweden	2%
Peoples' Republic of China	2%
Belgium	2%
Brazil	2%
Former USSR	1%
Switzerland	1%
Denmark	1%
Poland	1%
New Zealand	1%
Taiwan	1%
Argentina	1%
Israel	1%
South Korea	1%
Austria	1%
Portugal	1%
Czech/Slovak	1%

Finland	1%
Turkey	1%
Mexico	1%
Countries with less than 1%:	Chile, Greece, South Africa, Hungary, Ireland, Norway, Thailand, former Yugoslavia, Colombia, Egypt, Saudi Arabia, Nigeria, Morocco, Singapore, Costa Rica, Philippines, Tunisia, Bangladesh, Iran, Pakistan, Bulgaria, Cameroon, Cote Ivoire, Iraq, Jordan, Kuwait, Oman, Panama, Romania, United Arab Emirates, Uganda, Vietnam, Algeria, Cuba, Ecuador, French Polynesia, Guadeloupe, Hong Kong, Iceland, Lebanon, Luxembourg, Malawi, Malaysia, Mali, Nepal, New Caledonia, Peru, Senegal, Sri Lanka, Sudan, Syria, Uruguay, Venezuela, Zimbabwe

These results show that the toxicology literature has become more global in scope over 20 years. The predominance of the USA has declined slightly, while the distribution from other countries has widened, table 4.23.

Table 4.23 Distribution of countries over time

	1980	1990	2000
most dominant country (%)	50	46	40
countries with more than 1%	11	13	15
total number of countries	62	79	84

This increased globalisation involves both an increase in independent toxicology publishing from a wider range of countries, and also a greater extent of multinational joint publication. To gain an indication of the relative importance of this, the results for 1980 and 2000 were re-examined. Each publication with an author from a country contributing not more than 1% of the total publications was examined individually, to determine the proportion of multinationally authored papers. In 1980, the proportion of such papers was 15%; by 2000, it had increased to 50%. This suggests that multinational joint authorship is a significant means by which the international nature of toxicology publication is increasing, [see, for example, Haiqi 1996].

4.3.3 Summary for globalisation of toxicology

The findings of this aspect are clear. Toxicology publications, at least in ISI's high impact academic journal set (allowing for any limitations this may incur), appear to have become more globally spread, but less linguistically diverse, with the English language becoming ever more prominent. We may see some links here with ICTs. As information becomes more widely available through digital mechanisms, toxicological work is increasingly likely to be published in major international journals, which were hitherto the province of authors from a small number of countries. The influence of increased English language journal availability, as well as of the web, e-mail etc., will be to promote a greater use of English as a *lingua franca*.

4.4 Assessing impact of digital information in the toxicology literature

The purpose of this study was to assess the extent to which digital information has become significant in the formal literature of toxicology. More specifically, the interest was not in digital equivalents of printed products - electronic journals, computerised abstracting and indexing services, etc. - but in novel information entities - web pages, e-mail lists, web rings etc.

To assess this, a sample of toxicology literature was examined. Reference to new information items might be made in a number of places, particularly as entries in a cited references list, or as footnotes, or parenthesised items in the text; and its citation might be done in many ways. For these reasons, it was decided that no automated method would be reliable, and a set of printed journals would have to be examined cover-to-cover. This would also allow elements such as instructions to authors to be examined.

Four journals with a strong toxicology focus were chosen:

- *Toxicological Sciences* (formerly *Fundamental and Applied Toxicology*): a US journal, with a strong academic bias, and a coverage of all aspects of toxicology
- *Human and Experimental Toxicology*: a British journal, emphasising experimental toxicology studies
- *Archives of Toxicology*: a European journal, emphasising mechanistic aspects
- *Veterinary and Human Toxicology*: a US journal, with a 'practitioner' focus, emphasising clinical treatment of poisoning

It was thought that these four journals would give a good representation of the current journal literature.

All issues of each journal published in 2000 were scanned cover-to-cover. The following were recorded:

- total number of significant items - articles, reviews, summaries, commentaries
- number and % have any reference, in any form, to novel digital information formats

Then, for those articles having some reference to digital information:

- total number of references, and % of digital items

The results are shown in table 4.24.

Table 4.24 Reference to novel information formats in the toxicology literature in 2000

	All journal issues			Articles with digital refs		
	Items	Digital refs.	%	Refs.	Digital refs.	%
<i>Tox. Sciences</i>	297	13	4%	611	28	5%
<i>Hum. Exp. Toxicol.</i>	94	1	1%	38	2	5%
<i>Arch. Toxicol.</i>	111	1	1%	45	1	2%
<i>Vet. Hum. Toxicol.</i>	86	2	2%	39	3	8%

These results show the very limited penetration of novel information formats into the toxicology literature in the year 2000. Less than 5% of the articles in any journal had any reference to such a format; and even in those articles which did make such a reference, less than 10% of the references were of this form in all cases. The conclusion is that the overall penetration of these novel information entities is less than 1%.

All of the digital items found were web pages. [The only other 'contenders' were two Hazardous Substance Databank records, and a substance directory on CD-ROM, all from *Veterinary and Human Toxicology* - these were not included, as being digital counterparts of printed resources.] They were largely used to reference governmental agency material, particularly from the US sources such as the Environmental Protection Agency, National Institutes of Health, Food and Drug Administration and National Toxicology Program, and from the European Commission. Other references were to commercial data sources, and to statistics from groups such as the American Heart Association.

The great bulk of references were to 'traditional' information sources: largely journal articles, but also books, reports, conference proceedings, patents, theses, etc. Some of the reports, from government sources, would have been likely to be available on the web, but only the address of the issuing agency was given. Similarly, the 'methods' sections of many papers described equipment, laboratory supplies, methods, etc., identifying these by the name and postal address of the organisation, as required in the journal's 'instructions to authors'; it is likely that many of these organisations would have a web presence, but this form of reference was not used.

Personal communication was described as such, as a reference or an acknowledgement; it is likely that much of this might take the form of e-mail material, but this was not made clear. Similarly, 'data on file' or 'unpublished data' were a common form of reference, without any example of this being made available electronically.

The small extent of referencing of digital formats is perhaps surprising, in view of the apparent eagerness of the journals to embrace new technologies. *Toxicological Sciences*, for example, urges its readers to visit its website, and to utilise its online versions. Its authors must submit electronic forms of manuscripts, and must give an e-mail address for correspondence (though only one author added a personal web-page address). However, this enthusiasm for technology in producing and delivering the product does not appear to have yet affected the nature of the scientific record itself.

This is very much in accordance with the findings of researchers who have carried out extensive longitudinal studies of, largely American, scientists and technologists (Tenopir and King 2000, King and Tenopir 2001). While ICTs are used for many purposes, especially for informal communication, the traditional journal is still the overwhelmingly important medium for presentation of substantive information.

It is also noticeable that only two 'Internet journals' with toxicology content could be identified, compared with the many still current in printed (and, in some cases, also electronic) form, confirming the view that even peer-reviewed e-journals have had limited impact (Harter 1998). [These e-journals are included in the list of resources in section 3.5]

4.5 Communication of toxicology knowledge

In this section, three aspects of toxicology communication are examined: for how long it is used; by whom it is cited; what it cites. These issues give insight into the inter-relations between toxicology and other disciplines, and hence to influence of ICTs. Similar work for biochemistry is described by Bottle and Gong (1987), and for biochemistry and environmental biology by Kellard (1990).

4.5.1 How long it is used

The time period over which toxicology knowledge is regarded as useful can be assessed from the half lives of citations in specified journals, as listed in ISI's Journal Citation Reports.

The half-lives of the 63 periodicals categorised by ISI as 'toxicology' range from 'greater than 10' to 2 years, with a mean of 5.0 years, and with most of the major toxicology journals having half-lives between 4 and 6 years. The toxicology journals with the longest half-lives tend to be those dealing with clinical toxicology and with teratology, where observations and case reports are likely to have greater long term relevance than experimental and mechanistic studies.

In this respect, it can be compared to related sciences, and is seen to be generally very similar:

	Range	Mean
Biochemistry and molecular biology	>10 - 0.6	5.5
Pharmacology and pharmacy	>10 - 1.9	5.8
Pathology	>10 - 3.0	5.6

This suggests that the communication of toxicology information, in respect of its ageing, will be similar to that for other biomedical sciences, and that the influence of new ICTs will be correspondingly similar.

4.5.2 Citing of toxicology literature

This section of work aimed to indicate whether the toxicology literature is used mainly by toxicology itself, or by other disciplines, and whether this has changed over time.

The most straightforward, though 'broad brush', method of assessing this is by examining citations to specific journals. Four journals were chosen as exemplifying toxicology, for this purpose: *Toxicological Sciences* (formerly *Fundamental and Applied Toxicology*); *Human and Experimental Toxicology* (formerly *Human Toxicology*); *Archives of Toxicology*; and *Veterinary and Human Toxicology*. The rationale for the choice of these four journals is the same as in other sections.

Citations to these journals were identified, using the CW (cited work) field in the Science Citation Index on the Dialog system, allowing for journal name changes and variant forms of citation. Then the Dialog RANK command was used to rank the ISI subject codes for citing sources, and the sources themselves. This was repeated for citations in items published in 1985 (the earliest date this process could be used for the journals in these files) and in 2000. While this cannot be an exact measure, due to inconsistencies in citations, and changes in the ISI subject codes over time, it is adequate to show the general pattern.

The results are given in table 4.25, with the number of citations to the journal in that year which have subject codes or citing source respectively, the total number of different subject codes and citing sources, and the details of subject codes and citing sources amounting to more than 5% and 2% respectively of the total shown.

Table 4.25 Citations to four toxicology journals ranked by subject code for citing sources, and the sources themselves

Toxicological Sciences (formerly Fundamental and Applied Toxicology)

Subject codes of citing sources (as a % of the total)

	1985	2000
no. with codes	241	2109
no. subject codes	37	106
	Toxicology 40%	Toxicology 50%
	Pharmacy/Pharmacology 29%	Pharmacy/Pharmacology 20%
	Biochemistry/Mol Biol 10%	Environmental Sciences 14%
	Oncology 8%	Public, Env., Occ. Health 10%
	Environmental Sciences 8%	Biochemistry/Mol Biol 9%
	Neurosciences 7%	

Citing sources (as a % of the total)

	1985	2000
no. citations	244	2098
no. sources	107	562
	Fund Appl Tox 9%	Toxicol Sci 9%
	Tox Appl Pharmacol 8%	Tox Appl Pharmacol 5%
	Carcinogenesis 4%	Env Health Persp 4%
	Neurobehav Tox and Teratol 3%	Inhalation Toxicology 3%
	Biochem Pharmacol 3%	J Applied Toxicology 2%
	J Appl Toxicology 2%	Toxicology 2%
	J Pharm Exp Ther 2%	J Toxicol Environ Health 2%
	Mutation Research 2%	Toxicol Lett 2%
	Toxicol Lett 2%	Arch Toxicol 2%
	Teratology 2%	Toxicologic Pathology 2%

Human and Experimental Toxicology (formerly Human Toxicology)

Subject codes of citing sources (as a % of the total)

	1985	2000
no. with codes	153	962
no. subject codes	41	103
	Toxicology 28%	Toxicology 35%
	Medicine 18%	Pharmacology/Pharmacy 19%
	Pharmacology / Pharmacy 18%	Biochemistry/Mol Biol 10%
	Biochemistry / Mol Biol 8%	Environmental Sciences 9%
	Public Health 5%	

Citing sources (as a % of the total)

	1985	2000
no. citations	162	955
no. sources	101	468
	Human Toxicology 13%	Hum Exp Toxicol 4%
	Brit Med J 4%	Toxicol Sci 3%
	Teratology 3%	Env Health Persp 2%
	Toxicology 2%	Toxicol Lett 2%
	Biochem Pharmacol 2%	J Applied Toxicol 2%
		Arch Toxicol 2%
		Toxicology 2%

Archives of Toxicology

Subject codes of citing sources (as a % of the total)

	1985	2000
no. with codes	890	1875
no. subject codes	65	96
	Toxicology 32%	Toxicology 41%
	Pharmacy / Pharmacology 23%	Pharmacy / Pharmacology 21%
	Biochemistry / Mol Biol 12%	Biochemistry / Mol. Biology 13%
	Environmental Science 8%	Public, Enviro., Occup. Health 8%
	Public Health 6%	Neurosciences 5%
	Neurosciences 5%	Oncology 5%

Citing sources (as a % of the total)

	1985	2000
no. citations	933	1857
no. sources	325	603
	Arch Toxicol. 8%	Arch Toxicol 4%
	Tox Appl Pharmacol 5%	Tox Sciences 4%
	Mutation Res 4%	Tox Appl Pharmacol 4%
	Toxicol Letters 3%	Toxicology 2%
	Biochem Pharmacol 3%	Toxicol Lett 2%
	Carcinogenesis 2%	Env Health Persp 2%
	Fund Appl Toxicol 2%	J Tox Env Health 2%
	Chemico-Biol Interactions 2%	
	Neurotoxicity 2%	
	Env Health Persp 2%	
	Toxicology 2%	

Veterinary and Human Toxicology

Subject codes of citing sources (as a % of the total)

	1985	2000
no. with codes	118	547
no. subject codes	30	90
	Toxicology 34%	Toxicology 27%
	Veterinary Medicine 25%	Veterinary Science 25%
	Pharmacology / Pharmacy 16%	Pharmacology / Pharmacy 12%
	Medicine 10%	Environmental Sciences 9%
	Environmental Sciences 6%	Public, Environmental, Occupational Health 9%
	Paediatrics 6%	Biochemistry / Mol Biol 6%
	Genetics / Heredity 5%	Medicine 5%
		Analytical Chemistry 5%
		Emergency Medicine 5%

Citing sources (as a % of the total)

	1985	2000
no. citations	143	538
no. sources	87	311
	Veterinary and Human Tox. 10%	Veterinary and Human Tox. 8%
	Am J Veterinary Research 3%	J Toxicology - Clinical Tox 3%
	J Toxicology - Clin Tox 3%	J Emergency Medicine 2%
	Veterinary Medicine 3%	Env Health Persp. 2%
	Human Toxicology 3%	
	J Am Med Assoc 3%	
	Tox Appl Pharmacol 3%	
	Am J Emergency Med 2%	
	J Analytical Toxicology 2%	
	J Am Vet Med Assoc 2%	
	Toxicol Lett 2%	

The single most striking feature is the increase in the number of citations to these journals, ranging from a doubling for *Archives of Toxicology* to an increase of nearly 9-fold for *Toxicological Sciences*. When this is coupled with the high proportion of material cited by non-toxicology sources, it suggests an extended influence of toxicology outside its immediate disciplinary area. This in turn may be due partly to an increase in the availability and accessibility of the primary toxicology literature, and the secondary and tertiary sources which point to it, due to new ICTs. This factor has been noted for use of scientific journals in general (King and Tenopir 2001).

Having said that, the general profiles of citation appear largely unchanged over 15 years. Each of the four journals is cited more commonly by itself than by any other source, toxicology is still most commonly cited by other toxicology papers, whether assessed by source titles or by subject codes, and then by the medical, pharmacological and environmental sciences with which it is inter-related. *Archives of Toxicology* proves a slight exception here, as in 2000 it cites itself only slightly more than it is cited by *Toxicological Sciences* and *Toxicology and Applied Pharmacology*. The figure of exactly 4% for all three journals is the result of rounding. It is noteworthy that these are also toxicology journals

4.5.3 Citing by toxicology literature

This section aims to address the question whether toxicology is still a 'borrowing science', and if so from whom does it borrow. This is equivalent to asking, for the formal literature, what is cited by toxicology publications.

The only feasible way to assess what sort of material is cited by toxicologists is to inspect the original toxicology articles. No automated method available for this study can give a clear picture. Use of 'cited reference' features in ISI Journal Reports can show which sources are cited most by specified journals, but this gives only an indirect indication of the nature of the material being cited overall.

The four journals used in other sections were taken as exemplars of the toxicology literature, and all issues for 1985 and 1990 were examined. A random sample of references from the papers in these issues was taken. Totals were chosen to roughly match the numbers of papers, and the typical number of references, in each, so that, for each of the two years, the following numbers of references were selected:

- Toxicological Sciences / Fundamental and Applied Toxicology (TS) 500
- Experimental and Human Toxicology / Human Toxicology (HET) 200
- Archives of Toxicology (AT) 200
- Veterinary and Human Toxicology (VHT) 200

Each reference was assigned, on the basis of its title and source, to one of six categories:

- toxicology (including clinical toxicology)
- medicine (including veterinary medicine and environmental health) and pathology
- pharmacology, pharmacy, and metabolism (including analytical techniques)
- biomedical sciences (physiology, biochemistry, molecular biology, genetics)
- regulations and legislation
- other (including statistics, animal husbandry, instrumentation, and industrial processes)

Though broad, this categorisation is adequate for assessing broad trends. The results are shown in table 4.26 below, as percentages.

Table 4.26 Categories of references found in four toxicology journals

Category	1985				2000			
	TS	HET	AT	VHT	TS	HET	AT	VHT
TOX	25.5	29	27.5	32	25.2	27	17	28
MED	24	26	17.5	35	16	19.5	11.5	21
PHARM	25	31.5	25	18	16.4	13	13.5	33
BIOMED	20	12	25	10	40.2	32.5	55	15
REG	2	1	1.5	3	1	6	2.5	2
OTHER	3.5	0.5	3.5	2	1.2	2	0.5	1

The results are remarkably consistent across the journals. The 'toxicology' component stays roughly the same, 'medicine' and 'pharmacology' (except for VHT) decrease, and 'biomedicine' increases markedly. The two other categories are too small to be significant.

Toxicology appears to remain a borrowing science, with less than one third of its citations, in all cases, coming from its own literature. The nature of the borrowing, however, does seem to have changed, with the influence of basic biological sciences increasing, at the expense of the traditional bases of toxicology, medicine/pathology and pharmacology. This is another reflection of the increased importance of mechanistic studies, as opposed to observation of gross effects. In terms of ICTs, it suggests that toxicology has successfully accessed a new range of literature as input into its workings.

4.5.4 Summary for communication of toxicology knowledge

Toxicology is shown here as very much an interdisciplinary subject: still a 'borrowing science', largely citing from outside itself, though now from largely basic molecular sciences rather than medical subjects. Although it is still largely cited by itself, the proportion of citations by other disciplines has increased markedly. Both these factors are likely to have been enhanced by the ease of access to the literature provided by digital formats.

With a citation half-life for its major journals typical of similar life sciences, toxicology might, in this respect, seem likely to make similar use of ICTs as those sciences.

4.6 Conclusions

As suggested in chapter three, the formal, primary literature of toxicology has grown dramatically over the last 20 years, due largely to an increase in the number of sources. The volume of formal (printed or electronic) journal material, and of web-based material, is equivalent in rough terms.

The growth of all formal printed material is seen to have slowed towards the end of the 1990s, coincident with the expansion of the web. This leads to two possibilities:

- information is now being placed on the web instead of in the traditional resources
- the traditional system is now saturated, and the information being placed on the web is of a new kind

The evidence from the nature of the web material, and the penetration of cited novel resources into the traditional literature, suggests that the second is correct: that new ICTs are facilitating access to new forms of information, rather than duplicating that in traditional resources.

Aside from this, the influence of ICTs is seen to be facilitating access to material: extending the geographical reach of toxicology research, while reducing its language variability; and increasing both the extent to which toxicology material is cited by other disciplines, and the range of material cited by toxicology.

These studies also show changes in the nature of the science. Changes in the nature both of title words and of the material cited by toxicology papers show the science to have a much more mechanistic basis, while the core journal lists show the extent to which toxicology has matured as a science with its own literature base.

These results suggest that new ICTs give easier access to formal literature, but have not really affected its nature. Instead they have given rise to an entirely new range of accessible information.

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Chapter Five: Evaluation of toxicology information systems and services

5.1 Introduction

This chapter describes previous published work (including Internet sites) on the evaluation of toxicology information resources. 'Evaluation' is treated broadly, and includes selective and annotated listings, and recommendations for use of sources, as well as experimental evaluations.

The aim is to be comprehensive in including evaluations centred on toxicology; it also includes some publications dealing with related areas, e.g. pharmacy, when appropriate. The emphasis is on resource evaluation; user studies are not included.

Emphasis is on methods, techniques and principles rather than findings; hence older material is included, since methods are still valid. Indeed, much of the most useful material dates from a period of particular interest in the topic in the late 70s and early 80s.

The chapter is divided in four sections, roughly equating to an increase in complexity of evaluation procedure:

- annotated listings
- qualitative comparisons
- quantitative comparisons
- mixed quantitative / qualitative evaluations

The conclusions are used in the subsequent database evaluations carried out for this study.

5.2 Annotated listings

Lists of toxicology resources, or guides to the literature are introduced in chapter three, with the purpose of examining the nature of such guides. In this chapter, the idea is to look at examples of such lists in the context of resource evaluation. The simplest, and most common, form of evaluation of toxicology information resources is the selective, usually annotated, resource list. In some cases, the presence of a resource in the list alone implies some level of recommendation. The list presented in section 3.5 of this thesis falls into this category. In other cases evaluation is presented as a brief, qualitative comment on each resource. Some examples are discussed below.

An early offering, is that of Gerstner, Huff and Ulrikson (1975), who present a selective list of computerised and printed sources for drug toxicology, emphasising the uniqueness of some resources available at the Toxicology Information Response Centre, though without detailed annotation or comparison.

Kremin (1979) presents an evaluation of a small number of printed reference tools, with comments such as '...particularly useful for searches dealing with toxicology of industrial products' and '...although appearing difficult to use, both chemists and non-chemist analysts can quickly locate chemical names and toxicity information'.

Decker (1990) gives a summary of printed, computerised and organisational resources providing toxicological information relevant to emergency response to chemical hazard incidents, while Stirling (2000) presents a summary and description of online and printed literature and data sources for toxicology and risk assessment of chemicals.

A more comprehensive listing is that of Hargreaves (1980) who covers 'information sources for toxicology as it relates to man in his environment'. Her survey is divided by form of source:

- computer databases [bibliographic]
- computer databanks [factual / numeric]
- manual sources [printed, card and microform]
- institutions and research centres
- national and international toxicology information programmes

Information is provided on coverage, file size, indexing policies and searching hints.

The most comprehensive toxicology resource listing to date, Wexler (2000), has already been described in chapter three. This work comprises listings arranged by both format and location, some of which are accompanied by factual, descriptive annotation.

At the other extreme from this comprehensive collection of toxicology resources, Morton and Goldbolt (1992), as part of a wider overview text, present a small number of examples of printed and computerised resources for toxicology with brief description; their selection implying an evaluation as to significance.

Marra et al. (1996), discuss Internet sites providing toxicology information. A number of such sites are evaluated, and concerns raised about the quality of the information provided. Similar listings are given by Glander-Hobel (2001), who discusses the reliability of data found, and by Wukovitz (2001), who outlines issues of search strategy and data evaluation in locating toxicology information in search engines, directories, subject-oriented websites, and Internet-accessible library catalogues.

As shown in chapter three, many toxicology resource lists can be found on the Internet. These tertiary entities usually point to other Internet sites, but sometimes other forms of information are included. The format is usually a simple list, with or without categorisation or annotation. Many examples are included in section 3.5. Often, no selection criteria are given, other than the indication that resources on the list are found to be of use to the author or authors. Other problems stem from the fact that Internet sites may change their addresses, or disappear without warning, and that the lists convey little contextual information to the user.

5.3 Qualitative comparisons

Beyond the annotated list, with resources viewed essentially independently, is a qualitative comparative evaluation. This has often been combined with some form of advice to readers as to best practice in searching, and there have been a number of such evaluations for various aspects of chemical toxicology.

Bridges (1981) describes and recommends a selection of bibliographic databases and numeric databanks for toxicology and environmental health searching, and suggests search strategies. Bawden and Jackson (1978) review and compare databases and search techniques for the retrieval of chemical toxicology information from online databases. Kruse (1983) gives a similar analysis for the retrieval of pharmaceutical information, including toxicological aspects, and including discussion of indexing policies and sample search strategies. Bawden (1979) describes major bibliographic databases, giving recommendations, 'dos and don'ts' for searching, and suggestions for best combinations of sources (including numeric databanks, printed handbooks and older printed material), and Bawden (1988) describes and compares various implementations of three chemical toxicology databanks: the Registry of Toxic Effects of Chemical Substances, component files of the NIH Chemical Information System, and the Hazardous Substances Databank. Snow (1990) gives a selection of databases and recommended search strategies for the retrieval of information on toxicity testing without the use of animals. Halton (1986) categorises and exemplifies toxicology and environmental health databases, reviewing origins, style and content. Wassom (1985) discussed the kind of information needed for quantitative structure-toxicity studies, emphasising the importance of specialised information centres, such as the Environmental Mutagen Information Centre, and the equivalent centres for teratogens and carcinogens, and numeric databases containing evaluated (specifically peer-reviewed) information.

Huleatt (1978) provides a standard search strategy to make best use of the computerised databases of the National Library of Medicine - Chemline, RTECS, Toxicology Data Bank, Toxline, Cancerlit, and Cancerproj - for carrying out product literature safety searches. Karnovsky et. al. (1980) provide a similar 'framework' for searching and retrieving information on chemical toxicology and related topics, based on several selected chemical information resources. Johnson and Radar (1978) provide advice on search strategy in a variety of source, from basic reference

texts and printed journals to online databases, in retrieving information on the safety of cosmetic ingredients and products.

Stafford and Logan (1990) present a comparison of information resources for the specialised field of forensic toxicology. They emphasise a three stage process of finding relevant information - first by personal contact with an expert, second by literature search, and third by experiment observation - and give an extensive list of potential useful resources, though without any annotation or comparison.

Bresnitz, Rest and Miller (1985) present an algorithm outlining a logical approach to information retrieval for diverse sources in toxicology, including online databases, printed resources, poison control centres and government agencies. Cohen (1988) gives a similar 'stepwise approach' to selection and use of various resources for information on occupational dermatology. Although nothing similar has been suggested for the Internet for toxicology information, Akaho and Tinianow (1996) suggest a general approach to Internet searching, combining directories, search engines etc., based on experience with a search for apoptosis, programmed cell death.

Singh (1979) presents an essentially qualitative comparison of Chemical Abstracts and Biological Abstracts in their coverage of biochemistry, with toxicology considered as a related subject. His comparison refers to factors such as coverage, nature of indexing, length and content of abstract, and country coverage.

Evangelisti et al. (1994) gives a qualitative analysis of the usefulness of factual health and safety databanks, considering four such sources:

- Hazardous Substances Data Bank (HSDB)
- Environmental Chemicals Data Information Network (ECDIN)
- Registry of Toxic Effects of Chemical Substances (RTECS)
- Chemical Carcinogenesis Research information (CCRIS)

The quality of the information available was examined for five different compounds, and completeness of information was tested by an analysis of carcinogenicity and mutagenicity data.

A similar study is reported by Running (1996), who gives a qualitative comparison of two CD-ROM databases containing chemical occupational safety information - CCIS

and CCINFOdisc - by examining the information provided by both on each of three substances, and noting the nature, completeness and organisation of information provided.

Although such qualitative evaluations are of undoubted value to practitioners, particularly if produced by an experienced and authoritative author, they are subject to severe limitations of subjectivity, partiality and incompleteness. To remedy this requires an experimental approach, based on analysis of test queries; and these must be, at least partially, quantitative in nature.

5.4 Quantitative comparisons

The two forms of evaluation noted above are qualitative in nature, and do not involve any specific experiment or test of retrieval performance, although they may well be based on the compilers' experience in practical searching. Other approaches to the comparative evaluation of toxicology information resources have involved experimental work, with largely quantitative analysis.

In an early example of a 'single issue' quantitative study, Montgomery (1973) compared coverage of chemical toxicology material by a variety of secondary - abstracting and indexing - services. Six major sources were included: Chemical Abstracts, Biological Abstracts, Index Medicus, Excerpta Medica, Science Citation Index, and CBAC (Chemical-Biological Activities).

The method used by Montgomery was a modification of those of Orr and Crouse (1962) and of Garvey and Griffith (1969). First, the membership of a relevant professional organisation, the Society of Toxicology, was contacted by post, with a request for a complete list of publications; 41% of the membership, 221 scientists, responded. These were then screened by Montgomery, to produce a set of papers of clear toxicological relevance, likely to be covered by secondary services (i.e. excluding, for example, papers presented at most meetings and classified documents), and falling within the 10 year period of the study, 1960 to 1969. The resulting list of 1873 references was searched in the author index of each of the six sources. The results were quoted in terms of % coverage by each source, overlap, and delay in inclusion in the secondary source. Chemical Abstracts was found to be the best single source, covering over two-thirds of the sample, while a combination of four services (Chemical Abstracts, Biological Abstracts, Index Medicus and Science Citation Index) covered 98% of the sample. Montgomery notes, comparing her sample with that in the *Toxicology Bibliography* for 1968-69, that her sample is probably about 1% of the total toxicology literature, defined broadly. Her sampling procedure led to the emphasising of English-language and US-origin material, and research testing rather than clinical case reports [which may well account for the relatively poor performance of Excerpta Medica, which might be expected to be strong on European and clinical material].

Although not strictly a measure of quality, the extent of use of various information services may be a useful surrogate: an example, including information sources on side

effects of drugs, is given by Joy, Arana and Gallo (1986). These authors reviewed 1448 requests made to a hospital drug information service, and the 10 most frequently used sources, including Martindale and Meyler's Side Effects of Drugs, were identified.

Currency of material in secondary sources is another issue which has often been examined by quantitative comparisons: although no purely toxicological example is known, a related study examined the rapidity with which material from the primary literature was entered onto various online and CD-ROM implementations of the Medline database (Grainger and Lyon 1992).

Datta (1988) carried out a quantitative analysis on the coverage of the literature of mycotoxins in eight online databases: Biological Abstracts, CAB Abstracts, Medline, Chemical Abstracts, PASCAL, Science Citation Index, Agricola and Agris. Working with a total of 4554 relevant references, determined by an initial subject search, Datta determined coverage of each database, overlap and currency, finding that no database covered more than 20% of the total.

Ludl, Schope and Mangelsdorf (1996) describe a quantitative study of the retrieval of toxicological information from a total of 18 bibliographic databases. Searches for three chemicals, camphor, dimethyl sulphate and dinoseb were carried out, and each document retrieved noted as being of toxicological relevance, or otherwise, in order to assess the relative value of each database for toxicology searching. It was found that most of the relevant documents could be found using a combination of 8 databases: Biosis Previews, Chemical Abstracts, Chemical Safety Newsbase, Excerpta Medica, NIOSH, Scisearch, TOXLINE and TOXLIT. This was a relatively simple evaluation, not involving any form of failure analysis or other qualitative assessment; it is, perhaps, noteworthy that these authors do not cite any of the earlier evaluations. However, there is less scope for error in a specific substance search, than with other forms of search, so that the results are probably reasonable as a simple test of coverage.

Guerbet and Guyodo (2002) examined 35 data compilations, accessed on CD-ROM or via the Internet, for the presence of data on 14 test chemicals. Quality of results was assessed by the extent of information present, from a list of 27 data elements present in any of the sources.

Biarez et al. (1991), in a similar study, compared eight online systems, and one CD-ROM source: Medline, Biosis, TOXLINE, Iowa Drug Information System, PASCAL, Excerpta Medica, Pharmline, International Pharmaceutical Abstracts and core

Medline (CD-ROM). The aim was to compare their coverage of adverse drug interactions. Ten drugs were chosen randomly from a drug information centre's files, and searched in each of the databases, identifying recall and precision in each case. Overlap between databases was identified for one of the drugs.

Schirner and Lorent (1978), used a test query approach to compare retrieval from the Medline and TOXLINE bibliographic databases, using 16 test queries, taken from four sub-fields of toxicology:

adverse drug reactions

- liver damage caused by oral contraceptives
- correlation between Rauwolfia and breast cancer
- glafenine induced nephropathies
- gastrointestinal haemorrhages in children following aspirin administration

poisoning

- therapeutic use of physostigmine in poisoning
- management of paraquat poisoning
- all aspects of amanita poisoning
- haemoperfusion in the treatment of poisoning

environmental toxicology

- SO₂ pollution in urban air
- pollution due to fluorides
- analysis of pesticides in mothers' milk
- acceptable daily intake of pesticides

experimental toxicology

- mutagenicity tests using salmonella typhimurium
- animal experiments in antidote research
- carcinogenicity of cyclamates
- teratogenicity of diphenylhydantoin

Search strategies were designed to be as thorough as possible, using a combination of free-text, thesaurus terms and classification codes appropriate to each database; in all about 1200 relevant references were retrieved and analysed. Relevance was judged from the online record, i.e. title, abstract and keywords. Results were quoted with a detailed breakdown of recall and precision figures, including the contributions

from each TOXLINE sub-file, and overlap between files. The main conclusion was the limited overlap between files, 50% at most, indicating that both needed to be used for comprehensive recall. Only for the experimental toxicology queries was it possible to show that one source, in that case TOXLINE, had a clear advantage over the other. However, as Schirner and Lorent noted, this purely quantitative approach has shortcomings, even in giving a 'simple' comparison of two equivalent resources.

Cotton and Livesey (1980) carried out a similar quantitative comparison of two specifically toxicological sources, the TOXLINE bibliographic database and the RTECS numeric databank. A systematic random sample of 60 chemicals was chosen from the Toxicology Data Bank, a computerised list of chemicals with known toxic potential; for each of these substances a profile of search terms was produced, and searches carried out in the two sources. Where the substance was identified, an evaluation of the toxicity data provided was made, by noting when information on species affected, route of administration and numeric value of toxicity measurement was present. The results indicated, perhaps not surprisingly, that the numeric databank was considerably superior to the bibliographic database in providing immediate access to factual data, that search strategies needed to be more complex in the bibliographic file, while there was a considerable overlap (about 66%) in presence of some information about individual substances in the two files.

A novel form of comparative evaluation of information resources, pioneered within the chemical toxicology area, has been the collaborative, multi-participant evaluation, based on test queries. This has the advantage of bringing varied expertise to bear, hopefully ensuring that resources are being used to their full effect, and also allowing a wide range of resources to be investigated, including in-house databases. These studies are experimental in nature, and may involve either purely quantitative evaluation, or a mix of quantitative and qualitative.

The first study of this sort, a quantitative analysis, was reported by Bac (1980). This compared the relative performance of online bibliographic resources in retrieving toxicology information, at a time when this kind of resource was in the process of being widely adopted within industrial information departments. The study was carried out under the auspices of the Toxicity Data Committee of the Pharma Documentation Ring (PDR), a collaboration between the library/information departments of 11 research-based pharmaceutical companies, largely from Continental Europe.

The methodology used was based around a small number of test queries, each searched independently by a number of the participants. Four queries were chosen:

- toxicity of ponceau colorants
- corticosteroid induced glaucoma
- toxicology and side-effects of intra-articular administered corticosteroids
- carcinogenic, mutagenic or teratogenic studies on beta-blockers

Each search was carried out by between 7 and 11 participants, using their preferred search strategy on one or more of the following six online databases: Medline; Embase; Toxline; Biosis; Chemical Abstracts; Derwent Ringdoc. The results were combined in a simple way, simply noting a particular reference judged as relevant was found by at least one participant in a given database. From this, a matrix was constructed, noting for each database the number of references found uniquely in that database, in each pair, and so on. The total number of references from each database was typically between 100 and 200: total relevant references for the four searches were 128, 562, 300, and 42 respectively.

The general conclusions, noted by Bac as fairly consistent across all four queries, are that about 65% of all references were found in only one database, and 22% in two. At best, search of a single database yielded 60% of the total, so that for comprehensive recall, generally important for toxicology, search of several complementary databases was necessary.

One further analysis was carried out, checking whether references not found in the Ringdoc database, but retrieved from others, were in fact present in Ringdoc. It was found that between about 10% and 25% of the total relevant references were present, but not found from that database, which led Bac to suggest significant errors in indexing in Ringdoc.

Bac notes two particular difficulties with this study. Since some of the companies were only just beginning to use online systems, the levels of expertise of the searchers were different, and (one suspects) rather low in some cases, possibly invalidating some results. Even when the same database was used, albeit with different search strategies, the results were not directly comparable, since the searches were carried out over a long period of time, during which the database composition would have changed. He recommended that future studies be carried out in a way that would enable better quantitative comparison between results from different participants.

Despite the evident novelty and value of this approach, this study was criticised on a number of grounds, Smith (1981), for example, querying the validity of the results, and describing them as 'amazing'. Her main criticism were of poor search strategies, involvement of inexperienced searchers, and limited analysis of the results.

Purely, or primarily, quantitative studies, though they may provide useful information, have been found to yield insufficient understanding to be fully effective as an evaluation method. Although effective in comparing different resources of the same kind, e.g. a number of online bibliographic databases, or in comparing limited aspects of resources of different nature, e.g. coverage of particular substances, or inclusion of specific data elements, they are difficult to apply in general to the use of resources of different type. Precision of searching, for example, is notoriously difficult to compare for printed and computerised sources (Meschel 1984). Nor are purely quantitative measures readily applicable to the assessment of factors such as 'ease of use' or 'quality of information'. They need to be supplemented by qualitative analysis, in a mixed mode of study.

5.5 Mixed quantitative/ qualitative evaluations

A early example of a 'mixed' study is that carried out by Yokell, Sigell and Nelson (1978) on the resources for poisons information required by medical personnel. Four sources were included: Poisindex, ToxiFile, Clinical Toxicology of Commercial Products and National Clearinghouse for Poison Control Centers' cards.

The evaluation was centred on substances known to be involved in accidental poisoning in children, and included the coverage of the sources, the time taken to find information and the extent and nature of the information provided.

The collaborative evaluation concept, pioneered by the PDR (Bac 1980), was taken further by the Toxicology Information Working Party of the Association of Information Officers in the Pharmaceutical Industry (AIOPI), a predominantly British organisation (Bawden 1980). These studies (Bawden and Brock 1982, Bawden and Brock 1985) set out to refine the PDR approach by including a mix of qualitative and quantitative measures, and in particular including extensive post-search analysis. In particular a failure analysis was carried out to ascertain why items were not retrieved from each source, and thereby to minimise problems of searchers' failure to use a source to best effect. An 'umpire' for each test query consolidated and analysed the results, and made a decision in cases of doubt of the relevance of an item. 14 varied organisations from 3 countries took part, and this varied group ensured availability of, and expertise with, a wide variety of resources. These included online bibliographic databases and numeric databanks, printed indexes, printed handbooks and textbooks, and in-house files, both computerised and paper-based. In this case, all those involved as searchers had considerable experience searching in this subject area.

Eight test queries were used, chosen both so as cover a wide area of chemical toxicology (excluding side-effects of drugs) and to be likely to yield a sufficiently small number of answers as to allow detailed checking and analysis of results. They were:

- all toxicity of sodium bismuthate
- carcinogenicity and mutagenicity of quinoline compounds, excluding quinoline N-oxides
- long-term experimental carcinogenicity studies in animals with vinyl chloride monomer

- teratogenicity, or any other effect on the reproductive system, in humans occupationally exposed to methyl benzenes
- toxicity of popoxur [a pesticide] to fish
- hindlimb abnormalities in mammals, caused by teratogenic chemicals, excluding thalidomide
- mammalian toxicity of orally administered cinnamic acids, salts or alkyl esters
- all toxicity of nitrofen

The results were assessed as the number of relevant items retrieved, with qualitative comment on the usefulness of the information, the precision of searching, and other similar factors. Detailed findings for each query, and the issues raised, are discussed by the study leaders (Bawden and Brock 1982). In general, the findings included:

- the need to use a variety of sources for comprehensive retrieval
- the continuing need for printed resources [probably still relevant in 1997]
- the value of numeric databanks with chemical substructure searching facilities
- the value of various bibliographic databanks for different types of query
- some major failings of indexing in secondary sources
- deficiencies in reporting toxicity data in the primary literature

This type of analysis, with unrestricted inclusion of sources of diverse type and extensive failure analysis, seems to yield particularly rich information, and also allows for a degree of 'action research', in that the feedback allowed participants to immediately improve their searching skills (Bawden and Brock 1982). The main drawback was the time-consuming nature of the evaluation. This general approach has been used for comparison of resources in other subject areas (see e.g. Barber et al. (1988)).

A similar form of study, though not collaborative, was carried out by Cassidy and Kostrewski (1986) to evaluate information sources relevant to poisoning by household chemical products. This study was carried out in a specific context, that of a British hospital's Poisons Information Unit, using the resources readily available to that unit, and analysing a series 30 'real' queries received within it. The mixed set of resources comprised: two online bibliographic databases, one factual databank on microfiche, six printed reference sources and two in-house databases, one computerised, one on index cards. The 30 queries were chosen from those received over a 2 day period, which were felt to be typical of those received by the unit generally.

The searches were carried out to best effect in each source, though the authors note that the experimenter had minimal prior online experience, and no prior experience with any of the printed sources or in-house databases. The possible effect of this on the searches was not discussed further. For each query and each source, the information obtained was expressed in terms of its completeness:

- completely answers the query
- partly answers the query
- no useful information

Time taken was also noted, this being a crucial factor in the operational setting of a Poisons Unit.

General conclusions were that the in-house databases were superior to all other sources. Some limited qualitative reasons for the performance of specific sources were drawn, e.g. stated coverage and indexing policies of some printed sources. Some analysis of the comparative performance of the online sources, for which the authors noted that the poor performance of TOXLINE was 'surprising', was attempted, but no failure analysis was carried out. Qualitative remarks on such factors as the value of the browsing possible in printed texts were included, and recommendations for information sources most appropriate to Poisons Units were made.

This study was based, to a large extent, on the methods of an earlier study (Miles 1981), which examined a single source - the printed Martindale data compilation - for a series of 60 drug information queries, assessing the results on the completeness of information found. While Martindale was found to be superior to equivalent sources for toxicology queries, it was noted that specialised online sources would sometimes be needed as a complement.

King (1983) reports an evaluation of seven online databases with relevance to toxicology: Toxline, Medline, Cancerlit, Excerpta Medica, Biological Abstracts, Chemical Abstracts, International Pharmaceutical Abstracts and two printed card sources, CIS Abstracts and Iowa Drug information Service.

Test query evaluation examined recall and precision, overlap and currency, with a detailed analysis of retrieval failures. Supplementary studies included qualitative comparison on indexing policies. The results include the demonstration that unique

information is present in each file, that a combination must be searched for good recall, and that sub-disciplines within toxicology are well served by particular files.

An adaptation of the mixed qualitative/quantitative analysis based on test queries was used to compare different implementations of a single toxicology information resource, rather than different resources. This study evaluated three implementations of the RTECS (Registry of Toxic Effects of Chemical Substances) numeric databank: printed, computerised text search, and computerised substructure searchable (Costigan, Wood and Bawden 1985). Seven test queries were used:

- all toxicity studies of butyl adipate
- reviews of the toxicity of compound BAY9002
- any agricultural chemicals which are natural products and which have been determined to be carcinogenic
- quinoxaline derivatives reported as carcinogenic in the rat or the guinea pig
- relation between the functionality -N=N(=O)- with carcinogenicity
- aromatic amines for which Ames tests are negative, even for known carcinogens
- correlations between carcinogenicity and chain length in alkyl carbamates, with or without N-substitution

Each search was carried out separately in each databank implementation.

Searching was not necessarily exhaustive, the search being terminated when the query had been answered satisfactorily. Recall for the different implementations was assessed as a proportion of material found by any means. Precision factors were assessed qualitatively in terms of ease of identifying required material. This study showed marked differences in the searching performance of the implementations, especially in the value of chemical substructure searching, even for browsing. It also pointed up deficiencies in the consistency and detail of indexing, and the problem of the omission of 'negative' results.

This mixed, and multi-facted style of evaluation seems to be best fitted for detailed comparison of sources 'in the round', especially of the sources of different type.

5.6 Conclusions

The work cited above shows that a variety of techniques can contribute some understanding to the effectiveness of information resources. However, we can make some general conclusions:

- When a comparative evaluation is to be carried out, a mixed qualitative/quantitative analysis, with a failure analysis, is the method of choice for obtaining the most useful and reliable information; even allowing for the time consuming nature of this type of evaluation.
- Purely qualitative or purely quantitative analyses, though they may yield useful and specific information, are too limited to serve for a full comparative evaluation.
- Presentation of 'recommended' resources (e.g. printed resource guide or Internet gateway), however the background information may be gathered, is best presented in a qualitative manner, with careful categorisation and linking of resources.
- Evaluations, and construction of guides, must be carried out, or at least validated, by both subject specialists and information specialists, in order to carry conviction.

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Chapter Six: Comparative Evaluation of the Performance of Online Databases in Answering Toxicology Queries

6.1 Introduction

Toxicology has a diverse set of information resources. Among these are the secondary bibliographic abstracting and indexing services implemented as online databases: examples are CAsSearch (Chemical Abstracts), Biosis (Biological Abstracts), Medline (Index Medicus) and Embase (Excerpta Medica). These are characterised by a wide coverage of material within their subject area, by detailed indexing, and by provision of several access points for retrieval, including controlled indexing and classification, uncontrolled keyword indexing, and free-text searching of title and abstract. Given that they are general discipline-oriented resources, catering for a wide variety of user interests, they cannot be adapted specifically for the needs of the toxicologist. The ability to access a wide variety of such resources within the common interface of a host system such as Dialog is, however, a particular benefit for toxicology searching, where information from a variety of sources and a variety of perspectives may be needed.

Also among the resources available for toxicology searching are specialised databases, created and operated by research or commercial organisations, and generally referred to as 'in-house' databases. Being toxicology-oriented, these resources can employ specific criteria for coverage, and specific indexing languages and policies, to meet the needs of the toxicologist.

A comparative evaluation of the strengths and weaknesses of these two kinds of resources will be valuable in two respects, as part of a general study of the communication of toxicology information. First, it may indicate the current value of these two types of resource, and suggest any changes in the future. Second, it can cast more general light on such factors as coverage, indexing, and retrieval features in any resource.

The general research questions which this chapter is intended to address are therefore:

- how good are commercial online bibliographic databases at answering toxicology queries ?
- are there any particular problems and weaknesses with them ?
- how do they compare in performance with a specialised in-house database ?
- what is the future for these two kinds of source ?

More specifically, 6 hypotheses are to be tested:

1. That an in-house database, created specifically to deal with toxicology information, would be superior in performance to any commercial database, and usually to a combination of databases, over a range of queries
2. That, despite (1), commercial databases provide a useful complement to an in-house database over a range of queries
3. That a range of commercial databases is always needed to give adequate recall for any toxicology query
4. That searching for toxicology in commercial online databases always requires a relatively complex search strategy to achieve good recall
5. That there are still problems in attaining good recall and precision in commercial databases, associated with the definition of particular toxicology concepts, and with consistency and depth and indexing
6. That the problems noted in (5) may be overcome by the kind of indexing adopted in a specialised in-house toxicology database

This investigation evaluates two things. Firstly, the performance of commercial databases, which are important resources for toxicology information. Secondly, the performance of a specialised, in-house database, because this may perform particularly well as a result of its coverage and indexing. Both of these factors can reflect the specialised purpose of the database, i.e. that it is tailored in a way that is not possible in a general database.

If superior performance is offered by specialised databases, then making such files more widely available could improve the provision of toxicology information. Additionally, lessons could be learned from them, and applied to improve the performance of more general, commercial databases.

6.2 The TRACE database

This specialised database is maintained by the Information and Advisory Service of TNO BIBRA International, a contract research and consultancy organisation, specialising in toxicology. Its role is to support the consultancy activities of BIBRA in industrial, environmental and food and agricultural toxicology.

At the end of 1997, the database contained approximately 100,000 records, from over 3,000 publications, largely dating from 1987, but with the selective addition of older material. The database is updated daily by input from BIBRA staff, largely from the scanning of approximately 100 journals, other secondary sources and 'grey literature'. About 200 records per week are added.

Database records, comprise a brief bibliographic reference, with a reference to the BIBRA location in which the original document is held. Indexing is by chemical substance – Chemical Abstracts Registry Number for specific compounds, and other chemical identifiers (file codes) for types of substance – and a series of codes for toxicological concepts, e.g. acute exposure, study in humans, ecotoxicity. Free text searching of titles is also possible. Emphasis is placed on careful selection of material and on focused indexing. Records are prepared by toxicology specialists, who also perform searches of the database.

In-house databases of biomedical literature are relatively common, since they are maintained by many large science-based organisations, in both commercial and public sectors, most notably by pharmaceutical companies. Although a large proportion of such databases will contain some information on toxic effects of substances, only a small number are largely or wholly devoted to this aspect. These are limited to organisations for whom a *raison d'être* is toxicology in some form. Examples are given by Engler (1980), Bawden and Brock (1982) and Datta (1988).

The TRACE database was used in these analyses, since (1) it is a good example of such a source, and (2) its operators were willing to make it available, and to provide advice on aspects of its performance compared with public online services.

6.3 Methods; general outline

The work reported in this chapter is, in essence, a detailed, comparative evaluation of retrieval from a set of databases. The approach adopted was the mixed quantitative / qualitative approach, since this is capable of producing the richest, and most meaningful, results, as discussed in chapter 5.

The specific method chosen was that of test queries with detailed failure analysis. This enabled direct comparisons to be made with other studies of toxicology resources carried out 20 years previously (Bawden and Brock 1982,1985). The current study, and the way of reporting its results, parallels that reported by Bawden and Brock (1982,1985), so that the extent of change over time can be directly assessed. Some differences between the two studies include:

- the previous study was a multi-participant collaboration, with a different evaluator for each query; this meant that the results of each query could be, and were, expressed differently, with no chance of direct comparison. The present study analyses each query in exactly the same way, allowing comparison, consolidation and summarisation of results
- the current study is able to apply quantitative analysis across queries, consolidating and summarising results; the previous study used largely qualitative summarisations of individual queries, some of which were analysed quantitatively
- the present study focuses closely on the direct comparison of one in-house database with a combination of online databases; previously there was a more general comparison across all types of resources. This again allows for more direct comparison and consolidation of the results of the present study
- the previous study involved some participants who had only just begun to use online systems, and had a strongly educative focus; the present study involved only those with considerable experience in searching
- whereas the present study is restricted to online bibliographic databases, the previous study involved a wider set of resources, including factual databanks and printed material; while this allowed BB to make wide and general comments, it restricted their scope for in-depth analysis
- conversely, the present study had access to a much wider range of online bibliographic material – more databases and longer time periods - than did

the previous authors in the late 1970s; this study has the potential to be more informative on this particular kind of resource

- the present study is analysed in considerably greater detail – both qualitative and quantitative – than was the previous study, and involves some novel forms of analysis of this sort of data

6.4 Methods; queries

A series of 10 test queries was constructed, in order to investigate a broad section of toxicology. Queries were chosen to be representative of a variety of toxicology facets, and included specific and general chemical substances, and substances without a clear definition in terms of chemical structure. General and specific toxic effects, and factors such as route of administration, species affected, and the environment of the effect, were also included. An over-riding proviso was that the queries had to be sensible and realistic; the kind that could be encountered in practice. Queries were constructed by the author in conjunction with BIBRA Information Service staff. Whilst these were not real queries, they were felt to be typical of the sort of questions encountered in real life. Time period limitations were used when it was necessary to restrict the size of the output to be analysed.

The 10 queries used were:

1. Contact toxicity of lavender oils in humans.
2. Toxicity of sage oils
3. Acute toxicity of angelica
4. Carcinogenicity of chloro-cresols
5. Teratogenicity of formaldehyde, items published in 1995, 1996 or 1997.
6. Ecotoxicity of ethylene glycol, items published in between 1990 – 1997 inclusive.
7. Aquatic toxicity of propoxur
8. Cases of chloracne due to dioxin exposure, data published between 1987 and 1997 inclusive.
9. Evidence of increased mortality in humans due to occupational exposure to styrene, items published in 1995, 1996 or 1997.
10. Acute effects of inhalation of toluene in humans or other mammalian species, items published in 1995, 1996 or 1997.

6.5 Methods; details

Searches were carried out between December 1997 and April 1998, using databases on the Dialog system. This host system provided all the databases which were likely to be of use, given that the searches were confined to text-based bibliographic files, i.e. excluding factual/numeric databanks (such as RTECS or DOSE) and files with graphic chemical substructure searching capabilities (such as Chemical Abstracts CAS Online system).

Several of the files were updated during the progress of some searches, as part of Dialog's monthly / quarterly updating, but checking ensured that this did not affect the results, i.e. no potentially relevant new documents were entered.

6.5.1 Choice of databases

For each query, the set of files to be searched was initially determined from the searcher's prior knowledge and experience, from the Dialog database documentation, and from searches of the Dialindex database, examining all possible files. This set was then refined during a series of initial exploratory searches. In general, the focus was kept to scientific databases: regulatory files, though they would certainly contain relevant information, were excluded for this study, so as to keep the analysis feasible [but see future work section]. The final set of databases chosen was that which would be, in the investigator's judgement, that used by an expert searcher seeking high recall. Files were usually only included if they gave either good recall or some unique items; sometimes, however, databases were included in the analysis if this was not the case - even if they gave no useful material at all - if their inclusion exemplified some point of retrieval effectiveness, or lack of it, or if it gave an interesting comparison with other queries.

6.5.2 Initial search

Files were searched separately, or together using OneSearch, as convenient; in some cases, the number of hits was so great that separate searching was essential to avoid system space filling up. In all cases, specific searching features of particular files, e.g. CA Registry Numbers and Biosis Biosystematic Codes were used where appropriate;

there was no 'lowest common denominator' searching. Chemical dictionary and general reference files, such as ChemName, ChemSearch and Merck Index, were used as necessary in identifying chemical substance identifiers and other terminology.

Broad classificatory terms, such as Biosis concept codes (Prasek 1998), were not generally included in the search strategies, as it was considered that these would be likely to lead to too much irrelevance; however, it was found that for some searches, the Biosis concept codes relating to toxicology were essential for maximum retrieval from this database. Other possible useful Biosis codes, e.g. 37013 Public Health/Environmental Health/Occupational health, 37013 Public Health/Environmental Health/Air, Water and Soil Pollution, and 35500 Allergy, though possibly useful for optimal recall, were not included as being outside the practice of a searcher under normal conditions.

CA Search sections headings are automatically included in the basic index, and hence would be retrieved if equivalent text terms were put into the search: thus TOXIC? would retrieve any items in the Toxicology section (CA204XXX), while AIR and POLLUT? would find those in Air Pollution and Industrial Hygiene (CA 259005). Similarly, Excerpta Medica EmClass section headings, such as Toxic Substances and Protective Effects (3726060500), are included in the basic index, and hence accessible by text search.

6.5.3 Search refinement

The initial search strategy was refined in two ways. Firstly by inspection of the indexing terms assigned to records which appeared relevant, to see if any additional or alternative terms could be added to the strategy, and also to reveal terms responsible for the retrieval of large numbers of irrelevant records. The second approach was a failure analysis, carried out by checking for the presence of relevant items in other files by author name, or by title terms other than those used in the initial searches (so that, e.g., mis-spelling of a term would not affect the failure analysis as well as the initial retrieval). Items found in this way were examined to see if the search strategy could be improved, and the process repeated. It took between one and four iterations, according to the nature of the query, to arrive at an optimal search strategy.

6.5.4 Relevance judgements and final failure analyses

Once the optimal search strategy had been resolved, ie. no new relevant records were identified by the refined search, relevance judgements from the final record set were made by the searcher, usually on the basis of title and abstract, sometimes from the rest of the online record, e.g. index terms, and where necessary and feasible from examination of the original document. Although relevance judgements are notoriously subjective and variable, this process at least ensured consistency. No attempt was made to determine the novelty or quality of information provided (though it was noted that in several cases essentially the same paper, to judge from the abstract, had been published in more than one journal). Nor was extra weight given to items, such as BIBRA Toxicity Profiles, substantial review articles, or extracts from compendia, which might in themselves have provided much extra information.

Toxline was considered as a single database for the purposes of summarising recall, so that multiple hits from individual subfiles were counted only once; for assessing precision, however, each hit from each sub-file was counted once in the 'total hits'. Toxline's precision ratings are therefore, arguably, inconsistently poor.

A final failure analysis was carried out on the set of relevant records, and a matrix constructed to show the presence or absence of each record in each database, and where appropriate, the reason for record retrieval failure.

6.5.5 Measurement of recall in evaluations

Three measures of retrieval effectiveness are typically utilised in comparison of different search strategies and different databases: recall, precision and uniqueness.

Precision and uniqueness may be calculated precisely and unambiguously, since they require only the examination of the relatively small sets of retrieved items. Of course, they are dependent on having some sensible and consistent method of judging the relevance of every item retrieved.

Recall, however, has particular problems associated with it. It is, of course, also dependent on consistent and sensible determination of relevance. Blair (1996), for example, discusses methods of calculating recall so as to minimise uncertainty in recall estimations because of differing relevance judgements.

Beyond this, however, is the fundamental problem that assessment of absolute recall requires calculating the ratio of the number of relevant items retrieved to the number of relevant items present in the database. This latter figure can only be determined by examining each and every item present in the database being searched, and judging its relevance. This heroic expedient was in fact used on the test database used for the Cranfield II retrieval experiments, in which every document in a set of 1,400 items was individually checked for relevance against each of 287 test queries; this requiring 3 months work from a group of 6 subject experts (Cleverdon and Keen 1966). This approach is clearly not practical for any operational database, and alternative means are required; several have been proposed, and are discussed by Tague (1981) and by Bawden (1990).

One alternative is to choose a test query for which a comprehensive bibliography already exists. It is then necessary only to check the presence of each item in this bibliography in the database; those which are present form the complete set of relevant items against which retrieval performance is judged. However, this method is only feasible when such a comprehensive bibliography already exists. It also begs the question of how it is known to be comprehensive, i.e. how is it known that there are not other relevant items in the database to be evaluated, which may or may not be found by the test queries. These limitations are so severe that the method does not seem to have been used for evaluations of any operational retrieval systems. Tague (1981 p 68) describes this method, and similar ways of using predetermined relevant documents, as 'of questionable value', and they were not considered for these evaluations.

Another alternative is to use statistical sampling. If it is not feasible, on grounds of sheer numbers, to examine each item in the database for relevance, then it may be possible to examine one in 10, or 100, or 1000. The value of recall found for the sample can then be taken to be representative of that which would be obtained for the whole database. The difficulty with this approach is that it is not a trivial matter to determine what size of sample is necessary for valid results (Gilbert and Sparck Jones 1979). This is particularly so with most bibliographic databases, in which the material is likely to be 'clumped', by database section, journal issue, time period etc., so that relevant items are not likely to occur randomly throughout the file, as would be required to obey the independence assumptions for random sampling.

Furthermore, in large bibliographic databases, of the kind evaluated here, even a small sample size would be prohibitively large for individual inspection of each item,

while the sample size necessary to give accurate estimation of 'true' recall is typically quite large. For example, if there are 50 relevant documents in a file of 50,000, and it is desired to estimate absolute recall at the 95% confidence level, then (assuming independence) it will be necessary to examine over 44,000 documents ! (Tague 1981, p 68)

It was therefore concluded that sampling methods were of no value for these evaluations.

The only remaining alternative is the use of *relative* or *apparent*, rather than *absolute*, recall. By this, the evaluator makes no attempt to use the absolute number of relevant items in a database, or in a sample taken from it, but rather uses a surrogate set of relevant items, against which retrieval is judged. This surrogate set could be a comprehensive bibliography, with the qualifications noted above, but in a comparative evaluation is likely to comprise the total set of all relevant items retrieved by use of any database or search technique (Bawden 1990 p 79-80, Tague 1981 p 69). Any item present which was not found by any of the search procedures used, especially if failure analysis is employed, is likely to be so inadequately indexed, as to be effectively irretrievable, and hence can be safely ignored for purposes of comparison of databases, search terms, etc.

Tague (1981 p 69) argues that 'relative recall seems appropriate in comparative testing' (as here, where comparisons are being made between databases and search techniques, and it is the relative effectiveness of these, rather than the absolute number of items retrieved, which is of interest). She also suggests that this is 'virtually the only possible approach to recall in testing large operational systems'. Indeed, as noted in an earlier section, this approach was used in several earlier evaluations of toxicology resources.

This method of estimating recall was therefore adopted for these evaluations.

6.5.6 TRACE

BIBRA's TRACE database was searched according to normal best practice, and relevance judged from the title and where, necessary, inspection of the original document and personal knowledge of BIBRA staff. On the rare occasions on which relevance judgements initially differed, these were resolved by discussion of individual cases.

6.5.7 Comments on methods

This methodology is very time-consuming, with several working days typically taken up in the search and analysis process for each query, and a similar time in completing the overall analysis. Nonetheless, it proved very effective in casting light on the issues under investigation. Although only ten queries were used, several hundred records were examined, and many aspects of indexing were revealed.

6.6 Results

For each query, the following tables of values were calculated:

a)

- total number of relevant records present, whether retrievable or not, in any of the commercial databases searched (n)¹
- number of relevant records retrieved by each database (r)
- % recall for each database, calculated as the % of relevant records found from n
- number of unique records per database (u)
- total number of records retrieved from each database (t)
- % precision, calculated as the % of relevant records out of the total number retrieved from each database (r/t)
- % recall for each individual database, calculated as the % of relevant records found out of the total number of relevant records present in the database ($\text{recall}_{\text{ldb}}$)

b)

- total number of relevant records found from all databases searched, including TRACE (N)
- number of relevant records retrieved by each database (r)
- % recall for each database, calculated as the % of relevant records found from N
- number of unique records per database including TRACE (U)
- total number of records retrieved from each database (t)
- % precision, calculated as the % of relevant records out of the total number retrieved from each database (r/t)
- % recall for each individual database, calculated as the % of relevant records found out of the total number of relevant records present in the database ($\text{recall}_{\text{ldb}}$)

¹ The recall figures in the a) tables, for the commercial databases, are quoted against the total set of items present in any database, whether or not they were retrievable from any; those which were not retrievable were identified by the search of the BIBRA database.

Precision and recall are quoted rounded to the nearest percent. 'Unique' items are those judged retrievable only from that database by any feasible search strategy, whether or not they are present in others. For each individual database, the recall of items present in that database is also shown, denoted as $\text{recall}_{(\text{idb})}$

Cause of failure to retrieve relevant items is then summarised as due to coverage or to failings of indexing for each component of the search (tables c and d). If the failure is due to more than one reason, e.g. lack of adequate indexing for both chemical substance and toxic effect, each reason for failure is counted separately.

The initial and final search queries, with comments on the results of the failure analysis, are shown in appendix 6.6, and show how the strategies were developed. Searches were not necessarily carried on to exhaustive recall, the aim always being to simulate what would be the realistic 'best practice' of an expert searcher, while also throwing light on issues of indexing and retrievability. Sometimes, therefore, the notes on the search strategies indicate other terms which could be used to improve recall, but at the cost of great imprecision, so that they would probably not be used in practice. Similarly, it is sometimes noted that a long profile of individual species names would have to be entered for completeness.

6.7 Summary of results

The results of the individual queries were summarised in three ways.

1. First, the databases found to be valuable in at least one of the queries were ranked according to the extent of their usefulness. This gives an indication of the databases likely to be most useful for this kind of search, and for the range of databases which should be considered.
2. Second, for each of the set of six databases used in more than one query, three measures of retrieval performance are summarised across the set of queries.
 - Recall is summarised against the items present in each individual database, against those present in the set of commercial databases used, and against the total set including the TRACE database. The first of these measures indicates the ease with which material present in each database can be retrieved; it is essentially a measure of indexing quality. The second and third values measure the contribution of each database to retrieval of the total set of documents, and are therefore measures both of indexing quality and of extent of coverage.
 - Precision values are then quoted, as a summary of this measure of each database's capability for focused searching across the test queries.

All the values above are quoted as percentages, and maximum, minimum and mean values are given. Inspection of the data confirmed that the familiar mean value was as good, or better, a measure of 'average tendency' as the alternative median.

- Uniqueness is then summarised as a measure of the ability of each database to provide items which cannot readily be found from any other source. This is expressed in two ways.

First, simple counts of unique items provided by each database are given. Second, they are expressed as percentages of the total number of unique items for each query: this avoids the summarisation being dominated by the results of queries which happened to produce a large number of unique

items. It is arguable that provision of a single unique item in a search in which only two unique items are found overall (counting as 1 item, or 50%) is more significant than five unique items in a search providing twenty such (counting as 5 items, or 25%). The two ways of representing uniqueness allow these factors to be compared.

3. Finally, summaries of failure of retrieval are produced across all commercial databases, across all databases including the TRACE database, and for each individual database. These measures give detailed insight into why relevant documents are not returned when a 'best' search strategy is used.

6.7.1 Summary of 'valuable' commercial databases

'Valuable databases' are those found to provide either a significant amount of relevant material – generally 10% recall, as a minimum – or some unique references.

Because of the way in which identification of databases to be used was carried out – searcher's judgement, based on cross-index searches, examination of documentation, prior knowledge, and initial test searches – it is possible that some potentially useful databases were not included. Indeed, the provision of some useful material by other databases is noted for several queries. However, the process used should identify all the most useful databases, and give a reliable picture of the general pattern of database usefulness.

The databases found valuable in this set of test queries are given in table 6.1.

Table 6.1 'Valuable' commercial databases for toxicology searching

Database	No of queries
Toxline	10
Biosis	9
Embase	8
Medline	8
CA Search	7
Life Science Collection	4
Occupational Safety and Health	1
Scisearch	1
IAC	1
CAB Abstracts	1
Water Resources Abstracts	1

Pollution Abstracts	1
HealthStar	1
Pascal	1

This shows a 'core' of Toxline with the four major disciplinary services, useful for a majority of these queries. Life Science Collection, which includes Toxicology Abstracts, occupies an intermediate position. A tail of 8 databases each contribute to one query. It is likely that a slightly different set of test queries would add more databases to this 'tail'.

This form of Zipfian distribution is to be expected, as being common to most bibliometric situations (Zipf 1935, Brookes 1968). Its clear emergence here gives confidence that the results of this study are reliable².

² Zipf originated his law as part of a general study of language in the 1930s. In 1934, Bradford and Lancaster Jones at the Science Museum Library in London drew attention to a bibliometric distribution which was later recognised as a specific example of Zipf's distribution: hence the term 'Bradford-Zipf' distribution is often used.

6.7.2 Summary of recall, precision and uniqueness, across all databases

Table 6.2 Summary of recall, precision and uniqueness, across all databases

	Toxline	Biosis	Embas	Medl	CAS	LSC	TRACE
Number of queries	10	9	8	8	7	4	10
Recall (individual database)							
Maximum	92	61	77	78	86	75	100
Minimum	24	13	29	13	5	22	86
Mean	60	32	48	27	38	44	97
Recall (commercial databases)							
Maximum	78	56	64	58	55	67	
Minimum	17	9	13	7	3	6	
Mean	46	21	33	23	22	22	
Recall (all databases, including TRACE)							
Maximum	63	45	61	55	49	50	92
Minimum	15	5	8	6	3	5	26
Mean	34	17	27	18	16	16	64
Precision							
Maximum	73 ¹	100	91	100	100	100	100
Minimum	18 ¹	8	30	33	25	33	18
Mean	50 ¹	56	51	64	67	60	80
Uniqueness without TRACE (counts)							
Maximum	9	2	12	0	24	1	
Minimum	0	0	0	0	0	0	
Mean	4	1	4	0	5	1	
Uniqueness without TRACE (percentages)							
Maximum	82	10	80	0	63	33	
Minimum	0	0	0	0	0	0	
Mean	32	2	42	0	23	9	
Uniqueness with TRACE (counts)							
Maximum	8	2	11	0	20	1	24
Minimum	0	0	0	0	0	0	4
Mean	2	0	3	0	4	0	15
Uniqueness with TRACE (percentages)							
Maximum	35	7	50	0	40	2	100
Minimum	0	0	0	0	0	0	29
Mean	10	1	15	0	11	0	68

[Note the treatment of Toxline precision described above].

Recall

For the commercial databases, recall falls into a fairly clear pattern, with Toxline giving superior performance, Embase second, and the others roughly equal. No single database gives total recall, which can only be achieved by a combination of databases, as discussed in results for each individual query.

When the items present only in the TRACE database are also considered, the recall values for all databases fall, as TRACE adds a significant number of unique records. Toxline and Embase both give the best performance from the commercial databases, but TRACE database achieves a higher recall than both of these. Even so, TRACE's 64% average recall is considerably less than 100%, emphasising the need to use commercial resources as a complement to the in-house, specialist database. The TRACE database recalls more of the records present in the commercial databases, than vice versa. The limited recall demonstrated by the TRACE database is perhaps a reflection of its specific coverage and time period (ie. 1987 onwards).

It is noteworthy that, for three of the databases (Biosis, Medline and CA Search) only about one third of the relevant items present in the database could be retrieved using the 'best practice' search strategies proposed here. The TRACE database achieves the highest average for recall of relevant records actually present in any one database. This could be anticipated as a result of the highly structured and limited indexing system employed.

When recall of items present in at least one commercial system is measured over all queries, no single database gives half of the possible recall; Toxline, with 46%, performs best.

One clear lesson from these results is that, with the exception of one query for which Toxline alone or Embase alone was sufficient for complete recall, it was necessary to use combinations of databases to get good recall. As noted in the descriptions of the individual test queries, combinations of 3 or 4 databases were commonly required. When pairs of databases were used, the combination of Toxline with either CA Search or Embase, depending on the query, generally proved most valuable.

Precision

Precision shows a different pattern, with the best commercial performers here (CAS, Medline and Life Science Collection) being among the poorer for recall. Embase and Toxline, which are the only databases to give recall of above 20% of the total set

including TRACE's unique references, give below 60% precision. This illustration of the inverse relation of recall and precision confirms other studies (Cleverdon, 1972); though it should be noted that the differences in precision are not very great, and would be lessened if the duplicate items from Toxline sub-files were discounted. The high average precision for the TRACE database is notable, but so is the range of values achieved, which show a minimum precision of 18%. This indicates that the database may not perform well for queries which contain concepts which cannot be mapped exactly onto the indexing codes.

Uniqueness

Medline produces no unique records, although this could be expected as all Medline toxicology records are also contained in Toxline. The TRACE database provides the highest percentage of unique records, probably because of its specific coverage of grey literature such as government and international organisational material. Within the commercial databases, both the uniqueness measures show essentially two groups of database: one set (Toxline, Embase, and CA Search) which contribute a significant extent of uniqueness, and the remainder which do not. Nonetheless, these latter do, in some instances, provide unique records, and so must be searched if complete recall is required, as must databases located further from the 'core' set identified above. The percentage uniqueness measure, which attempts to standardise the effect of uniqueness regardless of the size of the set of relevant material, suggests that the order of success in the provision of uniqueness is Embase > Toxline > CAsSearch.

Ranking of databases

It is tempting to use these results to provide a ranking of the success of the commercial databases in answering these test queries, though the limited extent of the evaluation should dictate that this be done with caution as to the general applicability of results.

With that caveat, the ranking which emerge are:

Local recall (success of the database in providing material within its particular scope)
Toxline > Embase, Life Science Collection > others

General recall (success of the database in retrieving a wide range of material)
Toxline > Embase > others

Uniqueness (success of the database in providing material which other sources cannot)

Embase > Toxline > CA Search > others

Precision (success of the database in providing focussed access to relevant material)

CA Search > Medline > Life Sciences > others

6.7.3 Summaries of failure of retrieval

Across commercial databases

The reasons for failures in retrieval were consolidated and summarised for those references present in any commercial online database. This gave an indication of the relative importance of the general difficulties of toxicology searching in any online database.

Failures were categorised under four headings:

- Item not present (coverage)
- No substance identification (substance indexing)
- No general toxicity indication (subject indexing)
- No specific type of toxicity (subject indexing)

The last of these consolidates the specification of specific types of toxic effect (e.g. acute toxicity), route of administration (e.g. inhalation) and scope of toxic effect (e.g. ecotoxicity).

Over the 10 queries, and expressed as percentages, the relative importance of the four factors were:

• Coverage	60
• Specific toxicity concept	20
• Substance	15
• General toxicity	5

The dominant effect of coverage, as noted for several of the individual queries, is clear. This is particularly notable, since this analysis refers to items present in at least one of the databases searched.

Across all databases

Reasons for failure in retrieval across all databases, including TRACE, are summarised below, demonstrating little change from the previous table:

- Coverage 61
- Specific toxicity concept 20
- Substance 14
- General toxicity 5

Summary of failure of retrieval in each database

This set of figures shows the relative importance of different types of retrieval failure in each of the six databases used for more than one of the test queries and the TRACE database. This gives an indication of the relative weaknesses of each of the databases.

The four categories of failure factors used in the analysis above – coverage, substance indexing, general toxicity indexing, and specific toxic effect indexing – were also used here.

The failures of each type for each of the six main commercial and the TRACE databases are initially summed over all ten queries in table 6.3.

Table 6.3 Retrieval failure summary for each of the six main commercial databases and the TRACE database over all 10 queries a) and as percentages b)

a)	Emb	Toxl	Medl	CAS	Biosis	LSC	TRACE
Coverage	80	81	82	106	121	106	121
Substance	29	38	35	23	58	8	4
Toxicity (general)	9	17	13	11	14	6	5
Toxicity (specific)	40	56	44	69	54	10	18
Total	158	192	174	209	247	130	148

[They are then divided by the total number of failures for that database, and expressed as percentages.]

b)	Emb	Toxl	Medl	CAS	Biosis	LSC	TRACE
Coverage	51	42	47	51	49	81	82
Substance	18	20	20	11	23	6	3
Toxicity (general)	6	9	7	5	6	5	3
Toxicity (specific)	25	29	25	33	22	8	12

Perhaps the most surprising finding here is how similar the five major databases are in this respect; Life Sciences Collection seeming rather different. The TRACE database fails for the same reasons that the Life Sciences Collection does. This can be anticipated, as they are both smaller, more specialised databases. It should be noted however, that the above table indicates reasons for failure, and not overall database performance.

Coverage failures are the major factor for all databases; for the five main sources, these lie in a small range between 42% (Toxline) to 51% (Embase and CA Search), while the coverage factor for Life Science Collection is an overwhelming 81%, reflecting the smaller size of this database.

Substance indexing again lies within a small range. CA Search, not surprisingly performs best here with only 11% of failures due to this factor, while the four big biomedical sources lie between 18% and 23%.

Similarly, specific toxicity indexing failures for these four sources lie in a small range between 22% and 29%; CA Search performs relatively poorly on these factors at 33%, reflecting its relative lack of detailed indexing of biomedical concepts.

For both substance and specific toxicity, Life Science Collection performs relatively well, reflecting the preponderant role of coverage in this database's performance.

General toxicity specification causes less than 10% of failures for all databases. These summary figures support the general picture revealed in the previous failure analysis, indicating that coverage is the predominant difficulty, rather than any particular limitation in indexing. Choice of any particular database, among the five major ones used here, does not seem critical. Of course, this is based on the results of carefully designed and refined searches, taking advantage of the most appropriate searching facilities of each database. It does not necessarily reflect what might happen if simpler searches, using only 'obvious' terms, were carried out.

6.8 Discussion

These results demonstrate that the TRACE in-house database performs better on average than any single commercial database used in the test queries. Average percentage recall and precision values for the TRACE database are 64% and 80% respectively, compared to the 34% achieved by Toxline as second best performance for recall, and 67% second best precision percentage achieved by CAS.

The TRACE database provides a high percentage of unique records to the toxicology queries used in this analysis; an average of 68%. For each of the test queries used, no combination of the commercial databases used was able to retrieve all of the items located by the TRACE database. It therefore seems safe to conclude that the TRACE database will usually also perform better than a combination of commercial databases.

The recall and precision figures are averages taken over all ten test queries however, and it is important to note that the TRACE database does not always give the best performance for an individual query, indicating the need to supplement searches of the in-house database with additional searches of commercial databases. Recall from the TRACE database ranged between 26% and 92%, emphasising that successful recall is dependant on the toxicology query matching TRACE's specific coverage. Recall did not reach 100% for any query. This is a further indication of the need to supplement in-house searches with results from commercial databases if high recall is required. Unique references were found in commercial databases for nine of the ten test queries.

In recalling items present in any individual database, TRACE again demonstrated a superior performance in comparison to the commercial databases, 97% compared to the next best of 60%, achieved by Toxline. This may be expected as a result of the limited indexing terms and codes applied to the TRACE database. If an article has been entered and indexed, then the application of a limited number of codes, i.e. substance plus toxic effect, should recall the record. In contrast, the commercial systems demonstrated at best an average of only 60% recall of items that were actually present, indicating a deficiency in the record indexing. In these cases, even complex search strategies were unable to retrieve the records.

For average precision, TRACE performs better than the commercial databases, but achieves a minimum of 18% as well as its maximum of 100%, illustrating that the limited indexing can have limitations with regard to some specific toxicology concepts.

All of the queries could be answered to a greater or lesser extent by commercial databases. These databases are useful in answering toxicology queries, and as described above, form an essential complement to the use of the specialist in-house database used at TRACE. There are many commercial databases available, and although this study was restricted to those offered by the Dialog Corporation, it is clear that those providing at least one useful item are many and varied. The databases chosen for each of the queries were selected in a manner of 'best practice', i.e. those that would most likely be chosen in real life by an expert searcher. Although it is therefore possible that other databases would also contribute relevant and perhaps unique material, it can be seen from the analysis of the test queries that a core of databases can be identified as those likely to be most useful for toxicology queries. These include Toxline, Biosis, Embase, Medline, CAsEarch and Life Science Collection. These databases can then be ranked in terms of average recall, precision and number of unique items contributed. Here it can be seen that Toxline and Embase offer the best average recall (46%, 33% respectively) and number of unique items (32%, 42% respectively) whilst the highest precision is obtained by CAsEarch (67%). The relatively low recall achieved even by Toxline emphasises again the need to search a range of commercial databases in order to increase recall. Precision is inversely proportional to recall, linking those databases with high recall, e.g. Toxline, with lower precision. Again, this may illustrate a difficulty in the indexing of specific toxicity concepts.

While these rankings may be a good indication of general usefulness, it must be stressed that they are constructed from a limited number of test queries and that in any real life query different results may be obtained.

Further insight into the performance of the databases is given by the failure analysis, which examines reasons for retrieval failure in detail. Essentially, failure to retrieve items relevant to a query is due to a combination of factors which may be categorised as coverage and indexing. When reasons for failure are summarised across the commercial databases, and across all databases including the TRACE database, it is clear that coverage is the main factor, as 60% and 61% of retrieval failures respectively are due to the item not being present in the database. Retrieval

failure summaries for individual databases also confirm coverage as the highest reason for failure.

Failure due to substance indexing is apparent in all of the commercial databases, although it is low in CASearch (11%), as may be expected, and in the smaller Life Science Collection (6%). Failure due to lack of substance indexing is even less apparent (3%) in the TRACE database, emphasising its in-depth, if limited, indexing policy of substance and toxic effect. Failure due to general toxicity indexing is less than 10% in all databases. More problematic in every database is the failure to retrieve due to lack of specific toxicity indexing. This could be expected; as the definition of a toxicology concept increases in complexity, consistent and in-depth terminology is harder to apply. Over all databases, including TRACE, 20% of retrieval failures are due to specific toxicity concept indexing.

It is clear therefore, that retrieval of toxicology information could be improved by enhancing the coverage of any one database. However it is also unlikely that any single database is ever going to include records of all items relevant to such a multidisciplinary subject as toxicology. The most comprehensive approach taken so far in this respect can be seen with the Toxline database, which gathers together several relevant databases, and provides an option to search through all of them at once.

Despite the comparatively good recall demonstrated by the TRACE database, it is evident that even a specialised toxicology database is not comprehensive. If the aim is to retrieve the maximum number of relevant items from the literature, then a variety of databases must be searched. However, if the query falls within the coverage of a more specialised database, then this can be a sensible single option.

The Toxline database has addressed coverage by providing a single interface to a variety of toxicology databases, datasets and subfiles; a plausible extrapolation of this principle could be to provide a single, possibly graphical/web based interface to databases containing material relevant to toxicology, thereby resolving, to a greater or lesser extent, the issue of coverage.

Issues of indexing are somewhat harder to resolve. There are advantages and disadvantages to both the limited indexing approach taken by specialist in-house databases, such as TRACE, and the multi-level access point approach taken by the large, general, commercial databases.

The former system supports a high level of precision, but only when the concept required can be mapped directly onto the codes used in the indexing. This type of database seems ideal when the searcher has a clearly defined category of query, which does not require the recall of every item from the literature.

While the limited, highly structured indexing exemplified by the TRACE database does favour a high precision overall, it is clear that this is not applicable to all queries; specifically, for query 7, where the concept of 'aquatic' could only be addressed by the environmental aspects code, and query 9, where the concept of 'mortality' could not be expressed.

The latter approach clearly varies between databases, which is itself a problem for the searcher. Substance indexing varies in depth, and in the terminology used e.g. Registry Numbers, different synonyms and preferred terms. A variety of general toxicity descriptors and headings exists, augmented by a larger number of specific toxicity concept descriptors, codes and subject headings, all of which can be used in addition to free text searching of title and abstract. With the plethora of access points, retrieval from the larger commercial databases can be complex and lack precision. Incomplete indexing can mean that even complex strategies do not always retrieve relevant records which are present in the database. However, it must be remembered that with the exception of Toxline, the commercial databases used are not specifically designed to answer toxicology queries.

The matching of the analysis of document content by an indexer, resulting in a set of index terms, and the analogous analysis of an information need by a searcher, resulting in a set of query terms, is a major issue for effective information retrieval (see, for example, Lancaster 1998). While indexers will generally strive to assign terms describing what the document is 'about', their opinion may not coincide with 'aboutness' as perceived by a searcher (Swift et. al. 1978). Or, as Olafsen and Vokac (1983) put it:

'The indexer has to make guesses at what questions the future user of the system will put. Regardless of how cleverly the guesswork is construed, they are still guesses, while the user approaches the system with his own concrete question, and his associations may be different from those of the indexer'.

One possible way to improve the retrieval of toxicology information from bibliographic databases could be to apply a standard structure to the indexing of

items, thereby offering a standard framework from which to construct searches to retrieve items.

The present results can be considered with reference to the three-layer model, which will be further considered in chapter seven. The model breaks down a toxicology statement, such as a title or a query, into primary, secondary and tertiary layers, so that the primary layer describes the substance(s), the secondary layer the general toxic effect (toxicity, side effect, poisoning, carcinogenicity, teratogenicity etc.), and the tertiary layer the way in which the substance is encountered e.g. as an acute dose, as an ecotoxic effect etc. It is possible to add specificity to the general toxic effects of the secondary layer, by inserting a sub-layer to contain specific concepts such as resulting effect in man or animals.

Failure to retrieve relevant records which are, in fact, present in a database is seen to be due to incomplete indexing of either substance (1°), general toxic effects (2°), or most importantly, specific (3°) toxic effects. Few items failed to be retrieved due to incomplete indexing of general toxic effects, even though the terminology used to represent these concepts varies between databases, e.g. Biosis concept codes. There were failures due to incomplete substance indexing however, and more detailed and exhaustive substance indexing, such as that employed by the TRACE database, could clearly improve recall from the commercial databases. Often, in studies where a variety of compounds are tested, only the generic name or substance category is indexed, making relevant information impossible to find. Most failures occurred due to incomplete indexing of tertiary concepts however. Terms such as 'acute', 'mortality' or 'aquatic' toxicity are revealed to be frequently not indexed, or described in a variety of ways. The inconsistent and varied approach to 3° concept indexing does have advantages, in that free-text terms can be applied to enrich item description, but at the same time, this requires complex search strategies to ensure item retrieval. In many cases, even complex strategies fail to retrieve all relevant items.

It is possible that no complete solution exists to the problem of indexing toxicology literature, but it may be advantageous to consider each item with reference to the three layer model, so that each aspect is indexed in some way. This would alleviate the problems encountered due to incomplete indexing of substance, general or specific toxic effect. Problems of consistency could be addressed by applying a particular indexing scheme, or thesaurus at any one layer. For example, MeSH headings could be used at the 2° layer. This approach would offer the searcher some

guidelines as to how the item had been described, and subsequently improve retrieval. Overall, both searching and indexing could be facilitated.

Such an approach to indexing could be combined with the concept of adding together separate databases to improve recall. Many toxicology queries do not fall neatly into a single specialist domain, but encompass several. A unified approach to indexing could offer a consistent interface from which to search any toxicology dataset. This could perhaps be instantiated as a standard, web-based interface to any toxicology data.

The results obtained can be compared with those obtained by Bawden and Brock (1982,1985). This study confirms their findings that:

- Commercial online bibliographic databases are an essential part of any toxicity searching
- It is essential to use several complementary databases for good recall
- 'Peripheral' databases can give useful and unique items
- Complex search strategies are usually necessary, including portfolios of terms
- It is necessary to use the particular access points provided by each database
- An in-house file has particular value in covering material not present in commercial databases
- There are problems in specifying exact toxic effects, routes of administration etc.
- There are difficulties associated with searching for chemical substructures and classes of substance in these databases

Aspects which have changed include:

- Problems with the specification of a chemical substance have lessened – possibly due to changed indexing policies and the greater use of Chemical Abstracts Registry Numbers
- Specification of general toxicity is easier, causing few retrieval failures
- The most useful databases found by Bawden and Brock were CAsSearch and Toxline, with the biomedical databases providing a useful complement to searching. In this study, Toxline and Embase appear to be the most useful pair of databases for answering toxicology queries. This may reflect changes in both coverage and indexing policies.

6.9 Conclusions

With reference to the six original hypotheses, the following conclusions can be drawn from this investigation:

1) The TRACE specialist in-house database demonstrates better average recall and precision than any one of the commercial databases used to answer the test queries. For individual queries, however, TRACE's recall and precision figures were not always superior to each of the commercial databases. In no case was 100% recall achieved by the TRACE database. In all ten of the test queries, the TRACE database contributed unique records. On average 68% of unique material was provided by the TRACE database. This indicates that for most toxicology queries, its performance will not be matched even by combinations of databases.

2) Commercial databases are a useful complement to the TRACE in-house database in providing additional material in answer to the toxicology queries used here. All of the databases contributed some unique material, with the exception of Medline, the toxicology section of which is included in Toxline.

3) For eight of the ten queries, a range of commercial databases was needed to give adequate recall. For the test queries used here, Toxline offered the best average recall but even this was only 46%, indicating a need to use additional databases to improve search results. When retrieval failure was analysed for items present in at least one of the commercial databases, 60% of failures were due to coverage, again emphasising the need to use more than one database.

4) In contrast to the relatively straightforward search statements needed to query the TRACE database, search strategies for the commercial databases were in most cases complex and time consuming to create. Lack of standardised indexing terms in the commercial databases requires a number of synonyms, subject headings and alternative terms to be entered in order to ensure good retrieval.

5) The main reason (60%) for limited recall in commercial databases is coverage; i.e. items are not present in the databases. Failure to retrieve due to missing or incomplete indexing occurs in 40% of cases however, half of which are because of lack of specific toxicity concept indexing. This means that 1 in 5 failures to retrieve relevant information is due to lack of specific toxicity concept indexing. Retrieval

failure due to depth of indexing occurs in instances where, for example, a large number of compounds are tested, but are not indexed individually, and where indexing terms utilised do not adequately describe the concept being sought e.g. acute toxicity, ecotoxicity, cases, occupational exposure and inhalation.

In some cases, exemplified by query 5, teratogenicity of formaldehyde, precision was reduced as a result of imprecise indexing, so that more general terms had to be included to avoid loss of recall, but at the expense of precision.

6) Only 18% of retrieval failures from the TRACE database were due to indexing and so

it would seem that the adoption of more detailed and structured indexing could help reduce retrieval failures in commercial databases.

As may be anticipated, on average, a specialised toxicology database performs better in answering toxicology queries than any one or combination of the more general, commercial databases. No database currently offers 100% recall and precision however, and when examined in detail, the reasons for this can be identified as coverage and indexing failures. It is therefore recommended that toxicology searches are carried out over as wide a range of databases as possible, to ensure high recall, although for the commercial databases, this may be at the loss of precision.

Problems of coverage could be overcome by adding together databases likely to contain references to toxicology literature. Problems encountered by the varied and often incomplete approach to indexing toxicology items could be addressed by applying a standard model to every toxicology statement, so that each aspect of a statement is indexed in a standard way, to the same level, and using standard terminology. This level of indexing is to some extent employed by specialist databases, but naturally involves a high level of effort in its construction. Additionally, as yet no standard vocabulary exists for describing toxicology statements. The extent to which existing tools for knowledge representation perform for toxicology is examined in the next chapter.

The ease with which web-based technology allows access to distributed information suggests that a single interface could be designed which would allow access to any networked toxicology dataset. This idea is similar to that of the distributed structure-

searchable toxicity (DSSTox) public database network, proposed by Richard and Williams (2002).

6.10 Further Work

The results of the above investigation suggested a number of areas for further studies, in alternative types of information resources.

1. **substance-oriented databanks:** whereas all the files used here were structured by bibliographic record, there are a number of factual databases providing information, including toxicological data, arranged by chemical substance. Examples are RTECS (Registry of Toxic Effects of Chemical Substances); HSDB (Hazardous Substances Data Bank); Beilstein Handbook of Organic Chemistry; Merck Index; DOSE (Directory of Substances and Effects; etc. These might provide a useful alternative, or complement, to bibliographic databases, as is suggested by the few comparative studies of databanks for toxicology material, reviewed in chapter five.
2. **'grey literature' files:** it was evident from this study that relevant material from the TRACE database often came in the form of documents emanating from government bodies, regulatory agencies, etc. These are not well covered by the bibliographic databases tested here. These files were excluded from this study, which focused on scientific files. A specific search of such files as Federal Register (for US material), HSEline (for UK and other European information), SIGLE (for European information) and so on would show the extent of toxicological information present, the ease of retrieving it, and its general utility.
3. **citation searching:** rather than using subject terms to access bibliographic information, this approach uses citations by later documents as access points. In practice, this means use of some form of ISI's Science Citation Index.

Investigations on each of these are now reported.

6.10.1 Databanks

The measures of evaluation for databanks are necessarily somewhat different from those for bibliographic databases, since only one record will generally appear for each chemical substance; recall and precision are not appropriate measures. An

evaluation, assuming it is based on a query involving some toxicological properties of a chemical substance, or series of substances, must essentially answer four questions:

- does the substance of interest have a record in the databank ?
- is relevant toxicology information given in the record ?
- how extensive is that information ?
- how useful is that information ?

The first questions can be answered simply, the second and third fairly straightforwardly. The fourth is much more difficult, raising as it does issues of quality, accuracy, reliability, and completeness, and can only be answered satisfactorily as part of a case study, involving a 'real' information need, or a simulation of one. For the purposes of this work, the analysis aimed to answer the first two questions, and deal with the third only partly, by a consideration of the nature of the information provided by each source.

Each source was queried to identify records for the substance of interest, searching by Registry Number or text terms as appropriate. The records were then printed out and examined; usually this was the full record, though for files with very long records, such as HSDB or Beilstein, only the relevant section was printed.

The queries were based on modifications of the test queries from the evaluations above which involved single chemical substances. In the case of the chlorocresols query, one compound was chosen as representative, to avoid the complexities of a comparison of substructure searching facilities, since several of these databanks have this capability; although of relevance to their overall utility, it was not the main issue here (see, for example, Costigan, Wood and Bawden (1985) for a comparison of search interfaces to the RTECS databank). The toxicity aspects of some queries have been somewhat simplified, to allow for as clear a decision as possible as to whether the information was or was not present. The query was regarded as successfully answered if the databank gave information as follows:

lavender oil	contact toxicity
sage oil	any toxicity data
formaldehyde	teratogenicity
ethylene glycol	ecotoxicity
propoxur	aquatic toxicity
styrene	human mortality

toluene	acute inhalation toxicity
angelica	acute toxicity
4-chloro-o-cresol	carcinogenicity or mutagenicity
dioxin	chloracne

The following databanks were investigated:

- **RTECS Registry of Toxic Effects of Chemical Substances**
A comprehensive database of 'basic toxicity information' for over 100,000 compounds.
- **CHEMTOX**
A comprehensive collection of data on 6,500 'regulated toxic and hazardous substances'
- **DOSE Directory of Substances and Effects**
A compilation of essential data on 4,000 substances, providing a guide to 'their impact on humans, animals and the environment'
- **PFF Pesticide Fact File**
Provides information on the active components of agrochemical products
- **Merck Index**
A one-volume encyclopaedia of chemicals, drugs and biologicals, corresponding to the printed Merck Index
- **Beilstein**
Extensive collection of data on organic compounds, corresponding to the printed Beilstein Handbook
- **CHDC Chapman and Hall Chemical Database**
Source database for chemical identification and properties, including hazards and toxicity, corresponding to several printed chemical dictionaries
- **HSBD Hazardous Substances Databank**

HSDB was searched on the Datastar host, all the other sources were searched on Dialog.

Although it seemed obvious that some substances would not be present in certain files, e.g. styrene would not be included in the Pesticide Fact File, as it is not known to have such a biological activity, all substances were checked in all databanks, for completeness and consistency.

Results, in terms of coverage, toxicity data present, extent of data and usefulness of data, are given as appendix 6.10a.

The obvious limitation of the databanks is their coverage. In simple terms of inclusion of compounds of interest, only RTECS included all 10 compounds of the test query set. However, in terms of including relevant information, only 6 of the RTECS records were useful. The best performance, in this respect, was from DOSE and HSDB, each of which gave relevant information on 7 out of the 10 compounds.

It is therefore clear, on these grounds alone, that these resources are not a replacement in themselves for bibliographic databases, and other sources, and certainly should not be regarded as a kind of 'one stop shop' for toxicology information.

Furthermore, as with bibliographic databases, a combination of databanks will be needed to give reasonable coverage. In this example, to get some information on each of the 10 substances would have required a combination of RTECS with either HSDB or DOSE.

Beyond this, there is the question of the extent of information provided for each toxic manifestation for each compound, and the validity and reliability of the information provided. Both of these points are discussed in the appendix, with the conclusion that such sources cannot replace access to the primary literature.

Apart from their ability to provide toxicology information directly, as assessed in this study, it should be noted that databanks of this kind may also be valuable to the toxicologist in providing 'background information', such as uses and extent of use of a substance, legislative and regulatory requirements, physical and chemical properties, and so on. As with printed handbooks and data compendia, these resources have the advantage of offering such information conveniently and in one place.

It is not likely that databases and databanks would be searched simultaneously, even in those cases where they can be accessed through a common search system, (e.g. Dialog) because of the differences in record size and structure, and in access points. The best approach is likely to be to use one or more databanks first, since these will give a structured summary of information immediately. This may be sufficient to answer the question, but more probably will be useful as a starting point for a follow-

up search of databases, looking either for more instances of toxic effects, or for more specific information.

6.10.2 Grey literature

This part of the study focused on specialised online databases, which had not, for the most part, been used in the evaluations (the exception is Occupational Safety and Health, which was included in the 'formaldehyde' test query). The databases, all available on Dialog, and chosen as being likely to be useful, and as typifying this kind of resource, were:

- Occupational Safety and Health
- Chemical Safety Newsbase
- Federal Register
- NTIS (National Technical Information Service)

The first two, being geared to safety information, are likely to have some toxicology material. The third, reporting US government regulations and associated documentation, is not subject specific, but will include some toxicology material, in view of the extent of the regulations surrounding potentially hazardous substances. The fourth includes unpublished reports, particularly from US government sources but also including worldwide report literature; this type of material does include toxicology information, and is covered, to some extent, by databases such as Toxline and CA Search.

Searches were carried out on five of the evaluation queries, using essentially the same search logic; since these searches were undertaken some months after the evaluation queries, the results are not directly comparable. However, this is not significant, since only a general impression of the value of the value of these databases, in providing useful grey literature, is being sought. The results are given below, as simple measures of retrieval and relevance. A limited failure analysis suggested that little more would be found by expanding the search logics (to be expected, as an optimised search strategy was used from the first), and would not affect the overall results. Relevance from Federal Register was particularly difficult to decide, from very long and unstructured records without abstracts, and covering a variety of regulations, announcements and guidelines; they are therefore recorded as 'possibly relevant', without affecting the overall general results.

Occupational Safety and Health, Chemical Safety Newsbase, and NTIS, are typical bibliographic databases. Federal Register presents particular problems in searching, in that it is a full-text database, whose records are often very long and poorly structured, and title uninformative, and it is therefore difficult to use online. Results for these searches are given in appendix 6.10b.

Occupational Safety and Health, and Chemical Safety Newsbase, were of limited value. They returned a small number of items, which were largely relevant. They could not compete for recall with the biomedical databases, and all the useful items retrieved had been found, in the evaluations, from other sources. It is also worth noting that the items retrieved from OSH were, in the main, journal articles, rather than grey literature. CSN's small number of retrievals was a mixture of journal articles and BIBRA toxicity reports; the latter certainly count as grey literature, but these were the only examples retrieved.

NTIS returned only 3 relevant items in all; these were all BIBRA toxicity reports.

Federal Register was not useful. It presented a number of items for each search, but generally did not present anything which might be useful. Where toxicity data was given, it was often hard to identify in the lengthy record, and its provenance was not clear.

This study was not pursued, nor any failure analysis carried out, since the message seems clear; these databases are not very useful for 'general' toxicology searching, as typified by these queries, though they may be valuable for particular sorts of queries, e.g. those requiring specific information on occupational exposure, or safety regulations. Even here, they show no capability of retrieving any amount of useful grey literature.

6.10.3 Citation searching

Citation searching involves the retrieval of published articles, and similar items, by identifying those which cite an earlier item, known to be relevant, and therefore presumably have some similarity in content. This form of searching, which can form a useful complement to 'conventional' subject retrieval, can, for scientific information, in practice only be carried out on the citation indexes produced by the ISI. A general overview of citation searching is given by Bawden (2001), who emphasises its value as

a complement to subject searching; this aspect is also noted for biomedical subjects by Brown (1998) and by McCain (1989). It is especially useful for identifying particular perspectives, viewpoint, or schools of thought, and can lend an element of 'serendipity' to a search, showing possibly unexpected relations between subjects. However, it may compare badly in both recall and precision with conventional searching in some cases (Bawden 2001).

There are two aspects to be considered in assessing the value of citation searching: the database, and the citation process itself. The ISI databases have a smaller coverage than the major biomedical sources, concentrating on 'core' publications across a wide area: in the case of SciSearch, this would incorporate all of science, technology and medicine. This may be seen as both a strength, since it gives access to the 'important' literature across a wide subject range, and a weakness, since it omits many publications in the subject areas of interest.

An earlier study, comparing means of retrieving toxicology information, suggested that citation searching was not particularly useful for this purpose (Bawden and Brock 1982), and this was the subject of subsequent correspondence (Kimberley 1983, Bawden and Brock 1983). The evaluation study reported above did not use citation searching, though it indicated that subject searching on the SciSearch database was not generally very useful for toxicology information. It was therefore decided to investigate this issue further.

The 10 test queries used in the evaluations were considered unsuitable for this study for two reasons:

- there was no obvious 'starting point' paper, to be used as a 'seed' for citation searching
- the queries were all concerned with toxic effects of substances; while this is a valid type of query for citation searching, it was thought worthwhile including others, e.g. methods and general concepts, for which citation searching might be expected to have particular advantages

Six new example queries were therefore chosen to investigate the effectiveness of citation searching, and each was examined in the same way. First, a major article on an aspect of toxicity, such as might be the starting for a citation search in a 'real-life' setting, was chosen. Articles citing it, and published during an appropriate time period were identified; generally this period was taken by starting from the year

following the publication of the original cited reference, and going up to 1998, the last year for which complete citation records were available. A relatively simple subject search was constructed and carried out in SciSearch on Dialog, against the title, abstract and author keyword fields, over the same time period. Relevance was judged from title and abstract, and the two searching methods compared. In those few cases where the relevance could not be judged in any way - in particular for the results of citation searching, where the reason for the citation was unclear, the original article was examined.

The results are shown in appendix 6.10c.

Although this study is based on only six examples, the results seem clear. Citation searching generally did not perform as well, in terms of recall, as subject searching on the SciSearch database, the only exception being query 6, in which citation searching recall was superior.

Precision factors were more mixed, subject searching giving superior precision in queries 1, 2 and 3, citation search precision being superior for queries 4, 5 and 6.

Unique articles were found by citations searching only in query 6. The other unique items found were two letters, in query 3. These could not be found by a subject search on Scisearch, but could be found by subject searching other databases, though the coverage and indexing elsewhere was limited.

The superiority of recall of subject searching would obviously be greater if databases other than SciSearch, with their wider coverage and additional subject indexing and coding, were included. Given the importance of recall in toxicology searching, this seems to indicate severe limitations on the value of citation searching.

It is therefore likely that citation searching will not be a routine means of retrieval for toxicology queries. It may be useful in three circumstances:

- when comprehensiveness must be ensured, when it can be an additional means of ensuring that nothing has been overlooked
- if a particularly significant publication is found, and when citation searching will be a good way of finding follow-up comments - though, as shown by example 3, this can be achieved in other ways
- when it is useful to find a quick overview of an area, as in example 2 here

6.10.4 Summary of further work

These additional studies show that substance databanks can be useful complements to bibliographic databases for toxicology searching, that citation searching may be of use in specific circumstances, while the grey literature databases appear to be of limited use. It seems clear that bibliographic databases, for all their limitations, remain the primary tool for toxicology information retrieval.

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Chapter Seven: Toxicology vocabularies

7.1 Introduction

In this chapter, the most significant vocabularies - classification and coding schemes, thesauri / subject headings and dictionaries / glossaries - of relevance to toxicology are identified, described and evaluated. This includes those vocabularies which are currently widely used in practice, and those which are of historical interest.

The purpose for examining existing indexing vocabularies is two-fold:

- to assess how toxicology, and associated concepts, are treated within them, so as to better understand how the subject area has been, and is, understood in information terms
- to assess the adequacy of existing subject descriptions, and hence the quality of classification and indexing of toxicology material which is possible using them

Glossaries and dictionaries are examined so as to give another perspective on the perceived scope of toxicology, and the inter-relation of its constituent concepts. Of particular interest are those glossaries which include thesaural relations between at least some of the terms.

No attempt is made to give a full description of the principles underlying the construction and use of classification schemes, thesauri and other controlled vocabularies, as these are fully covered elsewhere; see, for example, Svenonius (2000), Aitchison, Gilchrist and Bawden (2000), Marcella and Maltby (2000), Taylor (1999), Foskett (1996), and Marcella and Newton (1994).

As a simple test of the capabilities of some of the vocabularies to deal with toxicology concepts, a 'toluene inhalation' example is used. This examines the way in which the vocabulary could be used to index a study on the acute toxicity of toluene vapour by inhalation, in the rat, demonstrating lung irritation and quoting an LD50 value. While using one example is by no means a conclusive comparison, it is sufficient to give an

immediate indication of which vocabularies can deal with all aspects of this, fairly typical, toxicology material, which cannot, and where their limitations may be.

Knowledge organisation tools originated as printed documents, used for the production of printed indexes and catalogues, and for the arrangement of physical materials. In recent decades, both the tools themselves, and the materials to which they are applied, are likely to be in digital form. This has many implications for the way in which these tools are developed and used [see, for example, Marcella and Maltby 2000, Aitchison, Gilchrist and Bawden 2001]. Most obviously, there is continuing debate about the value of such tools, when efficient full-text searching can be assumed to be possible [see, for example, Rowley 1994], and when automatic indexing and classification, based on analysis of full-text, is becoming feasible [see, for example, Roberts and Souter 2000, Toth 2002]

However, the view of the subject discipline provided by an examination of such tools is largely unaffected by such issues. The intellectual considerations in the design of 'traditional' classifications, thesauri and so on, largely relate to the subject area itself, and to the concepts and inter-relations within it. These are unchanged by the physical/digital nature of the tools, and their use in practice, so that an examination of such tools remains a valid means of studying a domain from an information science perspective [Hjørland 2002].

7.2 Bibliographic Classification Schemes

7.2.1 Dewey Decimal Classification

'The confusion of the contents of the Amherst College Library in 1872 must have presented to Melvil Dewey, student library assistant, a similar challenge to that of his mother's pantry when, at the age of five, he rearranged it systematically' (from the Editor's Introduction to the 16th Edition of the Dewey Decimal Classification)

The Dewey Decimal classification scheme claims to be the most widely used of the general classification schemes. Sweeney (1991) found that in the early 1990s it was used by over 200,000 libraries in 135 countries, and had been translated into 30 languages. It has recently been adapted for classification of Internet material, by services such as BUBL and OMNI. Its treatment of toxicology is therefore worth examination. With its various editions, it also serves as a good example of the way in which such large schemes change over time.

The classification was devised by Melvil Dewey, while still a student librarian, for subject arrangement of the bookstock of Amherst College, Massachusetts. It has been through numerous revisions, the current edition being the 21st, published in 1996. The history of the first eighteen editions has been discussed in detail by Comaromi (1976), who points out that the structure of knowledge as set out in the first, and even more so in the second, edition, is essentially the same as that found in subsequent editions. Other descriptions and analyses of the scheme are given by Marcella and Newton (1994), Foskett (1996), Scott (1998) and Mitchell (2000).

Dewey's basic idea was to select nine main classes of knowledge (ten including Generalities), and to represent these by an Arabic numeral; then to divide these into nine subordinate classes, each represented by a digit in the first decimal place; and to further subdivide in this way as far as necessary. Three points are worth emphasising.

First, although, in his initial writings on the scheme, Dewey claimed to have 'number[ed] a classification of all human knowledge in print', his primary concern was for the practicalities of library usage rather than of classification theory; and his scheme has been criticised on theoretical grounds ever since.

Second, the fact that DDC, or any other decimal classification, uses a notation with ten divisions at each stage, does not require that the subjects being classified must be divided into ten, and only ten, divisions. In some cases, there are more than ten entities, and several must therefore share a number; in other cases, there are less than ten, and they must therefore be 'spread' over the numbers, or some may be left 'spare'. 'Decimal' refers strictly to the notation, and not to the analysis of knowledge; such schemes are thus not as rigid as might be supposed simply from their name.

Third, from as early as the second edition, Dewey promised an 'integrity of numbers', that is to say that there would be no major changes in the allocation of numbers to subjects, thus assuring librarians of the stability of the scheme, and an avoidance of a consequent need for reclassification. This pragmatic attitude has had the effect of stultifying this scheme to a large extent, and thereby making it appear ill-suited to rapidly changing subject areas. The promise has, in fact, been broken in some areas, such as chemistry, where to retain the original structure would have condemned the scheme to complete obsolescence.

Dewey admits he did not obtain his ideas *de novo*; he is said, by various writers, to have been influenced by the classificatory theories of the philosophers Aristotle, Bacon, Locke and Hegel, by the ideas of Natale Battezzati (an Italian bookseller) for a system of classified card to announce to booksellers what books were being currently published, and by earlier library classifications of Jacques Charles Brunet (a French bibliographer), Jacob Schwartz (at the Apprentices' Library of New York), Edward W. Johnson (of the College of South Carolina), and William T. Harris (of the St Louis Public School Library). Be that as it may, his was the first decimal classification to attain wide usage.

Dewey's initial scheme had 10 main classes, which have remained essentially unchanged since, though their names have changed, as can be seen from this comparison of main class names in the 1st, 16th and 20th editions:

	1 st	16 th	20 th
000	unnamed	General works	Generalities
100	Philosophy	Philosophy	Philosophy and psychology
200	Theology	Religion	Religion
300	Sociology	Social sciences	Social sciences
400	Philology	Language	Language
500	Natural science	Pure science	Natural sciences & mathematics
600	Useful arts	Technology	Technology (applied sciences)

700	Fine arts	The arts	The arts
800	Literature	Literature	Literature and rhetoric
900	History	History	Geography and history

The place of toxicology and poisoning has, from the first, been rooted in the medicine sections of the 600 class. In the first edition, this class was sub-divided as follows:

610	Medicine
611	Anatomy
612	Physiology
613	Hygiene
614	Public Health
615	Materia Medica and Therapeutics
616	Pathology, theory and practice
617	Surgery and Dentistry
618	Obstetrics and sexual science
619	Veterinary medicine

These sections were not significantly changed in the seminal second edition, Dewey's explanation being that it seemed better to await more detailed subdivisions of medicine, which would be incorporated into the schedules at a later stage; and indeed, the incorporation of more detailed schema for medicine was a continuing task for the Dewey editors. This initial division of medicine set the scene, however, providing scope for the 'drug' and 'poison' aspects of toxicology within 615, and for the public health aspects within 614.

The classification scheme showed a steady growth up to the 14th edition, as noted in this list of numbers of pages for the classified schedules, taken from the introduction to the 16th:

Edition	Date	Pages
1	1876	12
2	1885	162
3	1888	227
4	1891	234
5	1894	235
6	1899	260
7	1911	420
8	1913	462
9	1915	465
10	1919	517
11	1922	551
12	1927	683

13	1932	902
14	1942	1048
15	1951	469
16	1958	1312

This growth was largely due to increased detail, but on a rather *ad hoc* and piecemeal basis; Comaromi (1976), for example, notes that the 610 medicine class was 'expanded to enormous proportions' in the 7th edition. As a reaction to this, the 15th edition was drastically shrunk in size, reflecting a desire to bring the scheme up to date, by basing the schedules firmly on literary warrant; for one thing, any subjects not represented by books in the Library of Congress were removed from the schedules. There was a dramatic reduction in detail across all subjects, with 31,000 headings reduced to 4,700; medicine, for example, dropped from 68 pages to 10. This was unpopular, particularly with librarians outside the USA, and the edition was not well accepted. The 16th edition largely reversed the changes, while retaining some of the up-dated features, and returned to the general pattern of the 14th edition, and of the development of the classification as a whole.

Subsequent progress has been generally conservative and incremental, though the necessity to restructure whole sections has been accepted, and dealt with by the introduction of 'phoenix schedules', later more prosaically termed 'complete revisions'; for inorganic and organic chemistry (546 and 547), for example, in the 16th edition.

Dewey edition 16

The 16th edition of Dewey's classification published in 1958, was generally regarded as a particularly successful variant, after the failures of the 15th (Comaromi 1976), and was described by Godfrey Dewey, Melvil's son, as 'far and away the most valuable and appreciated edition in DC history' (Comaromi 1976, p 518). EJ Coates, then chief subject cataloguer of the British National Bibliography, viewed that edition as the point at which Dewey's classification finally caught up with 'contemporary knowledge as found in books' (Coates 1959). This edition therefore seems an appropriate point to consider the place of toxicology in this scheme.

The concept of 'toxicology' occupies the 615.9 position in the 615 area, which is now 'Therapeutics and Pharmacology'. The detailed schedule is shown below:

615.9	Toxicology
615.902 4	Industrial toxicology

615.902	5	Detection of poisons and poisoning
615.91		Gaseous poisons
615.92		Mineral (inorganic) poisons
.921		Acidic poisons
.922		Alkaline poisons
.923		Nonmetallic poisons
.924		Phosphorous
.925		Saline poisons
.926		Arsenical poisons
.927		Mercurial poisons
.928		Lead poisons
.929		Copper poisons
615.93		Vegetable poisons
615.94		Animal and food poisons
.942		Venoms
.944		Food poisons
.945		Naturally poisonous foods
615.95		Organic poisons
		Cerebral, spinal, cerebrospinal and cerebrocardiac poisons
		<i>These are to be arranged alphabetically using A1 for comprehensive works,</i>
		<i>e.g. 615.95 A2 for aconite</i>

The schedules note that the organic poisons section had undergone a change since the 14th (1942) edition; the various 'neurotic poisons' - cerebral etc. - classed at 615.95, had previously had their own numbers at 615.96 - 615.99.

From today's perspective, the enumeration of the inorganic poisons seems distinctly old-fashioned. The alphabetical arrangement of organic substances at 615.95, while allowing more flexibility than for the inorganics, restricts the classifier to specific substances, or groups of substances, with a single, easily-alphabetised, name. Other than this, this schedule would serve to classify toxicology material understood as a simple 'action and detection of poisons' concept.

The discipline of toxicology was, even at this point in time, rather broader than the above single aspect implies. Other constituent concepts represented in this edition were located so as to build up a full picture of the way the scheme handled toxicology. It is perhaps not surprising that this proved to be a cumbersome task, as the purpose of the scheme was to arrange items in a library, and not to define any one discipline in its entirety. In order to identify all terms and classes within the frame of toxicology, it was necessary to look through the schedules, and consult the indexes. The following additional entries were identified:

Toxic or side effects of drugs are not referred to specifically, and would seem to fall under Pharmacology, 615.1.

'Toxins' are classed separately at 615.373, in the 'serum therapy' section.

Toxicology-related material also appeared in the 'Public Health' (614) section. 614.28 (within 614.2 'state control of medicine') dealt with control of sale of poisons, 614.3 covered 'food and drug control', including adulteration, while 614.7 ('sanitation and sanitary control') covered air (614.71), water (614.772) and soil (614.776) pollution.

Toxic chemicals are not mentioned (this being before the rise in concern about such matters), the schedules instead refers to 'noxious gases' and the like.

Although 'industrial toxicology', as noted above, is listed at 615.902 4, the closely related 'industrial hygiene' appears at 331.82, in the 'Industrial Sociology' (331.8) section of 'Labor economics' (331). Again, chemical hazards *per se* are not mentioned in these sections.

Likewise, although detection of poisons and poisoning is listed at 615.902 5, the broader Medical jurisprudence, or forensic medicine is classed at 340.6, within the 'law' (340) section.

It is clear that the different components of our discipline are scattered throughout this scheme, as with others, and that to extract everything relevant requires existing knowledge of the component topics. Simply looking up toxicology under 615.9 is not sufficient.

Also worth noting are the limitations of the scheme with respect to representing the toxicology of individual or groups of substances, or specific sub-disciplines. Chemical hazards (pollution/occupational safety) have also yet to make an impact, as have side effects of drugs.

Despite the success of this edition, it was still found wanting for specialist, particularly scientific, material. Brian Vickery, comparing Dewey unfavourably with UDC for these purposes, argued that the inability of DDC16 to deal with compound subjects, and a general inadequacy in providing for current scientific ideas, disqualified it for use in special libraries (Vickery 1959).

Dewey edition 18

Some changes had been made by the time of the publication of the 18th edition in 1971. To begin with, some finer details had been worked in to the main toxicology section, 615.9.

- For the first time, the concept of 'toxicologist' was introduced, at 615.900 92
- The 615.902 entries had been renumbered, and the general concepts of prevention and treatment of poisoning added to this sequence.
- The rather dated sequence of inorganic poisons in 615.92 (saline poisons, arsenical poisons etc.) had been replaced by 'specific inorganic poisons' at 615.925, with instructions to synthesise notations for specific poisons by adding the relevant notation for inorganic substances.
- The vegetable poisons class at 615.93 had been moved to be a sub-set of organic poisons at 615.952
- The distinction between food poisons (615.944) and poisonous foods (615.945) of the 16th edition had been abandoned, all these being amalgamated in 615.945, but with instruction to class specific kinds of food poisoning at either 615.945 (animal poisons), 615.952 (vegetable poisons), or outside the toxicology sections entirely, e.g. botulism at 616.9315.
- In 615.95, the alphabetic arrangement of organic poisons in the 16th edition was replaced by the alternative of this arrangement, or alternatively a synthesis of numbers of 615.951 or 615.952 with class numbers for synthetic compounds or vegetable-derived substances respectively.

The full 615.9 schedule of the 18th edition was thus:

615.9 Toxicology (poisons and poisoning)

Use 615.9001 - 615.9009 for standard subdivisions

615.902	Industrial toxicology
.905	Prevention of poisoning
.907	Tests, analysis, detection of poisons and poisoning
.908	Treatment of poisoning
615.91	Gaseous poisons
.92	Inorganic poisons
.921	Acids
.922	Alkalis
.925	Specific inorganic poisons (Add to 615.925 the numbers following 546 in 546.2-546.7, e.g. mercurial poisons 615.925663)
615.94	Animal poisons
.942	Venoms
.945	Poisonous food animals
615.95	Organic poisons

	(Arrange by kind as below, but, if preferred, arrange alphabetically) (organic gaseous poisons are classified at .91)
.951	Synthetic and manufactured poisons (add to 615.951 the numbers following 547.0 in 547.01-547.08, e.g. ethers 547.95135)
.952	Vegetable and vegetable-derived poisons (add to 615.952 the numbers following 58 in 583-589, e.g. opium 615.9523122)
.954	Food poisons and poisoning (Class pathology and treatment of a specific kind of food poisoning with the subject, e.g. botulism 616.9315, poisonous food animals in 615.945, vegetable and vegetable-derived poisons in 615.952)

Additionally, a new class number had been added at 604.7 for 'Hazardous Materials Technology', including the processing, handling etc. of toxic materials, presumably reflecting increased concern about, and publication on, this topic in the late 1960s.

The entry for Industrial Toxicology at 615.902 remains in this edition. However, the companion concept of Industrial Hygiene, listed at 331.82 in the 16th edition, is now present at 613.62, within Medicine, Hygiene. (This move occurred in the 17th edition).

Forensic medicine, previously classed within Law at 340.6, moves to 614.19, within Public Health, for the 18th edition. This places the legal aspects of toxicology with the regulatory issues, which so far cover sale of poisons, air, water and soil pollutants, and food and drug adulteration. This is rather ambitious, and later schemes separate these concepts into the more subtle divisions in use today.

Additionally, risks associated with Hazardous Chemicals are listed for the first time in the 18th edition, also under section 614. Specifically:

614.8	Safety
..	
614.83	Safety in making and use of hazardous materials
..	
614.832	Chemicals

In this edition, it seems that there is some attempt to consolidate toxicology concepts, bringing them into two main classes, Pharmacology and Therapeutics, 615, and Public Health, 614.

Dewey 20th edition

The 20th edition of Dewey's Classification (1989) had user convenience as its main aim, and featured more extensive faceting.

It retained essentially the same structure for the 615.9 section as in the 18th edition, with the following modification:

- new numbers at .900 1 had been added for 'philosophy and theory'

(This may perhaps reflect a new perceived status for toxicology as a science in its own right during the 1980s)

- the alternative for alphabetic specification of organic poisons had been withdrawn, with synthesis of numbers now the only approved method
- the definition of food poisons at 615.954 now reflected the increased significance of food additive toxicity

Thus, Toxicology *per se* still appears as 615.9, within the general area of medicine.

600	Technology (applied sciences)
610	Medical sciences. Medicine.
615	Pharmacology and Therapeutics

At this stage, however, there is an entry for toxic reactions of drugs at 615.704. The manual comments, on the choice between 615.7 (Pharmacodynamics) and 615.9 (Toxicology):

Class toxic effects and interactions of drugs primarily of pharmacodynamic interest in 615.704 or with the system affected in 615.71-.78. However, a drug primarily of pharmacodynamic interest may be considered a poison if it is so toxic that a single inadvertent ingestion would cause serious complications or death, e.g. pharmacodynamics of atropine (belladonna) 615.7 - not in any specific subdivision because it affects several systems - but the toxicology of belladonna 615.9523952. If in doubt, prefer 615.7.

Note that the number for belladonna toxicology is created from:

615.952	poisons derived from plants
583.952	Solanaceae (Nightshade family) in the botany section.

The detailed schedules for this area are:

615.9	Toxicology
615.900 1	Philosophy and theory

615.900 2	Miscellany	
615.900 3-9 e.g.	Standard subdivisions	
615.900 92	Toxicologists	[-092 being the standard sub-division for persons]
615.902	Industrial toxicology	including toxicology of pollution, environmental pollution
615.905	Prevention of poisoning	
615.907	Tests, analysis, detection of poisons and poisoning. Toxicity testing.	
615.908	Treatment of poisoning	
615.91	Gaseous poisons	
615.92	Inorganic poisons	
.921	Acids	
.922	Alkalis	
.925	Specific inorganic poisons (including specific acids and alkalis)	
615.94	Animal poisons	
.942	Venoms	
.945	Poisonous food animals	(e.g. poisonous fish, and including food animals made poisonous by microorganisms)
615.95	Organic poisons	(except gaseous organic poisons, which are 615.91)
615.951	Synthetic and manufactured poisons	
.952	Plant and plant-derived poisons	
.954	Food poisons	(including toxicology of food additives)

Synthesis is possible, to classify poisoning by specific agents, for 615.925 (specific inorganic poisons), for 615.951 (synthetic organic poisons), and for 615.952 (plant poisons).

For inorganic poisons, the numbers following 546 in 546.2 - 546.7, representing specific inorganic substances, are added to the 'base number', i.e. 615.925. For example, for mercurial poisons, 663 is added, to give 615.925663

For synthetic organic poisons, the numbers following 547.0 in 547.01 - 547.08, representing specific organic substances, are added to the 'base number', i.e. 615.951. For example, for ether poisons, 35 is added, to give 615.95135

For plant poisons, the numbers following 58 in 583-589, representing specific plants, are added to the 'base number', i.e. 615.952. For example, for opium, 3122 is added, to give 615.9523122. For bacterial food poisons, 99 is added, to give 615.95299

Aspects of toxicology can still be found within the Public Health section, 614. Forensic medicine is listed at 614.1, rather than 614.19, and specific mention is now made of forensic toxicology. The regulatory issues, sale of poisons, food and drug adulteration, are still listed under 614, but toxicology of pollution is now listed elsewhere. In the main 615.9 section, under Industrial Toxicology, there is an entry for toxicology of pollution:

615.902 Industrial toxicology
 including toxicology of pollution, environmental pollution

The pollution of air, water and soil has moved to 363.739 (within Environmental Problems and Services):

360 Social problems and services
363 Other social problems and services
363.1 Public safety programs
363.17 Hazardous materials
363.179 Specific hazardous materials

The index has a reference to 363.179 for 'toxic materials', but the more specific class is:

363.179 1 Toxic chemicals

and also:

360 Social problems and services
363 Other social problems and services
363.7 Environmental Problems and Services
363.728 Wastes
363.728 7 Hazardous wastes, toxic wastes, toxic spills

363.738 Pollutants
 (including chemical pollutants generally, and also
 specific pollutants in specific environments)
363.738 4 Toxic chemical pollutants
 (including lead emissions and pesticides)
363.739 Pollution of specific environments
363.739 2 Air pollution
363.739 4 Water pollution
363.739 6 Soil pollution

So, we now see an expanded emphasis on toxic chemicals, and pollution of specific environments. However, the two places for pollution are confusing, and indicate the complexity and interrelated nature of the field.

This edition also introduces the ability to specify target organ toxicity, the effects of poisons on specific systems and organs, at 616-618 (diseases, surgery, medicine).

The major distinction between this and earlier editions is the consistent usage of synthetic numbers for inorganic, organic and plant poisons, allowing the specification

of 'poisoning by ...' / 'toxicology of ...' in as much detail as the chemical and botanical schedules allow. This allows the rather general classes of the 20th edition's 615.925, 615.951, and 615.952 to replace the enumerations and alphabetical arrangements used previously.

Toxicology concepts are once again rather scattered, occurring within several sections and sub-sections, in contrast to the concise approach evident in the 18th edition. The discipline has once again become complex, and hard to define.

Dewey 21st edition

The 21st edition of Dewey, produced in 1996 is the latest version of this scheme [Dewey Decimal Classification and Relative Index, Edition 21, J.S. Mitchell (ed.), Forest Press, Albany NY, 1996] (Scott 1998). Its main distinction from the 20th edition was in facet capabilities, the introduction stating: 'this edition reaffirms faceting as a direction for future revisions and as a means of strengthening the subject retrieval capabilities of the Classification, especially in an online environment.'

No significant changes were made to the 615.9 Toxicology section from the 20th edition. The entries for side effects of drugs were modified slightly to separate out the concept of adverse reactions and side effects as shown:

615.7	Pharmacodynamics
	Physiological and therapeutic action of drugs
..	
615.704	Special effects and actions of drugs
	class here adverse reactions, toxic reactions
615.704 2	Side effects

Toxins, 615.373, remains at this point, at it has from the 16th edition.

No significant changes occurred in the 363 Pollution section. Toxicology entries under 614, Public Health, also remain stable. Industrial Hygiene is now termed Industrial Health, but stays at 613.62. The rather similar Industrial Toxicology heading is also still present at 615.902.

Target organ toxicity and chemical hazardous technology also remain.

However, the 560-590 Life Sciences sections were fully revised and faceted, providing two extra places for toxicology material.

571.95 provides an alternative placing for toxicology, defined as *diseases and stress caused by pollutants, water pollution, ecotoxicology, environmental diseases and poisons*.

The full schedule is:

570	Life Sciences. Biology.
571	Physiology and related subjects
571.9	Diseases. Pathology.
571.95	Toxicology
571.954	toxicology of spec. elements & groups of elements
571.956	toxicology of air pollutants
571.957	toxicology of organic compounds
571.959	toxicology of pesticides

The specific numbers for toxicology of elements and groups are created by adding to the 'base number' 571.954 the numbers following 546 in 546.3 - 546.7, in the chemistry section.

Thus	546.3	metals
	571.954 3	metal toxicology
	546.663	mercury
	571.954663	mercury toxicology

The second of the new sections introduced within Life Sciences is in the Ecology section:

577	Ecology
577.2	specific factors affecting ecology
577.27	effects of humans on ecology
577.275	polluting acids, specific elements and groups of elements

Specific numbers within the latter are created by adding numbers representing elements or groups of elements as above.

Dewey 21 thus provides six main places for toxicology material:

363.1 and 363.7	toxic materials and pollutants
571.95	toxic effects of substances
577.275	ecotoxicology
614.x	forensic toxicology/regulatory issues
615.9	toxicology <i>per se</i> , particularly human toxicology
616-618	system-specific toxicology

The notes to the schedules spell out the distinctions clearly:

Many works on hazardous materials are not classed in 363. The material as an environmental factor affecting the natural ecology is classed in 577.275, as a

cause of disease or injury in an organism in 571.95 and as a cause of injury to persons in 615.9.

and

In using 571.95 and 577.27 for the studies of the effects of pollution and other deleterious agents, keep in mind the former is part of pathology (571.9) while the latter is part of ecology (577). Use the former for pathological conditions caused by pollution or other agents. Use the latter for more generalised effects of substances upon communities of organisms.

The user is advised, if in doubt to prefer the 363 numbers to the others, and to prefer the pathology section to ecology.

The 21st edition of Dewey therefore extends the scope of the scheme to deal with multifaceted nature of toxicology, and to link substances with effects by number building.

An abridged edition of this version of Dewey, abridged edition 13, was produced in 1997, 'for users who do not need the extensive detail of the unabridged edition'.

Toxicology is dealt with largely under 615.9

615.9 Toxicology

including 'prevention, diagnosis, treatment of poisoning; environmental, industrial toxicology; specific kinds of poisons, e.g. food poisoning, lead. Class here poisons and poisoning.

Cross-references are made as follows:

Forensic toxicology	614
Toxic reactions and interactions of drugs	615
Effects of poisons on specific systems and organs	616-618
Hazardous materials (public safety programs)	363.1
Environmental problems	363.7

This generally reflects the six-fold structure noted for the main schedules, though it does not include a reference to toxicology in the life sciences sections, nor system-specific toxicology.

Use of Dewey

In order to provide an assessment of the way in which the Dewey classification is used in practice, a set of books clearly related to toxicology were selected from the British Books in Print file on Dialog, and their Dewey classes examined.

55 books published in 1998-2000 inclusive, and having Dewey (21st edition) classification assigned, had the word 'toxicology' in the title. They fell into the following classes:

615.9	toxicology	22
363.1/.7	toxic materials / pollution	10
616-618	system-specific toxicity	8
571.95	toxic effects of substances	2
	other	13

No books were assigned to the regulatory (614) or ecotoxicology (577) classes.

'Other' included pharmacology (2), adverse drug reactions (1), other life sciences/medical (3), environmental engineering (2), information sciences (1), and application areas such as agrochemicals and the paper industry (4).

The scatter of toxicology material - fairly strictly defined - through the schedules is notable, with only 40% assigned to the 'main' toxicology class, and 25% falling outside the six classes identified as being the appropriate sections for toxicology material.

As a further check, Internet resources in the BUBL subject gateway, which also uses Dewey numbers, were identified. Only 7 resources used any of the terms 'toxic?' or 'poison?' (with ? indicating truncation) in the title of the resource. They fell into the following classes:

615.9	toxicology	3
615	pharmacology/toxicology	1
	other	3

'Other' were various life classes, not generally associated with toxicology. This is a further, albeit limited, example of the scatter of the subject across Dewey classes.

Dewey summary

Examination of editions 16, 18, 20 and 21 of Dewey has given a broad picture of the development of its treatment of toxicology from the mid-late 1950s to the mid-1990s. Simplistically, we can say that, throughout the period, toxicology retained its position

at 615.9, a sub-set of 610 - Pharmacology and Therapeutics - within the more general medical area; but this disguises considerable changes.

The example of the DDC is particularly informative, though this is acknowledged as by no means the best classification for scientific material. Through the changes in the Dewey schedule may be traced changes in perceptions of toxicology from a branch of pharmacology, with main focus on the effects of a limited range of poisons, and limited links to forensics and aspects of public health, to a science in its own right, with strong links to environmental issues, and with a need for a flexible linking of substances with effects.

At the start, toxicology was treated largely by an enumerative listing of specific and general poisons, with mention elsewhere in the schedules of the 'traditional' concerns of pollution of air, water and soil, adulteration of food, and industrial hygiene. There was no mention of sub-disciplines within toxicology, nor of issues such as side-effects of drugs, ecological effects of toxic materials, chemical hazards. Nor was there any recognition of toxicology as a discipline in its own right, nor of such a thing as a toxicologist.

From the 18th edition, more synthetic capabilities were added, to allow the toxicology of particular substances to be specified, so that by the end of the period the cause of poisoning could be specified to the degree of precision allowed by the relevant chemical, botanical and zoological schedules. The revision of the life sciences section in effect added a second main place for toxicology in the classification, focusing on toxic effects in general, as opposed to the simple 'poisoning' of 615.9.

Specific places were added for concepts of newly recognised importance, including side-effects of drugs, ecotoxicology, chemical hazards, and forensic toxicology. The concept of 'toxicologist' was introduced.

The 21st edition presents a basically five-fold view of toxicology, reflecting the five main aspects of: legal and regulatory; poisoning; toxic effects; toxic substances; ecotoxicology. This reflects the emergence, over a period of forty years, of toxicology as a multi-faceted science, from its status as simply the study of poisons.

7.2.2 Universal Decimal Classification

The origins of the UDC lay in the concept of two Belgians, Paul Otlet and Henri LaFontaine, who, in 1885, conceived the idea of a 'universal index to recorded knowledge'. For subject access, they decided upon a systematic order, using a numerical notation understandable worldwide, and obtained Dewey's agreement to extend his classification, then in its 5th edition, for their purposes. They used their prototype scheme to classify several thousand documents as a demonstration for an International Conference on Bibliography in 1895, and the scheme was published in 1905, under the auspices of the Institut International de Bibliographie; after several names changes, this organisation, by the Fédération Internationale d'Information et de Documentation (FID), passed responsibility for the UDC to the UDC Consortium in 1992.

Intended from the first as a genuinely international and multilingual scheme, UDC has been translated into many languages: one consequence of the difficulty and resource-intensiveness of this was the introduction of 'medium' and 'abridged' editions in over 20 languages. The scheme was introduced in English through the enthusiasm of SC Bradford, librarian of the Science Museum Library, and the British Standards Institution became the official British editorial body. Unfortunately lack of funds slowed their work; the first full English edition, begun in 1943 was never completed. It was published in parts, throughout the 1960s and 1970s. As a result, British users have had to rely on abbreviated editions. The third abridged English edition, BS1000A published in 1961, served for many years as the basic English edition, supplemented by the full schedules, where they were available, for specific subjects. A medium edition, containing 40,000 entries, twice as many as in the abridged edition, was completed in 1985, and a second medium English edition in 1993. A standard 'pocket edition' was published in 1999, and a web based version in 2001.

UDC began life based on the Dewey scheme, and attempts were made to keep them consistent at the three figure level, but the schemes have drifted apart over time, though they retain the same general structure. The UDC is much more detailed than Dewey, particularly in the Science and Technology sections, and allows much more subject synthesis. This reflects a basic distinction, in that Dewey was, and is, primarily intended for helpful stock arrangement in library, whereas UDC is geared to subject retrieval. The scheme is widely used worldwide, particularly in non-English-speaking countries, and in special libraries. It has been described in detail by

McIlwaine (2000A and B, 1995, 1994), and overviews are given by Marcella and Newton (1994), and by Foskett (1996).

Although many medical libraries use the NLM classification scheme, there remain a number which prefer UDC. The medicine class, 61, which includes toxicology, has not been revised since the 1960s, and is therefore considerably out-dated; a radical change, involving an integrated approach with the Bliss classification, has been in progress during the 1990s (McIlwaine 1998).

The place of toxicology in four editions of the scheme will be considered: the abridged BS1000A, representing the situation in the 1950s/60s, the medium edition BS 1000M of 1985 (McIlwaine 1987), the second edition of this, 1993, and finally, the abridged version published in 1999.

BS1000A 1961

In the abridged 1961 scheme, toxicology *per se* has the same number as in Dewey, 615.9, an example in which the two schemes have managed to keep step:

6	APPLIED SCIENCES. MEDICINE. TECHNOLOGY.
61	Medical Sciences. Health and Safety.
615	PHARMACY. PHARMACOLOGY AND THERAPEUTICS. TOXICOLOGY.
..	
615.7	Drugs according to action. Chemotherapy.
615.71	Acting on circulatory system, heart.
615.72	Acting on respiratory system.
...	
615.9	Toxicology. Poisons generally.
	<i>Specific poisons, use</i> 615.7...-099
	<i>Systemic poisoning, use</i> 616...- 099
616	DISEASE. PATHOLOGY AND MEDICINE
..	
616.5	Skin diseases. Dermatology
..	
616.52	Pustules, blisters: eczema, impetigo

This gives a simple means of specifying 'toxicology', which is located with pharmacology; specific poisons are treated as drugs, and their effects as diseases. Side effects of medicines are not mentioned.

Occupational safety and public health aspects appear at various points within the 61 section, which brings health and safety together with medical sciences:

613	Health. Preventive Medicine.
..	
613.6	Occupational and Industrial Hygiene

..	
613.63	Noxious gases, dusts etc.
614.3	Food, drugs, health and sanitary inspection, supervision and control
614.31	Food inspection, control
614.35	Drug inspection, control
614.7	Air, soil and water hygiene and sanitation. Pollutions. Drainage.
614.71	Air pollution, purity
..	
614.77	Soil and water pollution, etc.

The legal aspects appear somewhat separated, regulations on poisons with medicine:

614	Public Health and Safety
..	
614.2	Official and professional organization
..	
614.28	Sale of poisons

while forensic toxicology is removed entirely into the Law section:

34	JURISPRIDENCE. LAW. LEGISLATION
..	
340	LAW IN GENERAL. COMPARATIVE LAW.
..	
340.6	Forensic medicine and chemistry. Medical jurisprudence. Scientific questions.
..	
340.67	Forensic chemistry and toxicology

Public Health Engineering, 628, also contains aspects of health and safety:

..	
628.5	Industrial sanitation, nuisances
628.51	Specific nuisances: prevention, protection
628.511	Dust: various kinds
628.512	Noxious gases and fumes
628.513	Micro-organisms, bacteria
628.514	Steam as a nuisance
628.515	Noxious liquids, polluted water
628.516	Soil contamination
628.517	Noise and vibrations
.2	Protection against noise
628.518	Optical, electrical and other nuisances
628.52	Special measures against pollutions, noxious exhalations, effluvia, smells
628.53	Smoke and smog abatement
628.54	Treatment of factory effluents and waste

BS1000M 1985

The English medium edition (BS 1000M) retains the same basic structure, but provides a more logical arrangement, and a greater number of specific classification numbers for particular aspects of toxicology. The general facilities for synthesis in UDC allow flexibility in specifying toxicity of particular types of substance. Toxicology itself retains the 615.9 place:

615 PHARMACOLOGY. THERAPEUTICS. TOXICOLOGY.
 ..
 615.9 General toxicology. General studies of poisons and poisoning.

There is a special auxiliary subdivision to the 615 section:

615-099 Poisoning (intoxication). Addiction. Special toxicology.

This is used with subdivisions of:

615.2 Medicaments according to their principal action
 and
 615.3 Medicaments according to their origin

to specify toxicology of substances according to their pharmacological action,
 e.g. 615.211 general anaesthetics, or according to their general nature
 e.g. 616.322 vegetable substances

Toxins appear in the 615.3 section, at 615.372 (same as with Dewey). Antitoxins and
 antidotes appear in the 615.2 section, at 615.279, as do carcinogens at 615.277.

Toxicology material appears in the 616 'pathology and clinical medicine' section,
 with two special auxiliary subdivisions:

616-037 Effect of chemicals ..
 616-049 Venemous bites, stings. Poisoning from animal bites.

applied to the diseases specified in the 616 section.

Aquatic toxicology has its own place in the scheme:

573 GENERAL AND THEORETICAL BIOLOGY
 ..
 573.6 Applied hydrobiology
 ..
 573.64 Aquatic toxicology

as does structure-toxicity relationships, albeit in a general 'structure-activity' class:

541 CHEMISTRY
 ..
 541.6 Chemical structure in general. Chemical structure in relation to properties ..
 ..
 541.69 Relation of chemical structure to physiological properties.
 Taste. Smell. Toxicity.

Poisonous and toxic substances in general appear in the technology section:

620.2	COMMERCIAL MATERIALS..
..	
620.26	Dangerous goods or materials
..	
620.266	Poisonous and pathogenic substances
620.266.1	Poisonous, toxic substances

Occupational toxicity appears in a section on occupational hazards:

613.6	OCCUPATIONAL HAZARDS. INDUSTRIAL HEALTH AND HYGIENE
..	
613.63	Working with, and absorption of, noxious substances, eg .. chemicals ..

Forensic toxicology now appears, along with forensic chemistry, in a section on auxiliary legal sciences:

340	LAW IN GENERAL
..	
340.6	Auxiliary legal sciences
..	
340.67	Forensic chemistry. Forensic toxicology.

Regulations on the sale of poisons and narcotics remain in a section on organisation of health services:

614	PUBLIC HEALTH AND HYGIENE ..
..	
614.2	Public and professional organisation of health
..	
614.28	Sale of poisons, narcotics

Other specific aspects of toxicology having a definite number in the UDC are:

toxic effects of carbon monoxide	612.234
toxic effects on the heart	612.174
poisonous wastes	628.4.045
toxicity of paper	676.017.8

BS1000M 1993 2nd edition

The 1993 medium edition retains 615.9 as the main position for toxicology in the schedules. Still regarding this as equivalent simply to 'poisoning', it provides for fully faceted specification of poisoning by inorganic and organic compounds, or by plants or animals, by combination with the appropriate schedules.

615.9	General Toxicology, general studies of poisons and poisoning (intoxication)
615.91	Poisons in general
..	
615.916	Inorganic poisons

- Denote particulars by colon combination with subdivisions of 546 or by '1, subdivided as 546
- 615.917 Organic poisons
 - Denote particulars by colon combination with subdivisions of 547.21.9 or by '2/9 subdivided as 547.2/9
- 615.918 Vegetable poisons (phytotoxins)
 - Denote particulars by colon combination with subdivisions of 58
- 615.919 Animal poisons
 - Denote particulars by colon combination with subdivisions of 59

Elsewhere in 615, side-effect and adverse reactions of drugs are not described as such, but, as in the previous edition, may be specified by combining 'special toxicology' - 615.009 - with description of medicine by action (615.2) or by origin (615.3). There are specific places for 'over doses', 'toxic doses' and 'lethal doses' in 615.015. Antitoxins are at 615.279 and antidotes generally at 615.246.9.

Other aspects appear throughout the schedules, little altered from the previous edition.

Forensic toxicology remains in the law schedules at 340.67, while toxic substances in the workplace remain at 613.6 (occupational health):

613.6 Occupational health hazards, Occupational health and hygiene

- ..
- 613.632 Contact with toxic substances
 - ..
 - 613.632.2 solid
 - 613.632.3 liquid
 - 613.632.4 gaseous

and also in 620s (commercial materials):

620 Commercial Materials, Goods and Wares

- ..
- 620.266 Poisons and pathogenic substances
 - 620.266.1 Poisonous, toxic substances
 - 620.266.2 Poisonous, infectious substances
- ..

628.5 Measures against industrial and other nuisances

- ..
- 628.512 Measures against toxic gases and vapours. Including: exhaust ducts

Aquatic toxicology has a slightly altered place in the schedule (574.64 rather than the previous 573.64), in a section termed 'ecology' rather than 'general and theoretical biology'.

DISC PD1000 1999

This abridged edition offers three places for toxicology material:

615.9 General toxicology, general studies of poisons and poisoning (intoxication)

574.6 Aquatic toxicology

628.5 Toxic effluents; measures against

UDC summary

The development of UDC's treatment of toxicology may be assessed in a similar manner to Dewey, through four variants of two editions, in English, from 1961 to 1999.

UDC began life as a variant of Dewey, and, superficially, has treated toxicology in much the same way; as in Dewey, its main position was, and remains, 615.9.

UDC, however, unlike Dewey, gave toxicology a status of its own from the start. The 615 section was denoted 'Pharmacology, Therapeutics, Toxicology', whereas Dewey still denotes it simply as Pharmacology and Therapeutics.

At the start of the period UDC, like Dewey, focused on toxicology as simply poisoning - specific and systematic - with other aspects separated through the schedules. These other aspects - including industrial and forensic toxicology, pollution and food and drug control, had a somewhat more modern aspect than Dewey at this stage.

The major development over the period was a fully synthetic approach to poisoning, based on combination of the poisoning concept with specification of inorganic, organic, vegetable and animal poisons; as with Dewey, allowing specification of poison to the capabilities of those parts of the schedules. Other aspects which have appeared, or been amplified, in the UDC over the period include forensic toxicology, toxicity of commercial substances, occupational health aspects, and ecotoxicology.

The index to the pocket edition of 1999, which, by its brevity may be taken to show the 'core' view of UDC on a topic, lists three aspects of toxicology: general toxicology/poisoning; aquatic (i.e. eco-) toxicology; and countering the effects of toxic pollution. This may be compared with the index to the equivalent abridged edition of 1961, which lists four aspects: general toxicology/poisoning, pathology of poisoning, soil toxicity and forensic toxicology. This may be taken as reflecting the shift in importance from regulatory/legal issues to environmental concerns.

The development of the UDC overall shows toxicology moving from the 'science of poisons' with some specific related subjects such as forensic toxicology, to a multi-

faceted science, with environmental and occupational aspects gaining more importance.

The UDC has always provided the most detailed and flexible approach to the specification of toxicological material of any 'general' classification schemes, although the latest version of Dewey approaches it, particularly in its new life science schedules. Nonetheless, it is still in some respects uneven and inconsistent, separates concepts which would, from a toxicologist's viewpoint, be regarded as related, and lacks some detailed concept specification for a fully detailed treatment of toxicology.

7.2.3 Library of Congress Classification

This scheme (Chan 1999) was devised to meet the particular needs of the Library of Congress, and is therefore designed exclusively for placement of books on shelves, and beyond that to deal with the collection of a specific library, albeit a very large one. It was produced to meet the needs of the Library following its move into its purpose-built home in 1897; previously it had been housed in an *ad hoc* arrangement of rooms within the Capitol, and arranged according to 44-class system of Thomas Jefferson, whose collection had formed the core of the original library.

The scheme was loosely based upon Charles Cutter's Expansive Classification, and to this day shows strong evidence of its origins. It is not so much a single unified classification as a coordinated series of special classifications. Each of its major classes is constructed, indexed and revised separately, and there is no overall index to the classification. It is almost entirely an enumerative scheme, with virtually no scope for synthesis of numbers.

The scheme consists of 21 main classes, divided into subclasses, with an alphabetical notation, e.g.

Q	science
QD	chemistry

Each subclass is then divided by numerical notation 1-9999, arranged in sequence without any further hierarchy, e.g.

HV	Criminology

HV 6254 Offences against the government

..

HV 6275 Treason

HV 6278 Regicide

To these class numbers may be added so-called 'Cutter numbers', to provide a place for alphabetical arrangement of subjects within the class; this is used, for example, for specifying chemical substances by name, or geographical areas, and is noted as (A-Z).

Library of Congress 3rd edition 1966

The Medicine section of the LCC, class R, entered its 3rd edition in 1952; this edition survived to be reprinted unaltered in 1966, and represents the LC view of toxicology immediately before the modern era. In this edition, medicine is divided into 17 sub-classes:

R	Medicine, general
RA	Public aspects of medicine
RB	Pathology
RC	Internal medicine
RD	Surgery
RE	Ophthalmology
RF	Otorhinolaryngology
RG	Gynecology and Obstetrics
RJ	Pediatrics
RK	Dentistry
RL	Dermatology
RM	Therapeutics and Pharmacology
RS	Pharmacy and Materia Medica
RT	Nursing
RV	Botanic, Thomsonian and eclectic medicine
RX	Homeopathy
RZ	Other systems of medicine

Toxicology *per se* appears in the RA sub-section, public aspects of medicine, rather than with pharmacology in sub-class RM or materia medica in RS. Its detailed breakdown is:

	History of toxicology
1195	General
1197	By country or region (A-Z)
	General works
1201	to 1900
1211	1901-present
1213	Popular and minor works
1215	Tables
1216	General special (e.g. Treatment of acute poisoning)
1221	Examination for poisons, tests, analysis.
1223	Special tests (A-Z)
1228	Medicolegal toxicology
	Special poisons and groups of poisons
	Inorganic poisons
1230	General works
1231	Special (A-Z)

- e.g. .A7 arsenic and arsenic compounds
- .N5 nitrogen oxide
- Organic poisons**
- 1235 General works
- 1242 Special (A-Z)
- e.g. .A8 atropine
- .S8 strychnine
- Gaseous poisons**
- 1245 General works
- 1247 Special (A-Z)
- e.g. .C17 carbon monoxide
- 1250 **Vegetable poisons** (general)
- Special see RA 1242 (organic poisons)
- 1255 **Animal poisons** (general)
- 1256 Special (A-Z)
- e.g. .S8 snake venom
- 1270 **Other poisons and groups of poisons** (A-Z)

Elsewhere in the scheme, industrial aspects of poisoning occur at HD 7263-7265, in the H-HJ Economics class, while criminal poisoning and poisoners occurs at HV 6549-6555, in the HC Criminology class. A cross-reference is made to the related topic of experimental pharmacology at QP 941, in the QP, physiology, class, under the main Q, science, heading.

Library of Congress 5th edition 1995

The most recent edition of the medicine class is the 5th edition, produced in 1995 (Chan 1999). Toxicology retains its position at numbers 1190-1270 at the end of the RA class. Other possibly relevant areas within RA are 1001-1171 (forensic medicine) and 565-600 (Environmental health, including air pollution). A notable feature is the sheer number of entries as every toxicology of every substance is given a unique coding.

The details of toxicology in this edition are as follows:

Toxicology		
Cross-references to specific forms, e.g. medicine	RC 374.5	neurotoxicology RC - internal
	RC 582.17	immunotoxicology
	RC 848.H48	hepatotoxicology
	RL 803	dermatotoxicology RL -
dermatology		
1190 et seq	forms of works	
1195 et seq	history	
1197.5	biography	
1198	study and teaching	
1199	research and experimentation	
	including special topics such as	
1199.4.A38	acute toxicity testing	
1199.5.A-Z	by laboratory animal A-Z	
1201	general works	
1215.5	statistics and surveys	
1221	analytical toxicology	
1224	behavioural toxicology	
1224.2	reproductive toxicology	
1224.3	genetic toxicology	

1224.45	developmental toxicology	
1224.5	toxicological emergencies	
1225	pediatric toxicology	
1228	medicolegal toxicology	cross-reference to criminal poisoning HV6549
1229	industrial toxicology	cross-reference to toxicology in specific industries
	RC965.A	
specific poisons and groups of poisons		cross-reference to carcinogens RC 268.6
1230	inorganic poisons	
1235	organic poisons	
1245	gaseous poisons	
1250	vegetable poisons	
1255	animal poisons	
1258	food poisons	
1270	other poisons	

each of these is enumerated with entries for individual substances. These are somewhat eclectic, mixing specific chemical substances (identified variously by chemical name or tradename) and generic substance groups, by chemical composition or by property, with materials including numerous substances. For example, the 'organic' section includes entries such as:

narcotics
zinc naphthenate
paraquat
oxalic acid
hydrocarbons
rattlesnake venom
plastics
wood

Although this enumerative approach allow specification of poisoning in detail, it has the disadvantage of all such schemes that it requires prior specification of each substance as a poison. The inconsistency of substance specification is also a drawback.

Other relevant entries are found within the Science Section; QH 90.8.T68, (natural history, water, aquatic biology) and QH 541.15.T68 (general biology, ecology, toxicity testing).

Use of LCC

In order to provide an assessment of the way in which LCC classification is used in practice, a set of books clearly related to toxicology were selected from the Books in Print file on Dialog, and their LCC classes examined.

37 books published in 1998-2000 inclusive, and having LC classification assigned, had the word 'toxicology' in the title. One of these was a work of cyberpunk fiction. The others fell into the following classes:

RA1190-1270	toxicology	22
RA427	public health	1
RC	internal medicine	3
RL	dermatology	1
RM	pharmacology	1
GE170	environmental sciences	1
Q	general science	1
QH545	ecology	1
QH671	cytology	1
QL	zoology	1
QP	biochemistry	2
SF991	veterinary science	1

The focus on the RA toxicology section, with over 60% of the books being so classed, is notable.

Library of Congress Subject Headings

Providing a complement to the LC classification *per se* is the alphabetical list of Library of Congress Subject Headings (LCSH). First issued in 1909, this subject heading list is produced annually. The relationship with the classification scheme is not exact, since only about one third of the subject headings have classification notations attached (Foskett 1996). Since the 11th edition of 1988, the headings have included thesaural relations (BT, NT, RT etc) to show term inter-relations, despite the fact that many headings are phrases, referring to complex subjects, rather than the single concepts required for a thesaurus. This aspect has been condemned by Dykstra (1988), who described the then current LCSH edition as a 'professional disgrace'. Although much work has since been done on remedying some of the inconsistencies of the scheme, the basic difficulty of the imposition of a thesaurus structure on a set of often pragmatically defined compound terms remains. Entries relevant to toxicology are shown in the appendix to chapter seven, section 7.2.a.

NB. Some of the toxicology narrower terms (NT) given, actually have narrower terms of their own. See for example: Toxicological chemistry, with the narrower term Biochemical toxicology.

Inconsistencies remaining in the scheme are exemplified by the hierarchy:

```

Toxicology
  Forensic Toxicology
    Poisoning
  
```

although Toxicology and Poisoning are also Related Terms.

Related terms Poisoning and Poisons are detailed below:

Poisoning

[HV6549-HV6555 (Criminology)]

[RA1190-RA1270 (Toxicology)]

- UF Toxicoses
- BT Assault and battery
Criminal law
Forensic toxicology
Homicide
Murder
Toxicological emergencies
- RT Toxicology
- SA subdivision Toxicology under
Individual chemical substances
Eg. Copper - Toxicology
- NT Food poisoning
Lead poisoning
Mycotoxicoeses
Poisoners
Self-poisoning
Toxic psychoses
Trials (poisoning)

Poisons

[RA1190-RA1270]

Works on the poisonous influence of individual chemical substances on man and animals are entered under the substance with the subdivision Toxicology. Eg. Mercury - Toxicology; Phosphorous - Toxicology.

Works on the effects of poisons on plants are entered under Plants, Effects of poisons on; Plants, Effects of arsenic on; and similar headings

- UF Chemicals - Toxicology
Poisonous chemicals
Poisonous substances
Toxic chemicals
Toxic substances
Toxicants
Toxics
- BT Bioactive compounds
Hazardous substances
- RT Toxicology
- SA individual poisons; also headings beginning with the word poison.
- NT Antidotes
Arrow poisons
Chemical agents (munitions)
Gases, asphyxiating and poisonous
Hypoglycin A
Neurotoxic agents
Pesticides
Strychnine
Synthetic poisons
Toxins

- Analysis

[RA1221- RA1223]

- RT Analytical toxicology
- NT Biological monitoring

- Dose-response relationship

USE Toxicology - Dose-response relationship

- Law and legislation

- Physiological effects

- NT Hormesis

- Safety measures

- UF Poisoning, Accidental - Prevention
- Testing
 - USE Toxicity testing

The entry for Toxicity testing also seemed relevant:

- Toxicity testing
 - [QH541.15.T68 (Ecology)]
 - [RA1199 - RA1199.5 (toxicology)]
 - UF Poisons - Testing
 - Toxicological testing
 - Toxicology - Testing
 - Toxicology - testing
 - BT Toxicology, Experimental
 - SA subdivision Toxicity testing under Individual chemicals and groups of chemicals. Eg. Copper - Toxicity testing
 - NT Acute toxicity testing
 - Chronic toxicity testing
 - In vitro
 - [RA1199.4.15]
 - UF In vitro toxicity testing
 - In vitro toxicology
 - BT Cell culture
 - Tissue culture
 - In vivo
 - [RA1199.4.153]
 - UF In vivo toxicity testing
 - Law and legislation

Testing this thesaurus with the 'toluene inhalation' example, described in 7.1, shows the following terms to be available:

acute toxicity	ACUTE TOXICITY TESTING
toluene	TOLUENE
vapour	VAPORS
rat	RATS; RATS AS LABORATORY ANIMALS plus NTs for rat species, e.g. RATTUS
LD50	-
lung	LUNGS
irritation	IRRITATION

Terms for all aspects are therefore available, with the exception of detailed specification of the acute end-point.

7.2.4 National Library of Medicine (NLM) Classification

This is the best known classification scheme specifically designed for biomedical areas, whose remit is primarily shelf arrangement of library materials; other medical schemes, such as the International Classification of Diseases (ICD), have other purposes.

The NLM scheme stems from an initial survey report on the US Army Medical Library (originally the Surgeon General's Library), carried out in 1944, which resulted in the publication, in 1951, of what was known at first as the US Army Medical Library Classification. Subsequent revised editions were issued in 1958, 1964, 1978 and 1994. The 5th, 1994 edition, whose foreword describes the scheme's origins, notes that its purpose is the 'shelf arrangement of library materials in medicine and related sciences'.

The scheme was designed from the first to be complementary to the Library of Congress (LC) classification, and uses schedules QS-QZ and W-WZ, which are permanently excluded from the LC schedules.

Toxicology appears at several places in these schedules. Its main location is at QV 600-647; it is to this that the entries for 'toxicology' and also 'poisoning', in the index point. This locates the subject within the pharmacology (QV) section of the schedules. The schedule here is:

QV	PHARMACOLOGY
	Toxicology
600	General works
601	Antidotes and other therapeutic measures
602	Detection of poisons. Tests. Laboratory manuals. Techniques
605	Directories of poison control centres. Lists of poisons and antidotes
607	Handbooks
610	Inorganic poisons
612	Acids, alkalis
618	Irritant poisons
627	Organic poisons
628	Alkaloids
632	Non-alkaloids
633	Hydrocarbons, volatile poisons, solvents
662	Gas poisons and poisoning
663	Chemical warfare agents
664	Lung irritants
665	Tear gases, toxic smoke
666	Irritant gases
667	Systemic poisons. Paralysants

A few specific substances appear in the index, with classification to a QV number. Carbon monoxide poisoning appears under QV662. However, others are classed elsewhere: lead poisoning is classed under QV292, in the 'heavy metals' section of the general pharmacology (QV) section.

Animal and plant poisons appear in the WD area of the classification, a 'series of small tables which deal with subjects that cannot be readily integrated into other schedules because of the underlying framework of the classification', at WD400 and WD500 respectively. Thus:

WD

Animal poisons

- 400 General works
- 401 Handbooks
- 405 Marine forms
- 410 Reptiles
- 420 Spiders, scorpions, centipedes, leeches
- 430 Insects

Plant poisons

- 500 General works
- 501 Handbooks
- 505 Ergotism
- 515 Fauvism
- 520 Mushroom poisoning
- 530 Milk sickness

'Toxins' are classified at QW630, part of the Immunology (QW) section.

Toxic substances, other than those noted in the above classes, appear scattered throughout the WA, public health, section of the classification. Thus:

WA	PUBLIC HEALTH
400	Occupational health and hygiene
..	
400-495	hazardous substances, occupational
<i>includes</i>	
465	Industrial poisons and poisoning (general)
670	Sanitation and environmental control
670-788	hazardous substances, environmental
<i>includes</i>	
700	Adulteration and contamination
..	
730	Drug adulteration and contamination

The index entry for 'industrial toxicology' points to WA465, that for 'public health aspects of toxicology' to WA730.

Other aspects of toxicology are further scattered throughout the classification:

'Medico-legal aspects of toxicology' appears in the W, health professions, section of the scheme, under:

W750	Examination of evidential material. Forensic chemistry

'Poison control centres in hospitals' (as distinct from lists of such centres under QV605) are classified at:

in the WX, hospitals and other health facilities, section.

Veterinary toxicology does not feature in this scheme proper at all; its index entry refers to SF757, in the veterinary science section of the LC schedules.

Finally, there is a historical 19th Century Schedule, for works published between 1801 and 1913. Toxicology appears in this schedule in a single place, QVB, under the general heading

QV: pharmacology, pharmacy and materia medica.

This classification does not treat toxicology as an integrated discipline. It is largely treated as a sub-set of pharmacology, with disparate references to industrial, public health, forensic, veterinary and similar applications. The emphasis is firmly on acute poisoning, with strong military associations (not surprising considering the origins of the classification). Toxic and poisonous substances are divided in, for the toxicologist, an unhelpful manner. To give one example noted in the index, a classifier of a work on substances causing irritation on inhalation must consider three possibilities:

QV618 irritant poisons
QV664 lung irritants
QV666 irritant gases

and it is not clear how this decision may be made.

The scheme offers no help in dealing with works on the sub-disciplines and specialisations within toxicology which, as noted in chapter four, form the major part of new book publication in toxicology. Nor does it offer scope for newer approaches to toxicology, such as elucidation of mechanism, environmental aspects, or alternatives to animals in toxicity testing. Despite its wide usage in medical and similar libraries, it must be regarded as too outdated and too limited in its framework, to be of great value for the classification of toxicology material. It is likely that it serves as well as it does, only because most of the libraries using the scheme have a very limited toxicology stock.

7.2.5 Rider's International Classification

This scheme, devised by Fremont Rider, and published in 1961, is now of historic interest only, since it has never gained the backing of a significant group of users, and hence has fallen into disuse. It is included as a further indication of the way in which toxicology was viewed in general subject schemes at that time.

Described by Marcella and Newton as 'a relatively modern... general system, cast on staunchly traditional lines', Rider's classification was intended, in his own words, 'for the arrangement of books on the shelves of general libraries'. It is therefore the antithesis of 'bibliographic classifications', of which Bliss is the most obvious example, which are intended for detailed subject access to material such as reports and articles in special collections.

The scheme has a brief and purely alphabetic notation, based on the conventional 26 letter alphabet. There are therefore 26 main classes, each divided into 26 sub-classes, each of which may be divided 26 times itself, giving a total of 15,756 sub-headings, the finest division of which this classification is capable. There are no facilities for synthesis of notation, nor for division by common attributes, such as place.

The main classes are:

A	Generalia
B	Philosophy and Psychology
C	Religion
D	History, general and America
E	History, Europe
F	History, rest of the world
G	Geography, America
H	Geography, Europe
I	Geography, rest of the world
J	Social science
K	Law
L	Economics
M	Political science and government
N	Education and recreation
O	Business and industry
P	War, transport, communication
Q	Physical science
R	Chemistry
S	Engineering
T	Biology
U	Medicine
V	Agriculture and home making
W	Fine arts and music
X	Languages
Y	Literature, Europe
Z	Literature, rest of the world

Toxicology-related appears scattered throughout the classification, in rather broad and unspecific classes, but concentrated in the U (medicine) class.

Toxicology and poisons *per se* are classed together in the UW (therapeutics) sub-class:

UW	Therapeutics
..	
UWU	Toxicology (poisons and their antidotes)
UWV	Mineral poisons
UWW	Vegetable poisons
UWX	Animal poisons

Toxins appear in the preceding UV sub-class (pharmacology), classed at UVP, along with specific vaccines and antitoxins.

'State control of the sale of poisons and narcotics' appears at UYB in the UY (public health) sub-class. Outside the U class, toxicology material appears scattered in a rather inconsistent way.

'Effects of drugs and poisons on mental health' appears as BNH, in the BN (mental hygiene) sub-class of the 'philosophy and psychology' class.

'Industrial hygiene', a very broad class including industrial poisons, appears at JGG in the JG (industrial sociology) sub-class of the 'social sciences' class.

'Plants harmful to man', including poisonous plants, have their own sub-heading, TCK, in the TC (botany) sub-class of 'biology'. There is no equivalent place for poisonous animals, nor any apparent means of relating this to the apparently similar UWW. The limitations of this classification for detailed analysis of toxicology material are clear; though it should be remembered that it was never designed for such a purpose. Even with this caveat, the treatment of this subject seems unhelpfully *ad hoc*, perhaps reflecting the difficulty of any 'general' scheme in dealing with the complexities of this subject, even at a general level.

7.2.6 Bliss's Bibliographic Classification, 2nd Edition

Bliss's Bibliographic Classification, though it is the most theoretically sound of the general classification schemes, being based entirely on faceted principles, has not found wide use in practice, though it has influenced the development of other schemes, particularly UDC.

Toxicology appears in section H of Bliss - Anthropology, Human Biology, Life Sciences - which has not been updated since 1981.

Sections HSQ - HSS of the scheme deals with poisoning, with toxicology subsumed under this. Poisoning is sub-divided by treatment, pathology (i.e. nature of harm caused), origin (i.e. cause), effect, state or constitution (i.e. general nature of the poison), and element or compound (i.e. chemical substance). The general structure is shown in the appendix to this chapter, section 7.2.b. Food poisoning is then dealt with in considerable detail, divided by state of food, and form of constitution of food, as shown in the appendix, section 7.2.c.

Bliss's capability for synthesising class numbers makes it inherently flexible for reflecting complex concepts, e.g. the state of food causing food poisoning, while the A/Z specifications allow for detailed description of animals, plants, etc. Nonetheless, the scheme has a distinctly old-fashioned air, perhaps reflecting the date of the most recent edition of this section. Toxicology is equated to human poisoning, in the classic view of the science. While newer concepts such as ecotoxicology and regulatory toxicology could no doubt be dealt with by appropriate synthesis from other parts of the scheme, this part of the schedules reflects such a dated viewpoint as to be of limited value in dealing with modern toxicology.

There are also a number of inconsistencies, suggesting an unfamiliarity with the subject on the part of the originators of this section. 'Toxic gases', for example, are put together in DWE with 'smokes' and 'lacrimators'; this section describes the effect of the poison, and in this case only lacrimators is appropriate. Similarly, in the chemical specification section, 'inert gases' are introduced linked to the concept of 'narcosis', which need not necessarily be the toxic effect. While these are not major faults, they would lead to a lack of confidence in a subject expert.

Drug toxicology appears in the HNV sections, as

HNV		Drug therapy, pharmacotherapy, pharmacology
..		
HNV	JB	side effects, after effects, etc.
	JH	drug poisoning

The schedules instruct that documents dealing with pharmacology and toxicology together are to be classed under HNV, those with toxicology alone at HSQ. This is another illustration of the rather old-fashioned treatment accorded toxicology, it here being regarded as a sub-set of pharmacology.

Overall, despite the flexibility and extensibility afforded by Bliss's facet structure, this part of the scheme is too dated to offer, in itself, a satisfactory organisation of modern toxicology knowledge.

7.2.7 Ranganathan's Colon Classification

Ranganathan's classification scheme, the pioneer of analytico-synthetic or faceted classification, is idiosyncratic in its nature, and has not found wide application outside the Indian sub-continent. Not does it appear that this classification is likely to gain any wide usage in the future, despite the urging of its supporters, such as Satija (1997). Nonetheless, its importance in the development of classification theory suggests that it merits an examination.

The Colon Classification, currently in its 6th edition, the last prepared under Ranganathan's direction, does not have an entry in its index for 'toxicology'. The closest entry is 'poison', which is found in two places in the schedules.

In the 'medicine' (L) facet, 'poison' or 'intoxicant' are to be found at 524, within the 'public health and hygiene' sub-facet, with instructions to sub-divide it by the chemical or 'chemical technology' facets. This would allow specification of 'poisoning by ..', the latter two schedules allowing for specification of elements, e.g. arsenic, classes of compound, e.g. alkaloid, or substance by use, e.g. edible oil.

Within the 'chemical technology' (F) facet, 'poison' is to found at 594 (between 58 for dyes and 596 for spices and condiments !) This is not present in the 1987 edition however.

Thus, the Colon Classification allows for reasonable detailed classification of poisoning due to particular agents (though the specification of such agents is distinctly Indian in nature, e.g. ankle cosmetics, and artificial silk). Scientific concepts, such as mechanism, cannot be expressed, nor can safety of drugs, nor industrial chemical hazards, nor any aspect of the discipline of toxicology.

The most recent edition is the 7th Basic and Depth Version, published in 1987.

Toxicology occurs in two places. Firstly, still within the 'medicine' (L) facet, under the heading Public Health and Hygiene, then State Control section:

And secondly, an entry for Poison occurs within the Biology section, under Disease

4	Poison
41	Snake poison
	To be further subdivided as [P] (personality) of "E Chemistry"

In both cases, it is possible to specify the poison by adding on the appropriate chemistry number.

7.2.8 Summary of bibliographic classification schemes

Of the schemes considered above, only Dewey, UDC, LCC and NLM are of real interest for the arrangement of toxicology material. The others, though of historical or theoretical interest, are insufficiently developed, or too outdated, to be considered for the purpose.

LCC and NLM are both truly enumerative schemes, and suffer from the deficiencies of any such scheme in dealing with a complex and multi-faceted discipline such as toxicology. NLM suffers from a lack of up-dating, so that it is ill-equipped to deal, in any degree of detail with modern toxicology material. LCC is more modern in outlook, and is therefore able to deal with, for example, many of the modern sub-disciplinary aspects of toxicology. However, its chemical substance specification is quite inadequate for it to be used for the organisation of toxicology material at a detailed level.

Dewey and UDC are the only 'general schemes' to have undergone regular updating. As has been shown above, their development both parallels, and sheds light on, the development of toxicology as a discipline, and its changing foci of interest. Both schemes, by virtue of the synthetic capabilities, by which the toxicity of particular materials may be described, and because of the way in which various aspects of toxicology may be specified, can be used for description and arrangement of modern toxicology material.

However, both these schemes still have two main disadvantages, considered as tools for organising toxicology knowledge. The first is the 'scatter' of toxicology material across the schemes, particularly between 'medical', 'biological' and 'regulatory' areas. This has the twin disadvantages of causing confusion as to where, in two or more possible places, an item may be put, and of splitting up material which, from

the viewpoint of a toxicology specialist, would appear closely related. The 'use of DDC/LCC' examples illustrate clearly how Dewey shows much more spread of material away from the main toxicology class than does Library of Congress.

7.3 Clinical Terminologies and Classifications

These vocabularies are variously referred to as clinical terminologies, coding schemes, classifications and nomenclatures.

Their purpose, unlike that of the other vocabularies reviewed in this chapter, is to assist in the recording of information by health services. They are the oldest form of classification for healthcare, pioneered by John Graunt's study of London Bills of Mortality in the early eighteenth century, which attempted to categorise infant mortality by cause of death. Reasons for their use include: epidemiology, studying the occurrence of health problems; compilation of healthcare statistics; encoding of patient records; administration and budgeting, providing a detailed account of the procedures carried out by health services; and evidence-based medicine, comparing treatments and their success at different centres (Benson and Neame 1994, Walker 1995, Cimino 1995, Jones 2001, Lernout and Hauspie 2000).

Vocabularies of this kind are numerous, and no attempt will be made here to enumerate them all; rather some of the more important exemplars will be chosen. Their potential significance for the organisation of toxicology knowledge is that they may offer a way of describing toxic effects in detail; they cannot provide a vocabulary for the whole field of toxicology.

These are typically very large and detailed vocabularies, their scale being indicated by a 1994 comparison of term numbers (Benson and Neame 1994):

	Diseases	Procedures	Drugs	Other	Total
ICD-9	12,943	3,735	0	0	16,678
Read	27,522	8,591	13,371	12,283	61,767
OPCS-4	7,858	0	0	0	7,858

7.3.1 International Classification of Diseases

International Classification of Diseases and Related Health Problems (ICD); classification of diseases, and to some extent medical procedures, for statistical analysis, originally promulgated by World Health Organisation. It has been extensively revised in successive versions, the current version being ICD10, which supplanted ICD-9 during the 1990s.

It is divided into 21 main sections, or 'chapters', chapter 19 being 'Injury, poisoning and other consequences of external factors. Each may be subdivided by up to three levels, e.g.

diseases of the respiratory system	J00-J99
acute respiratory infections	J01-J06
acute laryngitis and tracheitis	J04
acute tracheitis	J04.1

An extension of the ICD is used by the World Health Organisation for collecting statistics on adverse drug reactions.

7.3.2 NHS Clinical Terms

Formerly known as the Read Codes, and still often referred to in that way, this is an alphanumeric coded nomenclature of medical terms for patient record coding, used in the UK National Health Service. It includes highly detailed terms for patient characteristics, disease conditions, diagnosis, treatment and outcomes, and incorporating term lists for various specialities, and practitioner groups. These are the result of extensive development within the NHS, and have been designed to cross-refer with other terminologies, but have been criticised by many information specialists for lack of internal consistency. These codes form a thesaurus, with a five-level hierarchy of specificity, and an unlimited number of synonyms for each preferred term, e.g.

level	Read code terms	Read code
1	Circulatory system diseases	G
2	Ischaemic heart disease	G3
3	Acute myocardial infarction	G30
4	Acute anterior myocardial infarction	G301
5	Acute anteroseptal myocardial infarction	G3011

The Read Codes are being combined with the SNOMED vocabulary, with a view to producing a combined vocabulary.

7.3.3 Systematised Notation of Pathology / Medicine (SNOP / SNOMED)

These are detailed notations based on semantic analysis of concepts, applicable to artificial intelligence and correlative systems, as well as coding and retrieval. The SNOP coding for pathology was the first to be developed, and was succeeded by SNOMED, a more general scheme for much of medicine.

These systems have some similarity to a faceted classification, SNOMED having six main facets or 'axes':

Topography	T
Morphology	M
Etiology (ie cause)	E
Function	F
Disease	D
Procedure	P

However, unlike a faceted classification there is no mechanism to order the notation. Ordering can be used to convey information about the relation of concepts, but this is not standardised.

Tuberculosis - a granuloma in the lungs together with fever, caused by Mycobacterium Tuberculosis - may be described by the five SNOMED codes:

tuberculosis	D-0188
granuloma	M-44060
lung	T-28000
fever	F-03003
Mycobacterium tuberculosis	E-2001

SNOP and SNOMED are clearly capable of describing effects and causes of disease in considerable detail, but the complexity of their notations largely preclude their use for information retrieval.

A new version of SNOMED will be introduced during 2001. SNOMED Clinical Terms is intended to provide a new international standard for detailed encoding of clinical effects.

7.3.4 Broad categorisations

Used for categorising medical problems, procedures, and 'resource factors' such as length of stay in hospital, these are largely applied to health service administration and budgeting. They include:

- **Office of Population Census and Surveys Codes (OPCS)**

A classification scheme used in the UK for recording of statistics of illness and death, and of some medical interventions, especially surgical operations recorded in the OPCS4 classification.

- **Healthcare Resource Groups (HRGs)**

Used in the UK National Health Service for comparisons between treatments and geographical areas. These are rough equivalents to US **Diagnosis Related Groups (DRGs)**, a hospital patient grouping scheme relating clinical categorisation to cost incurred, and **Ambulatory Patient Groups**, which provide the same information for outpatients. They generally offer only rather general descriptions of health problems, e.g. HRG codes H01 (back problems) and H47 (tuberculosis of joint with complications).

7.3.5 Summary of clinical terminologies and classifications

None of these vocabularies is suitable, in themselves, for the organisation of toxicology knowledge; hardly surprising, in view of their intended purposes. The broad categorisations are too general to be of use, while the NHS Clinical Terms, though they are sufficiently detailed and have a *de facto* significance, at least in the UK, because of their wide use, suffer from too much internal inconsistency to be recommended for the purpose.

However, the more detailed and theoretically sound schemes - ICD and SNOP/SNOMED - could have a role where the detailed description of toxic effect, i.e. the disease or injury caused, had to be described in such detail. The new SNOMED Clinical Terms vocabulary may be particularly significant.

7.4 Thesauri

Thesauri relevant to toxicology were identified in four ways:

- by searching bibliographic databases for references to printed thesauri, and articles describing them
- by searching the Internet for thesauri in electronic form
- by consulting the documentation provided by database producers
- by examination of the main British collection of thesauri, housed in the Aslib library

In all cases, access to the full thesaurus, rather than sections of it viewed online, was regarded as essential in order to appreciate its structure and capabilities. This meant that a relatively old edition was sometimes consulted, but this was regarded as acceptable for the purpose of getting a general impression of the way in which toxicology was dealt with in each thesaurus. Older vocabularies are, in any event, of interest in assessing changing concepts and relationships. The older versions were augmented, where appropriate, by examining the latest online versions.

7.4.1 MeSH Vocabulary

The MeSH (Medical Subject Headings) vocabulary is maintained by the US National Library of Medicine. Designed for the indexing of the Index Medicus / Medline bibliographic database, it is now used for many other purposes, and is the best known of medical indexing vocabularies. It was examined in printed form, and through the NLM's online browser, <http://www.nlm.nih.gov/mesh/2002/MBrowser.html> (last visited 24/3/02).

MeSH comprised two listings: an alphabetical list of terms, and a classified listing. Terms in the alphabetic list have synonym and related term relations, and scope notes, but not narrower or broader term relations: each term has its notation in the classified list shown, and reference to these tables provides the hierarchical context for each term. Terms may appear in more than one place in the MeSH trees, giving a multi-hierarchy.

There are 15 categories in the classified 'tree structures':

A	Anatomy
B	Organisms
C	Diseases
D	Chemicals and Drugs
E	Analytical, diagnostic and therapeutic techniques and equipment
F	Psychiatry and Psychology
G	Biological Sciences
H	Physical Sciences
I	Anthropology, Education, Sociology and Social Phenomena
J	Technology, Industry, Agriculture
K	Humanities
L	Information Science
M	Named groups
N	Health care
Z	Geographicals

The term 'toxicology' is used in MeSH to refer only to the profession; the entry in the alphabetical listing is:

Toxicology

G1.703.795

G2.268.795

SPEC only: SPEC qualif: prefer /adv eff-pois-tox with specific D terms: Manual 19.7+, 19.8.73, 19.9+;

DF: TOXICOL

see related

Poisons

The two alphanumeric terms in the first line are the two places in the classification trees in which this term appears, both in the G (Biological Sciences) tree. The next two, rather impenetrable, lines are instructions to NLM indexers.

One related term, poisons, is given.

The two classification points both show toxicology as a sub-set of pharmacology:

G1.703.795 in the Biological Sciences section, and G2.268.795 in the Health Occupations section.

There are two principal places in the MeSH trees in which toxicology concepts appear, relating to the concepts of poisoning as a form of injury, and to poisons as substances respectively.

The first is in the C21 area of the classification, in the general C - diseases - tree, for 'Injuries, occupational diseases and poisoning'. The relevant section (omitting the tree notation for simplicity) is:

- POISONING
 - ALCOHOLIC INTOXICATION
 - ALCOHOLISM
 - CARDIOMYOPATHY, ALCOHOLIC
 - FETAL ALCOHOL SYNDROME
 - LIVER DISEASES, ALCOHOLIC
 - FATTY LIVER, ALCOHOLIC
 - HEPATITIS, ALCOHOLIC
 - LIVER CIRRHOSIS, ALCOHOLIC
 - PANCREATITIS, ALCOHOLIC
 - PSYCHOSES, ALCOHOLIC
 - ALCOHOL AMNESTIC DISORDER
 - ALCOHOL WITHDRAWAL DELIRIUM
 - ARGYRIA
 - BITES AND STINGS
 - ARACHNIDISM
 - INSECT BITES AND STINGS
 - SNAKE BITES
 - TICK TOXICOSES
 - TICK PARALYSIS
 - CADMIUM POISONING
 - CARBON TETRACHLORIDE POISONING
 - DRUG TOXICITY
 - AKATHISIA, DRUG-INDUCED
 - DRUG ERRUPTIONS
 - EPIDERMAL NECROLYSIS, TOXIC
 - ERYTHEMA NODOSUM
 - SERUM SICKNESS
 - DYSKINESIA, DRUG-INDUCED
 - NEUROLEPTIC MALIGNANT SYNDROME
 - ERGOTISM
 - FLUORIDE POISONING
 - FOOD POISONING
 - BOTULISM
 - FAVISM
 - MUSHROOM POISONING
 - SALMONELLA FOOD POISONING
 - STAPHYLOCOCCAL FOOD POISONING
 - GAS POISONING
 - CARBON MONOXIDE POISONING
 - INERT GAS NARCOSIS
 - HEPATITIS, TOXIC
 - LEAD POISONING
 - MERCURY POISONING
 - MYCOTOXICOSIS
 - ERGOTISM
 - MUSHROOM POISONING
 - PLANT POISONING
 - ERGOTISM
 - FAVISM
 - LATHYRISM
 - MILK SICKNESS
 - PSYCHOSES, SUBSTANCE INDUCED

This is a somewhat ill-assorted list, mixing the affected organ - e.g. HEPATITIS, TOXIC - with causative agents, both chemical and biological. Note also the repeat of terms at different points; ERGOTISM, most strikingly, is repeated in three places, in this very short piece of the tree, as an example of a poison *per se*, a mycotoxin and a plant poison.

The examples of poisoning by specific substances, e.g. mercury or carbon tetrachloride, may seem very limited and rather arbitrary. However, as will be noted

below, this precoordinated term is not the main way in which MeSH reflects poisoning by a specific substance.

The second main place for toxicology-related concepts is in the D5 area of the classification, in the general D - chemicals and drugs - tree, for 'Environmental pollutants, noxae, and pesticides'. The relevant sections (again omitting the tree notation) are:

```
ENVIRONMENTAL POLLUTANTS
  AIR POLLUTANTS
    ..
    ..
  HAZARDOUS SUBSTANCES
  INDUSTRIAL WASTE
    ..
  SOIL POLLUTANTS
    ..
  WATER POLLUTANTS
    WATER POLLUTANTS, CHEMICAL
    ..
```

(TOXIC SUBSTANCES, ENVIRONMENTAL in the alphabetic list gives a 'see' reference to HAZARDOUS SUBSTANCES)

```
NOXAE
  CARCINOGENS
    CARCINOGENS, ENVIRONMENTAL
  CAUSTICS
  IRRITANTS
    TEAR GASES
  MUTAGENS
  POISONS
    CHEMICAL WARFARE AGENTS
  RIOT CONTROL AGENTS, CHEMICAL
    IRRITANTS
    TEAR GASES
  TERATOGENS
```

Also in the D (chemicals and drugs) tree, TOXINS appear at D24.185.926, with twelve more specific types of toxin, e.g. BACTERIAL TOXINS, IMMUNOTOXINS and MARINE TOXINS, as narrower terms.

A third, smaller, section within MeSH deals with the concept of toxicity testing; this appears in the 'miscellaneous techniques' part of the E - analytical, diagnostic and therapeutic techniques and equipment - tree. The terms here are:

```
TOXICITY TESTS
  CARCINOGENICITY TESTS
  CYTOTOXICITY TESTS, IMMUNOLOGIC
  LETHAL DOSE 50
  MUTAGENICITY TESTS
```

NO-OBSERVED-ADVERSE-EFFECTS LEVEL

A few other toxicology related terms appear scattered throughout the tree structure.

They include:

POISON CONTROL CENTRES in the N tree
ADVERSE DRUG REACTION REPORTING SYSTEMS in the E, L and N trees

'Toxicokinetics' in the the alphabetical list has a 'see' reference to the broader PHARMCOKINETICS.

MeSH has a powerful facility for specifying a particular kind of toxic effect of a particular substance in its set of 'subheadings' These are a small number of terms which act as 'role indicators', qualifying other terms, and thereby allowing generation of a large number of combinations at indexing time. One example is DRUG THERAPY, represented as DT. This may be applied to a term for a disease, e.g. SUNBURN, as SUNBURN/DT.

The three subheadings of relevance to toxicology are:

TOXICITY	TO
POISONING	PO
ADVERSE REACTION	AE

TOXICITY and POISONING may be used to qualify terms from sections D (chemicals and drugs) and J (technology, industry, agriculture). ADVERSE EFFECTS may qualify these, and also E (equipment).

The distinctions between the three, as described in the scope notes, are somewhat subtle (so that many literature searchers in looking for toxic effects apply all three as a matter of course).

- ADVERSE EFFECTS refers to complications following various procedures, and subsumes 'injurious effects', 'undesirable effects', and 'side effects'
- TOXICITY refers to experimental human and animal studies, including margin of safety and experimental exposure to environmental agents
- POISONING is used for clinical and veterinary poisoning only.

i.e. if the harmful effect is caused deliberately as part of a test, TOXICITY is used; otherwise, if it is an undesirable result of a medical or veterinary procedure, ADVERSE EFFECTS is used; otherwise POISONING is used.

The use of the subheadings gives MeSH a particular power in describing toxic effects of particular substances. However, it must be said that the rest of the vocabulary has a somewhat inconsistent and uneven treatment of toxicology concepts, with a limited set of descriptors for toxicology testing, and a general assumption of toxicology as a subset of pharmacology.

Using MeSH for the 'toluene inhalation' example, the following set of terms and subheadings could be assigned:

TOLUENE/toxicity
LUNG/drug effects
ADMINISTRATION, INHALATION
RATS (plus terms for specific species)
IRRITANTS
LETHAL DOSE 50

The subheadings allow a precise definition of toxic effect.

7.4.2 Emtree Thesaurus

The Emtree thesaurus is used to index the Excerpta Medica / Embase bibliographic database. It is similar in conception to MeSH, described above, but enjoys less wide usage. It has been kept under continual revision, and incorporates a number of previously separate vocabularies (EMCLASS, EMTAGS, and MALIMET).

This thesaurus was used as a guide for the selection of index terms for a 13 volume monograph of toxicology (Sipes et al. 1997).

The thesaurus has both alphabetical and classified indexes. The classification notation is assigned only to those terms which have narrower terms, thus simplifying the notations. The alphabetic index shows terms with the following relations:

- class number for preferred terms which have narrower terms in a hierarchy
- 'see under' for preferred terms which have no narrower terms, relating them to the broader term
- 'use' for non-preferred terms
- 'see also' for related terms

Broader and narrower term relations are not shown in the alphabetical index, as they may be ascertained from the classification trees.

Typically, there is no great depth of hierarchy in the tree structures; rather a collection of collection of terms of varying degrees of generality are gathered together, with little or no detailed structure, under fairly general heading terms. 'Toxicity' and 'carcinogen' are good examples of this. There is also a tendency towards long lists of examples, e.g for toxins.

This is exemplified in the appendix, section 7.4.a, with terms beginning with the stem 'toxic' in the 1998 thesaurus.

The EMTREE system is divided into 15 main facets:

A	anatomical concepts
B	organisms
C	physical diseases, disorders and abnormalities
D	chemicals and drugs
E	analytical, diagnostic and therapeutic techniques, equipment and parameters
F	psychological and psychiatric phenomena
G	biological phenomena and functions
H	chemical, physical and mathematical phenomena
I	society and environment
J	types of article or study
K	geographic names
L	groups by age and sex
M	names groups of persons
N	healthcare
Q	biomedical disciplines, science and art

Toxicology as a discipline is found in the Q facet, together with related disciplines; all are in

the Q1 (biomedicine) subfacet:

Q1.340	Genetics
..	Genetic toxicology
..	
Q1.550.40	Forensic medicine
	Forensic psychiatry
Q1.550.40.70	Forensic pathology
	Forensic identification
..	
Q1.550.75.60	Occupational medicine
..	Occupational toxicology
..	
Q1.865	Teratology
	Behaviour teratology
Q1.880	Toxicology
	Ecotoxicology

Genetic toxicology
Neurotoxicology
Occupational toxicology

Most toxicology-related terms in EMTREE appear in two parts of the scheme; those relating to toxic effects appear in facet C (diseases and disorders), while toxic substances appear in facet D (chemicals and drugs). These are given in the appendix, as sections 7.4.b and 7.4.c respectively.

Toxicology-related terms occur at three places in the E - techniques, equipment and parameters - facet.

In the subfacet E1 - diagnosis, measurement and analysis:

E1.50.150	Chemical analysis
..	..
..	Toxin analysis
E1.880	Toxicity testing
	Chromium 51 release
	Dominant lethal test
	LD 50

and in sub-facet E8 - parameters of measurement and analysis:

E8.880	Toxicological parameters
	Body burden
	LD 50
	Lethal dose
	Maximum allowable concentration
	Maximum permissible dose

Environmental pollution is found within subfacet I2 in the 'Society and Environment' facet, while the term 'poison centre' appears under N1.10 Health care facility.

Applying this thesaurus to the 'toluene inhalation' example give the following set of terms:

ACUTE TOXICITY
LD50
TOXICITY TESTING
TOLUENE
VAPOR
LUNG
INHALATION
INHALED MATERIAL
IRRITATING GAS

The EMTREE thesaurus is capable of dealing with all aspects of this example.

7.4.3 Pharmline Thesaurus

This thesaurus is produced by the UK Drug Information Pharmacists Group, and used to index the Pharmline database, produced by, and primarily for, this group, and also available as a publicly available file via the Dialog Corporation, and on CD-ROM.

The database abstracts and indexes over 90 medical and pharmaceutical journals, plus publications from government and regulatory agencies, providing a service customised to the needs of those providing information services for drug prescribing in UK hospitals. 'Drug toxicity' is among 14 topics which are 'consistently included' in the database.

The 5th edition (1996) of this thesaurus was consulted.

The thesaurus, which contains 6,900 terms, is divided into three main sections:

- organisms and systems
- sciences and professional practice
- drugs and chemicals

each of which is in turn divided into about 20 general subject areas. Two of these are devoted, at least partly, to toxicological matters: 'environment, public health and toxicology' (B3) in the 'sciences and professional practice' section; and 'toxicological agents and antidotes' (C19) in the 'drugs and chemicals' section.

Section C19 contains the following hierarchical arrangement of terms

ANTIDOTES

ANTISERA

6 specific examples

DRUG ANTAGONISTS

48 specific examples

TOXICOLOGICAL AGENTS

CARCINOGENS

CARCINOGENICS

CHEMICAL WARFARE AGENTS

MUTAGENS

POISONS

PYROGENS

RIOT CONTROL AGENTS

TERATOGENS

TOXINS

BACTERIAL TOXINS

BOTULINIUM TOXIN

LIPOPOLYSACCHARIDES

CYTOTOXINS

ENDOTOXINS

ENTEROTOXINS

- EXOTOXINS
- MYCOTOXINS
 - AFLATOXINS
- NEUROTOXINS
- VENOMS
 - BEE VENOMS
 - SNAKE VENOMS
 - WASP VENOMS

The alphabetic term display largely repeats this information, since related terms and scope notes (described in this thesaurus as Message Aids, and abbreviated MA) are little used. Thus, e.g.

VENOMS
 BT TOXICOLOGICAL AGENTS
 NT BEE VENOMS
 SNAKE VENOMS
 WASP VENOMS

Section B3 contains the following hierarchical arrangement of terms:

ENVIRONMENT
 ..
 PUBLIC HEALTH
 ..
 ENVIRONMENTAL EXPOSURE
 MAXIMUM PERMISSIBLE EXPOSURE LEVEL
 OCCUPATIONAL EXPOSURE
 ..
 ENVIRONMENTAL POLLUTION
 AIR POLLUTION
 ENVIRONMENTAL POLLUTANTS
 WASTE PRODUCTS
 WATER POLLUTION
 ..
 FOOD CONTAMINATION
 HYGIENE
 ..
 TOXICOLOGY
 ADVERSE EFFECTS
 ADVERSE REACTION MONITORING
 POSTMARKETING SURVEILLANCE
 PRESCRIPTION EVENT MONITORING
 ADVERSE REACTION REPORTING
 HAZARD
 POISONING
 ALCOHOLIC INTOXICATION
 ERGOTISM
 GASTRIC LAVAGE
 LETHAL DOSE 50

TOXICOLOGY is not a broader term of ADVERSE EFFECTS. It is listed in the alphabetic listing as

TOXICOLOGY
 MA *use only for subject or occupation*
 BT MEDICINE
 RT ADVERSE EFFECTS
 POISONING

and situated in the Health Care Services (B7) section. (There is no mention of TOXICOLOGIST in the personnel section.) Particular aspects of toxicology could be described by combining TOXICOLOGY with other terms from this section, e.g. FORENSIC MEDICINE or PATHOLOGY, or other sections, e.g. ENVIRONMENTAL POLLUTION.

Related terms are used to link concepts in the two sections, e.g.:

POISONING

MA *coordinate with poisonous substance*

NT ALCOHOLIC INTOXICATION

ERGOTISM

GASTRIC LAVAGE

LETHAL DOSE 50

RT ANTIDOTES

POISONS

POISONS

BT TOXICOLOGICAL AGENTS

RT POISONING

Term co-ordination for concepts such as particular forms of toxicity are not used. The introduction to the thesaurus instructs that these be denoted by post-coordination of ADVERSE EFFECTS with the tissue or organ affected, and gives the example

hepatotoxicity = ADVERSE EFFECTS plus LIVER

Since this thesaurus has a detailed set of terms for anatomy and physiology, it should be possible to denote virtually all toxic manifestations in this way.

Similarly the harmful effects of particular substances are to be denoted by coordination of POISONING or ADVERSE EFFECTS with substance terms. The thesaurus contains an impressively detailed set of terms describing drugs, and, to a lesser extent, other chemicals.

The only other terms of relevance to toxicology, deal with information services, i.e.

POISON CENTRES under HEALTH SERVICES AND FACILITIES

and

INFORMATION SCIENCES AND COMMUNICATION

INFORMATION SCIENCES

.. INFORMATION PROCESSING

.. INFORMATION RETRIEVAL SYSTEMS

..
TOXLINE
INFORMATION SERVICES
..
POISONS INFORMATION SERVICES

There are no terms reflecting toxicity testing concepts, other than the single term LETHAL DOSE 50; the terms reflecting research methods all relate specifically to drug evaluation.

This thesaurus is specifically designed for drug-related material, and is therefore ideally suited for describing adverse reactions, and clinical toxicology, but has reasonable coverage of other aspects of toxicology.

Thus, for the 'toluene inhalation' example, the following set of terms could be assigned:

POISONING
LETHAL DOSE 50
TOLUENE
RATS
LUNG
INHALATIONS
IRRITANTS

7.4.4 Derwent Drug File Thesaurus

This thesaurus is used to index the bibliographic databases produced by Derwent Publications, which deal with human and veterinary medicines, and chemicals for crop protection. It has been developed to replace a series of disparate coding, keywording and categorisation systems, previously applied to the Derwent files, and now replaced by this single thesaurus in the so-called unified database (UDB).

The 1995 edition of the thesaurus was consulted, and relevant terms are shown in the appendix in section 7.4.d.

This thesaurus is not constructed or displayed according to thesaurus standards, and has the 'look and feel' of an augmented keyword list. There is a very limited degree of hierarchy within the thesaurus, as is evident from above. There is also a good deal of inconsistency in form of terms (e.g. singular vs. plural), assignment of hierarchical, assignment and symmetry of related terms, etc. Both of these factors result from its derivation from the previous non-thesaurus term lists, previously used to index the Derwent databases.

A series of classificatory groupings is provided. The only one apparently relevant to toxicology is 'activity terms, miscellaneous', which includes ANTIDOTES, TERATOGEN, TOXINS and ZOOTOXINS', but not MUTAGEN, CARCINOGEN or PHYTOTOXINS. Another grouping 'miscellaneous' includes TOX. but not INTOXICATION.

The thesaurus is rich in terms particularly from pharmacology, but also from medicine, pharmacy, botany etc. It can be used to specify other aspects of a toxicology statement, e.g. chemical substance, route of administration, species, etc. with precision.

Thus , for the 'toluene inhalation' example, following set of terms could be assigned:

TOX.
ACUTE
LD50
INHALATION
IRRITANT
IRRITATION
LUNG
TOLUENE
VAPOR
RAT
MAMMAL
LAB.ANIMAL

7.4.5 DHSS-Data Thesaurus

This thesaurus was developed to provide a controlled vocabulary for use in the database of the Library of the (then) Department of Health and Social Security in the UK; this database, started in 1983, is still in existence, and is publicly available as a file on the Datastar system. The subject emphasis is on health care and social welfare, but it encompasses many related areas.

The thesaurus contains approximately 22,000 terms. Its structure is based on an in-house version of the second edition of the Bliss classification scheme. This analysis is based solely on the printed alphabetical thesaurus listing: Aitchison J , Brewin PMR and Cotton JE (1985), DHSS-Data Thesaurus, Department of Health and Social Security, London.

The term records for those thesaurus terms judged relevant to toxicology are presented individually in appendix 7.4.e.

No classified schedule for the terms in this thesaurus is provided in its printed form, since, as noted above, the classificatory structure is derived from a version of the Bliss classification. Therefore, working back from the individual terms, the hierarchy around terms of relevance to toxicology was deduced.

Many of the toxicology-related terms in the DHSS-DATA thesaurus appear in two hierarchical sections: those for POISONING (in the section headed ACCIDENTS) and for TOXICITY STUDIES, which has no broader term.

ACCIDENTS

- ACCIDENTAL OVERDOSING (DRUGS)
- DROWNING
- ELECTRICAL ACCIDENTS
- FALLING
- GAS ACCIDENTS
- INDOOR ACCIDENTS
- INDUSTRIAL ACCIDENTS
- MAN-MADE ACCIDENTS
- RADIATION ACCIDENTS
- TRANSPORT ACCIDENTS
- POISONING
 - TOXICITY
 - ACID POISONING
 - FLUOROSIS
 - FOOD POISONING (multiple BTs)
 - ERGOTISM
 - MUSHROOM POISONING
 - SALMONELLA FOOD POISONING
 - TOXIC OIL SYNDROME
 - YUSHO
 - GAS POISONING
 - WAR GAS POISONING
 - HEPATOTOXICITY (BT liver diseases)
 - METAL POISONING
 - CADMIUM POISONING
 - LEAD POISONING
 - MERCURY POISONING
 - SILVER POISONING
 - VANADIUM POISONING
 - TOXAEMIA
 - PREGNANCY TOXAEMIAS
 - TOXIC SHOCK

TOXICITY STUDIES

- ACUTE TOXICITY STUDIES
- ALLERGY AND IRRITANCY STUDIES
- CELL TRANSFORMATION ASSAYS
- DOMINANT LETHAL STUDIES
- GENOTOXIC STUDIES
 - DNA DAMAGE ASSAYS
 - CYTOGENETIC ANALYSIS
 - DNA MODIFICATION ASSAYS
 - DNA REPAIR ASSAYS
 - SISTER CHROMATID EXCHANGE
 - MUTAGENICITY TESTS
 - HOST MEDIATED ASSAYS
- LONG TERM STUDIES
- REPRODUCTIVE TOXICITY STUDIES
 - FERTILITY STUDIES
 - FOETOTOXICITY STUDIES
 - MULTI-GENERATION STUDIES
- SUBACUTE TOXICITY TESTS

Other concepts appear in a less structured hierarchy. POISONS appears in a multi-hierarchy, having the broader term DANGEROUS MATERIALS and also the broader term CHEMICAL HAZARDS, itself having three broader terms.

CHEMICAL HAZARDS (BT DANGEROUS MATERIALS, ENVIROMENTAL HAZARDS, HEALTH HAZARDS)
GAS HAZARDS
OIL HAZARDS
POISONS (BT DANGEROUS MATERIALS)
ARSENIC
PESTICIDES
POISONOUS PLANTS (dangerous materials, plants)
BRACKEN
STRYCHNINE

TOXINS appears as part of a small hierarchy:

ANTIGENS (BT immunologic factors)
RHESUS FACTOR
TOXINS
ENDOTOXINS
MYCOTOXINS

Several terms are isolated from any hierarchical structure involving toxicology terms, e.g.: POISON CENTRES and POISON CONTROL; CARCINOGENS and CARCINOGENICITY, TERATOGENS, MUTAGENS and MUTAGENESIS; and TOXICOLOGY itself, whose only hierarchical relation is a narrower term DRUG TOXICOLOGY. Nor is there any linked hierarchy connected the various terms describing the concepts of drug toxicology / drug adverse effects / drug side effects, which would, from a toxicology perspective, be thought of as closely related. Indeed, apparently similar concepts are separated from each other in the hierarchical structure, though the related term relations will in practice allow users of the thesaurus to see some inter-relations.

This thesaurus gives a good structured description of much toxicity-related material. Its main weakness, from this specialised perspective, is its failure to link together very similar concepts, as noted above, other than by related terms, thereby making an overview of toxicology material difficult to obtain. There is also a degree of inconsistency in the detailed specification of genetic toxicity testing, compared with the single term allocated to acute toxicity. Similarly, a term is listed for hepatotoxicity, but not for any other organ-specific form, e.g. renal or lung. These could of course be generated by post-coordination, e.g. renal toxicity = KIDNEY plus TOXICITY. In the same vein, several examples of specific metal toxicity are listed as compound terms, while the toxicity due to other substances would have to be specified at indexing time by post- coordination.

For the 'toluene inhalation' example, the following terms would be available:

ACUTE TOXICITY STUDIES (nothing more specific for LD50)
INHALATION EXPOSURE
LUNGS
IRRITANTS (DRUGS)
RATS
VAPOUR
AROMATIC HYDROCARBONS and/or ORGANIC SOLVENTS (no specific term for TOLUENE)

7.4.6 Life Sciences Thesaurus

This thesaurus is used in the indexing of the set of bibliographical databases produced by Cambridge Scientific Abstracts, and including Toxicology Abstracts. It might therefore be expected to have good provision for toxicology abstracts. The thesaurus was examined online [www.csa.com/helpV3/lscthes.html].

This is the fourth edition of the thesaurus, containing 9,400 descriptors. The standard relations - SY, BT, NT, RT - are included, but many terms have no relations, and hierarchies rarely seem to go more than one level deep.

Names of chemicals and biological species are not included in the thesaurus *per se*, but are taken from other standard sources in indexing the CSA databases. Merck index and Chemical Abstracts are used for chemical names, and several biological taxonomies for species.

TOXICOLOGY is a single term in the thesaurus, without any relations. Detailed toxicity concepts are given under that term:

TOXICITY
ACUTE TOXICITY
CHRONIC TOXICITY
CYTOTOXICITY
GENOTOXICITY
IMMUNOTOXICITY
NEUROTOXICITY
OTOTOXICITY
PHOTOXICITY
PHYTOTOXICITY
SUBACUTE TOXICITY

with related terms:

LETHAL DOSE
LETHAL LEVELS
LETHAL LIMITS
POLLUTION EFFECTS

SIDE EFFECTS
THRESHOLD LIMITS
TOXICANTS
TOXICITY TESTING
TOXINS

Of these related terms, TOXINS has 15 narrower terms, including AFLATOXINS, CARDIOTOXINS AND IMMUNOTOXINS.

TOXICITY TESTING has two narrower terms: CYTOTOXICITY TESTING and GENOTOXICITY TESTING.

POISONING is a separate term, with six NTs, including FOOD POISONING and ACCIDENTAL POISONING, with POISON CONTROL CENTRES and INTOXICATION as related terms.

Other toxicity-related concepts are represented by CARCINOGENS, CARCINOGENICITY, CARCINOGENICITY TESTING, and similarly for MUTAGENICITY and TERATOGENICITY.

Taking the 'toluene inhalation' example, the following terms would be available:

TOXICITY TESTING
ACUTE TOXICITY
LETHAL DOSE
LUNG
IRRITATION
VAPORS

Toluene is represented in the thesaurus only by the general AROMATIC HYDROCARBONS, though the databases would be indexed by the specific compound name taken from Merck. Similarly 'rat' does not appear as a thesaurus term, but would be represented by its species name taken from a biological taxonomic listing.

This thesaurus, when complemented by the external sources for chemical and species names, gives a reasonably detailed coverage of toxicology concepts. However, the depth is limited, with no specification of end-points such as specific lethal doses, and the toxicology-related terms are scattered throughout the thesaurus structure, with no strong hierarchy to bring them together.

7.4.7 Biological Abstracts/Biosis

Biological Abstracts bibliographic databases are available in print and CD-ROM form, and online on several host systems. Their indexing vocabularies are described in detail in the printed search guides; the 1995 edition was consulted, with more recent material examined via the Biosis website.

This system uses several separate indexing vocabularies, including detailed Biosystematic coding for living things. The two aspects of relevance to toxicology are Keywords and the series of Concept Codes. Both are accessible from a Master Index. In the late 1990s, the producers announced the intention of removing the Concept Code and Biosystematic codes as from 1999, and relying on the detailed free-text indexing; however, this decision was subsequently reversed.

Biosis also uses terms from the MeSH thesaurus to index diseases (which could include toxic effects), and Chemical Abstracts Registry Numbers to denote specific chemical substances.

The Biosis vocabulary is not a thesaurus in the strict sense, since the keywords do not form part of any series of hierarchical relationships, though 'see also' (related term) relations are included. The Master Index lists a series of Main Headings, concepts which link together keywords, concept codes, and other forms of indexing vocabulary. For example, the Main Heading for 'toxicology' is as shown:

TOXICOLOGY
EX: TOXICOLOG\$
see also TOXIC
CC: TOXICOLOGY
(listing of 6 concept codes)

The corresponding entry for 'toxic' is:

TOXIC
EX: TOXIC, TOXICITY, TOXIF\$, TOXIGEN\$
see also INTOXICATION, POISON, TOXIN
CC: Toxic
see CC under TOXICOLOGY

for 'toxin':

TOXIN
EX: TOXIN\$
may appear with AFLA or ENDO or ENTERO or GLIO or MYCO or PODOPHYLLO
or TETRODO
see also POISON, TOXIC, TOXOID

and for 'poison':

POISON

EX: POISON\$
see also INTOXICATION, TOXIC, TOXICOLOGY, TOXIN, VENOM

Other toxicology related terms present in this list are: TOXICANT, TOXICATION, TOXICOSIS, TOXICODYNAMICS, TOXICOKINETICS. These generally have no, or few, related terms, and do not point to the Concept Codes.

'EX', standing for 'example', illustrates the ways in which this concept should be searched for in the computerised Biosis databases - \$ representing truncation - since the indexing is not controlled by this list of Main Headings. This list of terms therefore functions as a 'search thesaurus', directing the searcher to useful terms and forms of term. However, it does not help in bringing together toxicology related concepts, nor showing their inter-relation.

Two terms are present reflecting lethality quantification:

LC-50

EX: LC ADJ 50
abbreviation for median lethal concentration

LD-50

EX: LD ADJ 50
abbreviation for median lethal dose

'adj' describes the phrase searching necessary to find these phrases in a search system. Note that there is no relation between these terms and other toxicology concepts.

Terms for the mutagen concept are:

MUTAGEN

EX: MUTAGEN\$

MUTAGENIC

EX: MUTAGEN\$
see also MUTATION

MUTATION

EX: MUTAT?
see also CHANGE, MUTABILITY, MUTAGENIC, MUTANT

Note that it is recommended that MUTAGEN and MUTAGENIC be searched the same, by use of truncation, and that there is no linkage between the terms and toxicology concepts. Nor are any concept codes associated.

For carcinogenicity, there is only one term in the Master Index:

CARCINOGEN

EX: CARCINOGEN\$
see also CARCINO, ONCOGENIC
CC: one concept code is noted

For teratogenicity, there are three terms:

TERATOGEN

EX: TERATOGEN\$
see also TERATO
CC: Teratogen
see CC under TERATOLOGY

TERATO

EX: TERATO
see also TERATOGEN

TERATOLOGY

EX: TERATOL\$
CC: Teratology
(2 concept codes listed)

No relation is shown between carcinogenicity and mutagenicity, nor between any of these terms and toxicology.

Drug side effects are described by the terms SIDE EFFECT and ADVERSE REACTION, which have no related terms, apart from each other, and no associated concept codes.

This is essentially a set of keywords, with some limited inter-relations. For broader concept linking, it is necessary to use the Biosis concept codes, of which 9 have been noted above. These codes are organised into Broad Concept Headings. The Toxicology heading included the 6 codes listed under the term 'toxicology' in the Master Index:

Toxicology

- General; methods and experimental
- Foods, Food Residues, Additives and Preservatives
- Pharmacological Toxicology
- Antidotes and Preventative Toxicology
- Environmental and Industrial Toxicology
- Veterinary Toxicology

The code indicated by the term 'carcinogen' is:

Neoplasm and Neoplastic Agents

- ..
- Carcinogens and carcinogenesis
- ..

and the two for 'teratology' are:

Developmental Biology

- ..
- Descriptive Teratology and Teratogenesis
- Experimental Teratology and Teratogenesis

Other codes may be of some relevance for some aspects of toxicology, e.g.

Public Health

- Occupational Health
- ..
- Air, Water and Soil Pollution
- ..

as well as codes for methodologies such as tissue culture and in vitro techniques.

These concept codes are particularly useful complements to the more specific keywording, and it is interesting to note that the proposal to discontinue them has been dropped.

7.4.8 International Pharmaceutical Abstracts

This database is indexed from a set of preferred terms. The printed volume consulted was: Thesaurus of Subject Terms and Cross References (3rd edition), 1985, American Society of Hospital Pharmacists, Bethesda MA

This is not a true thesaurus, in that no hierarchical relationships are included. The tool comprises an alphabetical list of preferred terms, with see references from non-preferred terms, and with see *also* references to related terms.

The toxicology-related preferred terms included are these:

- Toxicity (*use for side effects*)
- Toxicity tests
- Toxicity, environmental
- Toxicology
- Toxins
- TOXLINE

- Poison control centers
- Poison information centers
- Poisoning
- Poisons

- Carcinogenicity
- Carcinogens

Mutagenicity
Mutagens

Teratogenicity
Teratogens

Drugs, adverse reactions

This set of terms, combined with a very full set of pharmacy descriptors, and terms for medicinal substances and other chemicals, should make it possible to index toxic effects consistently. However, the lack of index terms for toxicity testing - e.g. acute, lethal dose - and for particular aspects of toxicology make this thesaurus of limited value for this specific purpose. The lack of any hierarchical structure, and of any scope notes, means that it cannot be used to understand toxicology concepts in any way.

7.4.9 Medical and Health Related Sciences Thesaurus

US Department of Health, Education and Welfare, Public Health Service, 2nd edition, 1969

This thesaurus was compiled for use in indexing the Research Grants Index, a subject listing of research projects supported by the public health service.

It is unusual in two ways. For one thing, the relations used are distinctly non-standard. Setting aside several symbols used to indicate matters specific to the Research Grants Index, four relations are used:

1 SEE ALSO

this is indicated as used in two ways:

'see also related', e.g. PERCEPTION see also SENSORY MECHANISMS
and

'see also specifics', e.g. PROTEINS see also GLOBULINS

The reverse relation is noted as XX, e.g. SENSORY MECHANISMS XX PERCEPTION

2 SEE

this is also indicated as used in two ways:

'see synonymous', e.g. CARDIAC MASSAGE see HEART MASSAGE
and

'see specifics', e.g. FIBROSIS see CORONARY FIBROSIS

The reverse relation is noted as X, e.g. HEART MASSAGE see CORONARY MASSAGE

3 USE

This is 'an indexing instruction to indicate terms required to cover a particular concept', e.g. MULTIPLE SCLEROSIS AS AN AUTOIMMUNE DISEASE

USE IMMUNOPATHOLOGY, AUTOIMMUNE DISEASES

USE MULTIPLE SCLEROSIS

The reverse relation is UU

4 INDEX ALSO

Instructs an indexer to also apply generic headings

e.g. ABALONE index also MOLLUSKS [sic]

This usage of terms different from the standard, or indeed from any other thesaurus, leads to a considerable degree of confusion. In particular, it is not clear how they could be used with any consistency to establish hierarchical relations, given that these may be denoted by the 'see specifics', 'see also specifics' and 'index also'. Since the same notation is used to indicate related/specifics and synonyms/specifics, it is not possible to reconstruct any hierarchy from the thesaurus itself.

The second distinctive feature of this thesaurus is that individual terms are highly co-ordinated, often combining four or even five concepts, e.g.

IMMUNOLOGICAL TESTS AND IMMUNOASSAY, ANTIGEN BINDING CAPACITY

sometime forming a 'hierarchy' in their own right, e.g.

RESPIRATORY NEOPLASMS, LUNG NEOPLASMS, BRONCHOGENIC CARCINOMA

The aim of these unusual thesaurus practices is presumably to provide one single point in a printed index at which complex topics occurring in the research projects list can be placed.

Scope notes are not used, so that the thesaurus would only be of value to a user with considerable familiarity with the subject area.

Toxicology concepts occur at various points in the thesaurus; there are, for example, 45 terms beginning with the string TOXIC. They are not listed exhaustively, only sufficient to give an indication of how they are treated in this usual tool.

TOXICOLOGY

see also AIR POLLUTION

see also BLOOD TOXICOLOGY

see also PHARMACOLOGY-TOXICOLOGY REVIEW COMMITTEE

see also SOIL POLLUTION

see also WATER POLLUTION

TOXICOLOGY, ANIMAL POISONS

see also CARDIAC GLYCOSIDES, BUFOTOXIN

see also CARDIAC GLYCOSIDES, AGLYCONES, BUFADIENOLIDES

X ANIMAL POISONS

XX TOXICOLOGY POISONS

.. TOXICOLOGY, PLANT POISONING, TREMBLES

see also TOXICOLOGY, PLANT POISONS, TREMETOL

X ALKALI DISEASE (APLOPAPPUS)

X GOLDENROD (RAYLESS) POISONING
X 6 other specific plant poisons

Note that here, unusually, there is a specific link between poisons and poisoning.

..

..

TOXICOLOGY, POISONING
 see also ALCOHOLISM - DRINKING, ALCOHOLISM
 see also DRUGS ADVERSE EFFECTS
 see also IRON DISORDERS AND IMBALANCES, IRON POISONING (ACUTE)
 see also METALS POISONING
 see also RESPIRATORY DISEASES, SILO FILLER'S DISEASE
 see also TOXICOLOGY, CYTOTOXICITY
 see also TOXICOLOGY, DETOXICATION
 see also TOXICOLOGY, PLANT POISONING
X POISONING

TOXICOLOGY POISONING, AMMONIA INTOXICATION
 see also LIVER DISORDERS, HEPATIC COMA
X AMMONIA INTOXICATION

..

TOXICOLOGY, POISONS
 see also ANTIMETABOLITES
 see also PESTICIDES
 see also TOXICOLOGY, ANIMAL POISONS
 see also TOXICOLOGY, PLANT POISONS
 see also TOXINS
X POISONS
XX TOXINS

Note that the 'see also' relation is usually denoted by 'see also' one way and 'XX' the other; however, TOXICOLOGY, POISONS and TOXINS have both relations, and TOXINS appears as both 'see also' and 'XX' under TOXICOLOGY, POISONS. Since this occurs elsewhere in the thesaurus, it must be presumed to be deliberate policy, rather than an error.

Note also that there is often no link of any sort between the various TOXICOLOGY terms, even where one seems clearly a subset, or specific example, of another, other than their closeness in the alphabetical listing. The distinction between activity (POISONING) and substance (POISONS) is generally absolute, and 'see also' relations between these general concepts are made rarely. There is a link to the POLLUTION concepts from TOXICOLOGY, and to adverse effects of drugs from TOXICOLOGY, POISONING.

Other toxicology-related terms appear elsewhere, e.g.

TERATOGENIC AGENTS
 see CONGENITAL ABNORMALITIES, TERATOGENIC AGENTS

CONGENITAL ABNORMALITIES, TERATOGENIC AGENTS
 see also GENETICS MUTAGENS
X TERATOGENIC AGENTS

XX	GENETICS, MUTAGENS
MUTAGENS	
see	GENETICS, MUTAGENS
GENETICS, MUTAGENS	
see also	ANTIMETABOLITES
see also	ANTIMIOTIC AGENTS
see also	CONGENITAL ABNORMALITIES, TERATOGENIC AGENTS
see also	NEOPLASTIC TRANSFORMATION, CARCINOGENS
X	MUTAGENS
XX	CONGENITAL ABNORMALITIES, TERATOGENIC AGENTS
XX	NEOPLASTIC TRANSFORMATION, CARCINOGENS
AI	CROSSOVER INDUCERS

Note again the seemingly redundant use of 'see also' and 'XX'.

Teratogens, mutagens and carcinogens may therefore be found inter-related to one another, though through a web of 'see alsos' rather than a logical hierarchy, and without any link to the TOXIC... terms.

This thesaurus therefore provides highly co-ordinated and specific terms for a variety of toxicology related concepts, but without any overall hierarchical structure, and with a good deal of inconsistency. Many important concepts are missing: there is no way, for example, to index acute or chronic toxicity, or lethal doses. It seems likely that construction of the thesaurus has been based on 'literary warrant' that is to say selection of terms based on existing projects to be indexed. It does not therefore show any useful conceptual structure for toxicology, nor would it be useful for indexing toxicology material in general.

7.4.10 CAB Thesaurus

The CAB thesaurus is maintained by CAB International (formerly the Commonwealth Agricultural Bureau). It is used primarily for indexing a variety of secondary services produced by CAB, and has also been adopted for indexing Internet resources in two subject gateways within the UK-based BIOME resource guide: Vetgate and Agrifor, dealing with veterinary science and agriculture and forestry respectively.

The thesaurus has recently undergone a major revision, reflecting the expanded coverage of the CAB databases; the 1988 edition was examined in printed form, and the latest (1999) versions of the terminology was examined through BIOME.

The CAB thesaurus is, naturally, geared towards agricultural and environmental topics, and has a small set of toxicology-related terms, around the general concepts of poisoning / toxic substances and pollution. The main terms are listed in the appendix, section 7.4.f.

There is no extensive hierarchy - TOXICOLOGY, for example, having no broader term - and instead a rather general use of related terms, with lengthy lists of narrower terms for plants and chemicals.

This presents a rather limited and particular view of toxicology in a specific environment. It is evidently not suitable for dealing with general toxicology material. In its own area, however, it allows for detailed specification, for example poisonous plants. In these respects, it is typical of a number of such thesauri in the environment/agriculture area.

7.4.11 UCLA Biomedical Library

Subject Heading Authority List, 2nd edn., 1976, University of California Los Angeles Biomedical Library

This tool is not a thesaurus proper, but rather a list of subject headings and cross references, without scope notes, or hierarchical relations, and with few related terms. The headings are taken from four sources: MeSH; Library of Congress Subject Headings; US National Agriculture Library's vocabulary; and the UCLA Library's own subject headings.

Where the same term was present in more than one source, preference was given to the MeSH term, where one exists. Since the MeSH vocabulary caters well for toxicology concepts, from this perspective this tool offers little more than a set of un-annotated MeSH headings, with some UCLA headings, denoted as BIOMED, e.g.:

Toxicology - see also related Poisons -MeSH -
Toxicology -Abstracts -MeSH
Toxicology - Bibliography - MeSH
..
..
Toxicology, industrial see industrial poisons
..

Industrial poisons
x Industrial toxicology
x Poisons, industrial

x Toxicology, industrial - BIOMED -
Industrial poisons - Abstracts - BIOMED
Industrial poisons - Analysis - BIOMED
Industrial poisons - Congresses - BIOMED
Industrial poisons - Periodicals - BIOMED
..

Poisonous mushrooms, see mushrooms, poisonous by place
..

Mushrooms, poisonous by place
x poisonous mushrooms - LC-
Mushrooms, poisonous - Canada -LC-
Mushrooms, poisonous - U.S. -LC-
..

From the toxicology perspective, this offers little more than a set of MeSH headings, slightly expanded by headings from the other sources when no MeSH term was suitable. This could indicate the limitations of MeSH, compared with other systems, at least for the time at which this listing was produced. However, virtually all toxicology-related terms were taken from MeSH. The examples shown above - industrial poisoning from UCLA's headings, and poisonous mushrooms from LC Subject Headings, are the only two evident examples in this listing of toxicology terms taken other than from MeSH.

This listing is therefore rather uninformative as regards toxicology.

7.4.12 Biomedical thesaurus and guide to classification

Koch MS (1972), CCM Information Corporation, New York

This thesaurus was designed to serve as a guide to subject analysis for biomedical literature, by bringing together terms from three indexing languages, as they stood in the early 1970s: MeSH, Library of Congress Subject Headings, and the terms used in the National Library of Medicine printed catalogues of 1950-59. Classification numbers from LC and NLM classification are added where appropriate. The thesaurus contains about 5,000 subject headings and cross-references.

Full thesaural relations are not shown. 'see' relations, and the reciprocal 'x', and 'see also' and its reciprocal 'xx', are given, but there are no hierarchies or scope notes.

Records take the form:

TOXICOLOGY (QV 600)
 [LC, MeSH, NLM]
 sa POISONS
 xx POISONS

This shows that the term TOXICOLOGY occurs in the LC, MeSH and NLM subject heading lists, that it has a classification number QV 600, and that it has POISONS as a related term.

POISONS (QV 600-667)
 [LC, MeSH, NLM]
 sa Drugs - Toxicity
 Food poisoning
 Industrial poisons
 Poison control centres
 Poisoning
 Poisonous plants
 Toxicology
 Venom
 xx Poisoning
 Toxicology

INDUSTRIAL POISONS (WA 475)
 [NLM. Not in MeSH. LC: see Industrial toxicology]
 x Industrial toxicology
 xx Poisons

This indicates that this term is only used in the NLM subject headings.

This thesaurus is an interesting early example of a 'switching vocabulary' of which UMLS is the most recent and developed example. So far as toxicology is concerned, it is of limited historical interest.

7.4.13 Toxisaurus

This listing, the TOXicology theSAURUS, produced by the Bioscience Information Service, and produced as report PH 43-68-1329, dated 1970, is the only thesaurus in the Aslib collection designated as specifically relating to toxicology.

It comprises a computer-generated listing of approximately 2000 terms, most being general biomedical terms, shown with the standard set of relations: BT, NT, use, use for, and RT. There are also two relations - CF and QL - whose meaning is not obvious; they are usually, though not always, used symmetrically between two terms. There is no explanation of any aspect of the thesaurus, and no scope notes for any terms.

From the listing, the following hierarchical sections for specifically toxicology concepts can be derived:

ADVERSE EFFECT

NT	ACUTE
NT	CHRONIC
NT	CONTRAINDICATION
NT	NON-TARGET
NT	OVERDOSE
NT	REVERSIBLE
NT	SIDE-EFFECT
RT	HYGIENE
RT	POISONING
RT	TOXICITY

CARCINOGEN

BT	PATHOGEN
RT	NEOPLASM

DOSAGE

CF	INTENSITY
NT	ACUTE
NT	CHRONIC
NT	INNOCUOUS
NT	LETHAL
NT	LIMIT
NT	MASSIVE
NT	SUBACUTE
NT	SUBLETHAL
NT	THERAPEUTIC
NT	THRESHOLD
RT	CONCENTRATION
RT	HYGIENE
RT	POISONING
RT	TOXICITY

HYGIENE

CF	POISONING
CF	THERAPY
CF	TOXICITY
NT	CONTROL
NT	CRITERION
NT	DECONTAMINATION
NT	DESIGN
NT	ENGINEERING
NT	HAZARD
NT	MONITORING
NT	PREVENTION
NT	SAFETY
NT	SANITATION
RT	ADVERSE EFFECT
RT	CONTAMINATION
RT	DOSAGE
RT	EPIDEMIOLOGY

LETHAL

BT	DOSAGE

MUTAGEN

BT	PATHOGEN
RT	ABERRATION
RT	MUTATION

POISONING

CF	HYGIENE
NT	ACCIDENT
NT	ACUTE

NT	CHRONIC
NT	HOMICIDE
NT	SUBACUTE
NT	SUICIDE
RT	ADVERSE EFFECT
RT	DOSAGE
RT	TOXICITY

TERATOGEN

BT	PATHOGEN
RT	MORPHOGENESIS
RT	TERATISM

TOXICITY

NT	ACUTE
NT	CHRONIC
NT	CUMULATIVE
NT	SUBACUTE
RT	ADVERSE EFFECT
RT	DOSAGE
RT	HYGIENE
RT	POISONING

TOXIN

BT	BIOLOGICAL AGENT
BT	CHEMICAL
BT	PATHOGEN

VENOM

BT	BIOLOGICAL AGENT
BT	CHEMICAL
BT	PATHOGEN

This thesaurus has a 'flat' hierarchical structure; none of the terms specifically relating to toxicology has both a broader and a narrower term, though other terms in the thesaurus do, e.g.

STRUCTURE

- ULTRASTRUCTURE (and 22 other terms)
- GRANULE (and 42 other terms)
- PYRENOID

Some of the relations appear idiosyncratic, e.g. homicide as a sub-set of poisoning, rather than the other way around, reflecting the focus on toxicology.

Even so, less than 5% of the terms in the listing relate to specifically toxicological concepts.

7.4.14 NLM List of Compounds

This is a list of compounds entered in the National Library of Medicine's Toxicology Databank, and ordered by chemical name. Although it is present in the Aslib Library's

thesaurus collection, with an accession date of 1981, indexed under toxicology, it is in no way a true thesaurus.

7.4.15 COSTART

COSTART, Coding Symbols for Thesaurus of Adverse Reaction Terms, is a list of coding symbols used in the US Food and Drug Administration's National Adverse Drug Reaction Directory. Although it is among the thesauri in the Aslib collection, with an accession date of 1980, it is list of preferred terms and equivalent codes for symptoms and anatomical regions, e.g.

deafness, permanent	DEAF PERM
dermatitis, allergic	RASH (ST)

It is therefore an example of a medical coding system, such as the International Classification of Diseases, or the Read Codes, rather than a thesaurus proper.

7.4.16 Summary of Thesauri

It is clear that a wide variety of thesauri cover toxicology to some extent, but few to the depth and breadth required for them to be adequate for the organisation of toxicology knowledge.

Those which deal most adequately with toxicology are the thesauri developed for indexing the large 'general' biomedical databases. The few which claim to be toxicology-specific are far from complete, even allowing for their out-datedness. A considerable number deal adequately with certain aspects of toxicology; CAB is a good example, and more examples could have been given.

Taking the successful description of the 'toluene inhalation' example as a measure of adequacy of dealing with toxicology concepts, only four thesauri 'pass': MeSH, Emtree, Pharmline and Derwent. LCSH, and DHSS-Data and Life Science Abstracts thesauri give most, but not all, concepts required. It is interesting that LSA, which is used for indexing the subject-specific Toxicology Abstracts secondary service, does not perform as well as the 'general' tools.

While the Biosis indexing could deal adequately with the concepts, this would be done by use of the 'relational free text' approach favoured by Biosis, rather than by a thesaurus *per se*. It is interesting to note, however, that the decision by this provider to remove their controlled vocabulary part of their indexing (including the toxicology concept codes) was reversed; this shows the value of even limited controlled vocabulary in a largely free-text system.

One test example does not, of course, indicate the four thesauri which perform well are perfectly designed for dealing with toxicology material. However, it does give a clear indication of which kind of thesaurus is well adapted to the task.

The other major point of interest to emerge from this comparison of thesauri is the differences in how toxicology is dealt with. Although all of them provide some way of denoting significant toxicology concepts, the terminology used, the depth of detail to which it is taken, and the overall structure within which it is set, differ considerably. This is a reflection of the complex nature of toxicology, which may be viewed from various perspectives.

7.5 Glossaries and dictionaries

7.5.1 Glossaries

Toxicology, as is stressed elsewhere in this dissertation, is very much a multidisciplinary science, relying on the methods and concepts of other sciences, while developing methods and concepts of its own. Terminology may therefore be expected to be a particular problem, given a wide variety of potentially relevant subject terminologies, plus toxicology-specific terms. Newcomers to the area may have to consult several specialist dictionaries in order to find definitions of all the terms used (Duffus et al. 1993). Given this, it is perhaps surprising that more attention has not been devoted to this issue.

The link between glossaries and thesauri has been described clearly by Rada et al. (1993);

'Building glossaries and building thesauri are two different but related activities. For both thesauri and glossaries the terms selected for inclusion should be of relevance. The thesaurus places emphasis on the relations between concepts in the domain, whereas the glossary places emphasis on the relevance of the definitions for the terms.'

IUPAC glossary

The most extensive glossary of toxicology terms is provided by Duffus et al. (1993). This is a glossary of 'terms used in toxicology', intended primarily for chemists - although, as shown below, the usefulness of this glossary is by no means restricted to this professional group - and produced by the Commission on Toxicology within the framework of the Clinical Chemistry Division of the International Union of Pure and Applied Chemistry (IUPAC). The rationale for the glossary is clearly given:

'Over the years, toxicology has grown rapidly. A need has been recognised for globally acceptable definitions of terms used in toxicology and ecotoxicology... The glossary is compiled primarily for chemists who now find themselves working in toxicology or requiring a knowledge of the subject. Faced with an extensive literature and terms that are not always defined in accessible dictionaries, newcomers to the subject can have great difficulty in obtaining the background knowledge essential for their work. Further, many toxicologists, whose previous experience has been limited to

clinical and experimental toxicology, now have to assess possible environmental effects of chemicals and need to understand terms used in ecotoxicology. Equally specialists in ecotoxicology often lack knowledge of the terms used in clinical and experimental toxicology. There are also regulators and managers who have to interpret toxicological information and therefore need ready access to internationally accepted definitions of relevant terms in common use.'

This potentially wide audience led the glossary compilers to take a wide view of its scope: 'satisfying the requirements of the various groups now concerned with the generation or use of toxicological knowledge is a wide remit and hence the terms to be included in this glossary have come from a wide range of disciplines'. Specifically the glossary is said to include many medical terms and epidemiological, because of their frequent occurrence in the toxicology literature (and particularly because chemists, the main intended users of the glossary, would not be familiar with them. The compilers note that they erred on the side of redundancy in including peripheral terms. Furthermore, they gave alternative definitions where significant differences in usage occur between disciplines.

In order to check this point, a rough assessment was made of the proportion of terms in this glossary which were strongly related to toxicology, in any of its forms, including environmental, and which were 'background' terms, not directly related to toxicological concepts. A scan of the entire glossary suggested that about 50% of the terms were definitely toxicology-related.

The glossary makes no attempt to introduce 'preferred' definitions, nor to emphasise newer usage. For example, they note the IUPAC standard that abbreviations should not be used as symbols for physical quantities, whereas toxicologists have used LD50 (i.e. lethal dose 50) and similar abbreviations on this way. The compilers make recommendations on how some toxicology terms and symbolism could be brought into accordance with recommended formats, but include the commonly used format in the glossary. Terms regarded as obsolete are also included if they are still to be found in scientific articles; the example of 'cytochrome P448' (now referred to as P450 I, A1 and A2) is given.

The glossary contains 1206 terms (including cross references without definition), 112 abbreviations, and 63 acronyms for organisations. Most definitions are fairly short, e.g.

absolute lethal dose (LD100) Lowest amount of a substance which kills 100% of test animals under defined conditions. This value is dependent on the number of organisms used in its assessment.

and

chronotoxicology Study of the influence of biological rhythms on the toxicity of substances

though some, particularly those dealing with topics such as statistics and safety precautions, have definition and explanation taking over a page.

Approximately one third of the entries have a quoted source for their definition, taken from a list of 55 sources - dictionaries, glossaries, textbooks, articles, etc. - which is appended, e.g.

posology study of doses in relation to the physiological factors that may influence response such as age of the exposed organisms
Brown 1988

BROWN VK (ed.) (1988), *Acute and Sub-Acute Toxicology*, Edward Arnold, London

This glossary is rather unusual, and innovative, in including information on term relationships, after the manner of a thesaurus (see, for example, Aitchison, Gilchrist and Bawden 2000). The following relations are used:

Exact synonym	SN
Partial synonym	PS
Opposite, antonym	AN
Broader term	BT
Narrower term	NT
Related term	RT

They are simply stated as above, with no further definition, or indication of how they are to be applied or used.

However, only about 25% of the terms in the glossary have any relation assigned, so that they are clearly intended to function as an aid to the user, rather than as a foundation for a thesaurus as such.

The exact synonym relation is used for cross-referencing, e.g.

abiological See SN **abiotic**

abiotic Not associated with living organisms

SN **abiological**

The partial synonym (PS) relation is used somewhat inconsistently. In some cases, the 'see' relation is used to refer to another term, which refers back by SN, exact synonym, e.g.

super-threshold dose See PS **toxic dose**

toxic dose Amount of a substance which produces intoxication without lethal outcome. SN **super-threshold dose**

In other cases, separate definitions are given, and the PS relation is symmetric, e.g.

addiction Surrender and devotion to the regular use of a medicinal or pleasurable substance for the sake of relief, comfort, stimulation or exhilaration which it affords; often with craving when the drug is absent. PS **dependence**

dependence

1 A psychic craving for a drug or other substance which may or may not be accompanied by a physical dependency

2 Reliance on a drug or other substance to maintain health

PS **addiction**

In still other cases, the relation is one way, the relation back to the other term being given as a part of the definition e.g.

death rate Estimate of the proportion of a population which dies during a specified period ... PS **mortality, mortality rate**

mortality Death as studied in a given population or subpopulation. The word mortality is often used incorrectly instead of mortality rate. (*no relation back to mortality*)

mortality rate See SN **death rate**

This inconsistency in usage of the PS relation seems rather unhelpful, and it is likely that its replacement by either SN or RT, used appropriately and systematically would be more useful.

The antonym, or opposition, relation is used in two ways. First, for concepts which are literal opposites; e.g. **benign** and **malignant**, or **aerobic** and **anaerobic**. Second, for concepts which are commonly thought of as alternatives, though they are not literally opposites, e.g. **acute toxicity** and **chronic toxicity**.

The broader term relation is sometimes used to refer from one term, by a 'see' relation, to a broader term whose definition includes the narrower term. (In this example, the back relation is be RT rather than the expected NT, e.g.

secondary pollutant See BT **pollutant**

Pollutant Any undesirable solid, liquid or gaseous matter ... A secondary pollutant is a pollutant formed by chemical reaction in the atmosphere, water, sediments or soil.

PS **contamination**

RT **pollution, secondary pollutant**

More often, BT is used to refer from a defined term to a broader one, e.g.

monoclonal antibody Antibody produced by cloned cells derived from a single lymphocyte. BT **antibody**

Rather confusingly, the reverse term may be RT, PS or absent.

Similarly, the NT relation points to more specific examples of the term, but the reverse relation is inconsistent (there are examples of BT, RT, PS and none), e.g.

monitoring continuous or repeated observation ..

NT **ambient monitoring, biological effect monitoring, biological monitoring, environmental monitoring, health surveillance, personal monitoring**

In a thesaurus structure, these 6 narrow terms would each have a broader term relation to 'monitoring'. In fact, the relations are:

biological monitoring	BT monitoring
personal monitoring	BT monitoring
ambient monitoring	RT monitoring
environmental monitoring	RT monitoring
health surveillance	RT monitoring
biological effect monitoring	no relation to monitoring

The NT relation is also used with 'see' to refer to the specific example of this term, or its narrower meaning, used in this glossary, e.g.

activation see NT **bioactivation**

bioactivation Any metabolic conversion of a xenobiotic to a more toxic derivative

PS **activation**

BT **biotransformation**

There is no relation back to **bioactivation** from **biotransformation**

The related term relation is the most widely used relation between terms in this glossary. It is sometimes used in the thesaural manner, symmetrically between two terms, e.g.

concentration-effect relationship Association between exposure concentration and the magnitude of the resultant continuously graded change, either in an individual or in a population

RT **dose-effect relationship**

dose-effect relationship Association between dose and the magnitude of a continuously graded effect, either in an individual or in a population or in experimental animals

RT **concentration-effect relationship**

However, it is more commonly used unsymmetrically, with no reverse relation, or with PS, NT or BT, as in the examples above.

It would be unfair to judge this glossary by the standards of an information retrieval thesaurus, which is not its purpose. Even so, it seems clear that the benefits to the users of such a glossary from the introduction of relations between the terms would be substantially increased if the relations were applied consistently, and to a larger proportion of terms.

Even with this criticism, the value of this kind of hybrid glossary / thesaurus, particularly for a multidisciplinary subject field seems clear.

An abridged version of this glossary was published by Duffus and Worth (1996 pp 238-315). The nature of the 'abridgement' is not stated, but its effect is to reduce the size of the glossary by about a third, to a total of 819 terms. A repeat of the rough scan of the glossary suggests that the proportion of distinctly toxicology-related items has not been raised much above the 50% estimated for the IUPAC glossary. The abridgement must therefore have taken the form of a general pruning, rather than an elimination of classes of material; however, many of the longer definitions seem to have been removed. The definitions of terms, and the usage of the relations between them, seem to have been unaltered. The provenance of the terms is omitted, as are the lists of acronyms and abbreviations.

Pesticide toxicology glossary

Eesa and Cutkomp (1984) provide a glossary of 'pesticide toxicology and related terms', considering this to mean, primarily, toxicity to the target (insect) organism, rather than incidental toxicity to humans who may be exposed. Noting the link of this branch of toxicology with insect physiology and biochemistry, as well as with pharmacology, they see the need to include terminology reflecting all these aspects, as well as for other practical aspects of pest control. The glossary is intended for researchers, teachers, students, and 'others working with pesticides'.

The glossary contains just over 700 terms. They are given in alphabetical order, with no inter-term relationships, except for rare use of *c.f.* and *see*.

Entries are short and straightforward, e.g.

PISCICIDE	chemical used to kill fish
LETHAL DOSE (LD)	A term used to express the amount of a substance that will produce a given mortality within a given time (usually 24 hours) under specific conditions. This terminology is applied to

toxicants that are administered directly to the organism orally, topically or injected.

About one-third of the terms in this glossary are specifically toxicological in nature; the remainder deal with the more general issues noted above.

The *cf* relation is used to indicate related terms, which are usually opposites, e.g.

IN VIVO Refers to the fate or action of chemically defined substances within the intact biological system in the living state, *cf* *in vitro*

The *see* relation is used, in only a few cases, to indicate related material, when *see also* would be the usual indicator, e.g.

TEMPORARY TOLERANCE A tolerance established on an agricultural commodity by EPA ... in essence, an experimental tolerance (*see* tolerance)

and in some cases to indicate apparent opposites, seemingly as an alternative to *cf*, e.g.

GENERAL USE PESTICIDE A pesticide which can be purchased and used by the general public ... (*see* Restricted Use Pesticide).

Neither *see* nor *cf* is used reciprocally (i.e. referring from each term to the other) in all cases, though it is in some cases.

The glossary includes a number of appendices:

- significant dates in the history of insecticides
- information on labelling of pesticides
- conversion tables for weight and volume
- list of 'selected titles in pesticide toxicology'

Within its limited subject field, this glossary seems likely to have been useful at its time of writing. It is too limited to be of any value for toxicology in general, and also suffers from the inconsistency of its inter-term relationships.

Glossary of preventive toxicology

This glossary (Elstner and Luderitz 1985) was published under the auspices of the United Nations Environment Programme, and intended for 'toxicologists, hygienists and all those responsible for evaluation and control of harmful effects of chemicals to human health and the environment'. It is multilingual, with all term entries, introductory material, and indexing being presented in English, German and Russian.

The core of the glossary is a set of 213 terms, although some of these are divided into sub-terms (see below), of which there are 122, giving a total of 335 entries. Most of these have a definition / explanation, though some do not, and act simply as a 'hook' on which to hang sub-terms, e.g. 'monitoring', and 'preparative forms of pesticides'.

These are 'primarily concerned with terminology used in preventive toxicology, but also... some terms used in literature on toxicology from related disciplines'. The term 'preventive toxicology', though not formally defined, appears to cover both occupational and environmental toxicology. Approximately 50% of the terms appear to be 'strictly' toxicological in nature; the remainder are from other relevant sciences, e.g. 'pharmacodynamics', 'epidemiology' and 'herbicides', or from safety science, e.g. 'ventilation' and 'special footwear'.

No references or sources of definition are given, except in the limited number of cases where the terms is defined in the official documents of organisations such as the World Health Organisation (WHO), International Labour Organisation (ILO), etc.

Each entry has a numerical code, from 1 to 213. Sub-terms are indicated by a kind of decimal notation, but this does not amount to a systematic analysis of narrower terms, as is exemplified below. In all cases but one, there is only one level of sub-term; the exception is term no. 141 - Pesticides - for which the hierarchy is:

141	pesticides
141.1	acaricides
141.2	algicides
..	
..	
141.27	rodenticides
141.28	zoocides
141.19	preparative forms of pesticides
141.19.1	baits
141.19.2	concentrates of emulsions
..	
141.29.6	wettable powder

There is a limited number of 'see' references incorporated in the glossary. There is an additional, and separate, index, pointing from synonyms and quasi-synonyms; the English version of this index has 385 entries, i.e. the 213 main terms, 122 sub-terms, and an additional 50 'see' references. This alphabetic list also helps to identify sub-terms which are out of alphabetical order, e.g. in the example above, 'acaricides', 'zooicides', 'wetttable powder' etc. are sub-terms of 'pesticides' in the 'P' section of the glossary, but are found in their correct alphabetical place in the index, with a reference to their numerical position.

This glossary therefore takes the form of a systematic, decimal, classification scheme, with an alphabetic index, but lacks any depth of classificatory structure.

Where a definition incorporates another glossary term, this is denoted by the symbol ↗.

An asterisk indicates terms accepted in Russian usage, but not in English or German translation, e.g. 'zone of chronic effect'. A double asterisk indicates a quantitative measure depending on factors such as duration of observation.

Thus, the entry for 'absolute lethal dose' reads:

61.1 Absolute lethal dose

is the lowest amount of ↗poison that kills 100% of test animals. Denoted by DL₁₀₀.

The .1 numbering indicates that this is a sub-term, i.e. narrower term, of 61 - dose. The full set of narrower terms is

61	dose
61.1	absolute lethal dose
61.2	cumulative median dose
61.3	lethal dose
61.4	maximum tolerable dose
61.5	median effective dose
61.6	median lethal dose
61.7	median narcotic dose
61.8	minimum lethal dose
61.9	non-effective dose
61.10	threshold dose
61.11	toxic dose

This is not a true hierarchical relation, which would require a systematic sub-division, to bring, for example, lethal doses, or median doses, together: rather it is a simple clumping of all forms of dose. Nor is there any relation between these and other 'dose' concepts, e.g. 'dose-rate'.

The term is indicated as a 'variable' one, while it is shown that 'poison' occurs elsewhere in the glossary. The synonym DL₁₀₀ occurs in glossary as a 'see' reference:

DL₁₀₀ - Absolute lethal dose, No. 61.1

This form of glossary, within a fairly tightly defined subject area of toxicology, seems to be of value in clarifying concepts, as well as simply defining terms; this example, with its multilingual nature, explaining terms used in one language but without an equivalent in others, has particular value. This value would be considerably increased if a more systematic system of term relations were provided, to show inter-relations, a feature often lacking here.

Other glossaries

Niesink, de Vries and Hollinger (1996) provide a glossary of 587 terms, intended as 'a quick reference to keywords used throughout' their monograph 'Toxicology: Principles and Applications'. This is again a very mixed list, including numerous chemical substances as well as medical terminology. Strictly toxicology concepts account for less than half the terms. There is no use of term relations. It is notable that some of the definitions are word-for-word the same as in the IUPAC glossary, and must be taken from this, or from the same source.

Ottoboni (1991) gives a glossary of 209 terms, geared to the needs of the primary readership of intelligent, concerned lay-persons. Not all the terms are toxicological in nature, encompassing many needed for understanding of general scientific material, e.g. 'electron' and 'abscissa'. Definitions are short, e.g.

malignant: very injurious or deadly

xenobiotic: foreign to life

and informal, e.g.

nausea: stomach upset accompanied by the feeling that one is about to vomit.

Several smaller glossaries of particular aspects of the subject exist: often these are aimed as much at making a contribution to the understanding of the concepts in a developing subject, as at providing a general reference tool. Typical is a glossary of chemical carcinogens and carcinogenesis, which gives careful analytical definitions for 25 terms (Khudoley, Pliss and Schramm 1985).

7.5.2 Toxicology dictionaries

Two dictionaries devoted to toxicology are currently available:

1. Hodgson E, Mailman RB and Chambers JE (1998), Dictionary of Toxicology (2nd edn.) Macmillan, London
2. Lewis RA (1998), Lewis' Dictionary of Toxicology, Lewis Publishers/CRC Press, Boca Raton FL

Macmillan dictionary

The Macmillan dictionary is the 2nd edition of a reference work originally published in 1988, which the editors claim to have been the first published dictionary devoted to toxicology.

It includes approximately 4,000 entries, on 504 pages, covering 'all the most informative terms in toxicology', including aspects of analytical chemistry and molecular biology of importance to toxicology. It also includes entries for 'the most important toxic chemicals', with structure diagrams and CAS Registry Numbers. Some entries have been taken, adapted where appropriate, from other Macmillan dictionaries, including those for chemistry, for genetics and cell biology and for the environment. The editors note a desire for works of this kind to be available online, e.g. as a Web resource, partly for convenience, and partly so that they could be kept fully up to date.

The intended audience for this dictionary is primarily undergraduate and graduate students of toxicology, and for scientists in other disciplines, to introduce them to the terms and concepts of toxicology. Secondly, it is addressed to toxicologists requiring information which, while within the scope of toxicology, is outside their own speciality.

The entries are rather more of the form of the encyclopaedia than the usual dictionary, since many include lengthy explanation and 'tutorial' style exposition, though the length is very varied, and some are simply short definitions. Two entries dealing with lethal dose concepts exemplify this: although referring to apparently similar concepts, LD_{Lo} has an entry of 3 words, LD₅₀ has approximately 450. The latter has an extensive explanatory section of the significance of, and recent changes in, acute toxicity measures.

Approximately half the entries seem to have some strictly toxicology component, although many of these are entries for specific toxic substances. The remainder deal with relevant concepts from other sciences. Approximately 25%, including cross-references, deal with toxicology concepts *per se*.

The coverage of all aspects of toxicology seems to be generally comprehensive and consistent, although a specialist may always find deficiencies, for example the lack of coverage of *in vitro* testing methods (Balls 2001).

Coverage of societies, legislation, regulatory authorities etc. seems to be consistent for USA, UK and international organisations, but is not extended to other countries. A UK-based reviewer criticising the dictionary for its US-bias, and consequent omissions and errors for European issues, noting that the 3 editors, 1 assistant editor, and 66 contributors are all American, 'as if [the dictionary] were an entry in some kind of toxicological world series, analogous to the all-American World Series of baseball' (Balls 2001).

The arrangement of the dictionary is conventional alphabetic, with SEE references for synonyms and acronyms, and also to refer to broader entries dealing with specific topics, e.g.

Generally regarded as safe see FOOD, DRUGS and COSMETICS ACT

Food, Drugs and Cosmetics Act An Act passed ... This law also empowers the FDA to establish and modify a list of food additives that are "generally recognised as safe..." However, for some entries, the broader entry has no specific material related to the referring entry, e.g.

Organ weights, in subchronic toxicity testing see TOXIC ENDPOINTS

There is no specific mention of organ weights in the entry for toxic endpoints.

The term COMPARE is used rarely for opposites, e.g. *in vivo* and *in vitro*, and *dust, proliferative* and *dust, non-proliferative*.

SEE ALSO references are used liberally, being present in about half the entries, but are not applied symmetrically. No other relations are used.

Some of the entries deal with quite complex co-ordinated concepts, e.g.

Genetic differences in xenobiotic metabolism, *in vivo* toxicity

The entries generally appear to be written for comprehensibility, rather than precision, e.g.

Acute toxicity Toxicity manifested within a relatively short time interval after toxicant exposure (i.e. as short as a few minutes to as long as several days). Such toxicity is usually caused by a single exposure to the toxicant. *See also* ACUTE TOXICITY TESTING.

While probably adequate for the typical users noted above, this definition does refer to the various quantitative definitions which may be found elsewhere. There are no references included in the definitions, except for a limited number of references to toxicity profiles for particular substances; a general list of other reference works is given as an appendix to the dictionary. This is not likely to be important for most cases; however, even for the non-expert, some of the entries would seem to call for it: e.g. the entry for **Donated drugs** includes the assertion 'In one reported case closantel was supplied without package leaflets, and misidentified'.

The inclusion of concepts, and the cross-referencing of synonyms, is by no means exhaustive or consistent, and at times is positively idiosyncratic. Thus, for example:

- **LD50** appears as an entry, with a lengthy discussion of almost a page, but there is no cross-reference from LETHAL DOSE; nor is there any mention of related terms such as LD₁₀ or LD₉₀. LDLo (lowest lethal dose) does appear, but the acronym would have to be known; it is not cross-referenced from LOWEST or LETHAL.
- There is a clear description of the various ways of classifying toxic agents, under the heading **Toxicity classes**, but there is no cross-referencing from **Class..**
- The intriguing reference **London** see ENVIRONMENTAL DISASTERS refers to the London smog of 1952, in a list of well-known toxicity-related events.
- The entry for **E numbers** refers to EC Directives. **EC**, however, has a see reference only to **Effective Concentration**.

This dictionary appears to be a useful tool. Its main deficiencies, apart from its US bias, are a lack of consistency in the nature of the entries, and in the cross-referencing; for

some purposes, greater detail and precision, supported by references would be valuable.

Lewis's dictionary

Unusually, this dictionary contains no foreword, preface or introduction, nor other indication of its rationale, purpose, intended audience, or contents. The only suggestion of these factors is a note in the acknowledgements that the author has 'consulted a large number of standard references in biology, chemistry, physics, law, toxicology, and other fields of study and practice that enabled the emergence of toxicology as a mature science', indicating a wide scope of subject coverage.

Inspection suggests that the dictionary contains approximately 16,000 entries, on 1127 pages. It is arranged in conventional alphabetic format, with see references, and (rare) see *alsos*. There are no references, or other supplementary material.

Roughly half the entries are single phrase entries, particularly relating to chemical substances of biological species, e.g.

chrysanthemummonocarboxylic acid	pyrethrolone ester	pyrethrin I
COD	chemical oxygen demand	
Compound 42	warfarin	
Compositae	Asteraceae	
Congo burrowing adder	<i>Atractaspis congica</i>	

These are simple definitions, and do not relate to other entries in the dictionary; for that purpose, the see reference is used, e.g.

cocculin	see picrotoxin
cockle	see <i>Cardium edule</i>

Most other entries are of paragraph length, though a small proportion, less than 5%, are between half a page and one page, 400 to 800 words, in length. A few are longer: the entry for **toxicology** covers 3 pages, and that for **dose** covers 4 pages.

Many toxicology concepts do not have a definition at their entry, but rather a reference to a longer discursive entry, e.g.

acute toxicity	see toxicity
lethal concentration	see concentration
LD ₅₀	lethal dose/50% response. See dose.

Only about 10% of the entries, at a generous estimate, describe toxicology concepts *per se*. The remainder deal with concepts, substances and organisms for the wide range of relevant sciences. Rather than being strictly a toxicology dictionary, this could better be thought of as a general scientific dictionary, covering all the sciences of relevance to toxicology.

There is some geographical bias, in that the few legal cases which are cited are all from the USA, and plant distributions are described in detail only for the Americas.

The *see* relation is used for a variety of inter-relation between terms:

To point to synonyms, or quasi-synonyms, e.g.

birdshot	see lead shot
sweet flag	see <i>Acorus calamus</i>
Swift's disease	see acrodynia

sometimes this is used to point to alternatives for an unspecific term, e.g.

heart urchin	see Spatangoida, Echinoidea

To point to a broader term, where a mention of the original term occurs, e.g.

lead encephalopathy	see encephalopathy
cold damp	see damp
barium salt	see barium

To point to a more specific meaning ('narrower term'), e.g.

sweet clover hay	see sweet clover poisoning

To point to what related terms, e.g.

lead sulfate. A poisonous, heavy, white, crystalline powder. PbSO_4 , that is slightly soluble in hot water and insoluble in alcohol. Used as a paint pigment, and in lead-acid batteries, *q.v.* See also lead, lead poisoning.

(This last example also shows the occasional use of *q.v.* as an apparent alternative to *see*.)

See *also* is used occasionally, with its usual 'related term' implication, e.g.

swellfish one of the many common names of bony fish of the family
Tetraodontidae. See also puffer.

Lime calcium oxide. See also chlorinated lime.

The inconsistent use of relationships is an apparent flaw in this dictionary, though it is not likely to interfere with its main purpose of providing the user with the meaning of a wide variety of terms from toxicology-related sciences, and directing them longer expository entries on significant concepts.

7.5.3 Comparisons of dictionaries and glossaries

A comparison of the four major dictionaries and glossaries covering the whole field of toxicology, in terms of the approximate number of terms and estimated percentage of those relating to toxicology, yields data in table 7.1.

Table 7.1 Comparison of four major dictionaries and glossaries in toxicology

	Macmillan	Lewis	IUPAC	Duffus and Worth
No. of terms	4,000	16,000	1,400	800
% toxicology	25	10	50	50
No of toxicology terms	1,000	1,600	700	400

The very large number of terms in the Lewis dictionary reflects the high proportion of entries relating simply to names of specific chemical substances and biological organisms. As noted above, the figure of 10% toxicology-related is generous, and therefore the figure of 1,600 toxicology terms is likely to be an overestimate. Again as noted above, Duffus and Worth's glossary has been abbreviated from IUPAC by a general 'pruning', so that its 400 terms is likely to be a subset of the total.

On this basis, it seems reasonable to assume that the vocabulary of toxicology *per se* comprises between 500 and 1000 terms. However, it is also clear that compilers of all these tools have seen a need to include terms from other related sciences, emphasising the multidisciplinary nature of the subject.

It is also worth noting that all the tools considered used some form of term inter-relationship, that all of these were different, and that none made use of a standard set of thesaurus relationships (SY, BT, NT, RT).

7.6 Interconversion of vocabularies

With such a variety of vocabularies available, it is not surprising that effort has been put into attempts to convert between them, so as to make collections of information accessible for a variety of viewpoints.

On a large scale, only rather general interconversion, in very broad terms, has been attempted. One example is Scott's (1999) conversions between the Dewey and Library of Congress classifications, and the Library of Congress Subject Headings. These show equivalents between major concepts in the three schemes, for example:

Dewey	LC	LCSH
615.9	RA1190-1279	Toxicology
364.1791	HV6549-6555	Poisoning (criminal poisoning is implied)

In the medical area, with its many detailed vocabularies, the need for interconversion was recognised at an early stage, one example being the equivalencing of Library of Congress Subject Headings with MeSH headings (Muench 1979), the first edition of which was produced in 1971. This includes examples such as:

MeSH	LC	
TOXICOLOGY	Toxicology	Toxicology, Experimental Veterinary Toxicology Pediatric Toxicology Forensic Toxicology
POISONING	Poisoning	Poisoning, Accidental

The requirements of health services have led to extensive cross-referencing between clinical vocabularies. The NHS Clinical Terms (Read Codes), for example, are cross-referenced to the International Classification of Diseases (ICD) and Office of Population Census and Surveys (OPCS) codes, while links between Health Resource Groups (HRGs) with ICD are being made (Jones 2001, Lernout and Hauspie 2000).

The desire for cross relation between different vocabularies has led to ambitious proposals for all-encompassing meta-languages. Best known is the Unified Medical Language System (UMLS), maintained by the National Library of Medicine. This incorporates and links several vocabularies such as MeSH, SNOMED, ICD, and Read Codes. UMLS comprises three 'knowledge sources':

- a 'metathesaurus' showing the various terms for biomedical concepts and the relationships between them

- a 'semantic network' showing the semantic types, i.e. general categories, to which all concepts in the metathesaurus have been assigned
- a 'specialist lexicon' giving syntactic information about the terms in the metathesaurus

Given the multidisciplinary nature of toxicology, effective interconversions of vocabularies are likely to be particularly important. They should allow particular aspects of the subject to be organised by the most appropriate vocabulary, at the appropriate level of detail, without the necessity to select a single vocabulary for the whole area.

7.7 Conclusions – a three layer model

The work reported in this chapter had two main aims: to understand how the subject has been represented in information terms; and to assess the adequacy of existing subject descriptions.

The first point may be answered in general terms, by saying that it has been, and still is, represented in a variety of ways. The development, and current state, of the general classification schemes show how toxicology knowledge has expanded from describing a 'simple' study of poisons, generally located within a broader pharmacology context, to a complex and multifaceted subject, influenced by and influencing other disciplines. The spread of toxicology material throughout the various schedules, and the way in which it has been relocated over time, emphasise this point, as does the emergence of a need for places in the schedules for the sub-disciplines of toxicology.

We may say that the schedules represent toxicology knowledge as a duality; on the one hand a biomedical subject, and on the other, a topic associated with regulation, legislation and public policy. This has remained fairly constant over time, though the details of the assignment of specific concepts within each, and their relative importance, have changed greatly. From the schedules, it is not easy to see that these two subject spheres are part of a single discipline.

The study of thesauri reinforces these points, though the development over time is less easy to establish. The various thesauri show that toxicology knowledge can be viewed from disparate perspectives, and organised in different ways, even in those vocabularies which offer a full coverage of toxicology material.

Similarly, the glossaries and dictionaries emphasise the multi-disciplinary nature of toxicology, since even in those tools specifically devoted to the topic, a substantial proportion of the vocabulary deals with other disciplines and peripheral areas.

As the vocabularies become more complex, or new vocabularies are devised to deal with the emerging 'multi-disciplinary nature', we can see a pattern. To fully describe the subject, the vocabularies have to specify three rather distinct aspects:

1. the agent causing the injury; the toxic substance
2. the instance and/or kind of toxicology
3. the details of the toxic occurrence
 - species affected
 - route of administration
 - environment
 - toxic effect
 - etc.

Here again, as in the previous chapter, a three layer model for describing a toxicology statement is evident.

When toxicology was a simple 'science of poisons', this distinction between layers, and particularly the third component, was not of importance; the ability to specify the poison and the effect, in fairly simple terms, was all that was required, perhaps with some additional general terms to cover concepts such as legislation. [Route of administration would often also be of significance, and differing effects from different routes would be noted, subsumed under the general organisation of substance/effect. Only in relatively modern times has it been necessary to include this as an access point to toxicology information.] However, the new status of toxicology, and its burgeoning knowledge base, requires a more sophisticated approach.

The overall answer to the second question, of the extent to which existing vocabularies deal with toxicology material, is that the adequacy is varied. The number of vocabularies which deal with toxicology is remarkable, and an indication of the significance of the subject. Also notable is the inadequacy of several of the vocabularies which might have been expected to cater well for this subject.

There are three types of vocabulary which seem to be best able to cater for toxicology material. Consideration of these gives an overall picture of the current adequacy of provision.

At the broadest level, the organisation, for example, of the toxicology section of a large library, the general classification schemes are appropriate; broad coding in the thesauri, such as Biosis' concept codes, are too wide to be used alone. The one which might seem from its origins best suited, the National Library of Medicine classification, does not deal well with modern toxicology. Library of Congress classification is more modern in outlook and coverage, but its purely enumerative

approach is unhelpful in dealing with the inter-relationships of the current complex state of the science. Dewey and the UDC, in their rather different ways and despite their deficiencies, provide the best current solution to this problem. Nevertheless, these tools are designed to arrange items in a library and for bibliographic listings, and that is primarily what they do. Whilst it would be possible to assign a classification and subsequently a location to any toxicology related item, use of either scheme would not necessarily infer the detailed content of the item, nor the context within the toxicology discipline as a whole. Places for toxicology items are scattered, and the codings do not facilitate comprehension of the subject in its entirety, nor do they shed light on relationships between concepts. To some extent, the codes may be used for information retrieval, in that online library catalogue records are 'indexed' to some extent, although not to the level of detail that an information retrieval system per se would attempt.

To support description of items at a greater level of detail, (content/context) so that documents may be retrieval from an information system, the thesauri of the biomedical secondary services - MeSH, Emtree, Pharmline, and Derwent - provide generally adequate coverage of the biomedical aspects of toxicology, though, as noted above, in their different ways. None of the schemes attempt to propose a standard, or comprehensive view of the discipline, and this, as was shown in chapter six, renders the retrieval of toxicology information at best complex, and in some cases impossible.

Finally, there are tools available which deal with specific, rather than general, aspects of the subject. Toxic effect may be specified in great detail - probably as great as would be required for any toxicological purposes - by clinical terminologies such as ICD and the new SNOMED Clinical Terms. Specific chemical substances may be defined by Chemical Abstracts Registry Numbers, widely used in secondary services.

Given the multi-faceted nature of toxicology, and the consequent need for access to toxicology information for different purposes, and therefore at different levels of detail, the ability to interconvert representations, and specifically to move up and down between levels of details, is of importance. The interconversions between vocabularies noted above show the way in which might be done.

In summary, there are effective tools for handling toxicology information at several levels; though none of them is perfect and, in particular, none has been designed

with toxicology specifically in mind. In terms of the three aspects noted above, it seems that specification of chemical substance and of kind of toxicology are more effectively catered for than the third aspect; the details of the toxicology occurrence. This is not surprising, since specification of chemical substances may be catered for by tools developed for chemical information generally, and the sub-disciplines of toxicology are becoming more widely known and used. The third aspect is toxicology specific, and, as noted earlier, such toxicology-specific vocabularies as have been developed are not effective in dealing with modern toxicology knowledge. It is possible, however, that existing schemes can be utilised to describe certain aspects of a toxicology occurrence. For example, those designed to represent medical conditions, could be used to refer to toxic effects.

One solution to the lack of specific, modern tools would be the development of a toxicology thesaurus, designed for indexing toxicology occurrences at a detailed level, and covering those factors suggested in aspect three.

Overall, tools for describing toxicology knowledge need to be considered as a whole, rather than as disparate entities. Use of the three layer model as a framework for indexing any toxicology information resource could help further this process. Indexing should be completed at each of the three levels, using appropriate representation schemes. Whilst it would be possible to use currently available schemes, to describe substance and general effects, a new, toxicology specific tool would be needed to ensure every toxicology aspect of could be indexed.

At the present time, this would be a resource intensive procedure, but this may be an area in which automated technology can be applied in the future.

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Chapter Eight: The Impact of New ICTs on Toxicology Knowledge and Information

8.1 Disciplinary analysis

The original concept for this thesis was to define changes in toxicology information resulting from new information and communication technologies. The rationale was that the author was familiar with resources in this field, and had observed their development over the past 20 years, alongside the advancement of computers and telecommunications from the original IBM PC and acoustic coupler to the seamless networked equipment of the present day.

Indeed, it was envisaged at the outset that information resources would be significantly changed by developing technologies, although, over the course of the project, it became clear that the impact of truly novel information products was limited.

Furthermore, the initial framework expanded over the lifetime of the study, embracing the question of how a discipline can be defined, or understood *per se*. This aspect grew from attempts to answer the original research questions, combined with the author's experience of both teaching and practice in the field of information science.

Increasingly, more non-specialists attend information retrieval classes, particularly with the desire to know 'how to search the Internet'. Teaching the techniques for using online databases and Internet search engines is usually straightforward, even to those without a library and information science (LIS) background. However, trying to explain what to do with the retrieved information is a different issue entirely. In order to fully understand the results of any search, it is first necessary to understand the context of the information; ideally, to understand information communication within the given field, and to comprehend how the resources identified serve in answering the query.

In teaching about information resources, it is necessary to offer an infrastructure which places newer electronic and networked forms in context with printed and computerised information.

From a practical viewpoint, the way to manage the large amounts of work generated in probably every subject today, (often described as TMI – 'too much information'), would also seem to be to focus on patterns in communication, and to attempt to place individual resources in context, rather than to struggle with the impossible task of finding and evaluating everything.

The concept for the thesis thus became that to understand a discipline, from the point of view of a subject specialist or information professional, it is necessary to understand the information comprising the discipline. This necessitates an appreciation from several aspects; including the nature of the subject, the types and formats of its information products, the way it is communicated, the way the subject is described and the ways in which it can be retrieved. By comparing these characteristics over time, it is possible to comment on changes brought about by new ICTs, however these are defined, and to construct a model to represent the current state of communication within the subject. From this model, it is possible to make some predictions as to how things will develop in the future.

This approach to defining a discipline, and to examining the changes brought about by new ICTs, was taken in this thesis. It starts from an LIS perspective, and acknowledges that there are other (social science, subject specialist) approaches which could be made. Even within the LIS paradigm, there may be other aspects which could be considered. Nevertheless, this thesis suggests that the composite methodology described in chapter one offers a valid mechanism for obtaining a 'snapshot' of a field of study, which can then be used to examine changes and likely patterns for future development.

In the introduction to this thesis, three research questions were posed. In this concluding chapter, some answers will be attempted, based on the results presented in the intermediate chapters.

8.2 The nature of toxicology information

The first question related to understanding the nature of knowledge and information in toxicology.

Two approaches were used to derive a contemporary image of the discipline; firstly, an attempt was made to find out what toxicology is and what it does, largely by analysis of the literature. Secondly, a list of its information resources was created. These aspects were combined to derive a model of toxicology communication in 2002.

The first approach revealed the many ways in which it is possible to gain an understanding of the nature of toxicology. Clearly, it is helpful to consider how the subject has emerged historically, especially in relation to other fields. The rather dark art of poisoning throughout the ages makes fascinating reading, and is perhaps a unique underpinning to the growth of a contemporary scientific field. Despite the long history of the discipline, it is still helpful to consider how toxicology may be categorised by modern typologies – and here it is notable that toxicology is still hard to place exactly. It seems that there are two ways in which toxicology may be viewed: firstly as a 'practical discipline' within the physical sciences; and secondly, on account of the impact of social, political and ethical issues on the science, as a 'field of study'.

From chapter two, toxicology is identified as a discipline with a history which predates the modern scientific era. It focuses on the harmful effects of chemical substances, and shares the 'form of knowledge' (as defined by Hirst, and detailed in chapter two) with other empirical natural sciences. It is an interdisciplinary subject, perhaps best regarded as a multidiscipline, which has grown from other sciences. It has the image of a 'borrowing science'. The results in chapter four show that, to an extent, it still is, but that it is now very much a discipline in its own right, and an exporter of concepts to other sciences. Because toxicology also includes legal, social, ethical and political dimensions, it can also be regarded as a 'field of study' (again, with reference to Hirst as above), focusing on all aspects of the harm caused by toxic substances.

The nature of toxicology has changed, becoming mechanistic rather than descriptive. This process continues, introducing to toxicology topics including genomics, proteomics and genetically modified animals; this is also confirmed by the bibliometric studies in chapter four. Like other sciences, it has developed from a basic

core, to have a variety of specialised 'sub-disciplines'. As it has developed, its information and communication systems have also developed, being determined by, and to an extent determining, the nature of the discipline.

It has been noted in several places throughout this thesis that toxicology has much in common with related scientific disciplines. Its uniqueness lies in that it must combine information and knowledge, data and concepts, from biomedical science, and also from legal, regulatory, policy, public awareness, and ethical areas; this was shown, in various ways, in chapters two, three, four and seven. This means that its range of information sources must be wide and diverse, as was shown in chapters two, three and four. It was also among the first scientific areas to adopt ICTs for information storage and retrieval, and is still among the most frequent users of such systems.

Various attributes of the discipline can be regarded as valid markers of its nature. It is useful to try to think of all of the features which characterise a field, if the aim is to prescribe a methodology for defining it. In this thesis, such features included education, qualifications, job advertisements and learned societies. It is possible that there are more. Investigation of each of these features requires specific searching skills, to collect information, which once obtained and organised can be used to view changes with time and current status. All of these aspects are time consuming to research, and highlight areas for which new ICTs make no impact. An example is examining job advertisements: these do not always appear in the electronic equivalents of print journals; no database of past advertisements exists; and many libraries do not bind advertisements, even if they hold the original journal. The traditional skill of reading print may thus be considered a prerequisite for analysis of a discipline. In contrast, the availability of information from educational institutions and learned societies on the world wide web facilitates the retrieval of this type of information. In the case of organisations, the web pages provide more up-to-date organisational details than existing printed directories, although as was noted, not everything can be found on the Internet.

A second approach to gain perspective on the discipline of toxicology considered its information resources. These derive from the nature of the discipline, which, once understood, can be used as a foundation for listing the types of resources comprising the subject. The production of resource lists has a long history, but no standard method is available for their creation. A strategic methodology for constructing resource lists was put forward, and used to create a snapshot of toxicology communication at the beginning of 2002. The aim was not to create a

comprehensive listing, but rather to ensure that the most significant resources were drawn out, and that all forms of information were exemplified. This process required a focussed approach to searching for toxicology information, and resulted in an in-depth understanding of 'best-practice' in searching for toxicology information. This was further developed in a later, detailed evaluation of toxicology databases. Together, these retrieval studies provide insight into the current capabilities and limitations of toxicology information systems.

The listing, which may be of value to practicing specialists in itself, was combined with the initial theoretical consideration of the field, to create a contemporary model of information communication. Many modelling schemes were considered, but one based on the fundamental division of resources into types according to the position of the information in the communication chain (primary, secondary, tertiary and quaternary) was chosen. This model is an extension of existing categorisations, and allows for new forms of communication which have resulted from new ICTs. The model was then compared with similar models of scientific communication derived in the past, revealing a 'z'-shaped pattern in contrast to the linear forms of previous derivations, with more diffuse areas of information resources.

8.3 The impact of new ICTs

There then follows the question of the impact of new ICTs on toxicology communication. Some qualitative observations can be drawn from the model, which demonstrates an extension of the traditional primary, secondary and tertiary communication steps. In the new paradigm, pre-primary information, which would usually remain 'informal' can now enter the 'formal' communication system, in a variety of web-based forms. The link between primary article publication in refereed journals, and indexing by the secondary services remains at the core of the model. An increase in tertiary resources, such as listings, and organisations web-presences can be seen, accompanied by the presence of a number of quaternary resources. Undoubtedly, the presence of tertiary and quaternary listings is facilitated by the ease with which web pages can be created. In some limited cases, such as abstracting and indexing secondary services, digital resources have largely replaced their printed equivalents. In others, such as primary journals, print and digital equivalents co-exist, with very limited numbers of wholly digital examples. For some secondary sources, such as textbooks and encyclopaedias, print remains the predominant form.

To assess the extent to which toxicology journals are now available in electronic form, the lists of periodicals from Ulrich and ISI [chapter three] were examined. Electronic availability of each item in the lists was assessed by (1) checking the Ulrich database, which notes online vendors, (2) checking the remaining items against the e-journal lists of the main aggregators and some large e-journal collections, and (3) checking journal and publisher websites. The results are conservative estimates, in that there may be some journals for which the online equivalent was not identified.

Of the 71 journals identified from ISI, 64 (90%) are available online. For the 236 periodicals from Ulrich, 106 (45%) are available in this way. The difference is explicable in the ISI sources are all high impact academic sources, while the Ulrich list includes items which are irregularly published, ephemeral in nature, or of only local interest; all aspects likely to reduce their appeal in e-journal form.

In summary, it may be suggested that about half of all toxicology related periodical material is available electronically, but that for core academic journals virtually all is available in this way.

The model, although of value, cannot reveal the extent to which the new forms of information have affected communication in toxicology. For this, some bibliometric analyses were carried out.

Here, it can be seen that web-based resources are now roughly equal in number to conventional resources, whether these are print or digital in nature. However, new ICTs have facilitated access to existing information, and encouraged the 'formalisation' of information, rather than having been responsible for 'novel' information. The impact of new ICTs on the actual science of toxicology is not assessed in this study, although it is conceded that the improved communication between practitioners may have led, indirectly, to increased research, and thus an increase in 'novel' information.

As chapter four also shows, new resources have as yet had little impact on the primary journals, which remain the backbone of the formal communication system of toxicology. It is possible to postulate a 'core' of communication, consisting of primary publication in traditional, refereed journals, followed by secondary publication in the form of a value-added, i.e. indexed and abstracted, bibliographic reference. This part of the linear communication chain exemplified in previous communication models remains unchanged by ICTs at the present time, although there are indications that electronic publishing may change the economics of scientific paper publishing in favour of the authors, rather than the publishers.

Access to an author's work may be provided in various ways: through a free electronic source, or open access archive; through purchase of single articles as required; or through 'bundles' of electronic journals. In any of these ways, wider and cheaper access is likely to be possible than through the traditional printed journal. Copyright arrangements are also likely to be more advantageous to authors in electronic media. For perspectives on these developments, see, for example, Stankus (1999), King and Tenopir (1999), Halliday and Oppenheim (2001), Gass (2001) and Odlyzko (2002).

The bibliometric studies in chapter four illustrate other changes in toxicology communication, which may be attributed to the impact of new ICTs. These include the simultaneously increasing internationalisation of toxicology research and the mono-lingualism of its communication, and the increasing interchange of knowledge and concepts (as expressed by citations) between toxicology and other disciplines. They emphasise the dramatic growth of the formal literature over a 25 year period, which appears to be slowing at the end of the 1990s, and it is suggested that this

slowing may be due to the new forms of web-based communication made possible by new ICTs.

The effectiveness of the most important, 'core', information resources currently available in accessing toxicology information was assessed in chapter six, using methods based on the analysis of previous evaluations of toxicology information provision. These show that, despite the increase in number of sources, almost invariably digital, problems identified in early studies still persist. Bibliographic databases, accessed via subject terms, are still the most important and effective resource, though alternative resources such as substance databanks, and alternative search techniques for bibliographic sources, such as citation searching, may be useful complements. To obtain good retrieval performance usually requires access to a number of resources, and use of a number of search strategies. Although a specialised in-house toxicology resource proved the most effective single source, this also was far from perfect. Deficiencies are attributable to coverage of single sources, and to indexing policies and practices.

It seems clear that the former, coverage, problem will never be solved by the creation of a single 'all inclusive' source. The TRACE database, evaluated in chapter six, is as good an example of a proprietary source of this type as is likely to be developed, and was found wanting. As for public sources, as noted in chapter three, the TOXLINE file, introduced as a publicly-available solution of this source, and widely regarded as such for over 20 years, was abandoned by its maintainers in 2001. It seems clear that the solution to this problem must lie in the linking of disparate sources by a single interface. The National Library of Medicine's TOXNET system is an early, and limited, example. Longer-term, a web-based solution, such as the proposed DssTOX, (see chapter six) is most likely to be the way forward.

Indexing issues are unlikely to be solved by technology. The studies of toxicology vocabularies in chapter seven, and also the equivalent resources listed in chapter three, emphasised the wide variety of representations available, reflecting the multidisciplinary nature of the subject. However, both the simple analyses of vocabularies reported in chapter seven, and the evaluation of searching in chapter six, showed that none of these tools, however well applied by an indexer, is in itself adequate to deal with all aspects of toxicology information, at all the levels of specificity which might be required for good retrieval. A 'three layer model' was therefore presented, giving an indication of the ways in which existing vocabularies might best be used in combination, to ensure that all concepts may be described at

all levels of specificity realistically required. The use of this model in practice, and the derivation of any extra vocabularies which might be shown to be needed, is a subject for further research.

8.4 The future of toxicology knowledge and information

From the toxicology model, it is possible to postulate the ways in which information communication will develop over the near future. This implies a timescale of 5 – 10 years, during which time further technological developments may be expected, alongside their acceptance by the toxicology profession.

Developments in technologies are usually referred to being of an 'incremental' rather than revolutionary nature. Whilst far-reaching improvements cannot be ruled out, it is perhaps wise to consider that for toxicology communication, it is likely that there will be 'more of the same'. Undoubtedly, computers will continue to increase in speed, and therefore multimedia handling capability, and at the same time decrease in size and cost. Telecommunications seem to parallel computing technology, and it seems safe to envisage that the long promised availability of broadband communications will in fact be realised. This latter embraces the delivery of video quality services, to locations such as the home, via wiring designed to provide telephone and TV services as well, but also wireless communication.

Essentially, it is likely that 'new' technologies will provide for largescale data handling (text or video), independently of location.

It is rather difficult to imagine that technological advances of the near future will result in radically different information systems for toxicology. Database design is likely to remain largely unchanged, although it may be possible to get more information faster, from more remote areas. Journal publication may change its economic premise, but articles and the way in which they are read will likely be familiar to those still working in the field in 10 years time.

There is then the issue of 'acceptance'. From the studies carried out in this thesis, it is clear that members of the toxicology profession still communicate in the 'core' area of the model, which has remained unchanged over the past 20 – 25 years, and possibly longer. It is interesting to speculate on how this would alter; but as younger people enter the profession, it is inevitable that their terms of reference will include networked based services as the norm. This may mean that although the core of primary and secondary communication remains unchanged in principle if not in form, the extent of impact in the more diffuse areas of the communication chain may increase. That is that the tendency towards 'formalisation' of currently informal

information may increase. Newer forms of communication such as webrings may take on greater significance, and indeed the perceived 'value' of wholly digital publications may rise. Over the next 5-10 years, it may be that more authors will cite and publish digital works.

The current novelty of personal communication and information handling devices, currently defined as personal digital assistants (PDAs) and mobile telephones is likely to mature, and as members of the profession feel more comfortable with these devices, it is possible that information systems may develop to handle communications tailored for this technology. Examples could include educational materials and services, such as those described in chapter three from the University of Oxford, where staff and students are encouraged to access the course web resources via PDAs. This type of access requires that the information be rendered in a form suitable for transmission over wireless networks, and for display on small, personal screens. Another example could include an archive of text messages, in the same way as mailing list archives provide searchable databases of past communications.

The issue of archiving is one which perhaps deserves greatest concern, as a clear failure of network resources is their lack of persistence. Databases of 'historical' information such as job advertisements, course schedules, events listings and company profiles could be considered for toxicology as for other areas, as something which may well be lost in the enthusiasm to replace print (which may be kept somewhere) with quickly produced html, (which is simply replaced by a new version). Future studies of disciplinary development may be harder to undertake if no records exist.

In essence then, it seems likely that there will be an increase in what are described here as new forms of information. This will be accompanied by an increase in the extent to which information can be communicated regardless of location. It is also likely that the aspects of globalisation, described in chapter four, will continue.

Radical changes in information systems and communications are unlikely, although these can never be entirely ruled out, but additional methods of organising new information forms and archiving currently ephemeral information could appear.

8.5 Conclusions

The third question related to the methods used to investigate the communication of toxicology information from the LIS perspective, and whether these might be applicable to other subjects and disciplines.

The work reported in this thesis shows that it is indeed possible to analyse a discipline from an LIS perspective, and to derive interesting and novel results. It is shown to be essential to use a variety of methods for such an analysis, since, while the results of individual methods, as reported in various sections and chapters of this thesis are valid and interesting, it is only when they are combined and cross-related that a full picture can emerge.

The 'z'-shaped model derived in this study relates only to toxicology, being based on the results presented in this thesis. Further work would be required to establish its validity for other areas of science, or, more broadly, to other subjects and disciplines in general. However, as noted in chapter two, toxicology is similar in many respects to other interdisciplinary and multidisciplinary subjects. Its uniqueness, from an information perspective, lies in its combination of biomedical science and regulatory/legal/policy aspects. While these certainly affect the range of sources and systems required, they do not alter the basic structure of communication, represented by the model. It might therefore be expected that this is a generally applicable novel model for scientific communication at the turn of the millennium.

While this thesis does not present a 'toolkit' for immediate use for disciplinary analysis from an LIS perspective, it seems clear that a number of the elements reported here should be included, as a minimum:

- analysis of the nature, historical development, and current status of the discipline; chapter two provides an example
- construction of a resource list, by the novel method proposed in chapter three. It was shown there, and in chapter five, that alternative methods of resource list construction are not adequate to capture the diversity of resources within a discipline reliably
- simple bibliometric studies, as reported in chapter four, to illustrate factors such as: size of the 'literature' of the discipline, and its make-up in types of resources;

geographic and linguistic spread; core journals and other resources; extent of exchange with other disciplines

- comparative evaluation of disciplinary resources, by the methods described in chapter six, to identify the 'best' resources available, and the quality of retrieval which can be achieved. It seems clear, from the analyses in chapter five, that these methods - mixed quantitative/qualitative studies with failure analysis, with the involvement of both subject experts and information specialists - are the ones likely to lead to full understanding of the issues. Other forms of evaluation, though they may be adequate for some purposes, are too limited
- a comparison of vocabularies, as in chapter seven, illustrating the conceptual structure of the discipline, and the tools available in practice to help information access

Testing the validity of this method in other subjects and disciplines is a topic for further research. So, also, is the comparison of the results found here for toxicology with an analysis of the discipline by alternative methods, e.g. a social science approach by interview, questionnaire, etc., or a more detailed bibliometric study focusing on individuals and schools of thought.

A final conclusion is that toxicology communication has not changed extensively over the past 20 years. The traditional primary, secondary, tertiary model still serves, although in an extended form. What may be considered is that the volume of information for toxicology, as for any other science, extends far beyond the descriptive handle of 'too much information'; and it is this, rather than revolutionary changes in the science or infrastructural information agents, that is likely to underlie any quantum shift in the impact of new information and communication technologies on toxicology knowledge and information.

8.6 References

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Toxicology Knowledge and Information: the Impact of New Information and Communication Technologies

Appendices

Chapter Two: Appendix

Please note: references are in the main thesis.

2.2.a History of toxicology

'Toxicology is considered by many to be a very recently developed scientific discipline. On the contrary, observation of harmful effects of chemical substances on living organisms is rooted in prehistory' (Decker 1987, p 1)

'Modern toxicology is a multi-disciplinary science and as such had to await the development of many of the natural sciences before it could become a quantitative study. Although many descriptions regarding the actions of poisons and antidotes were published prior to the nineteenth century, little of this information was based upon scientific studies' (Loomis 1978, p 3)

'Toxicology... is a borrowing science that has evolved from ancient poisoners' (Gallo 1996, p 3)

Toxicology is somewhat unusual in its historical development, in that it has a very long history as a collection of pragmatic knowledge of poisons, but a rather short history as a scientific discipline (Tansey 1993). Despite advances, noted below, from the sixteenth century onwards, it was only during the mid-nineteenth century that developments in chemical analysis made possible the reliable detection and identification of poisons, providing the basis for the modern science.

The historical development of toxicology has been reviewed in detail by Borzelleca (1994), Decker (1987), Gallo (1996), Koeman (1996), Oser (1987), Goulding (1987), and Ottoboni (1991) with an emphasis on public health aspects, and, with respect to more recent developments, by Zbinden (1992). Thompson's classic work of 1931 deals with the application of toxicology to criminal poisoning. The historical development of sub-disciplines has also received attention: Oser (1987) emphasises regulatory toxicology in his account, Niyogi (1980) deals with forensic toxicology, while Hänninen (1985) gives a personalised account of the development of behavioural toxicology. Holmstedt and Liljestrand (1981) give an account of the history of pharmacology, but including much toxicological material, based on reprints from historical sources.

Here, only a summary outline will be given, with emphasis on those aspects affecting, and reflecting, developments in information and communications.

Ballantyne, Marrs and Turner (1993B p xi) note that 'some fifty years ago [i.e. about 1940 from their timepoint], toxicology was barely recognized as a discipline and had few active participants, although some experimental pathologists at that time would now be regarded as within the sphere of toxicology.' They date the rise in interest in the subject, and its recognition as a discipline, to the decades since then. However, as with most intellectual topics, the roots of the discipline go much further back in time. Borzelleca (1994) identifies three main phases through which toxicology has passed in maturing to a scientific discipline, and with slight modification, these are used as the basis for the discussion below:

- *observation*; phenomenology, listing of poisons and antidotes
- *experimentation*; analytical, forensic, mechanistic
- *application*; risk assessment, safety factors

Observation

Prehistoric societies would have been well aware of the harmful effects of natural substances; plants, fruits, insect and reptile venoms, etc., and these are still used to the present day by tribal peoples in Africa and Asia for hunting, warfare, etc. (Decker 1987). Archaeologists have found poisoned tips of arrows and spears, among other artefacts, (Tansey 1993).

The medicinal properties of plants were well known to the ancient Egyptians (Manniche 1989), and their writings show some knowledge of naturally-occurring poisons, as part of a system of medicine which influenced later developments (Nunn 1996). It is even suggested in some papyri that Menes, the first king of the unified land of Egypt, had an interest in poisons, cultivating poisonous plants and studying their effects (Borzelleca 1994). Aspects of the Egyptians' knowledge in this area are revealed by a number of 'medical papyri' of varied nature (Nunn 1996, chapter 2). Among these is the Ebers Papyrus, dating from between 1550 and 1500BC, and purchased in Luxor (ancient Thebes) in 1872 by the German Egyptologist Georg Moritz Ebers (1837-1898), having been discovered in the area a decade earlier by the American adventurer Edwin Smith. More than 20 metres long, the papyrus identifies more than 700 active substances, in about 900 formulae or recipes, with 47 'case histories', and is described by Dawson (1929), as 'not a book in the proper sense of the word; it is a miscellaneous collection of extracts and jottings from at least forty different sources', and by Nunn (1996) as 'a collection of different medical texts which have been run together in a rather haphazard order'. A partial translation and commentary in German, made at an early stage by H Joachim, was 'interpreted' into English by Bryan (1930), and a direct translation made into English by Ebell in 1937. Unfortunately all of these earlier translations suffer from over-imaginative interpretation, while the more recent, and definitive German translation has never been published (Nunn 1996), indicative of the difficulties of scholarship in this field. It seems clear, nonetheless, that the papyrus indicates knowledge of the toxic properties of various natural materials, including opium, aconite, hellebore, hemlock, hyoscyamus, lead, copper and antimony, as well as insect and animal venoms. Antidotes are described, commonly a mixture of chemical and physical measures, plus incantations, typical of the merging of rational observation and treatment with magic in Egyptian medicine.

By contrast with the multi-faceted, and confused, Ebers papyrus, the Brooklyn papyrus is concerned exclusively with snake bites. It has been dated to the late period of ancient Egyptian history, around 300BC, but is written in the style of the Middle Kingdom, either because it is a copy of a much older text, or because the writer chose an archaic style to lend authority. It is essentially a manual for the treatment of snake bite, and includes a guide to snake identification, with an accompanying prognosis and advice on treatment; the latter is largely rational, with some magical elements (Nunn 1996).

The Egyptians used hundreds of naturally occurring substances, from animal, vegetable and mineral origins, as medicines, and the papyri give detailed instructions for their preparation; however, as Nunn (1996) notes, the amount of substances to be used are generally denoted as ratios of volumes, with no indication of total quantity, and hence no indication of dose; it is difficult to understand how some potentially toxic substances could have been used in this way, and Nunn suggests that there may have been a well-understood standard volume, which was not explicitly stated.

Decker (1987) suggests that a cryptic exhortation to a priestly sect, found in an early papyrus, 'speak not of the name of I A O, under the penalty of the peach', may indicate a knowledge of the poisonous effect of amygdalin, a cyanogen contained in peach kernels. Borzelleca (1994) believes that this refers to a 'trial by ordeal',

involving a distillate of peach kernels containing hydrocyanic acid; the death of an accused person who drank this proved their guilt.

The second known list of poisons and antidotes, after the papyrus, comes from the civilisation of Ancient China. The *Pen Ts'ao* or *Pun Tsao*, the Great Herbal attributed to Shen Nung, the second of China's mythical emperor's, was written about 2700BC, although the earliest extant version dates from around 200AD, at the beginning of the Han dynasty. It contains lists of poisonous plants and other substances, with antidotes.

[Borzelleca (1994) noting that both the Ebers papyrus and the *Pen Ts'ao* present useful drugs and harmful substances together, sees in this the earliest evidence for the joint development of toxicology and pharmacology.]

Other Ancient Near East civilisations had similar listing of toxic substances. The dangers of medicinal products, particularly when adulterated, were well known to the Babylonians. There is no list of poisons in the Bible, although the book of Deuteronomy contains proscriptions on foodstuffs in considerable detail, but numerous references indicate an awareness of naturally-occurring poisons and their effects, e.g.: 'their wine is the poison of dragons and the cruel venom of asps' Deuteronomy 32:33; 'He shall suck the poison of asps, the viper's tongue shall slay him' Job 20:16 (Authorised Version). Borzelleca (1994) has further examples.

In the Hindu world, early Sanskrit medical writings including the Rig-Veda of 1500-1200 BC, and the Ayur Veda, of 700-900 BC, describe the effects of various poisons, mineral, vegetable and animal, as well as the effects of the bites of venomous insects and reptiles, but give only vague suggestions for prevention or treatment. The Shastras, commentaries on these early Sanskrit writings, produced about 300 years later, deal more extensively with antidotes.

Many Greek and Latin texts deal with matters of toxicological interest, and they are referred to in much classical literature, particularly with respect to arrow poisons Decker (1987); hence the roots of the term noted above. Homer relates that Odysseus went to Ephyra 'to learn the direful art to taint with drugs the barbed dart', while according to Ovid the arrows of Hercules were tipped with the venom of the Lerneian serpent. Many Greek myths and legends involve the use of poisons by gods and goddesses: Hecate used aconite as a poison, the Medes used colchicine, while Hercules himself was finally poisoned with cantharidin applied to his shirt (Borzelleca 1994).

The Greeks, not surprisingly in view of their seminal role in the development of the concepts upon which Western science would later be grounded, were foremost in the development of the study of poisons, moving beyond simple listings to detailed descriptions of the effects of various poisons, antidotes, and management. Though most of his teachings were mathematical and philosophical, Pythagoras (580-489BC) made contributions to toxicology, particularly in the effects of metals in the body. Hippocrates (460-355BC), generally described as the father of medicine, identified about 400 drugs, mainly of plant origin, for many of which he documented toxic properties, and made the first 'modern' recommendations for the management of poisoning, including the induction of vomiting and the use of carefully chosen antidotes. Diocles of Carystus (375-300BC), regarded as the second most notable Greek physician after Hippocrates, wrote a number of famous texts, including the first systematic description of poisonous plants. Theophrastus (372-287BC), a pupil of Aristotle, was the first to record the adulteration of food with potentially noxious substances, e.g. wheat adulterated with soil to increase its weight. Interest in poisons also spread to the nobility, although increasingly for pragmatic reasons: King

Mithridates of Pontus, a keen student of toxicology, carried out experiments on slaves and prisoners, developed the first of series of 'universal antidotes', named 'mithridatium' in his honour, and took daily doses of several poisons and antidotes in order to protect himself from poisoning by his enemies: later enthusiasts developed ever more complex form of mithridatium, culminating in Galen's, with 73 ingredients.

The Hellenic world produced the first written works dealing specifically with poisons (Decker 1987). These include two poems by Nikander of Colophon (185-135 BC), who was physician to Attalus, King of Bithynia, and who was said to have been allowed to experiment with the effect of poisons on condemned criminals. The first poem, the 'Theriaca' of about 1000 lines, deals with poisonous plants and animals, including aconite, hemlock, henbane, opium, and snake venoms; the second poem, the 'Alexipharmaca' of about 600 lines, deals with antidotes to these. While much of their content is fable, Decker (1987) suggests that they contain a considerable body of valid information which must have been gleaned by careful observation.

The 5-volume 'Materia Medica' of Pedanius Dioscorides (40-90AD), written around 77-78AD, and largely devoted to herbal medicines, contains information on poisons and their antidotes, in which well-known poisons were classified, for the first time, according to their origins. These included animal sources (serpents, toads, crustaceans, etc.), plants (aconite, colchicum, hemlock, opium, etc.), and minerals (arsenic, lead, cinnebar, and so on). Much of this is, clearly based on empirical observation, though the work also included 'fabulous' poisons, such as the blood of wild bulls, and materials which cannot be identified today, such as the Honey or Heraclea, believed to have been an infusion of poisonous roots, possibly aconite, in honey, and the sea hare, possibly a large snail or mollusc. Dioscorides' work remained the standard for some 1500 years, with many commentaries written on it, but no major advances or additions made.

Dioscorides' work was translated into English by the herbalist John Goodyer in 1655, and his text conveys the flavour of the original (Gunther 1959):

- for mercury: 'It hath a pernicious faculty being drank, eating through ye inward parts by its weight. But this is helped by much milk being drank, or wine with wormwood...'
- for hemlock: '...this also is of ye venemous herbs, killing by its coldness, but it is helped by unmixed wine.'
- for wormwood (*artemesia pontica*): '... we doe not allow of it in potions, it being bad for ye stomach and causing headaches.'

One commentator on Dioscorides, the Greek physician Galen of Pergamum (129-199 AD), considered by many the greatest Greek physician, writing in the second century AD, revealed a tendency to regard toxicology information as 'secret knowledge', by saying 'it is imprudent to treat of poisons and to make known their composition to the common people, who could only profit from this by committing crimes' (Decker 1987 p 4).

Borzelleca (1994) discusses these and other Greek contributions in detail, seeing in them the first evidence of the experimental approach to toxicology. Their school lasted for many centuries: Paul of Aegina (625-690 AD) is generally regarded as the 'last Greek compiler': his 7 volume medical encyclopedia, the *Epitome*, included a section on toxicology, specifically the bites and stings of venomous animals. The Roman civilisation, though they derived much of their medical knowledge from the Greeks, had a strong interest in poisons. Pliny the Elder (23-79 AD), produced a 37 volume compendium of natural history, including descriptions of poisonous plants and animals, and their effects. Aurelius Cornelius Celsus, described as the

'Hippocrates of the Romans', authored a number of medical texts, as well as a general encyclopedia: his classic text *De Medicus* (which survived to be one of the first medical books published after the introduction of printing in the 15th century) included a section on toxicology, largely drawing from Greek sources.

Both Greek and Roman physicians noted the poorer health of persons working in certain trades, or undertaking certain kinds of manual labour (Ottoboni 1991); in this can be seen the genesis of occupational medicine, and occupational toxicology. Hippocrates, for example, described severe colic in those working in the extraction of metals, which he ascribed to poisoning by lead, while Pliny wrote of mercury poisoning among slaves in the 'quicksilver' mines in Almaden in Spain.

Lead poisoning, in particular, was recognised in the classical world, and was described by writers including Nicander and Dioscorides, who both noted the significance of lead as an occupational poison, and described its classic symptoms; indeed it has even been suggested that lead poisoning among the upper classes, due to the extensive lead plumbing systems available to the wealthy, may have played a part in the deterioration of Roman civilisation (Hammond 1969).

In the Arab world, science and medicine flourished after the collapse of Roman civilisation, with most of the important Greek works being translated. Pharmacy, in particular, was developed beyond that known in the classical world, with some remarkably modern-looking information resources: the scholar al-Biruni (Abu al-Rayhan Mohammed ibn Ahmed al-Biruni 973-1048), at the age of 80, produced a guide to the properties of 720 medicines, listing each according to its name in five languages (Duncan 1998). The famous Arab physician and scholar Avicenna (Abu Ali Husain ibn Abdullah ibn Sina, 980-1037) produced a number of medical works, which included the nature of poisons and venoms, and their effects and treatment, and also some of the earliest speculations on the mechanism of actions of poisons. His works remained authoritative texts for 500 years.

Maimonides (Rabbi Moses ben Maimon, 1130-1204), a Jewish philosopher and physician, was another writer, whose works on poisons were remarkably long-lived. His book *Poisons and Antidotes/Upon Poisoning and its Treatment*, was translated into Latin in 1305, into French in 1865, and into German in 1873 (Borzelleca 1994). Like some of the earlier Greek writers, he noted the phenomenon of bioavailability, noting that milk, butter and cream could delay intestinal absorption.

Pietro de Abano (1250-1316), a teacher and physician in Padua, Italy, attempted to reconcile the Greek and Arabic traditions of medicine, including the treatment of poisoning, in his book *Conciliator Differentiarum*. Another work of his, *De venemis*, dealt with poisons under the, by now traditional, headings on animal, vegetable and mineral, and for the first time noted routes of administration other than oral: by inhalation, and through the skin. His book was published in 14 editions.

As noted above, poisons, usually of plant origin, were carefully and knowingly used in classical societies for murder, suicide, execution, hunting, and similar purposes, and the poisoner became, in a sense, the first applied toxicologist. As Decker (1987 p 2) puts it 'the focus of early toxicology quickly became the murder of fellow beings'. Indeed, much of the earliest impetus for the development of toxicology, apart from its value as a tool for the poisoner, was primarily forensic, as a response to the widespread use of poisons for murder over many centuries (Thompson 1931, Ballantyne, Marrs and Turner 1993C, Goulding 1987). Roman Emperors employed a Court Poisoner, a habit leading to the necessity for Official Tasters to test the food of potential victims.

During the so-called Dark Ages, these habits persisted, so that Decker (1987) suggests that the victims of poison included 5 popes, 7 Byzantine Emperors of the East, and 9 of Charlemagne's successors as Emperor in the West. Among the few developments in toxicology during this time was the discovery of white, or sublimed, arsenic, so convenient in use that it ushered in what Decker describes as the 'Golden Age' of poisoning.

In medieval and Renaissance Italy and France, skilful use of poisons for murder reached the status of a profession (Decker 1987); the habits of the Borgias and the Medicis in this respect are well-known, but not untypical. As noted above, Pietro de Abano's handbook of poisons, 'De Venemis', the 'laboratory manual' for the new profession, went through 14 editions during the 15th century, and, as Decker says, the present rarity of copies of this work speaks of the hard use to which they were put. In fifteenth-century Florence, poisoning was regarded a necessary political and diplomatic skill, while at the same time in Venice there was an official scale of poisoning charges, the price reflecting both the wealth and the accessibility of the victim (Tansey 1993).

There exist no records of official or professional poisoning in England. Decker points out, however, that the plays of Shakespeare show a wide knowledge of toxic substances, and how they may be administered, with suicide often occurring by poison, and assassination weapons tainted to produce certain death. Even the bizarre murder of Hamlet's father by the pouring of henbane into his ear may have a basis in fact; animal studies have shown that hyoscyamine, one of the toxic constituents of this plant poison, can be absorbed from the external auditory canal in sufficient quantity as to cause death. Much of Shakespeare's literary use of toxicology is likely to be based on popular knowledge than simple imagination.

Experimental

The experimental phase of toxicology is generally held to date from the 16th century, though, as noted above, some experiments (generally of a highly unethical kind) had been carried out from the earliest days, and some writers had speculated about mechanisms of toxicity. After this date, of course, the observation/descriptive tradition continued. European literature from the Renaissance onwards includes many examples of descriptive writings on natural toxins, often included in herbals: one well-known example is the Dutch 'Herbarium of Kruidtboeck', by Petrus Nylandt, of 1673.

The sixteenth century Swiss physician and alchemist Philippus Theophrastus Aureolus Bombatus von Hohenheim, commonly known as Paracelsus, (1493-1541) is often taken as one of the founders of the discipline of toxicology, writing what may be regarded as the precursors of toxicology textbooks (Deschamps and Morgan 1993), and introducing on a scientific basis, the concepts of an experimental and mechanistic approach to toxicology. In particular, he drew attention to the dose-dependency of toxic effects, and to the fact that every substance, in large enough quantity, will do harm, while 'toxic' substances, in appropriate doses, may be beneficial. This principle, which underlies toxicology to the present day, is often expressed as 'the dose makes the poison', a paraphrasing of Paracelsus' original 'Alle Ding sind Gifft .. allein die Dosis mact das ein Ding kein Gifft is'. This has been translated variously as 'everything is a poison .. it is only the dose that makes it not a poison' or as 'poison is in everything, and no thing is without poison - the dosage makes it either a poison or a remedy'. Deichmann et al. (1986) discuss in detail Paracelsus' *Third Defence*, from which this quotation comes - the 'defence' is of Paracelsus' teachings and methods against his detractors - and its significance in the development of present day concepts of toxicology. They suggest that he may be regarded as the originator, not merely of the general concept of dose-response, but also of no-effect or threshold levels, and tolerance limits, while Sipes, McQueen and

Gandolfi (1997) regard him as the originator of 'the two most important tenets of toxicology', that the level and duration of exposure will determine the nature and degree of the toxic response. Pagel (1958) gives a detailed account of Paracelsus' philosophical and medical views, and their sources and significance, in the context of Renaissance thought, though without any specific discussion of the toxicological aspects.

Paracelsus' other contributions to toxicology included the use of animals to test the effects of chemicals, the introduction of the concept of target organ toxicity, and further elaboration of the chemical hazards faced by miners, which, as noted above, had been recognised since ancient times, in his *Treatise on the Diseases of Miners* of 1567. He also promoted a focus on the 'toxicon', the main active toxic agent, by contrast with the Greek emphasis on a mixture or blend of substances; this led naturally to the concept of the active substance, as chemical theories developed.

Paracelsus' ideas were taken up by later scholars, including the French physician Jacques Grevin (1538-1570), who further developed the concept of chemical-biological interactions, earning the title 'father of modern biotoxicology' (Borzelleca 1994), and who published what became a classic work *Deux Livres des Venins* in 1568. Ambrose Pare (1510-1590), a pioneer of modern surgery, published a report on carbon monoxide poisoning in 1575, though a detailed understanding of its mechanism had to await 19th century developments in analytical chemistry. Felice Abbot Fontana (1720-1805), Italian physician and physiologist, elaborated the concept of target organ toxicology and is considered the first modern scientist to make a systematic study of venoms, which he published as *Ricerche fisiche sopra il veleno della vipera* in 1765. An earlier study of venoms, *A mechanical Account of Poisons* (1702) by Richard Mead (1673-1754), who was physician to the Royal family and also worked at St. Thomas's Hospital, lacked scientific rigour, though Mead went to the heroic expedient of swallowing snake venom, in order to demonstrate that it had only a parenteral toxic effect.

Another early figure of the modern era of toxicology was the Italian physician Bernardino Ramazzini (1633-1714), often regarded as the first practitioner of occupational medicine (Ottoboni 1991). Practising what would later come to be known as epidemiology, Ramazzini studied the diseases of occupations, including those caused by noxious chemicals, and was the first to advocate that doctors should always enquire into the occupations of their patients for diagnostic clues. As noted above, occupational diseases, particular in occupations such as mining, had been noted by ancient writers, by others such as Ellenborg, who wrote (about 1480) on the toxicity of lead and mercury used in goldsmithing, Agricola who produced a treatise on mining diseases (1556), and Paracelsus. However, Ramazzini was the first to publish a comprehensive, systematic and detailed account of industrial health problems, in his *De Morbis Artificum Diatriba* and in his famous *Diseases of Tradesmen*, originally published in 1700, and translated into English in 1705. His work was continued by Sir Perceval Potts (1714-1788), physician and surgeon at St. Bartholomew's Hospital, who first noted the relationship between scrotal cancer and soot exposure in chimney sweeps (1775); he also first identified an increased sensitivity to chemical exposure in young children.

With the beginnings of science-based medicine in the eighteenth century, the careful study of adverse reactions to medicinal preparations became another foundation for the discipline, an early example being the description of the toxicity of digitalis by William Withering in 1785. At about the same time, Samuel Hahnemann, best known as the founder of homeopathy, carried out toxicological studies on healthy human subjects, including himself, using current therapeutic agents, such as mercury, belladonna, and aconite. Similarly, Friedrich Wilhelm Adam Setürner, a pharmacist

from Westphalia, Germany, having isolated morphine, and named it for Morpheus, the Graeco-Roman god of sleep, studied its action in experiments upon himself and his friends.

As Oser (1987) points out, the most pertinent science underlying toxicology is chemistry, since without reliable analysis of toxic agents, no science of toxicology would be possible. This appears to have been first recognised explicitly by Joseph Plenck, an early, and arguably the first forensic toxicologist, who wrote in his 1781 treatise 'Elementa Medicinae et Chirurgiae Forensis': 'the only certain sign of poisoning is the chemical identification of the poison in the organs of the body'. The period from the mid-eighteenth century to the end of the nineteenth witnessed many chemical discoveries and innovations, and these were soon applied in toxicological studies; a listing of some of the most significant is given by Decker (1987). Two significant publications reflecting this were Henry Coley's 'Poisons and Asphyxia' (1832), which gave the first systematic procedure for the testing of gastric contents by chemical means, and Theodore George Wormley's 1867 text, 'Microchemistry of Poisons', which became a classic text on poison identification, and which is regarded as the first American book devoted entirely to toxicology. Both these authors were American, reflecting the increasing significance of the scientific contributions of that country. Finally, in 1884 AW Blyth produced 'Poisons: their effect and detection', the first comprehensive text of analytical toxicology. As with the rest of the chemical sciences, analytical toxicology has been revolutionised since the 1950s, with the development and routine application of spectroscopy, chromatography, immunoassay and computerised data collection and analysis; a detailed account is given by Decker (1987).

The founder of modern toxicology, particularly in its analytical and forensic aspects, is considered to be the Spanish chemist and physician Mathieu Joseph Bonaventura Orfila (1787-1853), born on Minorca, who studied chemistry and medicine in Paris, and applied the combination of these disciplines to the new science, finally becoming dean of legal medicine at the University of Paris (Beeson 1930). His two volume *Traité de Toxicologie: Traité des poisons tirés des règnes minéral, végétal et animal ou toxicologie générale considérée sous les rapports de la physiologie, de la pathologie et de la médecine légale*, commonly known as the *Traité des Poisons*, written in 1814-15, and published in English in 1817, is probably the first book devoted entirely to toxicology, and is regarded as certainly the first standard text on the subject, which was thereby established as an experimental science distinct from pharmacology. The book effectively combined clinical and forensic toxicology with analytical chemistry. Its systematic descriptions of the harmful effects of chemical substances, divided into six classes, including the 'traditional' animal, vegetable and mineral, dating from the Ebers papyrus. Orfila's work and writings are described and exemplified by Holmstedt and Löljestränd (1981).

Orfila was the first to apply what became the standard techniques of experimental toxicology: systematic animal testing, and chemical analysis of tissues and body fluids to identify poisons. He was the first to use autopsy material and chemical analysis as legal proof of poisoning. He devised, or furthered, the concepts of dose-response, target organ toxicity, and the relation between specific tissue damage and gross symptoms. In one of his later works, *Leçons de médecine légale* (1821), he proposed a division of poisons into four classes: irritants, narcotics, narcoticoacrids and putrefiants. His books were translated into many languages, and used in many countries, helping in the 'internationalisation' of toxicology. For example, his 1818 work 'Aid to be given to those who have been poisoned or asphyxiated', appeared in four editions, and was translated into English, German, Swedish, Italian and Portuguese (Beeson 1930). His lectures on legal medicine, which had a high toxicology component, were also

published in 1821, under the title *Traité de Médecine Légale*, an early example, certainly the first in toxicology, of published lecture notes.

His influence on toxicology, was great, and he influenced many other workers in the area (Borzelleca 1994). One notable example is Sir Robert Christison (1797-1882), a Scottish physician who studied under Orfila in Paris; though he attended few of Orfila's lectures, he commented that he 'caught somewhat of his spirit', and was the first to describe Orfila as having set toxicology on solid scientific foundations (Holmstedt and Liljestrand 1981, p91-92). He ultimately became professor of forensic medicine, materia medica and clinical medicine at Edinburgh, and published the well-known text *A Treatise on Poisons* (1829), of which the 4th edition (1845) was adopted as a standard text in the USA. He established a firm scientific basis for the role of the expert witness in forensic toxicology. Christison's scientific work is well exemplified by his 1855 investigations of the toxic effect of the ordeal (calabar) bean, including the heroic expedient, not uncommon in those days, of consuming some of the substance himself, and is reprinted by Holmstedt and Liljestrand (1981, p 94-96). Modern medical jurisprudence, which is a 'natural sequel' (Borzelleca 1994) is generally regarded as having been founded by Alfred Swaine Taylor (1806-1880), who taught at Guy's Hospital, and who presented the first course in medical jurisprudence in 1831. Famous as an expert witness, his *Manual of Medical Jurisprudence*, first published in 1842, was widely used, and had reached its 10th edition by the time of his death.

The nineteenth century saw much experimental work, following the example of Orfila, in the investigation of toxic effects and mechanisms. The development of toxicology paralleled, and drew from, that of organic and analytical chemistry, and went along with - indeed intertwined with - that of pharmacology and physiology. At the beginning of the century, toxicology was being recognised as a scientific discipline, with an extensive knowledge base of observed effects of, and antidotes to, many poisons, and with some limited experimental and analytical basis; but little had been done in providing any systematic answer to the basic mechanistic question 'how do poisons kill ?' (Borzelleca 1994). These questions could only now be answered, as the 'mechanistic' era of toxicology began, with the classic work of two physiologists, Magendie and Bernard.

The French physiologist Claude Bernard (1813-1878) carried out classic studies in elucidating the toxic actions of curare, of nicotine and of carbon monoxide, furthered the concept of target organ toxicity, and showed that chemicals could alter the structure and function of tissues. Bernard was also the first to demonstrate rigorously what had been assumed in writings since ancient times, and spelt out by Paracelsus: that the basic principles of pharmacology and toxicology are identical. He also propounded the value of using toxic agents to study the 'normal' workings of physiology. His treatise '*An introduction to the study of experimental medicine*' is regarded as a classic in the development of toxicology, but was translated into English, by HC Greene, only as recently as 1949.

Bernard was a student of Francois Magendie, who made many earlier contributions to physiology and toxicology, and who had studied the mechanisms of action of Borneo arrow poisons early in the century. In a precursor of current controversies, both Magandie and Orfila were severely criticised for their use of animals in toxicological research - 'Orfila, like his contemporary Magendie, has been accused of an inordinate sacrifice of animal life in carrying out his experimental inquiries, and met with much censure thereupon' (Anonymous commentator, in the British and Foreign Medico-Chirurgical Review, 1861, 27, 125, quoted by Decker, 1987, p 17). Throughout the nineteenth century, knowledge of mechanisms of toxic action increased rapidly, alongside the advances in chemistry enabling the isolation and precise identification of toxic substances.

The foundations laid by Bernard, in particular, were developed by several toxicologists throughout the century (Borzelleca 1994). Notably among them were Francesco Rognetta (1800-1857), who studied the mechanism of arsenic poisoning, and R. Bellini (1817-1878), an Italian physician, who published the first text devoted to experimental toxicology, *Lezioni Sperimentali di Tossicologia*. A great deal of progress was made by German toxicologists (Gallo 1996), including Oswald Schmeideberg (1838-1921), who originated the first major teaching laboratory of toxicology, from which over 100 students went on to academic careers worldwide, and Louis Lewin (1850-1929), whose work on the chronic toxicity of alkaloids remains a classic (Holmstedt and Liljestrand 1981).

Another founder of modern toxicology is Frederick Accum (born 1776, date of death unknown). A German by birth, he emigrated to London at the age of 24, finding initial employment as a pharmacist's assistant, and later working at the Royal Institution as a 'chemical operator' for Sir Humphrey Davy. He established his own laboratory, and provided consulting services, as well as retailing chemical supplies, and carrying out his own investigations, and publishing widely. Among his work was a series of investigations, the first of their kind, into the purity, and the detection of adulteration, in medicines, foods and drinks. He publicised the results widely, in the form of treatises and public lectures, his best known work being a *Treatise on Adulterations of Food and Culinary Poisons* (1820), and he may reasonably be regarded as the founder of the 'public safety' aspect of toxicological research.

Accum's work was followed up by other analysts, and, in the UK, culminated in the publication in 1855 of Dr Arthur Hill Hassell's book 'Food and its adulterations', published under the auspices of the medical journal *The Lancet*, whose Analytical Sanitary Commission was headed by Hassell. This book covered a variety of food and drink, including tea, coffee, bread, butter, sugar, cereals, etc. Its basis was somewhat different from Accum's work, in that it relied largely upon microscopical studies, rather than chemical analysis, to identify contaminants: Hassell was an expert microscopist. This led to the passing of the first British Food and Drug Adulteration Act in 1860, with stronger laws following in 1875. A similar process of scientific advances and public pressure led to the passing of the first Food and Drug Act in the USA in 1906.

Medical toxicology continued to develop throughout the nineteenth century, the most celebrated example being the enquiries into deaths due to chloroform anaesthesia. Another advance was the development, by Marsh in 1836, of a sensitive test for arsenic, allowing its reliable identification in foods and beverage as well as body tissues, and ending the 'Golden Age of Poisoning' referred to above. Together with other advances in forensic toxicology (usually taken, as noted above, to have begun with the work of Plenck at the end of the 18th century), this has ensured that in recent times 'poisoning, apart from suicides, has in large measure been a result, not of criminal activity, but of ignorance, thoughtlessness, and carelessness', particularly with respect to hazardous industrial materials, unsafe use of medicines, and misuse of pesticides (Decker 1987, p12).

The advances noted above, and others made throughout the 19th century, led to the recognition of toxicology as a distinct entity, though still closely bound up with pharmacology and physiology, drawing from a range of chemical, biological and medical sciences for its development. This feature of the development of toxicological science has continued to the present day, with Gallo (1996) noting that from 1900 the subject has developed and expanded by assimilating knowledge and techniques from most branches of biology, chemistry, mathematics and physics.

Application

The need for toxicologists to consider the 'incidental' exposure of individuals and populations to harmful substances, through the 'ignorance, thoughtlessness and carelessness' noted above, became increasingly recognised in the nineteenth century. At this time came the initial development of occupational toxicology, as a result of the industrial revolution, which involved large working populations exposed to potentially hazardous chemicals. This was given impetus by the passing of workers' insurance laws, initially in Germany (1883), later in Britain (1897) and the USA (1910).

By the end of the nineteenth century, the UK had passed seven Factories Acts, including reforms on chemical safety.

The early development of industrial toxicology in the USA is described in detail in the autobiography of Alice Hamilton (1943), the leading occupational physician of her time who researched and published widely on the topic, most notably in her text *Industrial Toxicology* (1934). One of the most interesting points repeatedly made by Hamilton, in her account of what she starkly terms the 'poisonous trades', is the national differences in access to, and understanding of, this aspect of toxicological knowledge. Ironically, in view of the predominant role played by the USA in regulatory toxicology in more recent years, in the early years of the twentieth century that country was far behind Europe in this respect. Thus, Hamilton writes 'American medical authorities had never taken industrial diseases seriously, the American Medical Association had never held a meeting on the subject, and while European journals were full of articles on industrial poisoning, the number in American medical journals up to 1910 could be counted on one's fingers' (Hamilton 1943, p1). She also refers to the 'strange silence' on the subject of industrial toxicology in American medical magazines and textbooks, by comparison with those of Europe, and suggests that it may have been due to a national perception that the subject was 'tainted with Socialism or with feminine sentimentality for the poor' (Hamilton 1943, p115); a striking example of the influence of socio-political factors on the knowledge base of a supposedly objective science. One specific example which she gives is that of 'phossy jaw', a disfigurement brought on by breathing phosphorus fumes. This was first described in Austria in 1845, with cases treated in the USA during the following decade. But, Hamilton notes, 'while all over continental Europe and England there was eager discussion of this new disease, many cases were reported and all sorts of preventive measures proposed, practically nothing was published in American medical journals from 1851 to 1909' (Hamilton 1943, p117). Further examples are those of benzol poisoning in rubber workers, described at an international medical congress in Moscow in 1897, but not reported in any American publication until 1910, and of carbon disulphide poisoning in rayon manufacture, for which 'the medical journals were full of reports, from Italy especially, and from all over Europe [but] for over ten years, during which time the viscose industry in [the USA] grew enormously, no American report of damage from this poison appeared ... foreign literature was full of detailed descriptions, but I doubt if any American medical student ever heard a word on the subject' (Hamilton 1943, p388). This neglect of toxicological knowledge extended into the record keeping of American doctors, as Hamilton notes with respect to the treatment of victims of lead poisoning: '... no hospital interne [sic] ever noted where the victim of plumbism had acquired the lead. Hospital history sheets noted carefully all the facts about tobacco, alcohol, and even coffee consumed by the leaded man, though obviously he was not suffering from those poisons; but curiosity as to how he became poisoned with lead was not in the interne's mental make-up' (Hamilton 1943, p10).

The rise of the chemical and pharmaceutical industries, in the nineteenth and particularly the twentieth centuries, has led to a change from a concentration on the toxic effects of natural, usually plant, compounds, to those of the products of

chemical manufacture (generally termed xenobiotics). The sheer number of different compounds, all with potential toxic effects, is a major challenge for industrial and regulatory toxicology; for example, Hamilton (1943) notes that the only poisonous substances used or encountered industrially in the state of Illinois around 1910 were lead, arsenic, brass, carbon monoxide, the cyanides and turpentine; by the 1940s, the list of chemicals used in even a single trade was many times as long. She also refers to the problems caused by the replacement of the small number of industrial solvents - petroleum distillates, wood alcohol, turpentine - used around the turn of the century by the wide variety of synthetic solvents following the 1914-18 war.

The vast number of compounds has also led to the origin of regulatory toxicology, the requirement for assessment of the potential harmful effects, which now accounts for the great majority of expenditure on toxicological research (Ballantyne, Marrs and Turner 1993C). This was hastened by the legislation on foodstuffs enacted in several countries at the turn of the century, which led to the development of standardised toxicity testing, to assess the numerous new preservatives and food colorants being introduced (Borzelleca 1994). One response to this was the establishment of internal toxicology research laboratories by a number of major chemical companies in the USA, including Dow, Union Carbide and Du Pont; laboratories of this sort, intended to help guide decisions on workers' health and on product safety have been major contributors to the knowledge base of toxicology since that time; see, for example, Scribner and Weiler (1995). Some of these laboratories have developed significant toxicology information resources in their own right; examples are the Central Toxicology Laboratory (formerly ICI but now part of Syngenta, Cheshire, UK) and TNO BIBRA, Surrey, UK, formerly the British Industrial Biological Research Association. The former has taken a lead in the development of systems and services for handling toxicology information, for example ARTEMIS, an early example of a comprehensive computerised toxicology data-handling system (Clapp and McNamee 1985). The latter was founded in 1960, as a joint venture of the British government and the UK food industry, with the aim of promoting research into chemical toxicology, with particular reference to foodstuffs. A later diversification into wider application areas of toxicology saw its name change to BIBRA Toxicology International; under its current title, its areas of interest are chemical toxicology, nutrition and ecotoxicology.

Governmental involvement with toxicology became more explicit at the beginning of the 20th century, a Division of Industrial Hygiene being established by the US Public Health Service in 1914. 1930 saw the foundation of the US National Institutes of Health, which has subsequently been the foremost exemplar of governmental involvement in toxicological research and information provision. Forensic science, including toxicology, advancing in capabilities with developments in analytical chemistry, was given greater importance by law enforcement agencies; one well-known example being Alexander Gettler, who served at the toxicology laboratory of the New York Medical Examiner for many years, and testified in hundreds of trials (Niyogi 1980).

One particularly significant event was the poisoning of a large number of persons in the USA in 1937, by a medical product containing the solvent diethylene glycol, which resulted in 107 deaths. This led to US legislation, the 1938 Amendment to the Food and Drug Act, forbidding the marketing of any new product until it had been assessed for safety by the Food and Drug Administration, setting the standard for the dramatic increase in regulatory toxicology which has followed. This can be traced to the influence of the 1939-45 war, with its very marked increase in the production of drugs, pesticides, munitions, synthetic fibres and industrial chemicals, which was the starting point for what Gallo (1996) describes as the exponential growth of toxicology, particularly in its regulatory aspect, since that time. Indeed, Doull (1984) argued that the development and evolution of toxicology in the 1980s was being driven by pressure from the regulatory arena. This resulted in the formalization of an

experimental programme of toxicity testing for all drugs, foods and cosmetics in the USA in 1955, later revised by the FDA in 1982.

In the UK, following the thalidomide tragedy, the Committee on Safety of Drugs was established in 1964, and the Medicines Act was passed in 1968.

Another stimulus to toxicological work came with the first systematic use of poisonous chemicals in warfare, during the 1914-18 War, and thereafter defence considerations have played a major part in stimulating toxicological research, particularly in the initial investigations of the mechanisms of toxicity, and in the development of clinical toxicology.

Concerns for the health of consumers, patients and workers, and for environmental protection have, of course, increased greatly during the last 50 years, fuelling the growth of toxicology; both basic research and regulatory requirements. Gallo (1996) argues, as a 'working hypothesis', that toxicology has expanded in response to legislation, itself passed in response to real or perceived tragedies. Highly publicised disasters such as thalidomide, Seveso and Bhopal, and the recognition of the environmental damage caused by organochlorine pesticides publicised by Rachel Carson's influential book 'Silent Spring' (1962), have added particular emphasis. A review of a number of 'disasters' is given by Illing (1993), and the wider context of these issues discussed in detail by Gallo (1996).

One immediate consequence of this was the further strengthening of governmental involvement in toxicology, particularly environmental toxicology, and especially in the USA, during the 1960s: this included the expansion of the role of the Food and Drug Administration, and the establishment of the Environmental Protection Agency, the National Institute of Environmental Health Sciences, and the National Center for Toxicologic Research (Gallo 1996). During the 1970s, concerns about hazardous chemical wastes, following the publicity surrounding the dangerous materials at the Love Canal site in the USA, led to the passing of the Toxic Substances Control Act and 'right to know' legislation, which in turn have led to great activity in creation of information resources in their support.

The UK Health and Safety at Work Act was passed in 1974, as a framework for modern chemical safety legislation. More recently, regulations for the control of substances hazardous to health (COSHH) have come into being.

Over time, toxicology in general has moved away from its origins in acute, particularly human, toxicology, towards long-term and non-target species studies, to studies of carcinogenicity, mutagenicity and teratogenicity, and to in-depth examination of mechanisms. This has been fuelled by developments in the other sciences on which toxicology depends, and Gallo (1996) regards modern (i.e. 20th century) toxicology as a continuation of the development of the biological and physical sciences in the late 19th and the 20th centuries.

Zbinden (1992) describes the momentum of the development of toxicology in terms of 'three eras' of experimental toxicology, since about 1920. In the first era, that of discovery, the basic foundations of this approach were laid, with the realisation of the many ways in which adverse effects of chemicals could manifest themselves, and the development of experimental means for assessing and quantifying these. In the second era, that of 'biomechanistic investigations', beginning in the 1940s, experimental toxicology evolved from a 'descriptive and tightly regulated routine procedure' to a truly scientific and rational investigation, appealing to academic investigators who would not wish to be involved in simple safety-testing procedures. This has led to deeper understanding of toxic responses, and provides explanations

such as species differences, organ affinities and chemical interactions. Even so, as Zbinden cautions, there are still relatively few chemical compounds whose toxic effects are fully understood. Finally, stemming from the 1980s, there is the era of 'individual expression', in which the influence of a variety of factors, but particularly genetics, in determining the response of individuals to potentially toxic substances may be understood.

This advance in scientific understanding has created something of a tension, in that it takes a considerable time for the insights and methods developed by toxicological research to be adopted in the safety testing procedures required by law. The latter must, to a degree, stand aloof from the rapidity of research, in order to provide the stability necessary for the practical operations of regulatory authorities and manufacturers of chemical products. Nonetheless, the slowness of adoption of newer findings and techniques has led to accusations that industrial toxicity testing is wasteful of money and resources, unethical in its excessive reliance of testing with large numbers of animals, and can lead to undue delay in the introduction of useful new products. Zbinden (1992) expresses this tension in measured tones: 'if the methods and the concepts of evaluation of toxicological studies were adapted continuously to the newest findings generated in research laboratories, a valid documentation of safety studies for regulatory approval could never be assembled. On the other hand, it is frustrating to see how slowly well-established, scientifically-based facts and concepts are incorporated into the industrial safety testing routine and the regulatory practice of risk assessment.... As in every other discipline of natural sciences, the speed with which new knowledge is accumulated in experimental toxicology is phenomenal. The task of identifying the relevant discoveries and their incorporation into the practice of industrial safety testing and risk evaluation is extremely difficult'. More tersely, Stitzel (1998) comments 'we are about to begin the 21st century using many toxicology methods that were originally developed in the 1940s. I can think of few other fields where acceptance of scientific progress has been so effectively blocked'.

At the same time as experimental (scientific) toxicology has been developing in these ways, clinical toxicology, the treatment of acute poisoning, hitherto carried out by general physicians, has developed into a specialist branch of medicine, supported, from the 1950s, by the specialist support of poisons information centres, responding to the greatly increased range of chemical substances available to the public (see, for example, Vale and Meredith 1993).

Since the 1970s, the use of computers has had a dramatic impact upon the practice of toxicology, as on other areas of science and medicine. Of particular importance has been the development of computerised methods for predicting toxic effects (see, for example, Coombes and Judson 1995, Benigni and Richard 1998, McKinney et. al. 2000). Wider use of these methods will have major impact upon the practice of toxicology, particularly the regulatory and risk assessment aspects.

Please note: references are in the main thesis.

2.3.a Toxicology qualifications

1980

3 January Beecham	Haematologist (Toxicology and Drug safety evaluation)	HNC haematology plus laboratory experience
Beecham	Histologist (Toxicology and Drug safety evaluation)	HNC MLS or 5 years experience
10 January Hazelton	Acute Toxicology (contract toxicity testing)	recent graduates, 1 or 2 years experience
24 January Fisons	Teratologist	HNC / Degree in relevant subject, teratology experience
Unilever	Mutagenicity Assistant (testing for bacterial mutagenicity) [repeated 3 July]	Degree in the biological sciences, preferably genetics/microbiology
31 January MRC Tox. Unit	Technician	ONC/HNC applied biology
7 February Met. Police	Drugs and Toxicology Forensic Science Service	Honours degree in chemistry, pharmacy, biochemistry
SKF	Toxicologist, Registration	Degree in biological sciences, 3-5 years experience in toxicology
SKF	Toxicologist, Quality Assurance	Degree in biological sciences, 2-3 years experience practical toxicology
14 February (agency)	Head of Toxicology (pharmaceutical company, drug safety)	several years experience in toxicity testing of pharmaceuticals
28 February New Cross Poisons Unit	Research Assistant, drug pharmacokinetics	experience of chromatography

20 March Shell Tox. Lab.	Inhalation Chemist	Honours degree, 4 years PG industry experience
ICI CTL LSR	Junior Toxicologist Cytogeneticist, genetic toxicology (contract toxicity testing)	'O' levels, including biology subject, toxicology experience degree or P/G qualifications, experience of cytogenetics
27 March Shell Tox. Lab.	Toxicologist, experimental toxicology	Honours degree in relevant biological science, 5 years toxicology experience, knowledge of QA
Wellcome	Toxicologist, animal toxicology	Degree in relevant biological subject, experience in animal toxicology studies
10 April ICI CTL	Team Leader Acute Toxicity	Biology degree or equivalent (e.g. MIBiol) an advantage 3 years short-term toxicology experience and HO licence essential
ICI Pharms	Biochemist in Clinical Toxicology	Degree or equivalent in biochemistry 3 years post-graduate experience
10 July Shell	Toxicology Laboratory Technician (Tox. Laboratory)	HNC/degree in biochemistry or pharmacology several years laboratory experience in toxicology/biochemistry/pharmacology
17 July Beecham	Safety evaluation technologist (repeated 24/7)	Graduate level qualifications Several years practical experience in toxicology testing
27 July ICI CTL	Information Officer (providing info to toxicologists)	Degree or equivalent in a biological science Several years experience of industrial biological experimental work
(Agency)	Head of Toxicology and Reproductive Studies	Higher degree in biological science or a medical discipline Several years experience in fertility/reproductive/teratology studies
31 July Hazelton	Acute toxicologist (contract toxicity testing)	Graduate in the biological sciences Some relevant experience
28 August Huntingdon	Rodent toxicologist (contract toxicity testing)	At least 5 years post-graduate experience in general toxicology, with at least 2 years experience in rodent toxicology

4 September Toxicol	Toxicologist (contract toxicity testing)	Degree or equivalent qualification [no subject specified] Experience in toxicology laboratory
11 September Life Sciences Res.	Genetic Toxicologist (contract toxicity testing)	Graduate [no subject specified] experience of tissue culture techniques
18 September Beecham	Reproductive Toxicology	Degree in a relevant subject Experience in conducting teratology/fertility and peri/post natal studies
Uniliver	Research Assistants for Safety Evaluation	Degree in relevant biological science, or training to equivalent level basic understanding of statistics and chemistry experience relevant to toxicological testing an advantage
2 October DHSS Tox. Unit (Barts Hospital)	Biochemist	PhD biochemistry relevant post-graduate experience
30 October RPMS (Hammersmith)	Research Officer (for Wellcome Trust Toxicity project) Drug Toxicity Technician	Degree in chemistry, biochemistry or pharmacology HNC in appropriate subject experience in general biochemical and/or analytical chemistry techniques
6 November Shell (Tox. Laboratory)	Research technician	HNC in chemistry desirable, knowledge of biochemistry an advantage 5 years experience in chromatographic, spectroscopic, radiochemical techniques
13 November SKF	Toxicology technician	experience in toxicology or pharmacology, HO licence
27 November New Cross Poisons Unit	Experienced analytical toxicologist	Nothing further specified
Wyeth	General toxicology and reproductive studies section (Drug Safety evaluation)	Broad-based degree in biology, preferably with some specialisation in embryology and/or behavioural studies - knowledge of biometrics and computing an advantage
4 December Huntingdon RC	Fish Toxicologist (contract toxicity testing)	sound scientific background, supported by supervisory experience and the ability to communicate well

11 December
SKF

Information Scientist - Toxicology

Degree in an appropriate science or in information science
experience in either toxicology or data handling

1990

6 January Boehringer	Toxicologist	university education in medicine, biology or toxicology, with emphasis on toxicology/pharmacology
20 January Glaxo	Toxicologist	Degree in biological sciences some experience in, or knowledge of, toxicology
27 January Hatfield Poly	Neurotoxicologist or neurobiologist (for FRAME in vitro neurotoxicity project)	PhD with broad neurochemical/neurobiological knowledge experience in neural tissue culture
Dow	Toxicologist	Degree in toxicology or a life science subject
Huntingdon	Toxicologist (contract toxicity testing)	Degree in a biological science preferably experience in a toxicology-related discipline
3 February DOE (studying environmental chemicals, air and water pollution)	Environmental scientist	Honours degree or equivalent in a chemical, biological or environmental science some experience
ICI CTL	Biochemical toxicologist	Degree in biochemistry or closely related discipline
Fisons Pharms	Toxicologist	3 years practical experience, plus 2 years in management of toxicology studies
10 February Toxicol	Toxicologist (contract toxicity testing)	Degree in a biological science 2 years experience in one or more aspects of practical toxicology
17 February MRC Tox. Unit	Scientist (1) Scientist (2) Scientist (3)	biochemical background, degree in related subject chemical or biochemical background, experience in chromatography/spectrometry chemical background
Schering	Toxicologist	Degree in pharmacology, biochemistry or related biomedical science experience in toxicology

24 February Inveresk	General toxicologist (contract toxicology testing)	Degree in biological science with relevant experience
Inveresk	Acute toxicologist (contract toxicology testing)	Degree in biological science with relevant experience
Fisons	Toxicology team leader	someone who has worked in toxicology for a number of years and gained significant technical experience
Safepharm	Study director, general toxicology (contract toxicity testing)	preferably graduate qualification
Safepharm	Team leader, general toxicology (contract toxicity testing)	HNC qualification and technical experience in toxicology
Safepharm	Senior technician, genetic toxicology (contract toxicity testing)	HMC and lab experience, preferably in genetic toxicology or in biochemistry/haematology
3 March Life Science Research	Ecotoxicologist (contract toxicity testing)	graduate or HNC with relevant practical laboratory experience
Wellcome	Histologist for drug safety evaluation	HNC in histology
AH Marks	Regulatory toxicologist	good degree in a biological science, preferably toxicology 2-5 years practical toxicology experience
10 March BP	Toxicologist	graduate in either chemistry or life sciences several years experience in experimental toxicology
Wellcome	Toxicology animal technician	ONC/HNC in appropriate science, HO licence
Guys Poisons Info Service	Information Officer	life science graduate, with proven interests in toxicology, pharmacology or biochemistry
31 March Bristol Health Authority	Medical Laboratory Scientist (Toxicology Section)	nothing stated

21 April National Rivers Authority	Aquatic biologist (for toxicity studies)	biology degree, experience of aquatic management practical experience in toxicity studies desirable
28 April Institute of Terrestrial Ecology	Ecotoxicologist	biochemistry degree
Boots	Genetic Toxicology	HNC with experience of cell culture
Du Pont	Toxicologist	preferably PhD [no subject specified] 5 years experience in toxicology studies
Beecham	Toxicologist	Honours degree in a biological subject, preferably biochemistry or pharmacology some formal toxicology training, 4-5 years experience in toxicology graduate in biological or chemical discipline
Sterling Research (project on in vitro mechanisms of toxicity)	Research worker	
12 May Syntex	Toxicologist	graduate, with several years experience in regulatory toxicology
MRC Toxicology Unit	Director	considerable research experience in toxicology or related disciplines
19 May Toxicol labs	study director, reproductive toxicology (contract toxicity testing)	good first degree in a biological science 2 years experience in reproductive toxicology
Toxicol labs	graduate trainee, reproductive toxicology (contract toxicity testing)	graduate in a biological science
26 May Huntingdon Res Centre	Supervisor (contract toxicity testing)	graduate [no subject specified]
Huntingdon Res Centre	Scientific officer (contract toxicity testing)	graduate in biological sciences or a related discipline
Huntingdon Res Centre	Analyst (contract toxicity testing)	HNC, plus experience in analytical chemistry

ICI CTL	Developmental toxicologist	good honours degree in a biological subject, desirably p/G qualifications in a discipline related to embryology
BIBRA	toxicology marketing/sales	experience in toxicology
9 June Medicines Control Agency ICI CTL	Adverse reactions monitoring Research Scientist (cancer / toxicology)	HNC or degree in pharmacy or pharmacology PhD in biochemistry or a related discipline experience in biochemistry or cancer research
23 June Australian govt. Dept of health	Pharmacologist / toxicologist	PhD in pharmacology, physiology or toxicology
7 July Huntingdon Res. Centre	Inhalation toxicology supervisor (contract toxicity testing)	Degree in a biological science experience in a toxicology related discipline
Huntingdon Res. Centre	Ecotoxicology analyst (contract toxicity testing)	Degree in chemistry, applied chemistry or analytical chemistry, or PhD with a thesis involving extensive use of analytical techniques
ICI Pharms	Experimental toxicologist	Degree [unspecified], knowledge of biochemical toxicology useful experience in a bioscience laboratory
21 July Inveresk	Toxicologist (contract toxicity testing)	biological science graduate several years experience in toxicology
28 July Lothian and Borders Police	Forensic chemist/toxicologist	Degree in chemistry or analytical chemistry experience in a forensic science laboratory
Schering	Adverse reactions officer	graduate in pharmacy or life sciences
4 August Medicines Control Agency	Toxicologist / pharmacologist	Degree in a relevant science 4 years relevant experience

11 August Ciba Geigy	Toxicology study director	Degree [unspecified] backed by substantial experience as a study director Diploma or other qualification in toxicology a definite advantage.
18 August Schering	Toxicologist	Honours degree in a relevant physiological subject experience of chronic toxicology an advantage 2-3 years of conducting toxicology studies
MRC Tox. Unit	Scientific Officer	chemical or biochemical background experience with chromatography / spectrometry an advantage
1 September Dept of Health	Toxicologist	Degree in a relevant science subject 2 years experience in practical toxicology and/or assessment of toxicological data
22 September MAFF, Vet. Medicine Directorate	Toxicologist	Honours degree in toxicology, and at least 4 years relevant P/G experience. PG degree in toxicology, Diploma in Toxicology of Royal College of Pathologists, or equivalent an advantage
29 September Hatfield Poly	Technical Officer, Cellular Toxicology	Degree / HNC plus lab experience in cellular toxicology, biochemistry or tissue culture
UCL	Junior technician toxicology	experience of biochemical and general laboratory techniques
6 October Huntingdon Res. Centre	Study supervisor (contract toxicity testing)	graduate [no subject specified]
Huntingdon Res. Centre	Scientific officer (contract toxicity testing)	graduate in biological sciences or related discipline
Safepharma	Marketing executive (toxicology)	Degree in a biological science 3 years experience in toxicology
13 October Roche	Drug Safety executive	life science degree (including nursing)
Fisons	Head of inhalation toxicology	8 years P/G experience in inhalation toxicology

20 October Fisons (contributing to all aspects of toxicology studies)	Head of Pathology	veterinary or MRCPPath qualifications pathologist experienced in safety evaluation
3 November Hazelton	study director, general toxicology (contract toxicity testing)	experience running toxicology studies
Hazelton	study director, reproductive toxicology (contract toxicity testing)	experience running reproductive toxicology studies
10 November Royal Lesotho Mounted Police	Forensic toxicologist	Degree in pharmacology or related subject 5 years experience in a forensic science laboratory
24 November RCC Notox	Senior toxicologist (contract toxicity testing)	Degree in an appropriate discipline 5 years experience in rodent toxicology
Inveresk	Toxicologist, study director, general toxicology graduates, or equivalent, with appropriate experience (contract toxicity testing)	
ICI Environmental Laboratory	Invertebrate toxicologist	HNC / degree in a biological science laboratory experience

2000

15 January Roche	Drug Safety Associates (aspects of adverse drug events)	Degree in life sciences, nursing, pharmacy, plus computer literacy
Euromedica	Drug Safety Manager	Life science degree, 4 years experience in drug safety
Aventis	Regulatory Toxicology	P/G qualification in toxicology, knowledge of registration process for agrochemicals
Aventis	Toxicology and Risk Assessment	P/G qualification in toxicology, knowledge of registration process
Aventis	Toxicological Pathologist	Pathologist, experience in pathology studies under GLP, familiar with computerised pathology data systems
Zeneca CTL	Investigative toxicology	Graduate with several years experience in in vivo and in vitro DMPK studies, strong bioanalytical background
22 January HSE	Risk assessment specialist (for chemical process industry)	Honours degree in relevant scientific discipline, 4 years relevant P/G experience
GlaxoWellcome	Safety pharmacologist	Degree/ PhD in pharmacology or applied biology, 2-3 years relevant experience
TNO	Environmental fate product manager	P/G degree, 5 years experience in environmental fate research, knowledge of biocide/pesticide legislation
12 February Pfizer	Residue scientist	PhD in chemistry or toxicology, experience in drug metabolism or pharmacokinetic residue studies
NAPAG	Head of pathology	Background in pathology or toxicology of the CNS, expertise in relevant techniques, strong experimental skills
LGC (Health related hazard and risk assessment of chemicals and consumer products)	Consultant toxicologist	Knowledge of toxicology, risk assessment, regulations. Use of toxicology data systems.
Amgen	Clinical safety co-ordinator	4 years experience in pharmaceuticals, 2 in pharmacovigilance
Amgen	Clinical safety associates	Degree in life science or nursing
University of Central Lancashire	Head of toxicology centre (forensic science)	Degree and PhD in relevant field, national research reputation
University of Central Lancashire	Lecturer in toxicology (forensic science)	Degree in relevant field, 5 years experience in academic/practice forensic science

18 March (forensic science consultancy)	Forensic scientists	no qualifications given
MAFF	Scientific Officers, Natural Toxicants	Honours degree in life sciences or chemistry plus lab. Experience. Training or experience in toxicology / biochemistry
CTRB	Study director general toxicology / immunotoxicology	3-5 years experience in general toxicology or a closely related discipline
CTRB	Scientist, genetic toxicology	experience in genetic toxicology, knowledge of general toxicology and lab. Techniques
Kent Police	Forensic Crime Manager	skilled forensic scientists
2 April National Centre for Environmental Toxicology	Principal Scientists, Human health	10 years experience in risk assessment of chemicals, and their impact on human health
20 May SKB	Senior Clinical Safety Scientists	life science degree, 4 years relevant experience
AstraZeneca	Senior Drug safety Officer	life science / biomedical degree, 2 years experience in drug safety
ICR/CRC Centre for Cancer Therapeutics	Scientific Officer	Degree in pharmacy/pharmacology/toxicology, experience in HPLC
8 July Imperial College Division of Investigative Science	Trainee Forensic Toxicologist	Degree in chemistry, pharmacology, analytical science or related subject
UK Government Advisory Committee on Pesticides	Toxicology Advisor	expertise in carcinogenicity, operator exposure estimation, pathology (particularly relevance to man of pathology of animal toxicology)
15 July Boehringer [repeated 22 July]	Pathologist, Non-clinical drug safety	MD or DVM, with good knowledge of the pathology of experimental animals, and an interest in general toxicology
22 July Astra Zeneca	Safety pharmacology (evaluating secondary pharmacological effects and predicting clinical side effects)	BSc or PhD pharmacology

29 July (agency)	Veterinary pathologist (interpretation of studies to evaluate toxicity of potential new products including immunotoxicology and neurotoxicology)	DVM with MSc/PhD pathology or MRCPPath
AstraZeneca	Senior genetic toxicologist	PhD and postdoc experience [subject unspecified]
12 August AstraZeneca	Senior molecular toxicologist	PhD in toxicology/cell biology/related field knowledge of bioinformatics and regulatory toxicology
2 September AstraZeneca	Scientific health and safety advisor (risk assessment of new chemical entities and laboratory chemicals)	chemistry or bioscience graduate, ideally with safety / environmental qualifications
9 September HSE	Regulatory Scientists (assess physicochemical, toxicological, environmental effects of pesticides, biocides and laboratory chemicals)	Degree in a scientific subject, especially chemistry, toxicology, ecotoxicology
Safepharma	Toxicology and analytical professionals (contract toxicity testing)	experience in mammalian toxicology, genetic toxicology, ecotoxicology, analytical chemistry
(agency)	Head, Drug Metab. and Molecular Tox.	PhD and experience in drug metabolism and/or toxicology
16 September Roche	Drug safety associates (monitoring adverse event reporting)	qualifications in life sciences, nursing or pharmacy
MCA	Pharmacovigilance scientists (adverse event data management)	preferably life science degree
Ersai	Drug safety administration	life science qualifications
30 September MAFF	Principal ecotoxicologist	knowledge of ecotoxicology, risk assessment
(agency)	Toxicology study director	Degree in a life science, preferably further toxicology training, experience in toxicology
Huntingdon Life Sciences	Senior Toxicologist (contract toxicity testing)	P/G qualification in toxicology, experience in regulatory toxicology
Huntingdon Life Sciences	Study manager (contract toxicity testing)	life sciences degree

7 October Dept of Health [repeated 18 November]	Medical device specialists (toxicology)	broad knowledge of toxicology, knowledge of risk assessment experience in toxicity studies
Huntingdon Life Sciences	Inhalation study director (contract toxicity testing)	P/G qualification in toxicology, PhD preferred experience with biopharmaceutical inhalation desirable
28 October CTL	Research assistant in biochemical toxicology	Degree in chemistry or biochemistry, some knowledge of molecular toxicology desirable experience of chromatography and spectroscopy
CTL	Analytical chemist, toxicological analyses	chemistry degree with analytical experience
Newcastle Drugs and Poisons Info Service	Medical Information Scientist	Degree in pharmacology or a biomedical subject including pharmacological sciences
18 November Pfizer	Toxicologist, general toxicology	DVM or PhD in relevant science 5 years experience in regulatory toxicology
25 November (agency)	Pharmacovigilance executives (maintenance of adverse event databases)	life science degree and experience of clinical safety
2 December (agency)	Pharmacologist / toxicologist	P/G research degree in toxicology, pharmacology or cell biology, plus R&D experience
9 December National Centre for Ecotoxicology	Scientists (hazardous substance monitoring)	Degree in chemistry or appropriate scientific discipline and preferably P/G qualifications knowledge of hazards and risk assessment an advantage
Sequami	Toxicologists	life science graduates with experience in a regulatory toxicology environment
Huntingdon Life Sciences	Senior scientist for SAR (contract toxicity testing)	strong background in chemistry, minimum BSc, some knowledge of metabolism and toxicology an advantage
16 December Unilever	Toxicologist	PG qualification or equivalent in toxicology or a related discipline, knowledge of toxicological risk assessment essential, at least 5 years experience
Novartis	Toxicology study director	PhD or DVM or other acceptable qualification in the life sciences 3-5 years experience in toxicology study positions

24 December AstraZeneca	Global Safety Assessment	suitable disciplines [no level of qualification specified]: genetic toxicology, biochemical and mechanistic toxicology, safety pharmacology, general toxicology, molecular biology, cell biology, clinical pathology, pathology
National Teratology Information Service	Senior Medical information Scientist	Degree in pharmacology or another relevant biomedical subject experience of toxicology preferred
Inveresk	Study director, reproductive toxicology (contract toxicity testing)	5 years experience of regulatory reproductive toxicology studies
Inveresk	Study director, general and acute toxicology (contract toxicity testing)	several years P/G experience in toxicology study management
Safepharm	Avian toxicologist (contract toxicity testing)	3 years conducting avian toxicity studies
Safepharm	Entomologist (contract toxicity testing)	entomologist with experience of regulatory toxicology

2.3.b Education for toxicology

Napier University (Edinburgh) **BSc in Toxicology**

This course, the only undergraduate course in toxicology offered in the UK in 1999, is studied over 3 or 4 years full-time, or over 5 years including a sandwich (industrial placement) year. It shares a common first year with other courses in the School of Biology, and students only opt to follow the toxicology route after that year.

The course is designed 'to allow further study in this area which has attracted increased public interest in recent times. In the early years of the degree, a broadly based grounding is given which includes cell biology, physiology and microbiology, in preparation for the later, more specialised areas. These topics encompass the factors which affect the toxicity of compounds together with the legislative background and major analytical techniques used to detect and quantify toxins [Toxicology 1]. In addition, the beneficial role played by the development of selectively toxic compounds (chemotherapeutic drugs and pesticides) will be examined as well as the search for improved products with an increased range of desired attributes, eg decrease in unwanted side reactions in patients [Toxicology 2]. These studies will run alongside modules covering the molecular responses to toxic insult: inflammation, fibrous and cancer, and modern molecular biological methods which are now essential tools for exploring DNA sequences, and isolating genes leading to improved diagnosis, monitoring and treatment.'

Courses followed are:

Year 1

Biology 1; genetics, evolution, diversity
Biology 2; human biology, microbiology
Biology 3; cell and animal biology
Biological chemistry
Learning Toolkit 1
Mathematics

Year 2

Biology 4; human and comparative physiology
Biochemistry
Cellular microbiology
Introduction to biomedical science and toxicology
Learning toolkit 2
Elective

Year 3

Toxicology 1
Molecular genetics
Microbial pathogenesis
Immunology 1
Environmental pollution
Statistics

Year 4

Toxicology 2
Environmental physiology and ecotoxicology
Molecular Biology

Project

Only two of the courses followed deal with toxicology *per se*:

Toxicology 1

An introduction to the science of toxicology, includes:

- dose-response principles
- toxicokinetics
- role of cytochrome p450 in biotransforming xenobiotics
- major sites and mechanisms of organ specific toxicity
- analytical techniques for identification and quantification of toxic substances
- legislative background to toxicology tests

Toxicology 2

deals with selective toxicity; general principles and examples, e.g. drugs, herbicides, pesticides.

King's College, London University
BSc Pharmacology with Toxicology

This undergraduate course has much in common with the pharmacology BSc.
Modules followed are:

1st year

- chemistry
- experimental pharmacology
- cells and molecules
- theoretical basis of pharmacology
- physiological systems
- experiment design and analysis

2nd year:

- cell and tissue pathology
- environmental pharmacology and toxicology
- applied pharmacology
- experimental neuropharmacology
- physiology and pharmacology of the CNS
- drug design and development

3rd year

- Laboratory placement

Final year

- toxicology
- cellular pharmacology
- library project,
- central neuropharmacology and neurotoxicology
- experimental cardiovascular pharmacology
- or
- experimental pharmacology of inflammation

The first year of the course is identical to the pharmacology BSc. In the 2nd year, 'cell and tissue pathology' is followed, and in the final year 'toxicology': all other modules are common with the pharmacology course.

This undergraduate course, therefore, treats toxicology as a close relation to pharmacology, requiring limited toxicology-specific material, and some additional preparation in pathology.

University of Surrey

MSc courses in Toxicology and in Applied Toxicology

These courses are provided by the School of Biological Sciences at the University of Surrey.

The School is committed to "protecting health, food and the environment by teaching and research" with research activities are thus focussed on Toxicology, Food Safety, Nutrition and Microbiology. Honours degree courses are offered in Biochemistry, Nutrition, Food Science, Molecular Biology and Microbiology. At the postgraduate level, MSc's are offered in Clinical Biochemistry with Molecular Biology, Pharmaceutical Medicine, Medical Microbiology, Nutritional Medicine and Experimental Pathology in addition to the MSc's in Toxicology and in Applied Toxicology.

The MSc in Toxicology is intended to 'give suitably qualified graduates a broad appreciation of the many aspects of toxicology', and focuses on the molecular mechanisms of chemically induced toxicity and the assessment of toxicological hazards, preparing graduates for employment in all aspects of practical and regulatory toxicology.

The Course may be attended either as:-

(i) a continuous full-time programme extending over twelve months (starting in October of each year) and consisting of three ten week terms and a three-month research period,

or:-

(ii) a programme extending over two years, consisting of a 10-week term in the first year followed by a further two terms and a three-month research period in the second year.

Lecture courses are:

- Animal Husbandry
- Drug Metabolism
- General Pathology
- Information Technology and Computing
- Introduction to Cell Biology
- Molecular Mechanisms of Cellular Signalling
- Pharmacokinetics
- Physiology and Pharmacology
- Refinement, Reduction and Replacement of the use of Animals in Toxicology
- Target Organ Morphology and Pathology
- Techniques in Pathology
- Toxicity Testing
- Biostatistics
- Ecotoxicology
- Food Toxicology
- Immunotoxicology
- Mechanisms of Toxicity
- Mutagenesis and Carcinogenesis
- Regulatory Toxicology
- Reproductive and Developmental Toxicology
- Safety Evaluation
- Case Studies

- Clinical Toxicology
- Epidemiology

plus a research project, literature review, and toxicology evaluation project.

The MSc in Applied Toxicology is a part-time modular training programme for those in full-time employment. The individual modules can either be taken separately as a one-off refresher course or modules may be accumulated over a period to give the award of MSc in Applied Toxicology. There are eight core modules and a number of supplementary modules. The core modules are an obligatory component of the MSc/Postgraduate Diploma in Applied Toxicology. Four core modules and two supplementary modules are offered each year. Each module is an intensive 5-day residential taught course, preceded by preparatory study, and followed by consolidation and assessment.

Core modules are:

- Carcinogenicity and Mutagenicity
- Reproductive Toxicology
- Toxicokinetics and Metabolism
- Principles of Toxicological Pathology
- Principles of Experimental Toxicology and Risk Assessment
- Target Organ Toxicology – Systems I: Liver, Kidney, Gastrointestinal Tract and Skin
- Target Organ Toxicology – Systems II: CNS, PNS, Endocrine and Musculo-skeletal Systems
- Target Organ Toxicology – Systems III: Cardiorespiratory and Haematopoietic Systems

Supplementary Modules are:

- Plant Protection Products and Plant Biotechnology
- Safety Assessment of Food Additives
- Safety Assessment of Pharmaceutical Agents
- Food Chemical Safety Evaluation
- Alternatives to Animal Testing
- Occupational Toxicology
- Ecotoxicology
- Immunotoxicology

University of Rochester, New York

Graduate Studies in Toxicology

This program is among the longest-established toxicology programs in the USA, commencing in 1966, and being one of only a few programs funded by the National Institute of Environmental Health Sciences. The teaching staff involved in the Toxicology Graduate Training Program are drawn largely from the Department of Environmental Medicine, but other staff from the Medical Center also contribute.

Graduate study in the program is intended primarily for students pursuing a Ph.D, and only under special circumstances are students accepted for study leading to a master's degree.

The curriculum provides broad exposure to biochemistry, molecular biology, physiology, pathology, pharmacology, and toxicology. While fulfilling the program's course requirements, students work on abbreviated research projects in several and attend seminars providing an opportunity to explore particular areas in greater depth as their interests focus upon specialized research problems

The major disciplinary areas within toxicology at Rochester, and hence the main foci for teaching are the following:

- Pulmonary (lung) toxicology
- Reproductive and developmental toxicology
- Neurobehavioural toxicology
- Cellular and molecular toxicology

These are taught in the following 'core' modules:

- Toxicology I

A study of the actions of toxic substances. Prediction of exposures, doses and critical cellular concentrations, adverse effects in organisms, and responses in populations. Mechanisms leading from reactions with molecular ligands to pathological signs and symptoms are emphasized. This course introduces principles and current theories of biochemical and molecular mechanisms, as they apply to certain organ systems including kidney, immune system, skin, pulmonary system, and nervous system.

- Toxicology II

This course continues Toxicology I, with a discussion of mechanisms of reproductive toxicology and carcinogenesis. The selective toxicity of certain chemicals is discussed to emphasize dose dependency and mechanisms of action. Finally, current issues and principles applied to the environment, clinical toxicology, modeling, and risk assessment are discussed.

in the following specialist modules:

- In Vitro Systems in Biochemical Toxicology
- Reproductive and Developmental Toxicology
- Behavioral Pharmacology and Toxicology
- Pulmonary Toxicology

in a series of 'special topics', including

- Molecular and Biochemical Neurotoxicology
- Cellular Defense Mechanisms
- Molecular Biological Approaches in Toxicology
- Principles of Health Risk Assessment
- Genetics and Carcinogenesis

and in research training and literature analysis.

North Carolina State University

This university offers MSc and PhD degrees in toxicology, and requires a profile of taught courses for each of them. There is also a general requirement that graduate students majoring in toxicology must have an adequate background in biological and physical sciences, or must take additional courses.

For PhD, students may follow programmes in Toxicology, Environmental Toxicology, or Molecular and Cellular Toxicology. For all three programmes, students must take:

- Toxicology Orientation
- Responsibility in Science
- General Toxicology
- Biochemistry - Metabolism and Molecular Biology
- Biochemical Toxicology
- Toxicology Seminar
- Toxicology Research
- Experimental Statistics for Biological Sciences
- Principles of Pharmacology

Students in the Toxicology, and the Molecular and Cellular Toxicology, programmes also take

- General Pathology

while students in the Environmental Toxicology programme take

- Environmental Toxicology
- Wildlife Toxicology

Additional courses are chosen from a wide variety available, including:

- Special Problems in Toxicology
- Environmental Fate of Chemicals
- Environmental Contaminants
- Developmental Toxicology
- Regulatory Toxicology and Quality Assurance
- Analytical Toxicology
- Chemical Carcinogenesis
- Chemical Risk Assessment
- Immunotoxicology
- Free Radicals in Toxicology
- Insect Toxicology
- Epidemiology
- Cell Biology
- Principles of Genetics
- Principles of Ecology
- Comparative Physiology
- The Practice of Environmental Impact Assessment

For a Master's degree, the following courses are required:

- Responsibility in Science
- General Toxicology
- Biochemistry - Metabolism and Molecular Biology
- Biochemical Toxicology

- Principles of Pharmacology
- Toxicology Seminar
- Toxicology Research

For master's students specialising in the subject

- Environmental Toxicology

is also required.

For PhD or MSc students following research programmes with toxicology as a secondary aspect, the following are required.

For MSc minor:

- General toxicology
- and either
- Biochemical toxicology
- or
- Environmental toxicology

For PhD minor:

- General toxicology
- Biochemical toxicology
- Environmental toxicology
- Toxicology seminar

University of Guelph (Canada)

The University of Guelph in Ontario provides a range of toxicology courses, although there is no department of toxicology, nor even any department with the word in its title, within the University.

Undergraduate courses

Toxicology has a long history at the University of Guelph, originally in mammalian toxicology as part of veterinary medicine and environmental toxicology in the context of agriculture. Formal programs in toxicology were initiated in 1982 with the establishment of the undergraduate four-year "specialized honours" B.Sc. degree in toxicology. Students in this program select between two "Areas of Emphasis", either Biomedical Toxicology or Environmental Toxicology. These programs complement the Pharmacology/Toxicology degrees available through medical schools in the Province of Ontario.

The courses followed in the programme are as follows. All students take the following courses:

- General Chemistry I and II
- Elements of Calculus I
- General Microbiology I
- Introductory Physics for the Life Sciences I and II
- Statistics I and II
- Analytical Chemistry I
- Introductory Biochemistry
- Organic Chemistry I
- Introductory Genetics
- Introductory Molecular Biology
- Epidemiology
- Structure and Function in Biochemistry
- Principles of Toxicology
- Analytical Toxicology
- Topics in Toxicology
- Introduction to Risk Assessment

Students following the Biomedical area of emphasis also take:

- Introductory Cell Biology
- Fundamentals of Nutrition
- Mammalian Physiology I and II
- Biomedical Histology
- Fundamentals of Pharmacology and Toxicology
- Principles of Disease
- Toxicological Aspects of Nutrition
- Pharmacology
- Medical Toxicology
- Biochemical Toxicology
- Toxicological Pathology

while those following the Environmental area of emphasis take:

- Ecology
- Introduction to Plant Biology
- Introduction to Aquatic Environments

- Comparative Animal Physiology
- Plant Physiology
- Soil Science
- Experimental Comparative Animal Physiology
- Environmental Chemistry and Toxicology
- Pesticides in the Environment
- Microbial Processes in Environmental Management
- Biology of Polluted Waters
- Environmental Pollution Stresses on Plants
- Ecotoxicological Risk Characterization

plus, in each case, several additional elective courses, including some from arts and social sciences.

The majority of these courses cover background sciences, with only a small number of specialised toxicology courses. Details of these are as follows (note that they are provided by several different departments, as there is no department of toxicology *per se*):

- Principles of Toxicology

This course will establish the scientific principles underlying the toxic actions of various substances and will introduce the various challenges within the field of toxicology. The chemical nature of injurious substances, their uptake and metabolism by non-target organisms, and their mode of toxic action will be studied in addition to the methods used in safety evaluations and risk assessment. [Department of Biomedical Sciences]

- Analytical Toxicology

A course in trace analysis designed for students in toxicology and related programs. Analytical techniques of value in analyzing samples of toxicological importance will be presented with emphasis also on sample collection and preparation prior to analysis. [Department of Chemistry and Biochemistry]

- Environmental Chemistry and Toxicology

The chemistry of the natural environment; the influence of pollutants upon the environment, including methods of introduction of pollutants to, and removal of pollutants from, the environment. [Department of Chemistry and Biochemistry]

- Medical Toxicology

The toxicology of mammalian body systems: dose-response, mechanisms and systemic sites of action of major groups of chemical toxicants. The course is designed for students majoring in toxicology. [Department of Biomedical Sciences]

- Toxicological Pathology

Evaluation of the pathologic responses of cells and tissues to toxic compounds. The course is designed for students majoring in toxicology. [Department of Pathology]

- Topics in Toxicology

Topics in toxicology will consist of oral and written presentations by students, faculty members, and guest lecturers. The emphasis will be on the broad integrative aspects of toxicology with particular reference to the whole organism and higher levels of natural systems; risk assessment and regulatory toxicology. This course is designed for B.Sc. Honours Toxicology students in their 7th or 8th semester. [Departments of Biomedical Sciences and Environmental Biology]

- Ecotoxicological Risk Characterization

A biologically based, advanced course that will give students working

knowledge of current processes and techniques for ecotoxicological risk characterization. The course material will cover the topics of problem definition, dose response characterization, exposure characterization, risk assessment, and risk management decision making. [Department of Environmental Biology]

- Biochemical Toxicology

The molecular mechanisms of action of carcinogens and other toxic compounds. Enzymes of biotransformation, including a detailed study of cytochrome P-450. Interactions of reactive species with DNA and other macromolecules. Designed for students specializing in toxicology, chemistry, or biochemistry. [Department of Chemistry and Biochemistry]

Graduate courses

Although research projects in toxicology have been followed for many years at the University of Guelph, a formal graduate degree was not instituted until 1990, with the inception of the Collaborative M.Sc. and Ph.D. degrees. Since Guelph does not have a separate Department of Toxicology, the degree is offered collaboratively between a number of interested participating departments, including Biomedical Sciences, Chemistry and Biochemistry, Environmental Biology, Horticultural Sciences, Mathematics and Statistics, Molecular Biology and Genetics, Nutritional Sciences, Pathology, and Zoology.

In addition to their research work, all toxicology graduate students must take three undergraduate or graduate courses in toxicology, plus a toxicology seminar course; these three courses may have been taken as part of an undergraduate program, as part of the required courses for the graduate program, or as "additional courses" during the graduate program. The undergraduate courses are those noted above. Graduate courses in toxicology are:

- Advanced Topics in Toxicology

Advanced topics in toxicology will include oral presentations by students, faculty members, and guest lecturers. The emphasis will be on advanced concepts and techniques in toxicology research with particular relevance to mechanistic, molecular and interpretive toxicology.

- Selected Topics in Biochemistry and Organic Chemistry

From time to time the Department of Chemistry and Biochemistry offers relevant selected topics courses with toxicological subjects which may be taken with permission.

- Physiology and Biochemistry of Herbicides

Chemical and biological fate of herbicides in soil. Physical, morphological and physiological factors influencing herbicidal selectivity and mode of action. (Offered in alternate years.) [Department of Environmental Biology]

- Advanced Toxicological Aspects of Nutrition

The occurrence, metabolism and nutritional implications of non-nutrients, additives and environmental pollutants in foods and feeds. Influence of drugs, environmental requirements [Department of Nutritional Sciences]

- Biomedical Toxicology

The course will examine chemical compounds injurious to animals and man, toxicity testing, teratogens, carcinogens, factors influencing toxicity and toxic drug interactions. The mechanism of action, metabolism, and principles of antidotal treatment will also be studied. [Department of Biomedical Sciences]

- Special Topics in Pharmacology-Toxicology

This course will comprise a combination of an experimental procedure (or project), seminars, selected reading or a literature review outside the thesis subject, developed depending on the student's requirements. Topics

could include clinical pharmacology/toxicology,
pharmaco-epidemiology/economics, gerontological or perinatal
pharmacology
and toxicokinetics. [Department of Biomedical Sciences]

University of Western Ontario

Another Canadian institution offering undergraduate degrees with a strong toxicology component is the University of Western Ontario, based in its Department of Pharmacology and Toxicology. This department, originally just Pharmacology, began teaching as part of a Medical School curriculum in 1960, and initiated its own undergraduate degree in Physiology and Pharmacology in 1967. This was replaced by the BSc in Pharmacology and Toxicology in 1980 'reflecting the increasing importance of the discipline of toxicology, and the demand for highly trained toxicologists' (academic programs information, at http://www.pharmtox.med.uwo.ca/undergrad/prog_overview.html)

In 1990, a multi-departmental undergraduate degree in Toxicology with Environmental Sciences was established.

The department also offers MSc and PhD programmes, with graduate students following undergraduate modules as necessary.

Both the undergraduate courses noted above are essentially taught in the fourth and final year of the undergraduate programme.

For the degree in Pharmacology and Toxicology, students must have taken a range of courses in biology, chemistry, physics, pathology and statistics. The final year course then comprises:

- Principles of Pharmacology
- Principles of Toxicology
- Environmental Toxicology
- Experimentation and Communication in Pharmacology and Toxicology
- Interactive Studies in Pharmacology and Toxicology

plus specialised options courses and seminars.

For the degree in Toxicology with Environmental Sciences, students must have completed courses including biology, biochemistry, chemistry, pathology, physiology, physics, earth sciences, environmental science and mathematics. The final year course then comprises:

- Principles of Toxicology
- Environmental Toxicology
- Experimentation and Communication in Pharmacology and Toxicology
- Interactive Studies in Pharmacology and Toxicology
- Environmental Science

plus specialised options courses and seminars.

Contents of the toxicology specific components of these courses are:

- Principles of Toxicology
Basic principles of how chemicals produce undesirable effects in biological systems, including absorption, biotransformation, mechanisms of action, risk evaluation, treatment of poisoning.
- Environmental Toxicology
Effects on human being of exposure (accidental or deliberate) to industrial, agricultural and household chemicals.
- Experimentation and Communication in Pharmacology and Toxicology

Laboratory techniques and experimental methods, research project; communication skills, poster presentation, report writing.

- Interactive Studies in Pharmacology and Toxicology

Case studies, paper critiques, seminar debates.

Swiss Postgraduate Education in Toxicology

In 1996, under the auspices of the Section of Toxicology from the Swiss Society of Pharmacology and Toxicology, the Swiss Register for Toxicologists (Schweizerisches Berufsregister für Toxikologie/ Registre Professionnel Suisse pour Toxicologues) was established. Requirements for the certification as "Registered Toxicologist" in Switzerland are:

- University degree in natural sciences (chemistry, biochemistry, biology, pharmacy, pharmacology or related subjects) including medicine and veterinary sciences.
- 5 years of full-time professional experience in toxicology (experimental work and training) under the supervision of a toxicologist/ pharmacologist recognized by the Registration Committee.
- having provided credentials to have specialized in at least one of the fields as defined by the modules (Nr. 3-12) of the Swiss Postgraduate Education Programme
- having knowledge in the remaining 11 areas at a level as provided by the Swiss Postgraduate Education Programme.
- having published at least three publications or having written equivalent professional assessments in toxicology.

The Swiss Postgraduate Education Programme was established in 1998. After a survey of the Swiss industry, universities and government in 1995, the most significant topics in toxicology were identified, and mapped onto a series of modules, and sub-topics (see below). Each module lasts 3 to 5 days, with the exception of the two modules dealing with animal experimentation, which last 10 days.

The modules are organized and take place at 4 universities (Basel, Bern, Lausanne, Zürich), at the Swiss Federal Institute of Technology Zürich (ETHZ), at industry (Roche Ltd., Basel, Novartis AG, Basel), at the Swiss Federal Institute for Water Research and Water Pollution Control (EAWAG), at the Intercantonal Office for the Control of Medicines (IOCM) together with a government agency (Federal Office of Environment, Forests and Landscape, FOEFL, Swiss Federal Department of the Interior). Nearly half of the lectures are given by experts from industry.

The programme has four 'target groups':

- Scientists wishing to apply for registration as toxicologists in Switzerland.
- Toxicologists wishing to extend their theoretical knowledge outside their specific expertise.
- Students enrolled in a PhD programme and wishing to broaden their knowledge of toxicology.
- Scientists working for industry or government agencies in applied toxicology, and wishing to expand their knowledge of toxicology.

The modules, with their topics, are these:

- Basic Principles of Toxicology
 - Introduction to Toxicology
 - Dose-response Relationship
 - General Toxicity Testing
- Laboratory Animal Sciences
 - Animal Welfare and Handling
 - General Techniques in Animal Experimentation
 - Alternatives to animal experimentation

- Animal Experimentations in Toxicology
 - Animal Experiments
 - Principles of Biometry
 - Behavioural Toxicology
- Organ-Toxicology and Pathology
 - Functional and Structural Manifestations of Toxicity
- Xenobiotic Metabolism
 - Toxicokinetics
- Cellular and Molecular Toxicology
 - Molecular Mechanisms
 - Signal Transduction Pathways
- In Vitro Toxicology
- Chemical Mutagenesis
 - Mutagenicity Testing
 - Repair, Mutation, Recombination
- Chemical Carcinogenesis
 - Carcinogenicity Testing
 - Tumor Histopathology
 - Receptor-mediated Carcinogenesis
- Reproductive Toxicology
 - Endocrine Toxicology
- Clinical Toxicology
 - Clinical Manifestation of Toxicity
- Dermatotoxicology and Immunotoxicology
 - Immunological Impairment and Adverse Effects
- Epidemiology and Toxicology
 - Biomonitoring
 - Occupational Toxicology
- Toxicology of Residuals
 - Food Toxicology
- Risk Assessment
 - Extrapolation and Assessment of Toxicological Data
 - Risk Management
 - Regulatory Toxicology
- Ecotoxicology
 - Aquatic Toxicology
 - Analytical Toxicology

The programme is designed to conform with a very similar programme for German toxicologists (Hesse-Callaway and Greim 1996).

2.3.c Learned societies for toxicology

'General' toxicology societies:

International Union of Toxicology

<http://www.toxicology.org/iutox>

Founded in 1980, IUTOX is a confederation of national and regional toxicology societies. As of mid-1999, there were 34 national societies represented, plus two European societies and one pan-Asian society.

IUTOX sees its unique role as the fostering of new toxicology societies where there are none, and in encouraging existing societies to join 'the international family of toxicologists' by membership of IUTOX.

IUTOX main events are the annual International Congress of Toxicology, and international workshops, particularly in risk assessment. Communication with the membership is by a printed newsletter and a website, as well as by direct liaison with member organisations. In recognition of the multilingual nature of toxicology, the IUTOX website provides access to toxicology materials in the Spanish language.

IUTOX regards one of its major achievements during the 1990s as its becoming a member of the International Council of Science (ICSU), a prestigious body representing science at the international level. Acceptance as a member of ICSU means, in IUTOX's view, that toxicology can be seen as an established scientific discipline, on a par with other scientific disciplines such as chemistry, pharmacology, astronomy, geology, and physics.

Society of Toxicology (USA)

<http://www.toxicology.org>

The Society of Toxicology was founded in 1961. It is 'a professional organization of scientists from academic institutions, government, and industry representing those who practice toxicology. The Society promotes the acquisition and utilization of knowledge in toxicology, aids in the protection of public health, and facilitates disciplines [sic]. The Society has a strong commitment to education in toxicology and to the recruitment of students and new members into the profession. The Society is dedicated to developing knowledge for the improvement of the health and safety of living beings and the protection of their environment.'

There are 15 'Speciality Sections':

- veterinary
- carcinogenicity
- epidemiology
- food safety
- immunotoxicology
- in vitro
- inhalation
- mechanisms
- metals
- molecular biology
- neurotoxicology
- occupational health

- reproductive and developmental toxicology
- regulatory and safety evaluation
- risk assessment

The society also has regional chapters within the USA.

The society has two official journals:

- *Toxicological Sciences* [previously *Fundamental and Applied Toxicology*] (12 issues per year), published by Oxford University Press, deals with all aspects of toxicology, descriptive, mechanistic, methodological, interpretive and theoretical.
- *Toxicology and Applied Pharmacology* (24 issues per year), published by Academic Press deals with effects on tissue structure or functions resulting from administration of chemicals, drugs or natural products to animals or man.

Its annual meetings, the largest professional toxicology meetings in the world involve over 5,000 participants with 2,000 presented papers, including the symposia of the speciality sections. Abstracts of all papers are published in a special issue of *Toxicological Sciences*.

American College of Toxicology

<http://www.landaus.com/toxicology>

The mission of this College is 'to educate and lead professionals in industry, government and related areas of toxicology by actively promoting the exchange of information and perspectives on the current status of safety assessment and the application of new developments in toxicology'. Among its 'strategic objectives' are:

- focus on interdisciplinary exchange of scientific information, especially as scientific information is used in regulations
- disseminate information of the results of toxicological research, standards and practices through the College journal and newsletter
- present the ideals and opinions of its membership
- sponsor scientific and educational programs in toxicology

The College sponsors one scientific journal. The *International Journal of Toxicology*, formerly the *Journal of the American College of Toxicology*, is published by Taylor and Francis. A bimonthly journal, it publishes 'fully refereed papers covering the entire field of toxicology, including research in risk assessment, general toxicology, carcinogenicity, safety evaluation, reproductive and genetic toxicology, epidemiology and clinical toxicology, mechanisms of toxicity, new approaches to toxicological testing, and alternatives to animal testing.' The proceedings of meetings and symposia are also included. Two particular features of the Journal are:

- State-of-the-art reviews of any area of toxicology, particularly in regulatory toxicology, international harmonization, risk assessment and related areas.
- Perspective-Counterperspective, including articles of opposing views in the form of a debate, in any area of Toxicology. Examples of subject areas are: (1) Discussion of mechanisms of toxicity based on scientific evidence, (2) Regulatory issues and risk Assessment, (3) any particularly contemporary issue.

The American College of Toxicology Newsletter is issued quarterly to all members. The text of back issues is made available in electronic form and publicly accessible from

the College's Web site; in some cases the content is modified from that in the printed newsletter to provide updated information.
An annual scientific meeting is held.

This Association, though having a stronger focus than the Society of Toxicology, with a concentration on regulatory and risk assessment issues, offers much the same range of information services and products.

Subdisciplines of toxicology:

Teratology societies

Several societies deal with this subject area. This is defined as 'the study of abnormal development. More particularly .. the study of the causes, mechanisms, and manifestations of abnormal development, whether genetically, gestationally, or postnatally induced; and whether expressed as a lethality, malformation, growth retardation, or functional aberration' (Landen 1986)

This is therefore clearly a genuinely multidisciplinary area. Although most known teratogens are chemical substances, others are not, e.g. ionising radiation, so that the specialism does not fall entirely within the field of toxicology, and certainly has many links outside.

The **Teratology Society** (USA) (<http://www.teratology.com>), is the best known. It was founded in 1960, with the purpose of exchange of information relating to congenital (birth) defects, including their nature, cause, mechanism and prevention.

Its mission is now stated as:

- to promote research, and the exchange of ideas and research results, that reveal the causes, improve the diagnosis and treatment, and prevent the occurrence of abnormal development and birth defects
- to communicate that information to physicians, public health officials, concerned health advocacy and lay groups, and other interested parties
- to provide education and training on the causes, mechanisms, treatment and prevention of birth defects

It is 'a multidisciplinary scientific society .. the members of which study the causes and biological processes leading to abnormal development and birth defects at the fundamental and clinical level, and appropriate measures for prevention.'

In 1997, the society had 798 members, 641 based in the USA, and the remainder worldwide. The membership was drawn from a wide disciplinary area, including industrial toxicology, pharmacology, developmental biology, pathology, anatomy, genetics, obstetrics, paediatrics, dentistry, and epidemiology, a reflection of the truly interdisciplinary status of this specialism.

The official journal of the society is *Teratology: the Journal of Abnormal Development*, published by Wiley. This publishes a mix of experimental, animal and clinical research papers. This journal was first published in 1968.

The society also maintains an electronic discussion list, WebBoard, which is part public, and part closed to society members.

An annual meeting is held, including specialist symposia and educational 'refresher' courses. The nature of the meetings has changed over time, reflecting changes in the

focus of the subject. Initially, there was a concentration on descriptive studies, and animal experimentation with teratogenic agents, which led to the society playing a leading role in the establishment of regulations for teratogenicity testing of pharmaceuticals. Since 1975, the predominant interest has been mechanistic, the basic pharmacologic, genetic and molecular aspects of congenital defects. Since 1985, *in vitro* techniques and epidemiological studies have gained in importance.

These annual meetings allow formal contact, and joint meetings, with newer societies with common interests. Two of these are more specialised in nature: the Behavioural Toxicology Society and the Neurobehavioural Teratology Society, which are discussed below as part of a discussion of the development of behavioural toxicology as a subfield. The third, the Organisational of Teratology Information Societies (OTIS), is an umbrella organisation for services providing medical consultation on prenatal exposure, interpreting scientific information on teratogenic risks for health care providers and lay people. (<http://orpheus.ucsd.edu/otis>)

There are also teratology societies in several European countries, Australia, and Japan; the latter society publishes the journal *Congenital Abnormalities*. The European Teratology Society, founded in 1969, has as its aim 'to ensure co-operation between European countries in research into congenital malformation', and has over 500 members in 34 countries worldwide (<http://www.etsoc.com>).

All these national societies join for a meeting each three years of the International Federation of Teratology Societies (IFTS). This Federation also sponsors a student fellowship programme.

At the opposite extreme from this worldwide linkage are the regional teratology societies, e.g. the **Midwest Teratology Association** (USA) (<http://www.midwest-teratology.org>). This is 'an organisation of scientists from academic institutions, government, and industry who are interested in the prevention and understanding of birth defects. Founded in 1976, the Association publishes a biannual newsletter, and holds two scientific meetings each year.

Its mission is 'to serve as a regional focal point for the dissemination of knowledge relating to developmental and reproductive toxicology, including the causes and prevention of birth defects. This mission will be accomplished through education and sharing of scientific information, methods and philosophies among students and governmental, industrial, clinical, and academic professionals.' [Note that this definition places teratology firmly within toxicology, while being somewhat broader in scope, e.g. by including reproductive toxicology, than those given above.]

The Association's primary goal is given as providing continuing education for its members, by workshops, demonstrations, panel discussions and symposia presentations, by providing information on the activities of related societies and on relevant meetings, and by sponsorship of student attendance at meetings of the Teratology Society and the Neurobehavioural Teratology Society.

Another main goal is the dissemination of information on current reproductive and developmental toxicology procedures, by promoting standardisation of nomenclature, and the development of harmonized guidelines for evaluations, and by encouraging Association members to provide critical reviews of the scientific literature.

Promotion of collaboration with regional and national scientific associations and societies is a further aim, to be achieved through joint symposia, workshops at national meetings and participation in joint projects.

The Association places importance on improving communication with its membership and with related societies. This is done through the printed newsletter and other postal mailings, through increased use of electronic mail, and through its web page.

The links provided on the Association's web page are informative, in showing the principal relationships which it believes are significant. Of 11 links, 4 are to other teratology associations or resources:

- Teratology Society
- Clinical Teratology Web
- IFTS Atlas of Developmental Abnormalities
- Neurobehavioural Teratology Society

1 is to a more general toxicology society:

- Society of Toxicology

2 are to more general scientific societies:

- Society for Developmental Biology
- Society for the Study of Reproduction

4 are to other 'local groups':

- Midwestern Regional Chapter of the Society of Developmental Biology
- Michigan Regional Chapter of the Society of Toxicology
- Ohio Valley Chapter of the Society of Toxicology
- Middle Atlantic Reproduction and Teratology Association

This clearly shows the mix of disciplinary and geographical relationships, being maintained in the networked environment.

Another regional teratology association is the Middle Atlantic Reproduction and Teratology Association (MARTA [<http://landaus.com/teratology/MARTAtext.html>]). This professional society was established in 1968, and is 'dedicated to encouraging proficiency and knowledge in the fields of animal reproduction and developmental toxicity'. It sponsors two meetings per year, held within its region, for exchange of ideas and information, as well as formal scientific presentations. It does not have a regular publication, apart from its directory of members, but has published several 'occasional papers', including a glossary of terms for developmental and reproductive toxicology, a bibliography of test guidelines for the field, and a compilation of control data for such studies.

Society of Forensic Toxicology

<http://www.soft-tox.org>

This society was founded in 1970, and is composed of 'practising forensic toxicologists, and those interested in the discipline for the purpose of promoting and developing the profession.' The Society 'provides a forum for the exchange of information and ideas among toxicology professions .. through its annual meetings and publications'.

The society does not publish or sponsor a journal, but occasional issues of the *Journal of Analytical Toxicology* (Preston Publishing) are published in collaboration with the Society, which takes responsibility for content. A newsletter, ToxTalk, is published regularly, and an extensive set of Internet links, WWW Toxilinks, maintained on the Society's website.

Other national forensic science societies, by contrast, do publish journals, according to Ulrich's Directory: e.g. the *Canadian Society of Forensic Science Journal*, published by that society since 1967, and the *Japanese Journal of Forensic Toxicology (Ho Chudoku)*, published by the Japanese Association of Forensic Toxicology, since 1983.

In vitro toxicology societies

Four organisations are considered under this heading. Two (ESTIV and IIVTG) deal specifically with *in vitro* toxicology, one (IIVS) deals with *in vitro* sciences including toxicology, while the fourth (FRAME) is involved with replacement of animal experimentation, including toxicology testing, with *in vitro* toxicology methods a major interest.

FRAME

<http://www.frame-uk.demon.co.uk>

FRAME, the Fund for Replacement of Animals in Medical Experimentation, is a society which, while not devoted specifically to toxicology, does play an important role in dealing with the subject, and with its information base. Frame is a UK-based charity, founded in 1969, whose purpose is to promote the minimisation, and ultimate cessation, of medical experiments with live animals. It pioneered the concept of the 'Three Rs' - Refinement, Reduction, Replacement - which are now accepted as the standard ethical scientific approach to animal experimentation. The organisation combines political lobbying and public education with scientific research into alternatives, including *in vitro* toxicology protocols, and the creation of information resources in support of use of alternatives.

Frame's interests are in all medical usage of animals, but toxicology testing has been a major interest, expressed through its Toxicity Committee. In particular, it has carried out sustained campaigns against the 'traditional' LD₅₀ test, against the Draize eye irritancy test, and against the use of dogs in toxicity testing, and has promoted the sharing and better use of toxicity data as a means of reducing unnecessary testing. The development and validation of *in vitro* methods for assessing toxicity is a long-standing interest of Frame, which works closely with European and international committees for validation and approval of 'alternative', generally *in vitro*, testing procedures.

Frame produces several information products of relevance to toxicology:

- Frame News, a newsletter aimed at supporters and decision makers
- ATLA (Alternatives to Laboratory Animals), a scientific journal carrying articles on alternatives
- INVITTOX, a databank of *in vitro* toxicity testing procedures, incorporating over 1000 test protocols, which forms part of the Scientific Information Service of the European Centre for the Validation of Alternative Methods (ECVAM)
- Conference and meetings proceedings, including the proceedings of two meetings based around reports of the Toxicity Committee:
 - M Balls et.al. (eds.) *Animals and alternatives in toxicity testing*, Academic Press, 1983
 - M Balls et.al. (eds.) *Animals and alternatives in toxicology; present status and future prospects*, Macmillan, 1991
- A range of educational material

Institute for In Vitro Sciences

<http://www.iivs.org>

The Institute, based at Gaithersburg Maryland in the USA, is a non-profit foundation for the advancement of alternative methods in animal testing, including, but not limited to, toxicology. Its main activities are the development of *in vitro* tests, and carrying out testing on a contract basis for industry and government.

A subsidiary purpose is to provide 'educational and technical resources for industry, government, trade associations, animal welfare proponents and the general public'. This is done by running courses, seminars and workshops, and by providing information and news on its website. The Institute does not currently produce any publications or databases.

European Society of Toxicology In Vitro

<http://www.shorbach/estiv>

This society was founded in 1994, after a decade of 'informal but productive collaboration' among European workers in *in vitro* toxicology. The Society's general information web page notes the starting point of interest being an initial International Workshop on the Application of Tissue Culture in Toxicology, held in the Netherlands in 1980, that a 'new scientific community' had since developed within the field of *in vitro* toxicology, and that new scientific societies and research institutes had been established in some countries, devoted to the field. The foundation of ESTIV was intended to 'give a more official status to this research framework at the European level'. In May 1999, ESTIV had over 100 members from 16 European countries.

The purpose of ESTIV is to promote *in vitro* toxicology, both scientifically and educationally, in all countries of Europe, by a number of means, including:

- promoting regular exchange of information on *in vitro* toxicology, by means of meetings, symposia, workshops and bulletins
- facilitating communication between professionals in business, government and academia to promote effective application of *in vitro* methods of hazard identification and risk assessment

The other means include encouragement of research, and of education and training, co-operation with other organisations, and 'developing other activities that are pertinent'. Therefore, of 5 clearly expressed aims, 2 are directly related to information and communication.

The only regular printed publication of ESTIV is its newsletter, which includes general news reports, summary reports of meetings, and a calendar of forthcoming meetings. ESTIV operates a electronic mailing list: estiv-l@nic.surfnet.nl. The Society also published scientific reports, organises training courses and workshops, and acts as 'an international forum' on *in vitro* toxicology.

Industrial In Vitro Toxicology Group

<http://www.invitro.org>

The Group's aim is to provide information and training on all aspects of *in vitro* toxicology for industrial workers in the United States.

The Group sponsors a scientific journal, *In vitro and Molecular Toxicology* (formerly *In vitro Toxicology*), published by Liebert, and runs symposia and training courses. It has

close links with the *in vitro* special interest group of the Society of Toxicology, which the group's material describes as 'an important source of information'.

Toxicology in a wider context:

Society of Environmental Toxicology and Chemistry (SETAC)

<http://www.setac.org>

SETAC was established in 1979, to fill a perceived lack of a forum for interdisciplinary communication among environmental scientists, including toxicologists as well as chemists and biologists, and other interested parties such as managers and engineers. It is an independent non-profit professional society that provides a forum for individuals and institutions engaged in:

- study of environmental issues
- management and conservation of natural resources
- environmental education
- environmental research and development

SETAC claims a unique strength in its commitment to balancing the interests of academia, business and government.

The fields of study embraced by the overall concept of 'environmental toxicology and chemistry' are understood by SETAC as:

- classical toxicology
- biology
- anatomy
- physiology
- genetics
- microbiology
- organic chemistry
- analytical chemistry
- ecology
- environmental chemistry
- atmospheric sciences
- soil sciences
- water sciences
- engineering
- economics

SETAC claims that its multidisciplinary approach gives it a 'scope of science .. much broader in concept and application than that of many other societies'.

From an initial membership of 230 in 1980, SETAC now has over 5,000 members worldwide. It has regional organisations for the USA, Europe and Asia/Pacific, but no specialist subgroups.

SETAC publishes *Environmental Toxicology and Chemistry*, its official journal, a monthly journal interdisciplinary in scope, and publishing 'integrative studies involving components of classical toxicology' together with the other fields of study noted above. The journal is 'dedicated to furthering scientific knowledge and disseminating information on environmental toxicology and chemistry, including the application of these sciences to risk assessment'. It is divided into three sections: Environmental Chemistry, Environmental Toxicology, and Hazard/Risk Assessment.

SETAC also publishes a series of reports. 1998 titles include:

- Advances in earthworm ecotoxicology, 456 pp
- Ecotoxicological risk assessment of the chlorinated organic compounds, 314 pp
- Radiotelemetry applications for wildlife toxicology field studies, 260 pp

SETAC's annual meeting attracts 2,900 participants and 1,800 presentations (1997 figures).

Chapter Three: Appendix

3.4.a Library/information services:

Aslib Directory of Information Sources, 1998 edition

This lists 23 sources under the heading 'toxicology'.

The directory is not sub-divided by type of library/source, and they have therefore been categorised for the sake of clarity, using seemingly appropriate divisions.

Governmental/Military

- Central Science Library (food science)
- DERA (defence)
- Forensic Science Service
- Institute of Naval Medicine

Consultancies

- Association of Consulting Scientists
- BIBRA
- Inveresk Research International
- Vital Information (information broker)

Academic

- Aberdeen University, Department of Environmental and Occupational Medicine
- Newcastle University, Department of Environmental and Occupational Medicine
- Surrey University Library
- Robens Institutes, Surrey University

Learned Societies

- Royal Pharmaceutical Society
- Royal Chemical Society (London)
- Royal Chemical Society (Cambridge)

Poisons Units

- Medical Toxicology Unit, New Cross
- National Poisons Information Service, Leeds
- Scottish Poisons Information Bureau
- Welsh National Poisons Unit

Industry

- Merck, Sharp and Dohme Ltd (pharmaceuticals)
- Zeneca, Brixham Environmental Laboratory

Miscellaneous

- Greenpeace UK
- Centre for Medicines Research

In some respects this listing seems idiosyncratic. Merck, Sharpe and Dohme are mentioned, alone among the many pharmaceutical companies which have information on the toxicity of their own products. Zeneca's environmental laboratory is mentioned, but their (arguably more relevant) Central Toxicology Laboratory is not. The academic departments and library listed are only a fraction of those supporting teaching and research in these areas.

British Library directories

Guide to Libraries in London, V McBurney, 1995

Under the heading 'toxicology', three libraries are listed:

- Department of the Environment, Romney House Library
- Poisons Information Unit, New Cross Hospital
- School of Pharmacy, London University

Under the heading 'poisons', the Poisons Information Unit is cross-referenced.

Scanning the guide suggests three other potentially relevant libraries:

- Medicines Control Agency
- Royal Pharmaceutical Society
- Wellcome Institute for the History of Medicine

Guide to Libraries and Information Sources in Medicine and Health Care (3rd edn.), P Dale, 2001

Scanning under the heading 'toxicology' gives 5 entries:

- Institute of Naval Medicine
- Medical Toxicology Unit, New Cross (ex National Poisons Information Unit)
- Royal Pharmaceutical Society, Edinburgh
- Royal Society of Chemistry
- National Poisons Information Centre, Cardiff

Scanning the entry 'poisons', gives cross-references to entry five above.

Scanning the whole volume, particularly for larger and more general library services, suggests the following six additional services:

- British Library Healthcare Information Service
- Royal Society of Medicine
- British Medical Association
- Institute of Occupational Safety and Health
- Medicines Control Agency
- Royal Pharmaceutical Society, London

Guide to Libraries and Information Units in Government Departments and Other Organisations (10th ed.), P Dale, 1992

Scanning the entry 'toxicology' gives 9 entries:

- Forensic Science Service
- Department of the Environment Romney House Library
- Fire Research Station
- ICI (now Zeneca) Central Toxicology Laboratory
- Ministry of Defence Chemical and Biological Defence Establishment
- Poisons Information Unit, New Cross
- Water Research Centre
- Zinc/Lead Library
- South West Water

Checking the entry 'poisons' gave a cross-reference to the Poisons Information Centre.

Scanning the whole volume, suggested the following additional entries:

- Department of Health and Social Security Medicines Library
- Warren Spring Laboratory (Department of Trade and Industry)
- Royal Pharmaceutical Society
- Royal Society of Medicine
- several water companies, in addition to South West Water

3.4.b Toxicology societies/organisations:

Scholarly Societies Project

This project, based at the University of Waterloo in Canada, identifies, and provides access to, the Web sites of scholarly societies. In February 1999 it included 1346 societies' Web site details. (www.lib.uwaterloo.ca/society/overview.htm)

Searching for the term 'toxicology' finds only 3 'active' sites:

- Society for Toxicology
- Society of Environmental Toxicology and Chemistry (SETAC)
- International Life Sciences Institute

Encyclopaedia of Associations, 30th edn., 1995

CA Fischer and CA Schwartz (eds.)

Gale, New York

Under the heading 'toxicology' this lists approximately 40 entries, with brief details of each. Not all seem to deal with toxicology *per se*. Typical of those of apparent relevance are:

- European Society for the Study of Drug Toxicity
- Society of Toxicologic Pathology
- American College of Veterinary Pathologists
- Fondo de Ayuda Toxicologica
- European Association of Poisons Control Centres and Clinical Toxicologists
- Society of Forensic Toxicologists
- Genetic Toxicology Association
- Society for Toxicology
- Toxicological History Society
- American Academy of Clinical Toxicology
- American College of Toxicology
- Centre d'Ecologie et de Toxicologie de l'Industrie Chimique Europeene
- World Federation of Associations of Clinical Toxicology Centres and Poison Control Centres
- American Board of Forensic Toxicology
- European Society of Toxicology
- Latin American Association of Toxicology

Yearbook of International Associations, 1994/95 edition

KG Saur, Munich

This lists approximately 20 societies and associations under the term 'toxicology'. Most of these are among those listed above. Additional apparently relevant societies include:

- International Union of Toxicology
- European Association of Veterinary Pharmacology and Toxicology
- African Toxicology Society

3.4.c Data compilations, reference works, handbooks and encyclopaedias:

The Hazardous Substances Data Bank (HSDB) includes extracts and summaries of toxicological evaluation from 'a core set of standard texts and monographs'. The frequent use of a source from this set indicates that HSDB's expert compilers, from the National Library of Medicine's Toxicology Information Program, regard it as a reliable source, and, by implication, that it may be included in any listing of 'significant' toxicology resources.

The HSDB records generated during the databank evaluation described in chapter five were reviewed, and those sources which were referred to on more than three occasions were listed. While this is far from an exact analysis, it gives a list of widely referenced material of this type, and 16 resources were found.

The resources are quoted 'generically' here without edition, volume etc., as these vary in the HSDB records.

- Patty's Industrial Hygiene and Toxicology, Wiley-Interscience
- Sax's Dangerous Properties of Industrial Materials, van Nostrand Reinhold
- IARC Monographs on the Evaluation of Carcinogenic Risk, World Health Organisation
- Clinical Toxicology of Chemical Products, RE Gisslin et.al. (eds.), Williams and Wilkins
- Browning's Toxicity and Metabolism of Industrial Solvents, Elsevier
- NIOSH Pocket Guide to Chemical Hazards
- Shepard's Catalog of Teratogenic Agents, John Hopkins University Press
- Veterinary Toxicology, DJ Humphries, Balliere Tindell
- Clinical Management of Poisoning and Drug Overdose, LM Haddad, WB Saunders
- Medical Toxicology - diagnosis and treatment of human poisoning, MJ Ellenham, Elsevier
- Neurotoxicity of Industrial and Commercial Chemicals, JL O'Donoghue, CRC Press
- The pharmacological basis of therapeutics, Goodman and Gilman, MacMillan
- Casarett and Doull's Toxicology, Pergamon
- Toxicology of the Eye, WM Grant, Charles Thomas
- Handbook of toxic and hazardous chemicals and carcinogens, M Sittig, Noyes Data
- Martindale's Extra Pharmacopoeia, Pharmaceutical Press

3.4.d Dictionaries, glossaries, thesauri:

In addition to using online databases and internet search engines, thesauri were also identified from the documentation provided by database producers, and by examination of the main British collection of thesauri in the ASLIB library.

The most significant items, shown below, are discussed in more detail in chapter five.

- E Hodgson, RB Mallman and JE Chambers 1998, Dictionary of Toxicology (2nd edition), Macmillan, London
- RA Lewis 1998, Lewis' Dictionary of Toxicology, Lewis Publishers/CRC Press, Boca Raton
- JH Duffle et al (1963), Glossary of terms used in toxicology: IUPAC Recommendations 1993, Pure and Applied Chemistry, 65(9), 2003-2122
- P Elster and P Luderitz 1985, Glossary of Preventive Toxicology, Verlag Tribune, Berlin
- NM Eesa and LK Cutkomp 1984, Glossary of Pesticide Toxicology and Related Terms, Thomson Publications, Fresno, CA
- VV Khudoley, GB Pliss and T Schramm 1985, Chemical carcinogens and chemical carcinogenesis – a glossary, Arch. Geschwulstforsch, 55(4), 295-298

Shorter glossaries are given in several textbooks. Only one thesaurus, apparently not in current use, was found devoted entirely to toxicology:

- Toxisaurus (TOXicology TheSAURUS), Bioscience Information Service, US government report no. PH 43-68-1329, 1970.

Several other thesauri cover toxicology to some extent, of which the most significant are:

- MeSH (National Library Medicine)
- Emtree Thesaurus (Excerpta Medica)
- Pharmline Thesaurus (UK Drug Information Pharmacists Group)
- Derwent Drug File Thesaurus (Derwent Publications)
- DHSS-Data Thesaurus (UK Department of Health)
- Biological Abstracts Thesaurus
- Chemical Abstracts Thesaurus
- International Pharmaceutical Abstracts Thesaurus
- Life Science Thesaurus, Cambridge Scientific Abstracts

3.4.e Online databases and databanks:

One means of identifying secondary sources of relevance to toxicology is to examine the resources offered by major host systems, using their subject categories and other facilities to identify useful material. Even the wide provision of access to a toxicology-related database on a number of hosts will indicate that it is a widely used resource, deserving of particular note. As noted in the section on tertiary sources, the two host systems which offer extensive collections of information relevant to science and technology are those of the Dialog Corporation and of STN. TOXNET, accessible via the National Library of Medicine or the British Library host system, offers a collection of toxicology databases.

The databases, databanks and other information sources offered by the Dialog Corporation are the widest range of potentially useful sources available. Three means were used to identify useful resources from among these:

- Dialog and Datastar subject groupings
- Dialog Bluesheets
- Dialindex

Dialog and Datastar subject groupings

Both the Dialog and Datastar online host systems allow several files to be searched simultaneously. A set of pre-defined subject grouping are provided for this purpose; 'toxicology' is a grouping on both systems. The resources in these groups are chosen by Dialog Corporation subject experts.

The resources within these subject groupings are listed here. The listing is somewhat simplified from that provided in the Dialog Corporation documentation, in that different files corresponding to essentially the same resource, which have different names or numbers on the host and are listed separately in the grouping (e.g. Embase and Embase Alerts), are brought together here.

The 39 files included in Dialog's TOXICOLOGY OneSearch category are as follows:

- Energy Science and Technology
- Adis Newsletters
- New England Journal of Medicine
- Biosis
- NTIS (government reports)
- Meteorological & Geostrophysical Abstracts
- SciSearch
- Enviroline
- Pollution Abstracts
- CAB Abstracts
- CAB Health
- Food Science and Technology Abstracts
- FOODLINE: Food Science & Technology
- FOODLINE: Current Food Legislation
- Inside Conferences
- Environmental Bibliography
- SEDBASE (side effects of drugs)
- EMBASE
- International Pharmaceutical Abstracts
- Life Sciences Collection

- JICST-EPlus (Japanese Science and Technology)
- Wilson Applied Science and Technology Abstracts
- Pascal
- Medline
- Toxline
- Occupational Safety & Health
- Pharm-line
- Drug Information Fulltext
- Pesticide Fact File
- DOSE (Dictionary of Substances and their Effects)
- Chemical Safety NewsBase
- Material Safety Data Sheets
- Material Safety Summary Sheets
- RTECS
- CHEMTOX
- CA Search
- American Medical Association Journals
- The Lancet (full text journal)
- USP DI (drug information)

The 13 resources included in Datastar's TOXICOLOGY CROS group are as follows:

- Biosis
- CA Search
- Current Contents Search
- Drug Information Fulltext
- Hazardous Substances Databank
- Martindale Pharmacopoeia
- Medical Toxicology and Health
- Medline
- Pascal
- RTECS
- Scisearch
- SEDBASE
- Toxline

Dialog Bluesheets

The Dialog Bluesheets offer descriptions of each of the databases hosted by the Dialog Corporation, and are made available as a searchable file.

Searching this file for subject terms offers a rapid, if crude, way of identifying the files which will offer this sort of material.

The Bluesheets file was therefore searched for the term 'toxicology'. The documentation for 18 databases, including the major bibliographic files, referred to this term (treating different time periods, and training and alerting variants, as a single database:

- CA Search
- Derwent drug file
- Chemtox
- Registry of toxic effects of chemical substances
- RAPRA: rubber and plastics
- Pesticide fact file
- Biobusiness
- Occupational safety and health (NIOSH/TIC)
- Toxline

- Medline
- Unlisted drugs
- Life sciences collection
- Embase
- Inside conferences
- Food science and technology abstracts
- Pollution abstracts
- Enviroline
- Biosis

In order to widen the search, so as to ensure that the term 'toxicology' was not too restrictive, the search was repeating using a set of truncated terms: toxic? or carcinogen? or mutagen? or teratogen? or poison?

This identified an additional 15 databases, largely databanks or full-text sources:

- BNA daily news from Washington
- Drugs of the Future
- Beilstein chemical databank
- Material safety data sheets
- Dictionary of substances and their effects (DOSE)
- The Merck index online
- Chapman and Hall chemical database
- Drug information fulltext
- CAB Health
- Cancerlit
- Pharmaprojects
- Textile technology digest
- International pharmaceutical abstracts
- Sedbase: side effects of drugs
- TSCA chemical substances inventory

Dialindex

The Dialindex database, which searches sets of Dialog databases to determine which contain a particular index term, was then searched for the term 'toxicology', against all available databases. A total of 383 out of 454 files had some reference to the term. These are shown below.

Items	File
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168	1: ERIC_1966-1998/Dec
232	2: INSPEC_1969-1999/Jan W1
270966	5: BIOSIS PREVIEWS(R)_1969-1998/Dec W2
31258	6: NTIS_64-1999/Feb W1
594	7: Social SciSearch(R)_1972-1999/Jan W1
935	8: Ei Compendex(R)_1970-1999/Jan W2
312	9: Business & Industry(R) Jul_1994-1999/Jan 13
36382	10: AGRICOLA_70-1999/Jan
282	11: PsycINFO(R)_1967-1998/Dec
55	13: BAMP_1999/Jan W1
54	14: Mechanical Engineering Abs_1973-1999/Jan
796	15: ABI/INFORM(R)_1971-1999/Jan 12
3504	16: IAC PROMT(R)_1972-1999/Jan 13
204	18: IAC F&S INDEX(R)_1980-1999/Jan 13
371	20: World Reporter_1997-1999/Jan 13
214	21: NCJRS_1972-1998/Nov
1	22: Employee Benefits_1986-1998/Jan
2	26: Foundation Directory_1998
89	27: Foundation Grants Index_1990-1999/Jan
551	28: Oceanic Abst._1964-1999/Jan
82	29: Meteor.& Geoastro.Abs._1970-1998/Dec
205	30: AsiaPacific_1985-1998/Nov B1
1158	31: World Surface Coatings Abs_1976-1998/Oct
999	32: METADEX(R)_1966-1999/Feb B2
461	33: Aluminium Ind Abs_1968-1999/Jan
6355	34: SciSearch(R) Cited Ref Sci_1990-1999/Jan W1
2830	35: Dissertation Abstracts Online_1861-1999/Jan
1	38: America:History & Life_1963-1998/Q3
7	39: Historical Abstracts_1973-1998/Iss52/A1
2230	40: Enviroline(R)_1975-1998/Oct
6230	41: Pollution Abs_1970-1998/Feb
881	42: PHARMACEUTICAL NEWS INDEX_1974-1999/Jan W2
133	43: Health News Daily_1990-1999/Jan 13
28	46: A-V Online_1998/Mar. Q2
2373	47: Magazine Database(TM)_1959-1999/Jan 13
46	48: SPORTDiscus_1962-1998/Dec
281	49: PAIS INT._1976-1998/Oct
13356	50: CAB Abstracts_1972-1998/Nov
760	51: Food Sci.&Tech.Abs_1969-1998/Dec
3685	53: FOODLINE(R): Food Science & Technology_1972-1999/Jan 11
1	57: Philosophers Index_1940-1998/Q3
12	58: GeoArchive_1974-1998/Oct
420	60: CRIS/USDA_1998/Sep
152	61: LISA (LIBRARY&INFOSCI)_1969-1999/Jan
3	62: SPIN(R)_1975-1999/Dec W3
Examined	50 files
113	63: Transport Res(TRIS)_1970-1999/Dec

49 64: Global Mobility Database (R)_1965-1998/Nov
 5482 65: Inside Conferences_1993-1999/Jan W2
 1861 66: GPO Mon. Cat._-1998/Apr
 37 67: World Textiles_1970-1998/Dec
 6123 68: Env.Bib._1974-1999/Jan
 330 70: SEDBASE_1996/Jan Q1
 34419 71: ELSEVIER BIOBASE_1994-1999/Dec W4
 91023 72: EMBASE_1985-1999/Jan W1
 217417 73: EMBASE_1974-1999/Jan W1
 737 74: Int.Pharm.Abs._1970-1998/Dec
 18 75: IAC Management Contents(R)_86-1999/Dec W3
 13996 76: Life Sciences Collection_1982-1998/Nov
 981 77: Conference Papers Index_1973-1998/Jan
 93 79: Foods Adlibra(TM)_1974-1998/Oct
 4 80: IAC Aerospace/Def.Mkts(R)_1986-1999/Jan 13
 71 85: Grants_1999/Jan
 4498 86: Mental Health Abstracts_1969-1998/Dec
 3050 88: IAC BUSINESS A.R.T.S._1976-1999/Jan 13
 124 89: GeoRef_1785-1999/Jan B1
 15 91: MANTIS(TM)_1880-1998/Dec
 119 92: IHS Intl.Stds.& Specs._1999/Jan
 2 93: TableBase(R) Sep_1997-1999/Jan W1
 487 94: JICST-EPlus_1985-1999/Oct W3
 22 96: FLUIDEX_1973-1998/Dec
 839 98: General Sci Abs/Full-Text_1984-1999/Dec
 283 99: Wilson Appl. Sci & Tech Abs_1983-1999/Dec
 41 100: Disclosure(R) Database_1999/Jan 13
 7 105: AESIS_1851-1998/Sep
 1082 108: Aerospace Database_1962-1998/Dec
 342 109: Nuclear Sci. Abs._1948-1976
 1197 111: Natl.Newspaper Index(SM)_1979-1999/Jan 13
 87 114: Encyclopedia of Associations_1998/
 484 115: Research Centers & Services_1998/Jul
 2333 117: Water Resour.Abs._1967-1998/Nov
 27 118: ICONDA-Intl Construction_1976-1997/Sep
 119 119: Textile Technol.Dig._1978-1998
 1273 120: US Copyrights_1978-1998/Dec 28
 7 122: Harvard Business Review_1971-1998/Dec
 1 126: TRADEMARKSCAN(R)-U.K._1998/Dec B2
 12 131: Pharmacontacts_1998/Apr
 38 132: S&P's Daily News_1985-1999/Jan 12
 13 133: S&P's Corp.Descrip.+News_1998/Jan B1
 307 137: Book Review Index_1969-1998/
 2 139: Econ. Lit. Index_1969-1999/Jan
 369 141: Readers Guide_1983-1998/Nov
 347 142: Social Sciences Abstracts_1983-1998/Nov
 Examined 100 files
 4165 143: Biol. & Agric. Index_1983-1998/Nov
 58899 144: Pascal_1973-1998/Dec
 145 145: (Tacoma) The News Tribune_1992-1999/Jan 12
 481 146: Washington Post Online_1983-1999/Jan 12
 142 147: The Kansas City Star_1995-1999/Jan 12
 5086 148: IAC Trade & Industry Database_1976-1999/Jan 13
 5238 149: IAC(SM)Health&Wellness DB(SM)_1976-1999/Jan W2
 713 150: Legal Resource Index(TM)_1980-1999/Jan 12
 4709 151: HealthSTAR_1975-1998/Dec

9709 155: MEDLINE(R)_1966-1998/Dec W4
 372104 156: Toxline(R)_1965-1998/Nov
 91 157: Aidsline(R)_1980-1998/Dec
 1164 158: DIOGENES(R)_1976-1998/Dec W3
 2633 159: Cancerlit_1975-1998/Nov
 18461 161: Occ.Saf.& Hth._1973-1998/Q3
 5409 162: CAB HEALTH_1983-1998/Nov
 11 163: Ageline(R)_1965-1998/Oct
 2606 165: EventLine(TM)_1990-1998/Dec
 4 166: GPO Publ.Ref.File_1998/Dec B2
 6 169: Insurance Periodicals_1984-1999/Jan W1
 466 171: Criminal Justice Periodical Index_1975-1998/Oct
 187 174: Pharm-line(R)_1978-1999/Jan W1
 2 177: Adv.& Agency Red Books:Advertisers_1998/Dec
 1 179: Architecture DB_1987-1998/Nov
 2941 180: Federal Register_1985-1999/Jan 07
 275 185: Zoological Record Online(R)_1978-1997/V133P22
 777 187: F-D-C Reports_1987-1999/Jan W1
 17 188: Health Devices Sourcebook_(1998)
 2 189: NDA Pipeline: New Drugs_1991-1999/Jan
 16 192: Industry Trends & Anal._1997/Jun
 10 196: FINDEX_1982-1998/Q4
 28 198: Health Devices Alerts(R)_1977-1999/Jan W2
 171 202: Information Science Abs._1966-1999/Oct
 3811 203: AGRIS_1974-1998/Dec
 204 211: IAC Newsearch(TM)_1997-1999/Jan 13
 24 226: TRADEMARKSCAN(R)-US FED_OG990105/AP981030
 1 228: TRADEMARKSCAN(R)-SPAIN_1998/DEC B2
 63 229: Drug Info._1998/98Q3
 235 230: Gale Dir Online-Portable-Internet DBS_1998/Q3
 17 233: Microcomputer Abstracts_1974-1999/Jan
 2511 234: Marquis Who's Who(r)_1998/Aug
 2328 236: Bowker(r) Biographical Directory_1997/Oct
 29 238: Abs. in New Tech & Eng._1981-1998/Dec
 82 239: Mathsci(R)_1940-1998/Dec
 Examined 150 files
 208 240: PAPERCHEM_1967-1999/Jan
 111 241: Elec. Power DB_1972-1999Dec
 64 245: WATERNET(TM)_1971-1998Q3
 3 246: TRADEMARKSCAN(R)-U.S. STATE_1999/Jan 06
 138 248: PIRA_1975-1999Feb W2
 19 252: Packaging Sci&Tech_1982-1997/Oct
 7 256: SoftBase:Reviews,Companies&Prods._85-1998/Dec
 37 257: API EnCompass(TM):News_1975-1999/Jan 12
 1160 258: AP News Jul_1984-1999/Jan 12
 263 261: UPI News_1996-1999/Jan 12
 251 262: CBCA Fulltext_1982-1998/Dec
 4 264: DIALOG Defense Newsletters_1989-1999/Jan 12
 188 269: Materials Bus.(TM)_1985-1999/Jan
 44 275: IAC(SM) Computer Database(TM)_1983-1999/Jan 13
 7 278: Microcomputer Software Guide_1998/Dec
 86146 285: BioBusiness(R)_1985-1998/Aug W1
 382 286: Biocommerce Abs.& Dir._1981-1999/Nov B2
 251 292: GEOBASE(TM)_1980-1998/Dec
 372 293: Eng Materials Abs(R)_1986-1999/Jan
 658 304: The Merck Index Online(SM)_/1998S1

239 305: Analytical Abstracts_1980-1999/Feb
 914 306: Pesticide Fact File_1998/Jun
 1320 307: DOSE_1998/S2
 444 315: ChemEng & Biotec Abs_1970-1998/Jan
 1358 317: Chemical Safety NewsBase_1981-1998/Jan
 380 319: Chem Bus NewsBase_1984-1999/Jan 12
 102 322: Polymer Online_
 471 323: RAPRA Rubber & Plastics_1972-1999/Jan B1
 24 332: Material Safety Data Sheets - OHS_1998/Q3
 14 335: Ceramic Abstracts_1976-1998/Q3
 234 337: CHEMTOX (R) Online_1998/Q3
 6 342: Derwent Patents Citation Indx_1978-98/9901
 1 347: JAPIO_Oct 1976-1998/Sep.(UPDATED 981229)
 440 348: European Patents_1978-1998/Dec W53
 58 357: Derwent Biotechnology Abs_1982-1999/Jan B2
 43 358: Current BioTech Abs_1983-1998/Jan
 14 360: Specialty Chemicals Update Program_1998/Q4
 Examined 200 files
 18 370: Science_1996-1999/Nov W3
 5 371: French Patents_1961-1999/\$F371BANC1
 32 382: Baton Rouge Advocate_1998-1999/Jan 11
 130 387: The Denver Post_1994-1999/Jan 12
 63 388: PEDS: Defense Program Summaries_1998/Jun
 68 392: Boston Herald_1995-1999/Jan 12
 61 397: Las Vegas Review-Journal_1997-1999/Jan 12
 69 410: Chronolog(R)_1981-1999 Jan/Feb
 11 413: DIALOG Product Code Finder(TM)_1998/Nov
 2363 414: Dialog Journal Name Finder(TM)_1999/Jan
 19 415: DIALOG Bluesheets(TM)_1999/Jan 12
 1122 416: DIALOG COMPANY NAME FINDER(TM)_1998/Nov
 1010 420: UnCover_1988-1999/Jan 13
 97 421: REMARC pre1900_1986/Jul
 155 422: REMARC 1900-39_1986/Jul
 167 423: REMARC 1940-59_1986/Jul
 245 424: REMARC 1960-69_1986/Jul
 228 425: REMARC 1970-80_1986/Jul
 4335 426: LCMARC-Books_1968-1999/Jan W1
 214 427: Fort Worth Star-Telegram_1993-1999/Jan 12
 586 430: British Books in Print_1998/Dec
 17 432: Tampa Tribune_1998-1999/Jan 11
 68 433: Charleston Newspapers_1997-1999/Jan 12
 2796 434: SciSearch(R) Cited Ref Sci_1974-1989/Dec
 9 436: Humanities Abs Full Text_1984-1998/Nov
 26 437: Education Abstracts_1983-1998/Nov
 14 438: Library Literature_1984-1998/Nov
 5 439: Arts&Humanities Search(R)_1980-1999/Jan W1
 6391 440: Current Contents Search(R)_1990-1999/Jan W3
 904 442: AMA Journals_1982-1999/Dec W4
 10 450: Publ., Distr.& Wholesalers_1998/Dec
 268 457: The Lancet_1986-1999/Jan W1
 14 461: USP DI(R) Vol. I_1998/Q3
 2 465: Incidence & Prevalence_1998/Q2
 3 467: ExtraMED(tm)_1998/Jun
 55 469: Gale DB of Publ.& Broad.Media_1992-1998/Nov
 1648 470: Books in Print(R)_1998/DEC
 12 471: New York Times Fulltext-90 Day_1999/Jan 13

229 478: Houston Chronicle_1990-1999/Jan 12
 5 479: Company Intelligence(R)_1999/Jan 12
 291 480: Ulrich's Int'l Periodicals DIR._1998/Dec
 1 481: Delphes Eur Bus_80-1998/Dec W3
 195 483: NEWSPAPER ABSTRACTS DAILY_1986-1999/Jan 11
 1651 484: Periodical Abstracts Plustext_1986-1999/Dec W3
 Examined 250 files
 20 485: Accounting and Tax Database_1971-1999/Jan W1
 92 486: Press-Telegram_1992- 1999/Jan 11
 52 487: Columbus Ledger-Enquirer_1994-1998/Dec 30
 20 488: Duluth News Tribune_1995-1999/Jan 10
 58 489: The News-Sentinel_1991-1999/Jan 12
 62 490: Tallahassee Democrat_1993- 1998/Dec 30
 421 492: Arizona Repub/Phoenix Gaz_1986-1999/Jan 10
 309 494: St LouisPost-Dispatch_1988-1999/Jan 11
 231 495: The Columbus Dispatch_1988-1999/Jan 11
 417 496: The Sacramento Bee_1988-1999/Jan 11
 234 498: Detroit Free Press_1987-1999/Jan 08
 12 501: EXTEL INTL NEWS CARDS_1989-1999/Dec W4
 2 502: Teikoku Databank:Japanese Companies_1998/Nov
 1 505: Asian Co. Profiles_1998/Oct
 27 510: ESPICOM Pharm & Med Co. Profile_1998/Oct
 9 511: ESPICOM Country Health Care Report_1998/Oct
 9 513: Corporate Affiliations Online_1998/Q4
 2 514: DIALOG Investment Res. Index_1995-1999/Jan 13
 108 515: D&B-Dun's Elec. Bus. Dir.(TM)_1998/09
 132 516: D & B - Duns Market Identifiers_1998/Nov
 4 518: D&B-Int.Dun's Market Identifiers(R)_1998/Jun
 19 522: D&B-Global Corp. Linkages_1998/Aug
 6 526: S&P Register-Biographical_1998/Apr
 3 527: S&P's Register-Corp._1998/Oct
 83 531: Amer. Bus. Directory_1998/Sep
 31 532: Bangor Daily News_1996-1999/Jan 12
 4 533: Canadian Bus. Directory_1998/Q2
 10 535: Thomas Register Online(R)_1998/Q3
 135 536: (Gary) Post-Tribune_1992-1999/Jan 09
 12 538: Boca Raton News_1994- 1998/Dec 09
 33 539: Macon Telegraph_1994-1999/Jan 10
 1797 545: Investext(R)_1982-1999/Jan 13
 83 547: Experian Business Credit Profiles_1999/Jan W1
 1 550: SDC's IPOs_1980-1999/Jan 13
 24 551: SDC Worldwide M&A_1980-1999/Jan 13
 240 553: Wilson Bus. Abs. FullText_1982-1999/Dec
 16 554: SDC's J V & Alliances_1990-1998/Nov 9
 2 555: Moody's(R)Corp.Profiles_1999/Jan W1
 31 556: Moody's(R)CorpNews-US_1983-1999/Jan W1
 2 557: Moody's(R)CorpNews-Int_1982-1999/Jan W1
 332 559: CORPTECH Dir of Tech Companies_1998/Sep
 Examined 300 files
 54 560: Spokane Spokesman-Review_1994-1999/Jan 10
 5 561: ICC British Co.Dir_1999/Jan W1
 3 562: ICC Brit.Co.Finan.Data_1999/Dec W4
 9 563: Key Note Market Res._1986-1999/Jan 10
 142 564: ICC Brit.Co.Ann.Rpts_1984-1999/Jan 11
 3 569: Decision Res Pharm Ind Rpts_1998/Aug 03
 50 570: IAC MARS(R)_1984-1999/Jan 13

12 576: Aberdeen American News_1995-1999/Jan 07
 75 577: Roanoke Times_1992-1999/Jan 12
 64 582: Augusta Chronicle_1996- 1999/Jan 10
 65 583: IAC Globalbase(TM)_1986-1999/Jan W2
 2 584: KOMPASS USA_1998/Jul
 34 590: KOMPASS Western Europe_1997/Aug
 10 591: Kompass UK_1998/Jul
 1 600: Early Edition-U.S._1997-1999/Jan 12
 24 603: Newspaper Abstracts_1984-1988
 28 605: U.S. Newswire_1995-1999/Jan 13
 4 606: Africa News_1996-1999/Jan 12
 3 607: ITAR/TASS News_1996-1999/Jan 12
 96 608: KR/T Bus.News._1992-1999/Jan 13
 86 609: Bridge World Markets News_1989-1999/Jan 13
 582 610: Business Wire_1986-1999/Jan 13
 3 612: Japan Economic Newswire(TM)_1984-1999/Jan 08
 1015 613: PR Newswire_1987-1999/Jan 13
 41 614: AFP English Wire_1991--1999/Jan 12
 1 615: AFP Intl French Wire_1991--1999/Jan 12
 57 616: Canada NewsWire_1996-1999/Jan 12
 8 618: Xinhua News_1996-1999/Jan 12
 147 619: Asia Intelligence Wire_1986-1999/Jan 13
 3 620: EIU:Viewswire_1999/Jan 12
 551 621: IAC New Prod.Annou.(R)_1985-1999/Jan 13
 17 623: Business Week_1985-1999/Jan W1
 228 624: McGraw-Hill Publications_1985-1999/Jan 12
 1 625: American Banker Publications_1981-1999/Jan 13
 3 626: Bond Buyer Full Text_1981-1999/Jan 12
 27 627: EIU: Country Analysis_1999/Jan W1
 Examined 350 files
 1 629: EIU:BUS. Newsletters_1999/Jan W1
 380 630: Los Angeles Times_1993-1999/Jan 12
 354 631: Boston Globe_1980-1999/Jan 11
 730 633: Phil.Inquirer_1983-1999/Jan 12
 533 634: San Jose Mercury_ Jun 1985-1999/Jan 08
 496 635: Business Dateline(R)_1985-1999/Jan 12
 3797 636: IAC Newsletter DB(TM)_1987-1999/Jan 13
 67 637: Journal of Commerce_1986-1999/Jan 12
 384 638: Newsday/New York Newsday_1987-1999/Jan 12
 172 639: The Houston Post_1988-1995/Apr 18
 289 640: San Francisco Chronicle_1988-1999/Jan 12
 276 641: Rocky Mtn News_Jun 1989-1999/Jan 03
 289 642: The Charlotte Observer_1988-1999/Jan 12
 31 643: Grand Forks Herald_1995-1999/Jan 12
 86 644: Boulder Daily Camera_1995-1998/Dec 11
 236 645: Contra Costa Papers_1995- 1999/Jan 12
 6 646: Consumer Reports_1982-1999/Jan
 42 648: TV AND RADIO TRANSCRIPTS_1997-1999/Jan W2
 127 652: US Patents Fulltext_1971-1979
 478 653: US Pat.Fulltext_1980-1989
 1666 654: US Pat.Full._1990-1999/Jan 05
 1519 655: BNA Daily News_1990-1999/Jan 13
 2 658: TRADEMARKSCAN(R)-Benelux_1998/Dec B2
 590 660: Federal News Service_1991-1999/Jan 12
 1 661: TRADEMARKSCAN(R)-Switzerland_1998/Dec B2
 1 671: TRADEMARKSCAN(R)-Intl Register_1998/Dec B2

1 672: TRADEMARKSCAN(R)-Germany_1998/Dec B2
 4 673: TRADEMARKSCAN(R)-Italy_1998/Dec B2
 1 674: Computer News Fulltext_1989-1999/Jan W2
 41 683: Omaha World-Herald_1998-1999/Jan 11
 47 684: Bradenton Herald_1992-1998/Dec 21
 7 696: DIALOG Telecom. Newsletters_1995-1999/Jan 12
 310 701: St Paul Pioneer Pr Apr_1988-1999/Jan 06
 657 702: Miami Herald_1983-1999/Jan 11
 127 703: USA Today_1989-1999/Jan 12
 588 704: (Portland)The Oregonian_1989-1999/Jan 08
 375 706: (New Orleans)Times Picayune_1989-1999/Jan 07
 356 707: The Seattle Times_1989-1999/Jan 11
 192 708: Akron Beacon Journal_1989-1999/Jan 12
 106 710: Times/Sun.Times(London)_Jun 1988-1999/Jan 12
 124 711: Independent(London)_Sep 1988-1999/Jan 12
 263 712: Palm Beach Post_1989-1999/Jan 10
 233 713: Atlanta J/Const._1989-1999/Jan 10
 271 714: (Baltimore) The Sun_1990-1999/Jan 12
 8 715: Christian Sci.Mon._1989-1998/Dec 31
 Examined 400 files
 251 716: Daily News Of L.A._1989-1999/Jan 08
 151 717: The Washington Times_Jun 1989-1999/Jan 12
 387 718: Pittsburgh Post-Gazette_Jun 1990-1999/Jan 12
 339 719: (Albany) The Times Union_Mar 1986-1999/Jan 10
 248 720: (Columbia) The State_Dec 1987-1999/Jan 11
 284 721: Lexington Hrd.-Ldr._1990-1999/Jan 10
 169 722: Cincinnati/Kentucky Post_1990-1999/Jan 11
 106 723: The Wichita Eagle_1990-1999/Jan 11
 135 724: (Minneapolis)Star Tribune_1989-1996/Feb 04
 214 725: (Cleveland)Plain Dealer_Aug 1991-1999/Jan 10
 33 726: S.China Morn.Post_1992--1999/Jan 12
 2005 727: Canadian Newspapers_1990-1999/Jan 12
 61 728: Asia/Pac News_1994-1999/Jan W2
 249 731: Philad.Dly.News_1983- 1999/Jan 12
 157 732: San Francisco Exam._1990- 1999/Jan 11
 330 733: The Buffalo News_1990- 1999/Jan 10
 150 734: Dayton Daily News_Oct 1990- 1999/Jan 10
 294 735: St. Petersburg Times_1989- 1999/Jan 12
 175 736: Seattle Post-Int._1990-1999/Jan 11
 67 737: Anchorage Daily News_1989-1999/Jan 12
 412 738: (Allentown) The Morning Call_1990-1999/Jan 11
 256 739: The Fresno Bee_1990-1999/Jan 10
 129 740: (Memphis)Comm.Appeal_1990-1999/Jan 12
 62 741: (Norfolk)Led./Pil._1990-1999/Jan 12
 265 742: (Madison)Cap.Tim/Wi.St.J_1990-1999/Jan 05
 281 743: (New Jersey)The Record_1989-1999/Jan 11
 70 744: Biloxi Sun Herald_1995-1998/Nov 26
 4 748: Asia/Pac Bus. Jrnls_1994-1999/Jan 12
 1 749: Latin American News Jan/_1994-1999/Jan 12
 3 750: Middle East News_1995-1999/Jan 12
 5 754: IPO Maven_1994-1998/Dec
 33 755: New Zealand Newspapers_1995-1999/Jan 12
 35 761: Datamonitor Market Res._1992-1998/Jun
 1 762: Euromonitor Market Res._1991-1999/Jan
 474 764: BCC Market Research_1989-1999/Jan
 269 765: Frost & Sullivan_1992-1998/Dec

26 766: FIND(R)/SVP Market Research_1993-1998/Dec
 7 768: EIU Market Research_1999/Jan 12
 1 778: EdgarPlus(TM)-10-K & 20-F Filings_1999/Jan 12
 864 781: UMI Newsstand(TM)_1998-1999/Jan 12
 Examined 450 files
 17 788: (Myrtle Beach) The Sun News_1996-1999/Jan 10
 170 929: Albuquerque Newspapers_1995-1999/Jan 12
 26 979: Milwaukee Jnl Sentinel Apr_1998-1999/Jan 11
 41 980: Sarasota Herald-Tribune_1996-1999/Jan 12

This set, which demonstrates the variety of sources providing some mention of toxicology, was then reduced to those having larger numbers of occurrences. This is a somewhat arbitrary process, process since the files are of very different nature, sizes and time period.

Restricting the set to those files showing more than 5,000 occurrences of the term, and simplifying by showing only one database name when several files may be mentioned, gives the following set (not in order):

- Biosis
- NTIS
- Agricola
- Scisearch
- Pollution Abstracts
- CAB Abstracts
- Inside conferences
- Environmental Bibliography
- Embase
- Life Science Collection
- Pascal
- IAC database
- Medline
- Toxline
- Occupational safety and health
- CAB Health
- Biobusiness

CA Search is the most notable omission from this list.

If the criteria are relaxed to 2,000 occurrences, then the following databases are added (again, not in order):

- Dissertation abstracts
- Enviroline
- Magazine database
- Foodline
- Mental health abstracts
- Water resources abstracts
- Healthstar
- Cancerlit
- Eventline
- Federal Register
- AGRIS
- Marquis Who's Who
- Bowker Biographical Directory
- Dialog Journal Name Finder

- LCMarc Books
- Canadian newspapers

The Dialindex search was then repeated, using the more general term 'toxic?'. In this case, 434 out of the 454 files had some mention of the term; a clear indication of the ubiquity of toxicology information.

The other major online host systems do not offer similar aids to identifying resources, and relevant files had to be judged from their descriptions in the host's documentation.

STN, a host system which aims to provide access to the sources primarily required for science and technology (see, for example, Ridley 1996), offers a variety of files with some apparent relevance to toxicology. Some are searchable by chemical substructure. They include both bibliographic databases:

- Chemical Abstracts files
- Biosis
- Medline
- Toxline
- Toxlit
- Scisearch
- Life Science Collection
- CAB Abstracts

and factual/numeric databanks:

- Beilstein
- Derwent drug file
- CHEMSAFE (flammable substances)
- HSDB (Hazardous Substances Databank)
- RTECS (Registry of Toxic Effects of Chemical Substances)
- Materials Safety Data Sheets
- Merck Index
- CHEMLIST (Environmental Protection Agency's Toxic Substance Control Act substances)

Orbit/Questel offers a relatively small number of toxicology-related files - Chemical Abstracts, Enviroline, HSEline, Merck Index, and the Derwent files - none uniquely.

OCLC's First Search offers no files of toxicological relevance, other than Medline.

TOXNET is a service offered by the US National Library of Medicine (NLM) Special Information Service. It consists of a collection of databases and databanks which may be queried via a common web based interface. Although the TOXNET service is not a host system per se, it does act as one in that it provides access to a series of databases. A list of the databases comprising TOXNET can be found from the relevant web page:

- <http://toxnet.nlm.nih.gov>

toxicity and other hazards of chemicals)

<u>HSDB</u>	Hazardous Substances Data Bank - Broad scope in human and animal toxicity, safety and handling, environmental fate, and more. Scientifically peer-reviewed.
<u>IRIS</u>	Integrated Risk Information System - data from the <u>Environmental Protection Agency</u> (EPA) in support of human health risk assessment, focusing on hazard identification and dose-response assessment.
<u>CCRIS</u>	Chemical Carcinogenesis Research Information System - carcinogenicity, mutagenicity, tumor promotion, and tumor inhibition data provided by the <u>National Cancer Institute</u> (NCI).
<u>GENE-TOX</u>	GENE-TOX - Peer-reviewed mutagenicity test data from the <u>EPA</u> .

For Toxicology Literature (Scientific studies, reports, and other bibliographic material)

<u>TOXLINE</u>	Extensive array of references to literature on biochemical, pharmacological, physiological, and toxicological effects of drugs and other chemicals.
<u>EMIC</u>	Environmental Mutagen Information Center - Current and older literature on agents tested for genotoxic activity.
<u>DART/ETIC</u>	Developmental and Reproductive Toxicology and Environmental Teratology Information Center - Current and older literature on developmental and reproductive toxicology.

For Toxic Release Information (Annual estimated releases of toxic chemicals to the environment - the Environmental Protection Agency's TRI (Toxics Release Inventory))

<u>TRI</u>	Toxics Release Inventory - reporting years 1995 - 1999.

For Chemical Information (Nomenclature, Identification, Structures)

<u>ChemIDplus</u>	Numerous chemical synonyms, structures, regulatory list information, and links to other databases containing information about the chemicals.
<u>HSDB Structures</u>	2D structural information on the HSDB chemicals.
<u>NCI-3D</u>	2D and 3D information compiled by the <u>National Cancer Institute</u> , and augmented by MDL

3.4.f CD-ROM resources:

CD-ROM sources may be identified in a number of ways. One is to examine the listings of information sources in this format which are produced as annual directories.

One of the most widely used of such sources is 'CD-ROMs in Print'. The latest edition of this printed product was consulted:

- AR Suchowski (ed) 1998, CD-ROMs in Print (12th Edition.) Gale, Detroit

The only relevant subject heading in the index is 'toxicology', and 29 items are listed under this heading. They are of very varied nature - not all, indeed, should be regarded as secondary sources - and are listed here according to my categorisation:

Bibliographic databases:

- CAB Health
- Toxline (3 variants)
- Drug information Fulltext
- Dialog On-disc Health Devices Alerts
- Dialog On-disc Healthcare product Comparison System
- NIOSHTIC

Sections of bibliographic databases:

- EMBASE CD - Pollution and Toxicology

Factual databanks:

- Materials Safety Datasheets (2 variants)
- FTSS: French language materials safety datasheets
- Registry of Toxic Effects of Chemical Substances
- Toxic Release Inventory (2 variants)
- Dangerous Substances CD: consolidated text of EU legislation on classification, packaging and labelling of dangerous substances
- Toxichem: information on hazardous chemicals which may be involved in chemical fires
- Tomes (2 variants): reference source on chemicals used in industrial settings, including toxicity, safety precautions, medical treatment for exposure, etc.
- Sax: health and safety information on over 20,000 substances, based on 9th edn. of Sax's Dangerous Properties of Industrial Materials
- Poisindex: quarterly product, detailed toxicology database for identification of substances (industrial, domestic, pharmaceutical, plants, etc.) likely to cause poisoning, with information on ingredients, symptoms, treatment. Searchable by brand, generic and scientific names, botanical terms, slang terms, 'street names', etc.

Compilations of bibliographical databases/ factual databanks:

- CCINFO (health and safety databases)
- Compact SST/OHS (Canadian health and safety databases)
- Euromed: databases for Swiss pharmacists
- Medirom: databases for Swiss physicians
- OSH-ROM: 4 databases for occupational safety and health
- PolTox: selection of pollution and toxicity databases

- Worksafe Australia: 5 databases/databanks for Australian chemical safety

Primary Resources:

- Infection and Immunity - archives of full text of the journal

The emphasis here is clearly on the 'health and safety' aspects of toxicology, rather than on the scientific or medical. The CD-ROM format is used largely as a convenient way of packaging single resources, as an alternative to online (e.g. RTECS) or print (e.g. Sax), or packaging several complementary sources. Few of these resources offer unique information or search facilities, Poisindex being the obvious exception.

3.4.g Monographs, textbooks, treatises:

For medical libraries, there are standard recommended 'core collections': the US Brandon/Hill recommendations, and the equivalent UK recommendations, compiled by Howard Hague and published by the Medical Information Working Party. These are general guides, recommended for 'a small or medium-sized library in a hospital or comparable medical institution' (Hague 1994/95).

Hague's list does not have toxicology as a subject section, and includes only a few toxicology-related items, in sections on accident and emergency medicine, and pharmacology.

The 1994/95 issue of the Hague list includes the following books:

- AT Proudfoot 1993, *Acute poisoning: diagnosis and management* (2nd edn.) Butterworth-Heinemann, 1993
- MO Amdur 1991, *Casarett and Doull's Toxicology: basic science of poisons* (4th edn.) Pergamon
- DM Davies 1991, *Textbook of adverse drug reactions* (4th edn.) Oxford University Press

and one periodical:

- *Adverse Drug Reaction Bulletin*

The US Brandon/Hill lists are provided for three settings:

- for small medical libraries
- for nursing
- for allied health professions

and are published biannually, with interim updates. These lists of books and journals are aimed at providing a balanced list of resources, and are chosen purely on the basis of the expert opinion of their compilers. They favour US-published and -oriented material, where it is available.

Toxicology-related material in the latest version of each list is as follows:

Small medical libraries (Selected list of books and journals for the small medical library, AN Brandon and DR Hill, *Bulletin of the Medical Libraries Association*, 1997, 85(2), 111-135)

This list includes 610 books and 141 journals, and is the 17th version of a recommended list first appearing in 1965. It is intended as a core collection for a library consortium, or a total stock for a small or medium hospital library.

There is a 'Toxicology' section, containing 6 items:

- MJ Ellenhorn, Williams and Wilkins 1997, *Ellenhorn's Medical Toxicology: Diagnosis and Treatment of Human Poisoning* (2nd edn.), Baltimore
- LR Goldfrank et al. 1994, *Goldfrank's Toxicologic Emergencies* (5th edn.). Appleton and Large, Stamford CT

- CD Klaassen (ed.) 1996, Casarett and Doull's Toxicology: The basic science of poisons (5th edn.) McGraw Hill, New York NY
- Basic Toxicology: Fundamentals, target organs, and risk assessment (3rd edn.), Taylor and Francis, Washington DC, 1996
- KR Olsen et al (eds.) 1994, Poisoning and drug overdose (2nd edn.) Appleton and Lange, Stamford CT
- P Viccellio (ed.) 1997, Handbook of emergency toxicology (2nd ed.) Lippincott-Raven, Philadelphia

'Casarett and Doull' is recommended as part of a 'minimal core list', and, together with 'Ellerhorn', for initial purchase.

No relevant journals are suggested.

Nursing (Brandon/Hill selected list of nursing books and journals, DR Hill, Nursing Outlook, 1998, 46(1), 71-18)

A book widely provided in UK nursing libraries is:

- KR Olsen et. al (eds.) 1990, Poisoning and drug overdose, Lange clinical manuals

Allied health (Brandon/Hill selected list of books and journals in allied health, DR Hill and HN Stickell, Bulletin of the Medical Libraries Association, 1998, 86(4), 447-463)

This listing of 410 books and 78 journals contains only one relevant item, under the 'Emergency Medical Technology' heading:

- LR Goldfrank et al. 1998 Goldfrank's Toxicologic Emergencies (6th edn.) Appleton and Large, Stamford CT

The UK Drug Information Pharmacists Group quality assurance scheme recommends three books on adverse effects

- I Stockley, Drug Interactions, Pharmaceutical Press
- PH Hansen and JR Horn, Drug Interactions and Updates, Lea and Febiger
- MNG Dukes (ed.), Mylers Side Effects of Drugs, Excerpta Medica

3.4.h Reviews and summaries of progress:

Reviews and summaries of progress may appear as books, or indeed as journal articles. Whilst journal articles reporting the first occurrence of an event are undoubtedly primary material, a review article, or even a whole edition of a journal devoted to summarising a topic, may be regarded as secondary resources, having added some value to the original first report. It was therefore decided to include journal based reviews with secondary resources. In order to identify the more important periodicals in which reviews of toxicology appear, two approaches were followed:

- searching Ulrich's International Periodicals Directory (via Dialog), and assessing the results
- searching for review articles in bibliographic databases, and ranking the sources

Identifying review articles from Ulrich's International Periodicals Directory

The above directory was searched for

REVIEW or REVIEWS

and

TOXIC? or CARCINOGEN? or MUTAGEN? or TERATOGEN? or POISON?

the terms being allowed to occur anywhere in the basic index, i.e. including notes and publisher information as well as title, to ensure comprehensiveness. There were 39 items found, of which 37 are rated 'active':

- CNS Drug Reviews
- Cardiovascular Drug Reviews
- Toxicology and Ecotoxicology News - Reviews (this has now ceased publication)
- Journal of Toxicologic Pathology
- Mutation Research - Reviews in Genetic Toxicology
- Journal of Aerosol Medicine; deposition, clearance, and effects in the lung
- Shuisheng Shengwu Xuebao Parallel Title: Acta Hydrobiologica Sinica
- Pakistan Journal of Pharmaceutical Sciences
- Chemical Research in Toxicology
- Arizona Poison Control System Newsletter
- Toxics Law Reporter; a weekly review of toxic torts, hazardous waste, and insurance litigation
- Mutagenesis
- Current Advances in Toxicology
- Lawrence Review of Natural Products
- Journal of Controlled Release
- Risk Abstracts; a quarterly journal of abstracts, reviews and references
- Poisoned Pen
- Adverse Drug Reactions and Toxicological Reviews
- Reviews in Toxicology; Formed by the merger of (1979-1995): Reviews in Biochemical Toxicology: ISSN 0163-7673; (1984-1996): Reviews in Environmental Toxicology: ISSN 0168-7255; (1991-1996): Reviews in Pesticide Toxicology: ISSN 1062-3965
- IARC Scientific Publications
- Reviews of Environmental Contamination and Toxicology

- Trace Substances in Environmental Health
- Annual Review of Pharmacology and Toxicology
- Environmental Carcinogenesis & Ecotoxicology Reviews; Variant title: Journal of Environmental Science and Health. Part C: Environmental Carcinogenesis & Ecotoxicology Reviews
- Journal of Toxicology. Toxin Reviews
- Drug Development Research
- Trends in Analytical Chemistry; a magazine publishing short, critical reviews and news on trends and developments in analytical chemistry
- Pharmacology and Therapeutics; journal of the International Encyclopedia of Pharmacology and Therapeutics
- Toxicological and Environmental Chemistry; Formerly: Toxicological and Environmental Chemistry Reviews
- Veterinary and Human Toxicology
- Journal of International Medical Research
- E H P Supplements; (Environmental Health Perspectives)
- Critical Reviews in Toxicology
- Review of Medical and Veterinary Mycology
- European Journal of Pharmaceutical Sciences
- Mutation Research; international journal on mutagenesis, chromosome breakage and related subjects
- Pharmacological Reviews

On inspection, it seems clear that some of these are medical or scientific journals with toxicology or toxicity as a small component of their scope. Others are local or ephemeral in nature. Removal of these suggests the following list as being a core set of 17 periodicals carrying toxicology reviews:

- Journal of Toxicologic Pathology
- Mutation Research
- Chemical Research in Toxicology
- Mutagenesis
- Current Advances in Toxicology
- Adverse Drug Reactions and Toxicological Reviews
- Reviews in Toxicology; Formed by the merger of (1979-1995): Reviews in Biochemical Toxicology: ISSN 0163-7673; (1984-1996): Reviews in Environmental Toxicology: ISSN 0168-7255; (1991-1996): Reviews in Pesticide Toxicology: ISSN 1062-3965
- Reviews of Environmental Contamination and Toxicology
- Trace Substances in Environmental Health
- Annual Review of Pharmacology and Toxicology
- Environmental Carcinogenesis & Ecotoxicology Reviews; Variant title: Journal of Environmental Science and Health. Part C: Environmental Carcinogenesis & Ecotoxicology Reviews
- Journal of Toxicology. Toxin Reviews
- Pharmacology and Therapeutics; journal of the International Encyclopedia of Pharmacology and Therapeutics
- Toxicological and Environmental Chemistry; Formerly: Toxicological and Environmental Chemistry Reviews
- Veterinary and Human Toxicology
- E H P Supplements; (Environmental Health Perspectives)
- Critical Reviews in Toxicology

Identifying reviews sources from bibliographic databases

This was done initially in SciSearch and then in a combination of other bibliographic databases. This ensured that alternative journal selection policies by the database producers were allowed for, and also allowed the alternatives of Scisearch's 'document type' category and a search on titles and abstracts.

In each case a selection of review articles, defined as noted above, was selected, duplicates were removed, and the resulting set ranked by journal name, using the automatic Dialog procedures. The resulting lists were edited manually, to allow for idiosyncrasies in the duplicate removal, journal names changes over time, equivalencing of journals and their supplements, etc.

SciSearch was searched, for the time period from 1990, for items with TOXIC, TOXICITY, TOXICOLOGY or TOXICOLOGICAL in the title, and with the document type REVIEW assigned. There were 979 such items. RANKing by source name gives the following, down to those with 10 or more items:

1	50	CRITICAL REVIEWS IN TOXICOLOGY
2	48	ACS SYMPOSIUM SERIES
3	24	ADVERSE DRUG REACTIONS AND TOXICOLOGICAL REVIEWS
4	19	ENVIRONMENTAL HEALTH PERSPECTIVES
5	18	MUTATION RESEARCH
6	17	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
7	17	REVIEWS OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
8	16	REPRODUCTIVE TOXICOLOGY
9	15	VETERINARY AND HUMAN TOXICOLOGY
10	14	DRUG SAFETY
11	14	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH
12	12	CANCER TREATMENT REVIEWS
13	12	DRUG METABOLISM REVIEWS
14	11	FOOD AND CHEMICAL TOXICOLOGY
15	11	HUMAN & EXPERIMENTAL TOXICOLOGY
16	11	PROGRESS IN HISTOCHEMISTRY AND CYTOCHEMISTRY
17	10	SEMINARS IN ONCOLOGY

In order to widen this very specific title word search, the title terms:

CARCINOGEN? OR MUTAGEN? OR TERATOGEN? OR POISON?

were combined with the REVIEW document type. This gave 876 items, for which the source ranking is as follows (after correcting for the variant forms of citation of the *Mutation Research* journals):

1	68	MUTATION RESEARCH
2	39	METHODS IN ENZYMOLOGY
3	35	ACS SYMPOSIUM SERIES
4	19	ENVIRONMENTAL HEALTH PERSPECTIVES
5	19	VETERINARY AND HUMAN TOXICOLOGY
6	15	ENVIRONMENTAL CARCINOGENESIS & ECOTOXICOLOGY R
7	14	PHARMACOLOGY & THERAPEUTICS
8	13	CHEMICAL RESEARCH IN TOXICOLOGY
9	13	CRITICAL REVIEWS IN TOXICOLOGY
10	13	FOOD AND CHEMICAL TOXICOLOGY
11	12	EKSPERIMENTALNAYA ONKOLOGIYA
12	10	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
13	10	FASEB JOURNAL

This set is actually quite similar to the first, with 6 sources occurring in the 'top 10' of each:

- Critical Reviews in Toxicology
- American Chemical Society (ACS) Symposium Series
- Environmental Health Perspectives
- Annual Reviews of Pharmacology and Toxicology
- Mutation Research
- Veterinary and Human Toxicology

When the two sets of title terms are combined, giving 1817 unique items, after duplicate removal, the overall sources ranking is as follows:

1	84	MUTATION RESEARCH
2	82	ACS SYMPOSIUM SERIES
3	58	CRITICAL REVIEWS IN TOXICOLOGY
4	44	METHODS IN ENZYMOLOGY
5	35	ENVIRONMENTAL HEALTH PERSPECTIVES
6	33	VETERINARY AND HUMAN TOXICOLOGY
7	30	ADVERSE DRUG REACTIONS AND TOXICOLOGICAL REVIEWS
8	26	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
9	23	PHARMACOLOGY & THERAPEUTICS
10	22	FOOD AND CHEMICAL TOXICOLOGY
11	21	DRUG METABOLISM REVIEWS
12	20	REVIEWS OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
13	19	ENVIRONMENTAL CARCINOGENESIS & ECOTOXICOLOGY REVIEWS
14	18	DRUG SAFETY
15	18	REPRODUCTIVE TOXICOLOGY
16	17	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH
17	16	CHEMICAL RESEARCH IN TOXICOLOGY
18	16	PROGRESS IN HISTOCHEMISTRY AND CYTOCHEMISTRY
19	15	FREE RADICAL BIOLOGY AND MEDICINE
20	13	CANCER TREATMENT REVIEWS
21	12	EKSPERIMENTALNAYA ONKOLOGIYA
22	12	HUMAN & EXPERIMENTAL TOXICOLOGY
23	11	PROCEEDINGS OF THE SOCIETY FOR EXPERIMENTAL BIOLOGY
24	11	YAKUGAKU ZASSHI-JOURNAL OF THE PHARMACEUTICAL
25	10	ENVIRONMENTAL CARCINOGENESIS REVIEWS-PART C OF
26	10	FASEB JOURNAL
27	10	LIFE SCIENCES
28	10	SEMINARS IN ONCOLOGY

At the top here are the six titles already noted, plus those strongly featuring in one of the lists:

- Adverse Drug Reactions and Toxicological Reviews
- Reviews of Environmental Contamination and Toxicology
- Reproductive Toxicology
- Drug Safety
- Methods in Enzymology
- Environmental Carconogenesis and Ecotxicology Reviews
- Pharmacology and Therapeutics
- Chemical Research in Toxicology

In order to widen the scope of this investigation, four other bibliographic databases - CA Search, Medline, Embase and Biosis - were searched together; these were chosen so as to cover all perspectives on toxicology, and hence obtain a good overview of its review literature. These databases were searched for the years 1996, 1997 and 1998, using the same subject specification as in SciSearch, but explicitly searching for the term REVIEW in the records, rather than using a document type indicator.

A search for TOXIC, TOXICITY, TOXICOLOGY and TOXICOLOGICAL in the title, together with REVIEW anywhere in the basic index, gave 2204 items, reducing to 1692 after removal of duplicates. The source ranking was as follows:

1	68	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
2	29	ENVIRON. HEALTH PERSPECTIVES (and supplements)
3	26	CRITICAL REVIEWS IN TOXICOLOGY
4	21	MICROSCALE TEST. AQUAT. TOXICOL.
5	22	REPORT (BIBRA)
6	15	REGULATORY TOXICOLOGY AND PHARMACOLOGY
7	15	TOXICOLOGICAL METHODS
8	15	FOOD AND CHEMICAL TOXICOLOGY
9	14	ARCHIVES OF TOXICOLOGY (and supplements)
10	14	TOXICOLOGICAL RISK ASSESSMENT
11	13	PLOMB, CADMIUM MERCURE ALIMENT.: EVAL. GESTION
12	13	TOXICOLOGY
13	12	CHEM. EXPOSURE TOXIC RESPONSES
14	11	MUTATION RESEARCH
15	10	REPRODUCTIVE TOXICOLOGY
16	10	ADV. EXP. MED. BIOL.
17	10	JOURNAL OF TOXICOLOGICAL SCIENCES
18	10	SPEC. PUBL. - R. SOC. CHEM.

Several of the journals noted in the equivalent SciSearch ranking feature highly, plus some others which are not included in the ISI database, including: Microscale Testing for Aquatic Toxicology, and the BIBRA toxicity report series.

An equivalent search with

CARCINOGEN?, MUTAGEN?, TERATOGEN? or POISON?

in the title gave 1761 items, reducing to 1272 after duplicate removal. Source ranking was:

1	93	MUTATION RESEARCH
2	26	ENVIRONMENTAL HEALTH PERSPECTIVES (and supplements)
3	25	METHODS IN MOLECULAR BIOLOGY
7	14	VETERINARY AND HUMAN TOXICOLOGY
8	14	METHODS IN ENZYMOLOGY
4	14	JAPANESE JOURNAL OF TOXICOLOGY
5	13	IGAKU NO AYUMI
6	10	TOXICOLOGIC PATHOLOGY

The large number of items in Mutation Research is notable, as is the importance of the two 'general biology' methods journals, for molecular biology and enzymology.

Combining the two search results, for a total of 2906 records after duplicate removal gave the following source ranking:

1	107	MUTATION RESEARCH
2	69	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
3	58	ENVIRONMENTAL HEALTH PERSPECTIVES (and supplements)
4	31	CRITICAL REVIEWS IN TOXICOLOGY
5	25	METHODS MOLECULAR BIOLOGY
6	23	MICROSCALE TEST. AQUAT. TOXICOL.
7	23	TOXICOLOGICAL METHODS
8	22	REPORT (BIBRA)
9	20	FOOD AND CHEMICAL TOXICOLOGY
10	19	TOXICOLOGIC PATHOLOGY
11	19	REGULATORY TOXICOLOGY AND PHARMACOLOGY
12	19	JOURNAL OF TOXICOLOGICAL SCIENCES
13	19	REPRODUCTIVE TOXICOLOGY
14	19	VETERINARY AND HUMAN TOXICOLOGY
15	18	ADVANCES IN EXPERIMENTAL MEDICINE AND BIOLOGY
16	18	ARCHIVES TOXICOLOGY (and supplements)
17	18	JAPANESE JOURNAL OF TOXICOLOGY
18	17	IGAKU NO AYUMI
19	17	TOXICOLOGICAL RISK ASSESSMENT
20	15	JOURNAL OF TOXICOLOGY; CLINICAL TOXICOLOGY
21	15	INTERNATIONAL JOURNAL OF TOXICOLOGY
22	14	METHODS IN ENZYMOLOGY
23	14	SPECIAL PUBLICATION, ROYAL SOCIETY OF CHEMISTRY
24	14	TOXICOLOGY
25	13	CHEMICAL EXPOSURE TOXIC RESPONSES
26	13	PLOMB, CADMIUM MERCURE ALIMENT.: EVAL. GESTION
27	12	PROGRESS IN CLINICAL AND BIOLOGICAL RESEARCH
28	12	SAISHIN IGAKU
29	11	AMERICAN CHEMICAL SOCIETY SYMPOSIUM SERIES
30	11	TERATOLOGY
31	10	DRUG METABOLISM REVIEWS
32	10	HANDBOOK OF EXPERIMENTAL PHARMACOLOGY
33	10	JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH
34	10	ORGANOHALOGEN COMPOUNDS

When the SciSearch and 'other databases' rankings are compared, five journals appear with 20 or more items (roughly the 'top 10') in each:

- Mutation Research
- Annual Review of Pharmacology and Toxicology
- Environmental Health Perspectives
- Critical Reviews in Toxicology
- Food and Chemical Toxicology

and these could reasonably thought of as the 'central core' from this study.

More fully, if those sources with more than 20 items in either list are set out with their positions in each list shown, then the following pattern emerges, with the presence of the items on the list derived from Ulrich (see above) added:

source Ulrich	SciSearch	others	
MUTATION RESEARCH	1	1	Y
ACS SYMPOSIUM SERIES	2	29	-
CRITICAL REVIEWS IN TOXICOLOGY	3	4	Y

METHODS IN ENZYMOLOGY	4	22	-
ENVIRONMENTAL HEALTH PERSPECTIVES	5	3	Y
VETERINARY AND HUMAN TOXICOLOGY	6	14	Y
ADVERSE DRUG REACS. AND TOX. REVS.	7	-	Y
ANNUAL REVIEW OF PHARM. AND TOX.	8	2	Y
PHARMACOLOGY & THERAPEUTICS	9	-	Y
FOOD AND CHEMICAL TOXICOLOGY	10	9	-
DRUG METABOLISM REVIEWS	11	31	-
REVIEWS OF ENV. CONTAM. AND TOX.	12	-	Y
METHODS MOLECULAR BIOLOGY	-	5	-
MICROSCALE TEST. AQUAT. TOXICOL.	-	6	-
TOXICOLOGICAL METHODS	-	7	-
REPORT (BIBRA)	-	8	-
JOURNAL OF TOXICOLOGIC PATHOLOGY	-	10	Y
CHEMICAL RESEARCH IN TOXICOLOGY	17	-	Y
MUTAGENESIS	-	-	Y
CURRENT ADVANCES IN TOXICOLOGY	-	-	Y
REVIEWS IN TOXICOLOGY	-	-	Y
TRACE SUBSTANCES IN ENVIRONMENTAL HEALTH	-	-	Y
ENVIRON. CARCINO. ECOTOX. REVS.	25	-	Y
JOURNAL OF TOXICOLOGY	-	20	Y
TOXICOLOGICAL AND ENVIRONMENTAL CHEM.	-	-	Y

This listing gives a good indication of the range of journals which carry significant numbers of toxicology reviews, and others which may be of interest for the topic.

3.4.i Journals

Identifying toxicology periodicals from Ulrich's International Periodicals Directory

The directory was searched to identify toxicology related journals.

The directory is sub-divided into subject groupings, but none of these overlap exactly with toxicology

A search for the term 'toxicology' retrieves records for 294 periodicals. 114 of these have 'toxicology' in the title, and 198 have it in subject descriptors; the 63 records which have neither of these have the term in either a 'notes' field, or in the name of the publisher or sponsor.

236 out of the 194 periodicals indexed in some way with 'toxicology' are 'active' in Ulrich's list, as are 87 out of the 114 with 'toxicology' in the title.

As a check on the subject headings used, those assigned to the list of 294 periodicals were identified, using the Dialog RANK command. The results were as follows:

Rank	Number	Heading
1	209	ENVIRONMENTAL STUDIES
2	198	TOXICOLOGY AND ENVIRONMENTAL SAFETY
3	112	PHARMACY AND PHARMACOLOGY
4	63	MEDICAL SCIENCES
5	41	BIOLOGY
6	27	PUBLIC HEALTH AND SAFETY
7	18	ABSTRACTING, BIBLIOGRAPHIES, STATISTICS
8	17	ABSTRACTING AND INDEXING SERVICES

The 114 records with 'toxicology' in the title were ranked according to classification codes, Dewey and Library of Congress. The purpose of this was to see how classification of toxicology material works in this instance.

The results were restricted to classifications applied to 3 or more periodicals, in order to eliminate errors and 'oddities', and to focus on the classifications used for the bulk of material. The results were as follows (since both classifications codes are held in the same field of the database on Dialog, the rank command displays them together; they have been separated for clarity in these tables):

Dewey classification

Rank	Number	Classification
1	69	615.90
2	10	615.00
3	4	613.62
4	4	614.70
5	3	016.00

Library of Congress

Rank	Number	Classification
1	24	RA1190
2	3	RA1199
3	3	RA1221

This was repeated for the 294 periodicals indexed in any respect as 'toxicology':

Dewey

Rank	Number	Classification
1	129	615.90
2	20	615.00
3	16	628.00
4	9	614.70
5	9	615.10
6	8	610.00
7	7	613.62
8	6	016.00
9	6	576.54
10	6	614.00
11	5	616.07
12	4	614.19
13	4	614.85
14	4	619.00
15	4	636.08
16	4	664.00
17	3	016.57
18	3	016.61
19	3	340.60
20	3	387.20
21	3	540.00
22	3	570.00
23	3	604.70
24	3	614.40
25	3	614.80
26	3	616.99

Library of Congress

Rank	Number	Classification
1	26	RA1190
2	8	X
3	3	QH545.W3
4	3	QP901
5	3	RA1199
6	3	RA1221
7	3	RA565.A1
8	3	RM1
9	3	TX501

The titles of the 236 'active' periodicals with any 'toxicology' indication - title, indexing, etc. - are listed in table 1, using English titles where these are alternatives, or translations where provided. They give a good exemplification of the breadth of publication media for toxicology. They include largely primary material, but also some secondary sources: review journals (e.g. Critical Reviews of Toxicology), abstracting and indexing services (e.g. Excerpta Medica sections), current awareness services (e.g. Current Contents), and databanks (e.g. RTECS).

While some of these periodicals, to judge from their titles, are indeed largely devoted to toxicology, others seem not to be so, and are included because toxicology is noted as a part of their remit. These cover a wide spectrum from analytical chemistry to medicine to ecology to transport regulations, to law.

Particularly notable are the periodicals devoted to specialisms within toxicology e.g.:

- Advances in Combustion Toxicology
- Ecotoxicology
- Toxicology in Vitro
- Reproductive Toxicology
- Inhalation Toxicology

and those indicating the overlap with other disciplines, e.g.:

- Journal of Toxicologic Pathology
- Annual Review of Pharmacology and Toxicology
- Cell Biology and Toxicology ; an international journal devoted to research at the cellular level

Sometimes, these two effects may be seen simultaneously, e.g.:

- Focus on Pulmonary Pharmacology and Toxicology
- Environmental Toxicology and Pharmacology.
- Regulatory Toxicology and Pharmacology

Ulrich's listing indicates name changes of periodicals. This information is needed for later studies of periodical rankings, when name changes may affect the results, and a list of periodicals from the toxicology list is shown in table 2.

It is informative to consider the nature of, and reasons for, name changes. While some are presumably carried out for the publisher's own internal reasons, some indication of changes within the disciplines covered can be gained.

In this list, 11 periodical names have changed to add 'toxicology' to an existing title, e.g.:

Journal of Pharmacological Methods
to
Journal of Pharmacological and Toxicological Methods

and

Experimental Pathology
to
Experimental and Toxicologic Pathology

as against three where toxicology was removed, i.e.:

Pediatric Therapeutics and Toxicology
to
Pediatric Primary Care

and

International Journal of Clinical Pharmacology, Therapy and Toxicology
to
International Journal of Clinical Pharmacology and Therapeutics

These latter are likely to reflect the publishers' perceptions of the 'best' title for the medical market; as is the evolution of another title:

Medical Toxicology
to
Medical Toxicology and Adverse Drug Experience
to
Drug Safety

The general trend to the inclusion of toxicology reflects the growing importance of toxicology in its own right, rather than as simply an aspect of other disciplines.

Other reasons for name change include:

- conversion of a title in a non-English language to English, e.g.:

Archiv fuer Toxikologie
to
Archives of Toxicology

- conversion of a 'archaic' Latinised title to English, e.g.:

Acta Pharmacologica et Toxicologica:
to
Pharmacology & Toxicology

- conversion of a journal name reflecting a learned society publisher into a more 'general' title, e.g.

Society of Pharmacological and Environmental Pathologists Bulletin
to
Toxicologic Pathology

These latter are part of the general move within scientific information to publication on a commercial basis, or by learned societies 'simulating' commercial publishers, and to publication largely in English.

Other name changes stem from a need to reflect a changing, often a wider, orientation of a journal, e.g.:

Veterinary Toxicology
to

Veterinary and Human Toxicology

and

In Vitro Toxicology
to
In Vitro & Molecular Toxicology
and

Food and Cosmetics Toxicology
to
Food and Chemical Toxicology

These are indicative of the dynamic nature of the scientific communication process, in toxicology as in other disciplines.

The list of periodicals found from Ulrich's Directory was also used to provide information on the role of learned societies as journal publishers and sponsors, as discussed in chapter two.

Table 1: Active periodicals with some 'toxicology' indication from Ulrich's International Periodicals Directory

IUPAC Series on Analytical and Physical Chemistry of Environmental Systems

New Solutions; a journal of environmental and occupational health policy

Democracy and Ecology

SHE Alert; (Safety, Health and the Environment)

Journal of Magnetic Resonance Analysis; applications in food science, toxicology, clinical biology, pharmacology, environmental science

Russian Journal of Experimental and Clinical Pharmacology (English translation of: Eksperimental'naya i Klinicheskaya Farmakologiya)

The Dictionary of Substances and Their Effects

Toxic Tort and Hazardous Substance Litigation

Courtroom Toxicology

Environmental and Toxic Tort Trials

Journal of Environmental Medicine

Toxic Exposure Advisory Newsletter

Journal of Toxicology and Environmental Health. Part B

JETOC Information Sheet

CIIT Activities (Activities - Chemical Industry Institute of Toxicology)

CIIT Impact

Directory of Personnel Responsible for Radiological Health Programs

Technomark Register. European Contract Research Organisations. Toxicology & Analysis

NIOSH Pocket Guide to Chemical Hazards

NIOSH Manual of Analytical Methods

Recent Advances in Clinical Pharmacology and Toxicology

Archives of Toxicology, Kinetics and Xenobiotic Metabolism

Methods in Toxicology

IMO - UNEP Guidelines on Oil Spill Dispersant Application; including environmental considerations

Advances in Modern Environmental Toxicology

Online Journal of Veterinary Research

Ret - Info

Chemical Health and Safety

Australian Toxic Network News

Afvalvademecum

Sepsis

Hazard Alert: Managing Workplace Hazardous Substances

World Directory of Environmental Testing, Monitoring and Treatment

CNS Drug Reviews

Studies and Researches in Veterinary Medicine

Lead Action News

Environment Information Bulletin

Strahlentelex mit Elektromog-Report; unabhaengiger Informationsdienst zu Radioaktivitaet, Strahlung und Gesundheit

Environmental and Molecular Mutagenesis. Supplement

Cardiovascular Drug Reviews

Technical Instructions for the Safe Transport of Dangerous Goods by Air

Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods

Analyses of Hazardous Substances in Biological Materials

Issues in Nutrition and Toxicology Series

Journal of Natural Toxins

Toxicological Evaluations

Ship Safety and Pollution Prevention - Ship Management and Port State Control

Environmental Protection News

Solas - International Convention for the Safety of Life at Sea. Amendments

Recommendations on the Safe Use of Pesticides in Ships

Drug Safety

Chapman & Hall Ecotoxicology Series

Conference of Radiation Control Program Directors Newsbrief

Organohalogen Compounds

Annual Report on Pipeline Safety

Toxicology and Ecotoxicology News - Reviews

Maikotokishin (Japanese Association of Mycotoxicology. Proceedings)

Kikanshi J E T O C (Japan Chemical Industry Ecology - Toxicology Information Center)

Journal of Toxicological Sciences

Japanese Journal of Toxicology

Abstracts of Current Literature in Toxicology

Pesticide Litigation Manual

Journal of Forensic Medicine

Dialog OnDisc Environmental Chemistry, Health and Safety

Japanese Journal of Forensic Toxicology

Agricultural and Biological Research

Current Toxicology and Therapy

The Quad Report; covering efficiency, demand-side management, and energy policy

Trends in Pharmacological Sciences (Reference Edition)

International Journal of Medical and Biological Frontiers

Third World Science & Environment Perspectives

Journal of Ecotoxicology & Environmental Monitoring

Altlasten - Spektrum; Erfassung - Bewertung - Sanierung

Toxicology and Industrial Health; an international journal

SAR and QSAR in Environmental Research

Current Topics in Pulmonary Pharmacology and Toxicology

Comparative Haematology International

Advances in Combustion Toxicology

Focus on Pulmonary Pharmacology and Toxicology

Journal of Toxicologic Pathology

Lactic Acid Bacteria

Pharmaceutical and Pharmacological Letters

Trace Metals in the Environment

Ethel Browning's Toxicity and Metabolism of Industrial Solvents

Food & Water Journal

Nongyao Kexue yu Guanli (Pesticide Science and Management)

Journal of Clean Technology, Environmental Toxicology, and Occupational Medicine

Natural Toxins

Zhongguo Yaolixue yu Dulixue Zazhi (Parallel Title: Chinese Journal of Pharmacology and Toxicology)

Ecotoxicology

Environmental Toxicology and Pharmacology

Hazardous Substances & Public Health

Foedevarenyt

International Journal of Occupational Medicine and Environmental Health

Mutation Research - Reviews in Genetic Toxicology

Mutation Research - Genetic Toxicology and Environmental Mutagenesis

Toxicology Methods

Journal of Environmental Sciences

Alternative Methods in Toxicology Series

In Vitro & Molecular Toxicology; a journal of basic and applied research

Biofouling

Sensitivity Matters

Journal of Veterinary Diagnostic Investigation

Acta Hydrobiologica Sinica

Toxic Substances Control Act - Test Submission Database

Pakistan Journal of Pharmaceutical Sciences

Excerpta Medica. Section 52: Toxicology

Pediatric Primary Care; practical pediatrics for the pediatric practitioner (formerly Pediatric Therapeutics and Toxicology)

Phytotherapy Research; an international journal devoted to medical and scientific research on plants and plant products

Toxicology in Vitro

Reproductive Toxicology

CA Selects. Steroids (Biochemical Aspects)

In Vivo; international journal of in vivo research

CA Selects. Beta-Lactam Antibiotics

Mycotoxin Research

Biomedical and Environmental Sciences

Chemical Research in Toxicology

Arizona Poison Control System Newsletter

Inhalation Toxicology

Journal of Clinical Laboratory Analysis

Cell Biology and Toxicology ; an international journal devoted to research at the cellular level

Journal of Biochemical Toxicology

Environmental Toxicology; an international journal

Comments on Toxicology

Acta Toxicologica et Therapeutica; international journal of toxicology, pharmacology and therapy

Current Issues in Toxicology

Drug and Chemical Toxicology Series

Mutagenesis

Forskningscenter Risoe. Aarsberetning

Trends in Pharmacological Sciences

Toxicological Sciences (formerly, until Dec. 1997, Fundamental and Applied Toxicology)

Journal of Applied Ichthyology

Placenta

Hazardous Waste Regulatory Analysis Service

Environmental and Safety Technology

Current Advances in Toxicology

Archives of Environmental Health

Pharmacology

Journal of Controlled Release

Risk Abstracts; a quarterly journal of abstracts, reviews and references

International Journal of Toxicology

Journal of Environmental Biology; an international research journal of environmental pollution & toxicology

Journal of Applied Toxicology

Plant Protection Bulletin

Progress in Pesticide Biochemistry and Toxicology

Human & Experimental Toxicology; an international journal

Toxic Substance Mechanisms

U.S. National Toxicology Program. Report on Carcinogens

Adverse Drug Reactions and Toxicological Reviews

Reviews in Toxicology

Developments in Toxicology and Environmental Science

Archives of Toxicology. Supplement

Ecotoxicology and Environmental Safety

Current Topics in Environmental and Toxicological Chemistry

RTECS; (Registry of Toxic Effects of Chemical Substances)

Reviews of Environmental Contamination and Toxicology

Annual Review of Pharmacology and Toxicology

Pharmacology & Toxicology. Supplementum

Journal of Toxicology. Cutaneous and Ocular Toxicology

Environmental Carcinogenesis & Ecotoxicology Reviews

Regulatory Toxicology and Pharmacology

Journal of Toxicology, Toxin Reviews

Environmental Toxicology and Chemistry

Drug Development Research

Aquatic Toxicology

Neurotoxicology and Teratology

Trends in Analytical Chemistry

Environmental and Molecular Mutagenesis

Immunopharmacology and Immunotoxicology

Annales des Falsifications de l'Expertise Chimique et Toxicologique

Journal of Pharmacological and Toxicological Methods

Immunopharmacology

NeuroToxicology (Little Rock); an international journal

Journal of Food Safety

Journal of Environmental Pathology, Toxicology and Oncology

Marine Environmental Research

Drugs under Experimental and Clinical Research

Toxicology Abstracts

Drug and Chemical Toxicology; an international journal for rapid communication

Health, Safety and Environment Bulletin

Journal of Environmental Science and Health. Part A: Toxic Hazardous Substances and Environmental Engineering

Toxicology Letters

Journal of Analytical Toxicology

Pediatrics (Edicion Espanola)

Comparative Biochemistry and Physiology. Part C: Comparative Pharmacology & Toxicology

Journal of Toxicology and Environmental Health. Part A

Pharmacology and Therapeutics; journal of the International Encyclopedia of Pharmacology and Therapeutics

Excerpta Medica. Section 30: Clinical and Experimental Pharmacology

Pesticides Abstracts

Toxicologic Pathology

Acta Entomologica Sinica

Pharmacology, Biochemistry and Behavior

Toxicological and Environmental Chemistry

Veterinary and Human Toxicology

Micologia Italiana

International Journal of Legal Medicine

Toxicon

Current Awareness in Biological Sciences

Journal of International Medical Research

Toxicology

Renal Physiology

Archives of Environmental Contamination and Toxicology

Arhiv za Higijenu Rada i Toksikologiju (Archives of Industrial Hygiene and Toxicology)

Toxicology and Applied Pharmacology

Teratology; the international journal of abnormal development

Research Communications in Molecular Pathology and Pharmacology

Journal of Occupational and Environmental Medicine

Food and Chemical Toxicology

Experimental and Molecular Pathology

Current Contents: Life Sciences

Journal of Toxicology. Clinical Toxicology

Chemosphere; chemistry, biology and toxicology as related to environmental problems

Critical Reviews in Toxicology

Sudebno-meditsinskaya Ekspertiza (Medico-Legal Expert Testimony)

Meditsina Truda i Promyshlennaya Ekologiya

Ekspperimental'naya i Klinicheskaya Farmakologiya (Russian Journal of Experimental and Clinical Pharmacology)

Latvijas Fizikas un Tehnisko Zinatnu Zurnals (Latvian Journal of Physics and Technical Sciences)

Xenobiotica; the fate of foreign compounds in biological systems

Pharmaceutica Acta Helvetiae

Panstwowy Zaklad Higieny. Roczniki

European Journal of Pharmaceutical Sciences

The Science of the Total Environment

Mutation Research; international journal on mutagenesis, chromosome breakage and related subjects

Excerpta Medica. Section 13: Dermatology and Venereology

Chemico-Biological Interactions; a journal of molecular and biochemical toxicology

Japanese Journal of Toxicology and Environmental Health

Naunyn-Schmiedeberg's Archives of Pharmacology

International Journal of Clinical Pharmacology and Therapeutics

Bulletin of Environmental Contamination and Toxicology

Archives of Toxicology

Experimental and Toxicologic Pathology

Journal de Medecine Legale Droit Medical; expertise medicale, deontologie, urgence medicale

Pharmacology & Toxicology

Czech Mycology

Vyzkumny Ustav Rybarsky a Hydrobiologicky. Bulletin

Canadian Society of Forensic Science Journal

Table 2: Toxicology journals which have changed name (from Ulrich's International Periodicals Directory)

This list is restricted to periodicals classed as 'active'; it excludes changes to sections within secondary sources.

Recent Advances in Clinical Pharmacology and Toxicology

Formerly (until 1989): Recent Advances in Clinical Pharmacology: ISSN

Cardiovascular Drug Reviews

Key Title: Former titles (until 1988): New Cardiovascular Drugs: ISSN

0891-3692: (until 1985): New Drugs Annual, Cardiovascular Drugs: ISSN

Drug Safety

Key Title: Former titles (until 1990): Medical Toxicology and Adverse

Drug Experience: ISSN 0113-5244: (until 1987): Medical Toxicology:

Toxicology and Ecotoxicology News - Reviews

Formerly (until 1997): Toxicology and Ecotoxicology News: ISSN

Current Toxicology and Therapy

Formerly: Currents in Toxicology and Therapy: ISSN 1122-3804

International Journal of Medical and Biological Frontiers

Formed by the merger of: International Journal of Medicine and Biology:

Journal of Microbiology: Incorporates: Current Toxicology : ISSN

International Journal of Occupational Medicine, Immunology and Toxicology

Formerly: Journal of Occupational Medicine and Toxicology

C O P E Backgrounders

Formerly: C O P P E Quarterly

Food & Water Journal

Formerly: Safe Food News

Journal of Clean Technology, Environmental Toxicology, and Occupational Medicine

Formerly: Journal of Clean Technology and Environmental Sciences: I

Environmental Toxicology and Pharmacology

Formerly (until 1996): European Journal of Pharmacology. Environmental

Toxicology and Pharmacology Section: ISSN 0926-6917

Foedevarenyt

Formerly: L S T Nytt: ISSN 0904-5198

International Journal of Occupational Medicine and Environmental Health

Former titles (until 1993): Polish Journal of Occupational Medicine and

Environmental Health: ISSN 0867-8383: (until 1991): Polish Journal of

Occupational Medicine: ISSN 0860-6536

Mutation Research - Genetic Toxicology and Environmental Mutagenesis

Former titles (until 1997): Mutation Research - Genetic Toxicology:

(until 1994): Mutation Research - Genetic Toxicology Testing: ISSN

0165-1218: Incorporates (in 1996): Mutation Research - Environmental Mutagenesis and Related Subjects: Which had former titles (until 19

Sensitivity Matters

Formerly (until 1994): A A A News: ISSN 0817-1300

Pediatric Primary Care; practical pediatrics for the pediatric practitioner

Formerly: Pediatric Therapeutics and Toxicology

Solid Waste Technologies; recycling, composting, waste-to-energy, landfilling, landfill gas-to-energy

Formerly: Solid Waste and Power: ISS

Environmental Toxicology; an international journal

Former titles: Environmental Toxicology and Water Quality: ISSN 1053-4725: Toxicity Assessment: ISSN 0884-8181

Forskningscenter Risoe. Aarsberetning

Former titles: Forsoegsanlaeg Risoe. Aarsberetning: Formerly (until 1977): Beretning om Atomenergikommissionens Virksomhed: ISSN 0415-326X

Toxicological Sciences

Formerly (until Dec. 1997): Fundamental and Applied Toxicology: ISSN 0272-0590

Current Advances in Toxicology

Formerly (until 1992): Current Advances in Pharmacology and Toxicology: ISSN 0741-1685

International Journal of Toxicology

Formerly (until 1997): American College of Toxicology. Journal: ISSN 0730-0913: Incorporates: Acute Toxicity Data: ISSN 1044-2049: Online edition: ISSN 1092-874X

Progress in Pesticide Biochemistry and Toxicology

Formerly: Progress in Pesticide Biochemistry: IS

Human & Experimental Toxicology; an international journal

Formerly: Human Toxicology

Toxic Substance Mechanisms

Key Title: Formerly (until 1994): Toxic Substances Journal

U.S. National Toxicology Program. Report on Carcinogens

Formerly: U.S. National Toxicology Program. Annual Report on Carcinogens:

Adverse Drug Reactions and Toxicological Reviews

Formerly (until 1991): Adverse Drug Reactions and Acute Poisoning Reviews

Reviews in Toxicology

Formed by the merger of (1979-1995): Reviews in Biochemical Toxicology: ISSN 0163-7673: (1984-1996): Reviews in Environmental Toxicology: ISSN 0168-7255: (1991-1996): Reviews in Pesticide Toxicology: ISSN 1062-3965

Annual Review of Pharmacology and Toxicology
Formerly (until vol.15, 1975): Annual Review of Pharmacology

Pharmacology & Toxicology. Supplementum
Formerly: Acta Pharmacologica et Toxicologica. Supplementum: ISSN
0065-1508

Environmental Carcinogenesis & Ecotoxicology Reviews
Variant title: Journal of Environmental Science and Health. Part C:
Environmental Carcinogenesis & Ecotoxicology Reviews: Former titles
(until 1991): Environmental Carcinogenesis Reviews: ISSN 0882-8164:
(until 1984): Journal of Environmental Science and Health. Part C:
Environmental Carcinogenesis Reviews: ISSN 0736-3001: Journal of
Environmental Science and Health. Part C: Environmental Health Sciences
(ISSN 0360-1242); Supersedes in part: Environmental Letters (ISSN
0013-9300)

Neurotoxicology and Teratology
Former titles: Neurobehavioral Toxicology and Teratology: ISSN
0275-1380: Neurobehavioral Toxicology

Environmental and Molecular Mutagenesis
Key Title: Formerly: Environmental Mutagenesis

Immunopharmacology and Immunotoxicology
Former titles: Journal of Pharmacology and Immunotoxicology: Journal of
Immunopharmacology: ISSN 0163-0571

Journal of Pharmacological and Toxicological Methods
Key Title: Formerly (until 1992): Journal of Pharmacological Methods:

Journal of Environmental Pathology, Toxicology and Oncology
Formerly: Journal of Environmental Pathology and Toxicology

Marine Environmental Research
Incorporates (1982-1991): Oil and Chemical Pollution: ISSN 0269-8579:
Which was formerly: Journal of Oil and Petrochemical Pollution: ISSN
0143-7127

Health, Safety and Environment Bulletin
Incorporates in part (in 1995): Health and Safety Bulletin: ISSN
1358-2208: Which was formerly (until 1994): Health and Safety
Information Bulletin

Journal of Environmental Science and Health. Part A: Toxic Hazardous
Substances and Environmental Engineering
Former titles: Journal of Environmental Science and Health. Part A:
Environmental Science and Engineering and Toxicology: ISSN 1077-1204:
Journal of Environmental Science and Health. Part A: Environmental
Science and Engineering

Comparative Biochemistry and Physiology. Part C: Comparative Pharmacology
& Toxicology
Formerly: Comparative Biochemistry and Physiology. Part C: Comparative
Pharmacology: ISSN 0306-4492

Pharmacology and Therapeutics; journal of the International Encyclopedia of Pharmacology and Therapeutics

Formed by the Jan. 1979 merger of: Pharmacology and Therapeutics. Part A.

Chemotherapy, Toxicology and Metabolic Inhibitors: ISSN 0362-5478:

Pharmacology and Therapeutics. Part B. General and Systematic

Pharmacology: ISSN 0306-039X: Pharmacology and Therapeutics. Part C.

Toxicologic Pathology

Key Title: Formerly (until vol.6, no.2, 1978): Society of Pharmacological

and Environmental Pathologists. Bulletin: ISSN 0094-1824

Toxicological and Environmental Chemistry

Formerly: Toxicological and Environmental Chemistry Reviews

Veterinary and Human Toxicology

Former titles (1973-1976): Veterinary Toxicology : ISSN 0091-5300:

(1970-1973): News from the American College of Veterinary Toxicologists

International Journal of Legal Medicine

Former titles (until 1992): Zeitschrift fuer Rechtsmedizin - Journal of

Legal Medicine: ISSN 0044-3433: Deutsche Zeitschrift fuer die Gesamte

Gerichtliche Medizin

Research Communications in Molecular Pathology and Pharmacology

Formerly (until 1994): Research Communications in Chemical Pathology and

Pharmacology

Journal of Occupational and Environmental Medicine

Former titles: Journal of Environmental Medicine: ISSN 0096-1736: J O M:

Journal of Occupational Medicine: ISSN 0022-3212: (until 1968): Journal

of Occupational Medicine

Food and Chemical Toxicology

Formerly (until 1982): Food and Cosmetics Toxicology:

Critical Reviews in Toxicology

Formerly: C R C Critical Reviews in Toxicology

Meditsina Truda i Promyshlennaya Ekologiya

Formerly (until 1993): Gigiena Truda i Professional'nye Zabolevaniya:

ISSN 0016-9919

Eksperimental'naya i Klinicheskaya Farmakologiya

Formerly (until 1992): Farmakologiya i Toksikologiya: ISSN 0014-8318:

English translation: Russian Journal of Experimental and Clinical

Pharmacology: ISSN 1026-3241

Latvijas Fizikas un Tehnisko Zinatnu Zurnals

Parallel Title: Latvian Journal of Physics and Technical Sciences: Former

titles: Latvijas Zinatnu Akademijas. Fizikas un Tehnisko Zinatnu Serija:

Akademiya Nauk Latviiskoi S.S.R. Izvestiya. Seriya Fizicheskikh i

Tkhnicheskikh Nauk: ISSN 0321-1673

European Journal of Pharmaceutical Sciences

Formed by the merger of (1977-1992): Acta Pharmaceutica Fennica: ISSN

0356-3456: Which was formerly (1928-1976): Farmaseuttinen Aikakauslehti: ISSN 0367-259X; (1989-1992): Acta Pharmaceutica Nordica: ISSN 1100-1801: Which was formed by the merger of (1964-1988): Acta Pharmaceutica Suecica: ISSN 0001-6675; (1983-1988): Norwegica Pharmaceutica Acta: ISSN 0800-2606: Which was formerly (1939-1982): Norsk Farmaceutisk Selskap. Meddelelser (ISSN 0029-1927) & Farmaci. Scientific Edition (ISSN 0904-0897); Which was formerly (until 1987): Archiv for Farmaci og Chemi. Scientific Edition (ISSN 0302-248X); (1926-1972): Dansk Tidsskrift for Farmaci (ISSN 0011-6513)

Japanese Journal of Toxicology and Environmental Health
Key Title: Eisei Kagaku Formerly: Journal of Hygienic Chemistry

Naunyn-Schmiedeberg's Archives of Pharmacology
Formerly: Naunyn-Schmiedebergs Archiv fuer Pharmakologie und Experimentelle Pathologie: Online edition: ISSN 143

International Journal of Clinical Pharmacology and Therapeutics
Former titles (until 1994): International Journal of Clinical Pharmacology, Therapy and Toxicology: ISSN 0174-4879; (until 1980): International Journal of Clinical Pharmacology and Biopharmacy: ISSN 0340-0026; Internationale Zeitschrift fuer Klinische Pharmakologie, Therapie und Toxikologie: ISSN 0020-9392

Archives of Toxicology
Former titles: Archiv fuer Toxikologie: ISSN 0003-9446: Fuehner-Wieland's Sammlung von Vergiftungsfaellen

Experimental and Toxicologic Pathology
Former titles: Experimental Pathology: ISSN 0232-1513: Experimentelle Pathologie: ISSN 0014-4908

European Journal of Toxicology and Environmental Hygiene
Former titles (until 1976): European Journal of Toxicology and Hygiene of the Environment: Until 1974: Journal Europeen de Toxicologie: ISSN 0021-8219

Journal de Medecine Legale Droit Medical; expertise medicale, deontologie, urgence medicale
Supersedes in part (in 1981): Medecine Legale, Toxicologie, Urgence Medicale, Centre Anti-Poisons: ISSN 0241-6751: Which was formerly (until 1980): Bulletin de Medecine Legale, Toxicologie: ISSN 0181-0154; (until 1978): Bulletin de Medecine Legale, Urgence Medicale, Centre Anti-Poisons: ISSN 0395-4374; (until 1976): Bulletin de Medecine Legale et de Toxicologie Medicale: ISSN 0007-4365; (until 1964): Bulletin de Medicine Legale (ISSN 0994-8430)

Pharmacology & Toxicology
Formerly: Acta Pharmacologica et Toxicologica:

Czech Mycology
Formerly (until 1993): Ceska Mykologie

In Vitro & Molecular Toxicology ; a journal of basic and applied research
Formerly (until 1998): In Vitro Toxicology

Identifying toxicology journals from secondary service coverage

The Science Citation Index, and its online implementation, Scisearch, produced by the Institute of Scientific Information, is a multidisciplinary bibliographic database, based on coverage of a set of journals regarded as the 'most significant' in all fields of science. Selection of these journals, and assignment to subject groups, is carried out on the basis of expert judgement of ISI editors plus subject specialist advisors, backed up by extensive citation analysis as a measure of 'impact'. Presence of a journal in the toxicology section of this database's coverage is therefore a *de facto* indication of probable significance as a primary source for the subject.

The 1998 ISI journal listing includes over 5,300 periodical titles, assigned to 164 subject categories: a journal may be assigned to more than one subject category. One of the sections is 'toxicology'. Other sections might be expected to contain some toxicology-related material, e.g. 'allergy', and 'public, environmental and occupational health', but their scope is too wide to be useful for this purpose, and the 'overlap' facilities suggests that any journals with strong toxicology leanings will be included in this section. The 71 journals in the 'toxicology' section are as follows:

Adverse Drug Reactions and Toxicological Reviews

Alcohol

Annals of Occupational Hygiene

Annual Review of Pharmacology and Toxicology

Aquatic Toxicology

Archiv fur Lebensmittelhygiene

Archives of Environmental Contamination and Toxicology

Archives of Toxicology

Biomarkers

Bulletin of Environmental Contamination and Toxicology

Cell Biology and Toxicology

Chemical Research in Toxicology

Chemical Speciation and Bioavailability

Comparative Biochemistry and Physiology C- Pharmacology, Toxicology and Endocrinology

Critical Reviews in Toxicology

Drug and Chemical Toxicology

Drug Safety

Ecotoxicology

Ecotoxicology and Environmental safety

Environmental and Molecular Mutagenesis
 Environmental Carcinogenesis and Ecotoxicology Reviews
 Environmental Toxicology and Chemistry
 Environmental Toxicology and Pharmacology
 Environmental Toxicology and Water Quality
 Experimental and Toxicologic Pathology
 Fluoride
 Food Additives and Contaminants
 Food and Agricultural Immunology
 Food and Chemical Toxicology
 Fundamental and Applied Toxicology
 Human and Experimental Toxicology
 Immunopharmacology and Immunotoxicology
 In vitro Toxicology
 Industrial Health
 Inhalation Toxicology
 International Journal of Toxicology
 Japanese Journal of Toxicology and Environmental Health
 Journal of Analytical Toxicology
 Journal of Applied Toxicology
 Journal of Clean Technology, Environmental Toxicology and Occupational Medicine
 Journal of Exposure Analysis and Environmental Epidemiology
 Journal of Pharmacological and Toxicological Methods
 Journal of Toxicology and Environmental Health Part A
 Journal of Toxicology and Environmental Health Part B Critical Reviews
 Journal of Toxicology - Clinical Toxicology
 Journal of Toxicology - Cutaneous and Occular Toxicology
 Journal of Toxicology - Toxin Reviews

Marine Environmental Research

Mutation Research - DNA Repair

Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis

Mutation Research - Genetic Toxicology and Environmental Mutagenesis

Mutation Research - Reviews in Mutation Research

Neurotoxicology

Neurotoxicology and Teratology

Pharmacology and Toxicology

Regulatory Toxicology and Pharmacology

Reproductive Toxicology

Teratogenesis, Carcinogenesis and Mutaegenesis

Teratology

Therapeutic Drug Monitoring

Toxic Substance Mechanisms

Toxicologic Pathology

Toxicology

Toxicology and Applied Pharmacology

Toxicology and Industrial Health

Toxicology in vitro

Toxicology Letters

Toxicology Methods

Toxicon

Veterinary and Human Toxicology

Xenobiotica

Derwent

Derwent Publications is a British company, producing secondary services covering drugs and patents. Among these databases are:

- Derwent Drug File: aims to include 'all important articles relating to drug development, manufacture, evaluation and use', including toxicology, and chosen so 'to ensure that the database contains the important papers from as wide a range of journals as possible'.
- Derwent Veterinary Drug File: covers all aspects of veterinary drug and vaccine development, regulation and use, and including toxicology, adverse effects and intoxications
- Derwent Crop Protection File: deals with all aspects of products other than fertilisers which protect crops of all kinds against pests, diseases, weeds, etc., and including the toxicity of such products.

The list of journals from which material for these sources is gathered is publicly available, and was scanned for journals of relevance to toxicology, as assessed from the title.

Those judged relevant to toxicology were:

Annual Review of Pharmacology and Toxicology
Aquatic Toxicology
Archives of Environmental Contamination and Toxicology
Archives of Toxicology
Bulletin of Environmental Contamination and Toxicology
Chemosphere
Clinical Toxicology
Drug and Chemical Toxicology
Drug Safety
Environmental Pollution
Environmental Toxicology and Chemistry
European Journal of Pharmacology: Environmental Toxicology and Pharmacology
Section
Fundamental and Applied Toxicology
Journal of Pharmacological and Toxicological Methods
Journal of Toxicology and Environmental Health
Pharmacology and Toxicology (Copenhagen)
Teratogenesis, Carcinogenesis and Mutagenesis
Teratology
Toxicology
Toxicology and Applied Pharmacology
Toxicology Letters
Veterinary and Human Toxicology
Xenobiotica

[14th edition of Journal List (1995) used].

Identifying key toxicology journals by RANKing

One approach to identification of key journals in a subject area is to search for a set of items clearly reflective of that subject in a database, and identify the journals from which they come.

This was tested for toxicology by searching individually on a series of databases on the Dialog host, which might be expected to have reasonable coverage of toxicology literature. 'Core' toxicology material was selected by specifying that the items must have the term 'toxicology' in the title. This also ensured that the analysis was not affected by the indexing policies of each database. Time periods were chosen so as to analyse roughly equivalent numbers of items from each database. The journals, or other sources, from which these items were taken were then listed by the Dialog RANK command, down to journals containing 10 or more items, with the results corrected to allow for cases of journal name changes (identified from Ulrich). Correction was also necessary to allow for differences in journal name citations within the various files, which are due to variant editorial practice over time or in various sub-files, though these have been corrected as much as possible. Examples of variant citations in the original RANKed lists are:

Embase:

```
2    71  FUNDAM. APPL. TOXICOL.
33   15  FUNDAMENTAL AND APPLIED TOXICOLOGY
```

Life Science Collection

```
2    156  TOXICOL. IN VITRO
3    148  TOXICOL. IN VITRO.
```

Toxline

```
26    13  TOXICOL LETT
37    10  TOXICOLOGY LETTERS (SHANNON)
```

The results cannot be taken as exact, due to these problems, but they give an adequate guide to the situation. Use of International Standard Serial Numbers (ISSN) would have avoided some of these problems, but these are not present in all files, and present their own problems with name changes, journal merges etc.

Databases searched were:

Scisearch	1990-current	1603 items
Medline	1985-current	1978 items
CAB Abstracts	1972-current	1180 items
Biosis	1993-current	2453 items
Embase	1985-current	2103 items
Life Science Collection	1982-current	2830 items
CA Search	1990-current	1804 items
Toxline	1990-current	2671 items

Toxline is, of course, a special case, being a composite file; the search initially generated 3562 items, which were reduced to 2671 by the Dialog duplicate removal procedure. Life Science Collection also comprises sub-files, but it was thought unlikely to have sufficient overlap to make duplicate removal necessary or sensible.

The rankings are now shown for each database.

SciSearch

1	70	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL S
2	65	ENVIRONMENTAL HEALTH PERSPECTIVES
3	57	HUMAN & EXPERIMENTAL TOXICOLOGY
4	44	JOURNAL OF THE AMERICAN COLLEGE OF TOXICOLOGY / INT J TOXICOL
5	41	ATLA-ALTERNATIVES TO LABORATORY ANIMALS
6	41	FUNDAMENTAL AND APPLIED TOXICOLOGY
7	40	MUTATION RESEARCH
8	33	TOXICOLOGY
9	29	TOXICOLOGY IN VITRO
10	27	FOOD AND CHEMICAL TOXICOLOGY
11	24	TOXICOLOGY LETTERS
12	24	VETERINARY AND HUMAN TOXICOLOGY
13	22	REGULATORY TOXICOLOGY AND PHARMACOLOGY
14	21	CHEMICAL WEEK
15	21	JOURNAL OF TOXICOLOGY-CLINICAL TOXICOLOGY
16	20	TOXICOLOGIC PATHOLOGY
17	19	CLINICAL CHEMISTRY
18	17	ADVERSE DRUG REACTIONS AND TOXICOLOGICAL REVIE
19	17	ENVIRONMENTAL AND MOLECULAR MUTAGENESIS
20	17	JOURNAL OF APPLIED TOXICOLOGY
21	16	MUTAGENESIS
22	13	TOXICOLOGY AND APPLIED PHARMACOLOGY
23	12	NEUROTOXICOLOGY AND TERATOLOGY
24	12	REPRODUCTIVE TOXICOLOGY
25	12	SCIENCE
26	11	ARCHIVES OF TOXICOLOGY
27	11	CRITICAL REVIEWS IN TOXICOLOGY
28	11	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
29	11	JOURNAL OF ANALYTICAL TOXICOLOGY
30	11	JOURNAL OF FORENSIC SCIENCES
31	11	PHARMACOLOGY & TOXICOLOGY
32	11	THERAPEUTIC DRUG MONITORING
33	10	CLINICS IN LABORATORY MEDICINE
34	10	COMPARATIVE HAEMATOLOGY INTERNATIONAL

Medline

1	175	ENVIRON HEALTH PERSPECT
3	82	FUNDAM APPL TOXICOL / JOURNAL OF TOXICOLOGICAL SCIENCES
3	81	MUTAT RES
4	54	HUM EXP TOXICOL / HUMAN TOXICOLOGY
5	49	TOXICOLOGY
6	40	FOOD CHEM TOXICOL
7	37	REGUL TOXICOL PHARMACOL
8	35	ARCH TOXICOL SUPPL
9	35	J TOXICOL CLIN TOXICOL
10	35	TOXICOL LETT
11	35	VET HUM TOXICOL
12	28	TOXICOL APPL PHARMACOL
13	24	PROG CLIN BIOL RES
14	23	TOXICOL PATHOL
15	20	J APPL TOXICOL
16	19	CRIT REV TOXICOL
17	18	ENVIRON MOL MUTAGEN
18	18	MUTAGENESIS
19	17	ARCH TOXICOL
20	17	GIG SANIT
21	17	NAUNYN SCHMIEDEBERGS ARCH PHARMACOL
22	16	J ANAL TOXICOL
23	16	VET CLIN NORTH AM SMALL ANIM PRACT
24	15	REPROD TOXICOL
25	15	REV ENVIRON CONTAM TOXICOL
26	14	ANN EMERG MED
27	14	PHARMACOL TOXICOL
28	14	TOXICOL IND HEALTH
29	13	ADVERSE DRUG REACT TOXICOL REV
30	13	ANNU REV PHARMACOL TOXICOL
31	13	DRUG METAB REV
32	13	J TOXICOL ENVIRON HEALTH
33	13	NEUROTOXICOL TERATOL
34	12	CLIN CHEM
35	12	J FORENSIC SCI
36	12	J TOXICOL CLIN EXP
37	12	PRZEGL LEK
38	12	THER DRUG MONIT
39	11	AM J EMERG MED
40	10	ECOTOXICOL ENVIRON SAF

CAB Abstracts

1	30	VETERINARY AND HUMAN TOXICOLOGY
2	14	NOTES DE TOXICOLOGIE VETERINAIRE
3	12	FOOD AND COSMETICS TOXICOLOGY

Biosis

1	137	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
2	102	ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
3	100	ASTM SPECIAL TECHNICAL PUBLICATION
4	81	METHODS IN TOXICOLOGY
5	80	ASTM STP
6	51	ARCHIVES OF TOXICOLOGY SUPPLEMENT
7	44	FUNDAMENTAL AND APPLIED TOXICOLOGY
8	42	MUTATION RESEARCH
10	39	DRUG AND CHEMICAL TOXICOLOGY
11	39	ENVIRONMENTAL HEALTH PERSPECTIVES
12	37	ADVANCES IN MODERN ENVIRONMENTAL TOXICOLOGY
13	34	CURRENT PROBLEMS IN DERMATOLOGY (BASEL)
14	31	JOURNAL OF TOXICOLOGY CLINICAL TOXICOLOGY
15	30	HUMAN & EXPERIMENTAL TOXICOLOGY
16	29	ABSTRACTS OF PAPERS AMERICAN CHEMICAL SOCIETY
17	24	ENVIRONMENTAL SCIENCE AND POLLUTION CONTROL SE
18	23	PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR CA
19	22	INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY IPC
20	21	FOOD AND CHEMICAL TOXICOLOGY
21	21	TOXICOLOGY
22	20	ENVIRONMENTAL AND MOLECULAR MUTAGENESIS
23	19	TERATOLOGY
24	16	REGULATORY TOXICOLOGY AND PHARMACOLOGY
25	16	TOXICOLOGIC PATHOLOGY
26	16	TOXICOLOGY LETTERS (SHANNON)
27	14	MEDICAL TOXICOLOGY
28	14	SOCIETY FOR EXPERIMENTAL BIOLOGY SEMINAR SERIE
29	13	TOXICOLOGY IN VITRO
30	13	VETERINARY AND HUMAN TOXICOLOGY
31	12	CANADIAN TECHNICAL REPORT OF FISHERIES AND AQU
32	11	CELL BIOLOGY AND TOXICOLOGY
33	11	CLINICAL CHEMISTRY
34	10	NAUNYN-SCHMIEDEBERG'S ARCHIVES OF PHARMACOLOGY

Embase

1	117	ENVIRON. HEALTH PERSPECT.
2	101	J TOXICOL SCI / FUNDAM. APPL. TOXICOL.
3	71	HUM. TOXICOL./ HUM. EXP. TOXICOL.
4	68	FOOD CHEM. TOXICOL.
5	55	TOXICOL. LETT.
6	52	REGUL. TOXICOL. PHARMACOL.
7	47	TOXICOLOGY
8	44	MUTAT. RES.
9	42	J. AM. COLL. TOXICOL. / INT. J. TOXICOL.
10	42	TOXICOL. VITRO
11	37	VET. HUM. TOXICOL.
12	36	TOXICOL. APPL. PHARMACOL.
13	35	ENVIRON. TOXICOL. CHEM.
14	29	JPN. PHARMACOL. THER.
15	24	TOXICOL. PATHOL.
16	23	ARCH. TOXICOL.
17	22	J. APPL. TOXICOL.
18	21	J. ANAL. TOXICOL.
19	21	J. TOXICOL. CLIN. TOXICOL.
20	21	MUTAGENESIS
21	19	J. TOXICOL. ENVIRON. HEALTH
22	18	ENVIRON. MOL. MUTAGEN.
23	17	BULL. ENVIRON. CONTAM. TOXICOL.
24	16	TOXICOL. IND. HEALTH
25	15	DRUG CHEM. TOXICOL.
26	15	PHARMACOMETRICS
27	14	CRIT. REV. TOXICOL.
28	13	ANNU. REV. PHARMACOL. TOXICOL.
29	13	CHEM. RES. TOXICOL.
30	13	J. FORENSIC SCI.
31	12	ADVERSE DRUG REACT. TOXICOL. REV.
32	12	DRUG METAB. REV.
33	12	J. TOXICOL. CLIN. EXP.
34	12	REV. ENVIRON. CONTAM. TOXICOL.
35	11	ARCH. ENVIRON. CONTAM. TOXICOL.
36	11	CLIN. CHEM.
37	11	JPN. J. TOXICOL. ENVIRON. HEALTH
38	11	NEUROTOXICOLOGY TERATOL.
39	11	THER. DRUG MONIT.
40	10	CURR. OPIN. PEDIATR.
41	10	DRUG INF. J.
42	10	DTSCH. APOTH.-ZTG
43	10	PHARMACOL. TOXICOL.

Life Science Collection

1	304	TOXICOL. IN VITRO
2	166	TOXICOL. LETT.
3	140	FOOD CHEM. TOXICOL.
4	133	ENVIRON. HEALTH PERSPECT.
5	113	ARCH. TOXICOL.
6	87	J. AM. COLL. TOXICOL. / INT. J. TOXICOL.
7	66	FUNDAM. APPL. TOXICOL.
8	64	VET. HUM. TOXICOL.
9	59	TOXICOLOGY
10	50	SCI. TOTAL ENVIRON.
11	46	MUTAT. RES.
12	45	HUM. TOXICOL.
13	42	J. TOXICOL.: CLIN. TOXICOL.
14	37	ENVIRON. HEALTH PERSPECT. SUPPL.
15	34	AQUAT. TOXICOL. HAZARD ASSESS.
16	32	J. HYG. CHEM.
17	31	J. APPL. TOXICOL.
18	30	HANDBOOK OF NATURAL TOXINS.
19	29	REPROD. TOXICOL.
20	25	CLIN. LAB. MED.
21	24	AQUAT. TOXICOL. RISK ASSESS.
22	24	ENVIRON. TOXICOL. CHEM.
23	23	REV. BIOCHEM. TOXICOL.
24	21	TOXICOL. APPL. PHARMACOL.
25	20	FAO PLANT PROD. PROT. PAP.
26	17	ATLA.
27	17	ENVIRON. MOL. MUTAG.
28	17	NEUROTOXICOLOGY.
29	17	REGUL. TOXICOL. PHARMACOL.
30	14	TARGET ORGAN TOXICOL. SER.
31	13	J. ANAL. TOXICOL.
32	13	SPEC. TECH. PUBL. AM. SOC. TEST. MATER.
33	12	ENVIRON. MUTAG.
34	11	J. TOXICOL. ENVIRON. HEALTH.
35	10	AQUAT. TOXICOL.
36	10	XENOBIOTICA.

CA Search

1	73	REPORT
2	54	NATL. TOXICOL. PROGRAM TECH. REP. SER.
3	47	MUTAT. RES.
4	29	FUNDAM. APPL. TOXICOL.
5	27	PATTY'S IND. HYG. TOXICOL. (4TH ED.)
6	22	TOXICOLOGY
7	21	FOOD CHEM. TOXICOL.
8	19	ENVIRON. HEALTH PERSPECT. SUPPL.
9	18	J. APPL. TOXICOL.
10	17	ENVIRON. HEALTH PERSPECT.
11	17	TOXICOL. IN VITRO
12	15	ENVIRON. MOL. MUTAGEN.
13	15	YAKURI TO CHIRYO
14	14	ARCH. TOXICOL., SUPPL.
15	13	OYO YAKURI
16	13	TOXICOL. LETT.
17	12	REGUL. TOXICOL. PHARMACOL.
18	11	J. ANAL. TOXICOL.
19	10	D.A., DIF. AMBIENTALE
20	10	INHALATION TOXICOL.
21	10	J. AM. COLL. TOXICOL. / INT. J. TOXICOL.
22	10	MUTAGENESIS

Toxline

1	264	GOVT REPORTS ANNOUNCEMENTS & INDEX (GRA&I)
2	139	ENVIRON HEALTH PERSPECT
3	128	EPA/OTS
4	93	NATIONAL TOXICOLOGY PROGRAM TECHNICAL REPORT S
5	60	MUTAT RES
6	58	FUNDAM APPL TOXICOL
7	50	HUM EXP TOXICOL
8	40	TOXICOLOGY
9	26	FOOD AND CHEMICAL TOXICOLOGY
10	23	TOXICOL LETT
11	25	J TOXICOL CLIN TOXICOL
12	23	ARCH TOXICOL SUPPL
13	22	REGUL TOXICOL PHARMACOL
14	21	WARE
15	20	TERATOLOGY
16	16	MUTAGENESIS
17	16	NAUNYN SCHMIEDEBERGS ARCH PHARMACOL
18	16	TOXICOL APPL PHARMACOL
19	16	VET CLIN NORTH AM SMALL ANIM PRACT
20	14	J TOXICOL SCI
21	13	HAYES
22	13	PHARMACOL TOXICOL
23	12	ADVERSE DRUG REACT TOXICOL REV
24	12	PRZEGL LEK
25	12	VET HUM TOXICOL
26	11	FEDRIP DATABASE
27	11	J APPL TOXICOL
28	11	REPROD TOXICOL
29	11	TOXICOLOGY IN VITRO
30	10	NEUROTOXICOL TERATOL
31	10	TOXICOL PATHOL

Combining ranked lists from bibliographic databases

In order to find a crude estimate of the most significant set of journals, those occurring in 3 or more of the above lists were ranked, according to the number of databases in which they appear, as shown below. This is not an accurate, or strictly quantitative procedure, but it does give an indication of the most 'visible' journals, as indicated by the appearance of numerous abstracts in several secondary services.

It is debatable whether Toxline should be included in such a process, since it reproduces subfiles from other sources, and items may thereby be 'counted twice'. Given that the purpose of this list is assessment of 'perceived significance' or 'visibility', rather than bibliometric analysis, it is justified.

8	FOOD AND CHEMICAL TOXICOLOGY /FOOD AND COSMETIC TOX
7	TOXICOLOGY LETTERS
7	VETERINARY AND HUMAN TOXICOLOGY
7	REGULATORY TOXICOLOGY AND PHARMACOLOGY
7	ENVIRONMENTAL HEALTH PERSPECTIVES
7	FUNDAMENTAL AND APPLIED TOXICOLOGY / J TOXICOL SCI
7	MUTATION RESEARCH
7	TOXICOLOGY
7	ARCHIVES OF TOXICOLOGY (including supplements)
6	HUMAN & EXPERIMENTAL TOXICOLOGY / HUMAN TOXICOLOGY
6	TOXICOLOGY IN VITRO
6	JOURNAL OF TOXICOLOGY-CLINICAL TOXICOLOGY
6	ENVIRONMENTAL AND MOLECULAR MUTAGENESIS
6	JOURNAL OF APPLIED TOXICOLOGY
5	MUTAGENESIS
5	JOURNAL OF ANALYTICAL TOXICOLOGY
5	TOXICOLOGY AND APPLIED PHARMACOLOGY
5	TOXICOLOGIC PATHOLOGY
4	NEUROTOXICOLOGY AND TERATOLOGY
4	REPRODUCTIVE TOXICOLOGY
4	CLINICAL CHEMISTRY
4	JOURNAL OF THE AMERICAN COLLEGE OF TOXICOLOGY / INT. J. TOXICOLOGY
4	ADVERSE DRUG REACTIONS AND TOXICOLOGICAL REVIEWS
4	PHARMACOLOGY & TOXICOLOGY
3	THERAPEUTIC DRUG MONITORING
3	ANNUAL REVIEW OF PHARMACOLOGY AND TOXICOLOGY
3	NAUNYN-SCHMIEDEBERG'S ARCHIVES OF PHARMACOLOGY
3	CRITICAL REVIEWS IN TOXICOLOGY
3	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
3	JOURNAL OF FORENSIC SCIENCES

Although this is an informal means of ranking journals, the resulting set of 30 journals seems to be a reasonably good compilation of 'core' toxicology material.

3.5.a Toxicology Information Resource List

Quaternary Resources

Lists of lists: web pages

American College of Medical Toxicology Resource Listing - Key Sites Providing Links to Multiple Sources of Information.

<http://www.acmt.net/toxresor.htm#anchor311101>

(last visited 20/10/01)

Brigham Young University, Teratology list links from "A Teratology Training Guide".

<http://ucs.byu.edu/teratology/sites.html>

(last visited 20/10/01)

Iowa University, Hardin Library for Health Sciences, subject specific links for toxicology and public health and preventative medicine respectively.

<http://www.lib.uiowa.edu/hardin/md/tox.html>

(last visited 20/10/01)

<http://www.lib.uiowa.edu/hardin/md/publ.html>

(last visited 20/10/01)

Labanimal Online Journal.

<http://www.labanimal.com/rel/rel.htm#toxicology>

(last visited 20/10/01)

National Library of Medicine, USA, Toxicology and Environmental Health Information Web Links.

<http://sis.nlm.nih.gov/Tox/ToxMain.html>

(last visited 20/10/01)

Novosibirsk State University 'super list' – this listing points to other lists of lists, including SciCentral and the WWW Virtual Library Resources.

<http://src.nsu.ru/biology/courses/internet/loflists.html>

(last visited 20/10/01)

Rouen University, Centre Hospitalier Universitaire de Rouen Hopitaux de Rouen Toxicologie: sites Monde.

<http://www.chu-rouen.fr/ssm/toxico.html>

(last visited 20/10/01)

SciCentral Gateway.

[http:// http://www.sciquest.com/cgi-bin/ncommerce3/ExecMacro/sci_level3.d2w/report?nav_banner=health&gateway=H-toxico&resource=cd&Tmstmp=44156](http://http://www.sciquest.com/cgi-bin/ncommerce3/ExecMacro/sci_level3.d2w/report?nav_banner=health&gateway=H-toxico&resource=cd&Tmstmp=44156)

(last visited 20/10/01)

Safety Equipment Australia Pty Ltd.

<http://www.seasafe.com.au/docs/links.htm>

(last visited 20/10/01)

Science of Anticipation, Recognition, Evaluation and Control of Health (SAREC), Occupational Health and Industrial Hygiene Consultancy.

<http://www.sarec.ca/english/l-frames.htm>

(last visited 20/10/01)

South Australia University Library, Internet Resources for Biomed Science.

<http://www.library.unisa.edu.au/internet/pathfind/biomed.htm#toxicology>

(last visited 20/10/01)

Tampere University of Technology, Finland, OSHWEB, Institute of Occupational Safety Engineering
<http://Oshweb.me.tut.fi/index.html>
(last visited 20/10/01)

Washington University, Department of Environmental Health, School of Public Health and Community Medicine, Environmental Health Bibliographies on the Web. Selection of printed bibliographies and web links, arranged by subject.
<http://www.staff.washington.edu/ehlib/outlinks/bibliog2.html>
(last visited 20/10/01)

Lists of lists: printed works

List of Lists of Worldwide Hazardous Chemicals and Pollutants. 1990. The Forum for Scientific Excellence, Inc., Lippincott, Philadelphia PA

Lists of organisations: web pages

American Association of Poison Control Centres, List of Members.
<http://www.aapcc.org/pcclists.htm>
(last visited 20/10/01)

Association of Societies for Occupational Safety and Health (ASOSH), South Africa, World Links.
<http://www.asosh.org/WorldLinks/societies/toxicology.htm>
(last visited 31/10/01)

British Toxicology Society List of Societies.
<http://www.thebts.org/info/pages/framelin.html>
(last visited 20/10/01)

Eurotox Member Societies.
<http://www.uta.fi/eurotox/noframes/mem-soc.htm>
(last visited 20/10/01)

IUTOX Member Societies
<http://www.toxicology.org/iutox/iutoxms/memsoc.html>
(last visited 31/10/01)

Swisstox.net links
http://www.swisstox.net/en/links_e.php?st_link_key=SOCOR
(last visited 1/11/01)

Tertiary Resources

Academic and research departments:

Arizona University, Center For Toxicology
<http://toxcenter.pharmacy.arizona.edu/>
(last visited 31/10/01)

Central Toxicology Laboratory (Syngenta)
Alderley Park, Cheshire

Edinburgh Centre for Toxicology
<http://www.bio.hw.ac.uk/edintox/edintox.htm>
(last visited 1/11/01)

Medical Toxicology Unit, New Cross, London
<http://www.medtox.org.uk/>
(last visited 29/10/01)

Regional Laboratory for Toxicology, Birmingham
<http://www.toxlab.co.uk/frmain.htm>
(last visited 6/7/99)

Saskatchewan University, Toxicology Centre
<http://www.usask.ca/toxicology/>
(last visited 1/11/01)

Associations and societies:

African Society for Toxicological Sciences
<http://www.ast99.com>
(last visited 6/7/99)

Agency for Toxic Substances and Disease Registry (ATSDR)
<http://www.atsdr.cdc.gov/>
(last visited 29/10/01)

American Academy of Clinical Toxicology
<http://www.aactox.org/>
(last visited 29/10/01)

American Association of Poison Control Centers
<http://www.aapcc.org>
(last visited 29/10/01)

American Board of Forensic Toxicology
<http://www.abft.org/>
(last visited 29/10/01)

American College of Medical Toxicologists
<http://www.acmt.net>
(last visited 29/10/01)

American College of Toxicology
<http://actox.org>
(last visited 29/10/01)

ASIATOX – Asian Society of Toxicology
<http://yes.snu.ac.kr/asiatox/>
(last visited 31/10/01)

British Toxicology Society

<http://www.thebts.org>

(last visited 20/10/01)

Canadian Network of Toxicology Centers

<http://www.uoguelph.ca/cntc/>

(last visited 29/10/01)

Centre d'Ecologie et de Toxicologie de l'Industrie Chimique Européene

<http://www.ecetic.org>

(last visited 13/02/02)

European Association of Poison Centres and Clinical Toxicologists

<http://www.eapcct.org/>

(last visited 29/10/01)

EUROTOX – Association of European Toxicologists and European Societies of Toxicology

<http://www.eurotox.com/>

(last visited 29/10/01)

Genetic Toxicology Association

<http://www.ems-us.org/gta/>

(last visited 29/10/01)

IUPAC – International Union of Pure and Applied Chemistry

http://www.iupac.org/dhtml_home.html

(last visited 29/10/01)

International Union of Toxicology (IUTOX)

<http://www.who.int/ina-ngo/ngo/ngo138.htm>

(last visited 29/10/01)

ALATOX - Latin American Association of Toxicology

<http://www.toxicology.org/iutox/iutoxms/memsoc.html#mems25>

(last visited 13/02/02)

London Toxicology Group

<http://londontox.org>

(last visited 29/10/01)

National Toxicology Program

<http://ntp-server.niehs.nih.gov>

(last visited 31/10/01)

Sociedade Brasileira de Toxicologia

<http://www.sbtox.org.br/>

(last visited 31/10/01)

Society for Chemical Hazard Communication

<http://schc.org>

(last visited 31/10/01)

Society of Environmental Toxicology and Chemistry (SETAC)

<http://www.setac.org/about.html>

(last visited 31/10/01)

Society of Toxicology, USA

<http://www.toxicology.org>

(last visited 31/10/01)

Society of Forensic Toxicologists (USA)

<http://www.soft-tox.org/>

(last visited 31/10/01)

Society of Toxicologic Pathology (USA)

<http://www.toxpath.org/>

(last visited 31/10/01)

Swiss Society of Pharmacology and Toxicology

<http://www.swisstox.ethz.ch>

(last visited 31/10/01)

Teratology Society

<http://landaus.com/teratology>

(last visited 31/10/01)

The International Association of Forensic Toxicologists (TIAFTnet)

<http://apf.cbft.unipd.it/tiaft/info/tiaftnet.html>

(last visited 31/10/01)

Toxicology Forum

<http://www.toxforum.com>

(last visited 31/10/01)

Toxicological History Society

Grand Rapids, Michigan, USA.

World Federation of Associations of Clinical Toxicology Centres and Poison Control Centres

<http://www.who.int/ina-ngo/ngo/ngo165.htm>

(last visited 31/10/01)

Bibliographies and reading lists:

List of current toxicology literature, by Eugene Kisly and Victor Kisly, in association with Amazon.com

http://www.arkanar.minsk.by/medicine/167/Pharmacology_Toxicology_index.htm

(last visited 26/10/01)

Course listings:

British Toxicology Society, Training in Toxicology

www.thebts.org/info/pages/training.html

(last visited 7/2/02)

California University, Riverside, Environmental Toxicology Graduate Program

<http://cnas.ucr.edu/~etox/courses.html>

(last visited 1/11/01)

Central Lancashire University, Centre for Toxicology, Courses

<http://www.uclan.ac.uk/research/centre/old/toxic/courses.htm>

(last visited 1/11/01)

Finnish Society of Toxicology, Forthcoming Congresses and Courses in Toxicology

<http://www.uta.fi/fst/fort.htm>

(last visited 1/11/01)

Toronto University, Institute for Environmental Studies, Toxicology Courses

<http://www.utoronto.ca/env/tox/course.htm>

(last visited 1/11/01)

Internet directories, subject gateways, virtual libraries:

Amazing Environmental Organisation Web Directory

<http://www.webdirectory.com/>

(last visited 31/10/01)

Directory of Sites in Occupational and Environmental Health – personal listing by Raymond Agius, Professor of Occupational and Environmental Health at the University of Manchester

<http://www.agius.com/hew/links>

(last visited 26/10/01)

HealthWeb - Toxicology

<http://healthweb.org/>

(last visited 31/10/01)

Open Directory Project - Toxicology

<http://dmoz.org/Science/Biology/Toxicology>

(last visited 26/10/01)

Medical Matrix – Toxicology

http://www.medmatrix.org/_SPages/Toxicology.asp

(last visited 31/10/01)

OMNI Toxicology Listing

<http://omni.ac.uk/browse/mesh/detail/C0040541L0040541.html>

(last visited 31/10/01)

Toxicology Online Resource Directory

<http://www.toxicologyonline.com/directory/xcdirectory.asp>

(last visited 24/10/01)

Yahoo! Toxicology

<http://asia.dir.yahoo.com/Health/Medicine/Toxicology>

(last visited 26/10/01)

Libraries and information services:

Drug and Poisons Information Service, Leeds

<http://www.ukdipg.org.uk/leeds.htm>

(last visited 31/10/01)

European Monitoring Center for Drugs and Drug Addiction (EMCDDA)

<http://www.emcdda.org>

(last visited 29/10/01)

Forensic Science Service Library

Central Research and Support Establishment, Home Office, Aldermaston, Reading, Berkshire

Institute of Occupational Medicine Library, Edinburgh

National Library of Medicine Toxicology and Environmental Health Information Program

<http://sis.nlm.nih.gov/Tox/ToxMain.html>

(last visited 31/10/01)

Romney House Library (This library serves Her Majesty's Inspectorate of Pollution)

Romney House, London

Royal Society of Chemistry Library and Information Centre

<http://www.rsc.org/lic/library.htm>

(last visited 31/10/01)

Scottish Poisons Information Bureau, Edinburgh

<http://www.show.scot.nhs.uk/spib/>

(last visited 31/10/01)

TNO BIBRA International Information Advisory Service

Carshalton, Surrey

http://www.bibra.co.uk/html/information_advisory_service.html

(last visited 31/10/01)

TOXBASE Poisons Information Service

<http://www.spib.axl.co.uk/>

(last visited 6/3/02)

Welsh National Poisons Unit, Cardiff

<http://www.uwcm.ac.uk/uwcm/llandough/ttc/wnpu.html>

(last visited 31/10/01)

Lists of abstracting and indexing services:

Silverplatter Abstracting and indexing Services T-Z

http://www.silverplatter.com/newFieldGuides/uigp/Abstracting_and_Indexing_S-6.htm

(last visited 31/10/01)

National Library of Medicine Abstracting and Indexing Tools in the Main Reading Room

http://www.nlm.nih.gov/services/onsite/abstracts_index.html#T

(last visited 31/10/01)

Lists of mailing lists:

MedList International - Toxicology

<http://www.medlist.co.uk/>

(last visited 31/10/01)

Lists of newsgroups or discussion lists:

Usenet Newsgroups in Environment, Waste Treatment and Toxicology

http://www.stir.ac.uk/departments/naturalsciences/Aquaculture/Fishing/enviro/env_news.htm

(last visited 31/10/01)

Forensic Toxicology Related Discussion Lists

<http://www.soft-tox.org/toxilinks/Toxilinks.asp?CatID=984118008>

(last visited 31/10/01)

Lists of expertise:

Expert Witness Network

<http://www.witness.net>

(last visited 26/10/01)

Literature guides:

Association of Information Officers in the Pharmaceutical Industry (AIOPI) and UK Online User Group (1980), A guide to sources in chemical toxicology, Sandwich, Kent, AIOPI

Copestake PT (2000), Information Resources for Toxicology, in General and Applied Toxicology (2nd edn.), Ballantyne B, Marrs TC, Syversen T (eds.), London, Macmillan, 471-483

Cosmides GJ (1990), Toxicological Information Series I, Toxicological Information, Fundamental and Applied Toxicology, 14, 439-443

Halton DM (1986), Computerized information resources in toxicology and industrial health – a review, Toxicology and Industrial Health, 2(1), 113-125

Hargreaves JM (1980), Literature sources in toxicology: a survey: BLRD report 5542, London, British Library

Kissman HM and Wexler P (1983), Toxicological Information. Annual Review of Information Science and Technology (ARIST), 18, 185-230

Kissman HM and Wexler P (1985), Toxicology Information Systems: A Historical Perspective, Journal of Chemical Information and Computer Science, 25, 212 – 217

Liverman CT, Ingalls CE and Fulco CE (1997), Toxicology and environmental health information resources for health professionals, Bulletin of the Medical Libraries Association, 85(4), 423-425

Morton LT and Godbolt S (eds.) (1992), Information sources in the medical sciences (4th edn.) London, Bowker-Saur

Robinson L (1989), Information sources in toxicology, paper presented at the British Toxicology Society annual meeting, September 1989, Newcastle, UK

Wexler P (1990), Toxicological Information Series II, A Survey of Toxicological Information, Fundamental and Applied Toxicology, 14, 649-657

Wexler P (1990), The Framework of Toxicology Information, Toxicology, 60, 67 – 98

Wexler P, Hakkinen PJB, Kennedy Jr. G, Stoss FW (eds.) (2000), Information Resources in Toxicology. (3rd Edn.), New York NY, Academic Press

Online hosts, lists of databases, and searchable sites:

Dialog Corporation

<http://www.dialog.com>

(last visited 31/10/01)

DIMDI

<http://www.dimdi.de>

(last visited 31/10/01)

Material Safety Data / Toxicity Databases

<http://www.agius.com/hew/links/toxic.htm>

(last visited 26/10/01)

MedNets Toxicology Databases

<http://www.mednets.com/stoicology.htm>

(last visited 26/10/01)

Poisonous Plant Databases, University of Maryland

<http://www.wam.umd.edu/~mct/Plants/poisonous.html>

(last visited 7/9/99)

Search Engines in Toxicology collected by Stéphane Babo

<http://www.cam.org/~babos/search.htm>

(last visited 31/10/01)

STN Databases

<http://info.cas.org/stnonline.html>

(last visited 31/10/01)

Toxnet

<http://toxnet.nlm.nih.gov>

(last visited 31/10/01)

Portals:

Environmental Toxicology Portal from Queensland Government

http://www.health.qld.gov.au/HealthyLiving/Environmental_Toxicology_P.htm

(last visited 26/10/01)

Toxicology Arena from Taylor Francis

http://www.toxicologyarena.com/toxicologyarena/home/tox_home.htm

(last visited 26/10/01)

Resource lists, recommended or core resources: Hazards/Chemical Safety

Chemical Safety Information, University of Oxford PhysChem Laboratory

<http://physchem.ox.ac.uk/MSDS>

(last visited 31/10/01)

Hazardous Materials and Safety, Guide to Reference Sources, Louisiana State University Libraries

<http://www.lib.lsu.edu/sci/chem/guides/srs103.html>

(last visited 31/10/01)

Web Guide to Chemical Safety Information, Japan National Institute of Health Sciences

<http://www.nihs.go.jp/GINC/webguide/index.html>

(last visited 31/10/01)

Resource lists, recommended or core resources: Environmental Toxicology

Environmental Health Information Service

<http://ehis.niehs.nih.gov>

(last visited 31/10/01)

Mississippi State University Environmental Toxicology Listing

<http://www2.msstate.edu/~rlcarr/toxicology/envtox.html>

(last visited 31/10/01)

Resource lists, recommended or core resources: Forensic Toxicology

Alan Barbour's Forensic Toxicology Page

<http://userzweb.lightspeed.net/~abarbour>

(last visited 31/10/01)

Society of Forensic Toxicologists' List of Forensic Resources

<http://www.soft-tox.org/toxilinks/default.asp>

(last visited 31/10/01)

Resource lists, recommended or core resources: General Toxicology

Academic Press, Toxicological Science Related Links

<http://www.academicpress.com/www/journal/tx/txli.htm>

(last visited 31/10/01)

American College of Medical Toxicology, Resources on the World Wide Web

<http://acmt.net/toxresor.htm>

(last visited 31/10/01)

Canadian Network of Toxicology Centers, WWW Links

<http://www.uoguelph.ca/cntc/links/links.shtml>

(last visited 31/10/01)

Colorado State University Library, Toxicology Source List

<http://manta.library.colostate.edu/research/tox.html>

(last visited 31/10/01)

Instem LSS Toxicology Links

http://www.instem-lss.co.uk/useful_links.htm

(last visited 24/10/01)

Maastricht University, Department of Pharmacology and Toxicology Links

http://farmaco0066.unimaas.nl/links/links_Toxic

(last visited 31/10/01)

MedPharm Toxicology Resources

<http://www.medfarm.unito.it/toxicol/toxicol1.html>

(last visited 31/10/01)

MedWebPlus Toxicology

www.medwebplus.com/subject/Toxicology.html

(last visited 31/10/01)

Oregon Health Sciences University Toxicology Information Resources

<http://www.ohsu.edu/croet/tox.html>

(last visited 31/10/01)

Rouen University Hospital World Wide Toxicology Sites

<http://www.chu-rouen.fr/ssf/toxfr.html>

(last visited 31/10/01)

San Diego State University Library, Principles of Toxicology

<http://infodome.sdsu.edu/research/guides/class/ph638a.shtml>

(last visited 31/10/01)

SciQuest Toxicology Research News

<http://www.sciquest.com/>

(last visited 31/10/01)

Society of Toxicology, USA, Sites of Interest

<http://www.toxicology.org/Information/siteofinterest/sites.html>

(last visited 31/10/01)

SRI International Links Providing Toxicology Informationt visited 31/10/01)

Western Ontario University, Pharmacology and Toxicology Resources

<http://www.pharmtox.med.uwo.ca/www/resource.html>

(last visited 31/10/01)

Resource lists, recommended or core resources: Genetic Toxicology

Human Genome and Toxicology Group

<http://www.hsrp.ornl.gov/taraweb/hgt.htm>

(last visited 31/10/01)

Resource lists, recommended or core resources: Health and Safety

Australian National Occupational Health and Safety Commission (NOHSC) Homepage

<http://www.nohsc.gov.au/OtherRelatedSites/>

(last visited 31/10/01)

Birmingham University, Institute of Occupational Health Links

<http://www.bham.ac.uk/IOH/links.htm>

(last visited 31/10/01)

Canadian Center for Occupational Health and Safety, Toxicology Resources

<http://ccohs.ca/Resources/toxicolo.htm>

(last visited 31/10/01)

National Institute of Occupational Health and Safety (NIOSH) Toxicology Web Sites
<http://www.cdc.gov/niosh/toxicol.html>
(last visited 31/10/01)

Resource lists, recommended or core resources: Medical Toxicology

The Toxikon Multimedia Project: Toxikon is a Medical Toxicology Consortium including Cook County Hospital, The University of Illinois Hospital, and Rush Presbyterian St. Luke's Medical Center, Chicago, IL
<http://toxikon.uih.uic.edu/toxikon>
(last visited 31/10/01)

Resource lists, recommended or core resources: Pesticides

EXTOXNET - the Extension Toxicology Network
<http://ace.orst.edu/info/extoxnet>
(last visited 31/10/01)

Resource lists, recommended or core resources: Plants and Herbs Toxicology

About.com's Herbs for Health Toxicology Links
<http://herbsforhealth.tqn.com/msubtoxic.htm>
(last visited 31/10/01)

Resource lists, recommended or core resources: Poisons Information

American Association of Poison Control Centers List
<http://www.aapcc.org/findyour.html>
(last visited 31/10/01)

Botulinum Web
<http://www.botulinumweb.com>
(last visited 31/10/01)

Karolinska Institute Library Poisoning Information Resources
<http://www.mic.ki.se/Diseases/c21.613.html>
(last visited 31/10/01)

Resource lists, recommended or core resources: Teratology

Clinical Teratology Web Site
<http://depts.washington.edu/~terisweb>
(last visited 31/10/01)

Teratology Society Links
<http://teratology.org/comm/commlinks.htm>
(last visited 31/10/01)

Webrings:

Forensic Entomology Web Ring
<http://nav.webring.yahoo.com/hub?ring=forent&list>
(last visited 26/10/01)

Secondary Resources

Data compilations, reference works, handbooks, encyclopaedias:

Derelanko MJ and Hollinger MA (eds.) (2001), CRC Handbook of Toxicology, Boca Raton FL, CRC Press

Gosselin RE, Smith RP, Hodge HC (1984), Clinical Toxicology of Chemical Products (5th edn.), Baltimore MD, Williams and Wilkins

Harris RL (ed.) (2001), Patty's Industrial Hygiene and Toxicology (5th edn.), New York NY, Wiley

Hildebrand S (ed.) (2001), NIOSH Pocket Guide to Chemical Hazards, Washington DC, DIANE Publishing Company

Lewis RJ (2000), Sax's Dangerous Properties of Industrial Materials, (10th edn.), New York NY, Wiley

O'Donoghue JL (ed.) (1985), Neurotoxicity of Industrial and Commercial Chemicals, Boca Raton FL, CRC Press

Shepard TH (ed.) (2001), Catalog of Teratogenic Agents (10th edn.), Baltimore MD, Johns Hopkins University Press

Sittig M (1992), Handbook of toxic and hazardous chemicals and carcinogens (3rd edn.), Park Ridge NJ, Noyes Publications

Thurman RG and Kauffman FC (3 volumes, published 1989-1995), Ethel Browning's Toxicity and Metabolism of Industrial Solvents, New York NY, Elsevier

Wexler P and Gad SC (eds.) (1998), Encyclopaedia of toxicology, New York NY, Academic Press

Dictionaries, glossaries:

Duffie JH, et al., Glossary of terms used in toxicology: IUPAC Recommendations 1993, Pure and Applied Chemistry, 1993, 65(9), 2003-2122

Eesa NM and Cutkomp LK (1984), Glossary of Pesticide Toxicology and Related Terms, Fresno CA, Thomson Publications

Elster P and Luderitz P (1985), Glossary of Preventive Toxicology, Berlin, Verlag Tribune

Gangolli S (ed.) (1999), The Dictionary of Substances and their effects, (2nd edn.), Cambridge, Royal Society of Chemistry

Khudoley VV, Pliss GB, Schramm T (1985), Chemical carcinogens and chemical carcinogenesis – a glossary, Arch. Geschwulstforsch, 55(4), 295-298

Hodgson E, Mallman RB, Chambers JE, (1998), Dictionary of Toxicology (2nd edn.), London, Macmillan

Lewis RA (1998), Lewis' Dictionary of Toxicology, Boca Raton, FL, Lewis Publishers/CRC Press

Thesauri:

Chemical Abstracts Thesaurus (CA Lexicon)

<http://www.cas.org/ONLINE/STN/STNOTES/stnote25.html>

(last visited 12/02/02)

Derwent Drug File Thesaurus (Derwent Publications)

http://www.derwent.com/userguides/lit_guide.html

(last visited 12/02/02)

DHSS-Data Thesaurus (UK Department of Health)

Aitchison J, Brewin PMR, and Cotton JE, London, 1985

EMTREE Thesaurus (Excerpta Medica)

http://www.silverplatter.com/newFieldGuides/embx/EMTREE_Thesaurus.htm

(last visited 12/02/02)

International Pharmaceutical Abstracts Thesaurus

American Society of Health System Pharmacists, Bethesda MA

Life Science Thesaurus, Cambridge Scientific Abstracts

<http://www.csa.com/helpV3/lscthes.htm>

(last visited 12/02/02)

MeSH Thesaurus (National Library of Medicine)

<http://www.nlm.nih.gov/mesh/meshhome.htm>

(last visited 12/02/02)

Pharmline Thesaurus (UK Drug Information Pharmacists Group)

www.pharmweb.net/pwmirror/uk/guys/pharmline/pharmline.htm

(last visited 12/02/02)

Toxisaurus (TOXicology TheSAURUS), Bioscience Information Service, US government
report no. PH 43-68-1329 (1970)

FAQs

Agency for Toxic Substances and Disease Registry – ToxFAQs

<http://www.atsdr.cdc.gov/toxfaq.html>

(last visited 7/2/02)

Online databases and databanks:

From Dialog host system (<http://www.dialog.com>)

Agricola

<http://library.dialog.com/bluesheets/html/bl0010.html>

(last visited 12/02/02)

Biobusiness

<http://library.dialog.com/bluesheets/html/bl0285.html>

(last visited 12/02/02)

Biosis

<http://library.dialog.com/bluesheets/html/bl0005.html>

(last visited 12/02/02)

CAB Abstracts

<http://library.dialog.com/bluesheets/html/bl0050.html>

(last visited 12/02/02)

CAB Health

<http://library.dialog.com/bluesheets/html/bl0162.html>

(last visited 12/02/02)

CA Search

<http://library.dialog.com/bluesheets/html/bl0399.html>

(last visited 12/02/02)

Embase

<http://library.dialog.com/bluesheets/html/bl0072.html>

(last visited 12/02/02)

Enviroline

<http://library.dialog.com/bluesheets/html/bl0040.html>

(last visited 12/02/02)

Environmental Bibliography

<http://library.dialog.com/bluesheets/html/bl0068.html>

(last visited 12/02/02)

Inside Conferences

<http://library.dialog.com/bluesheets/html/bl0065.html>

(last visited 12/02/02)

Life Science Collection

<http://library.dialog.com/bluesheets/html/bl0076.html>

(last visited 12/02/02)

Medline

<http://library.dialog.com/bluesheets/html/bl0154.html>

(last visited 12/02/02)

Merck Index

<http://library.dialog.com/bluesheets/html/bl0304.html>

(last visited 12/02/02)

NTIS

<http://library.dialog.com/bluesheets/html/bl0006.html>

(last visited 12/02/02)

Occupational Safety and Health (NIOSH)

<http://library.dialog.com/bluesheets/html/bl0161.html>

(last visited 12/02/02)

Pascal

<http://library.dialog.com/bluesheets/html/bl0144.html>

(last visited 12/02/02)

Pollution Abstracts

<http://library.dialog.com/bluesheets/html/bl0041.html>

(last visited 12/02/02)

RTECS (Registry of Toxic Effects of Chemical Substances)

<http://library.dialog.com/bluesheets/html/bl0336.html>

(last visited 12/02/02)

Scisearch

<http://library.dialog.com/bluesheets/html/bl0034.html>

(last visited 12/02/02)

Sedbase (Side effects of drugs)

<http://library.dialog.com/bluesheets/html/bl0070.html>

(last visited 12/02/02)

Toxline [as from October 2001, Toxfile]
<http://library.dialog.com/bluesheets/html/bl0156.html>
(last visited 12/02/02)

From Datastar host system (<http://ds.datastarweb.com>)
HSEline
<http://ds.datastarweb.com/ds/products/datastar/sheets/hsli.htm>
(last visited 12/02/02)

Chemical Safety Newsbase
<http://ds.datastarweb.com/ds/products/datastar/sheets/csnb.htm>
(last visited 12/02/02)

Medical Toxicology and Health
<http://ds.datastarweb.com/ds/products/datastar/sheets/dhmt.htm>
(last visited 12/02/02)

Hazardous Substances Databank
<http://ds.datastarweb.com/ds/products/datastar/sheets/hsdb.htm>
(last visited 12/02/02)

From TOXNET host system (<http://toxnet.nlm.nih.gov>)
Chemical Carcinogenesis Research Information System

ChemIDplus

DART/ETIC: Developmental and Reproductive Toxicology and Environmental Teratology
Information Center

GENE-TOX

EMIC: Environmental Mutagen Information Center

Hazardous Substances Data

Integrated Risk Information

NCI-3D: 2D and 3D information compiled by the National Cancer Institute, and augmented by
MDL

TRI: Toxics Release Inventory - reporting years 1995 - 1999

CD-ROM compilations

Dangerous Substances CD: consolidated text of EU legislation on classification, packaging
and labelling of dangerous substances
<http://www.ellispub.com/default.htm?cdrom/dangerous.htm>
(last visited 12/02/02)

Poisindex: quarterly product, detailed toxicology database for identification of substances
(industrial, domestic, pharmaceutical, plants, etc.) likely to cause poisoning, with information
on ingredients, symptoms, treatment. Searchable by brand, generic and scientific names,
botanical terms, slang terms, 'street names', etc.
<http://www.micromedex.com/products/poisindex>
(last visited 12/02/02)

Poisonous plants and fungi in Britain and Ireland
<http://www.rbgekew.org.uk/data/poisplts.htm>
(last visited 12/02/02)

Sax's Dangerous Properties 2000: health and safety information on over 20,000 substances, based on 10th edn. of Sax's Dangerous Properties of Industrial Materials

<http://www.chipsbooks.com/saxcd.htm>

(last visited 12/02/02)

Tomes: reference source on chemicals used in industrial settings, including toxicity, safety precautions, medical treatment for exposure, etc.

<http://www.micromedex.com/products/tomes>

(last visited 12/02/02)

Toxichem: information on hazardous chemicals which may be involved in chemical fires

<http://math.cd-rom-directory.com/cdrom->

[2.cdprod1/008/212.Toxichem.Hazardous.Chemical.Information.shtml](http://math.cd-rom-directory.com/cdrom-2.cdprod1/008/212.Toxichem.Hazardous.Chemical.Information.shtml)

(last visited 12/02/02)

Other –

ECDIN: Environmental Chemicals Data Information Network

<http://ecdin.etomep.net/>

(last accessed 31/12/01)

Reprotox Database, Reproductive Toxicology Center

<http://reprotox.org>

(last accessed 1/11/01)

Toxicology Abstracts (Cambridge Scientific Abstracts)

<http://www.csa.com/detailsV3/toxicology.html>

(last accessed 31/12/01)

Monographs, textbooks, treatises: general toxicology

Ballantyne B, Marrs TC, Syversen T (eds.) (2000), General and Applied Toxicology (2nd edn.), London, McMillan

Bingham E, Cohrssen B, Powell C (2001), Patty's Toxicology (5th edn.), New York NY, Wiley

Hayes AW (2000), Principles and methods of toxicology, (4th edn.), Washington DC, Taylor and Francis

Duffus JH and Worth HGJ (1996), Fundamental Toxicology for Chemists, Cambridge, Royal Society of Chemistry

Klaassen CD (ed.) (2001), Casarett and Doull's Toxicology: The basic science of poisons (6th edn.), New York NY, McGraw Hill

Lu FC (1996), Basic Toxicology: Fundamentals, target organs, and risk assessment (3rd edn.), Washington DC, Taylor and Francis

Marquardt H, Schoifer S, McClellan R, Welsch F (eds.) (1999), Toxicology, New York NY, Academic Press

Niesink RJM, de Vries J, Hollinger MA (1996), Toxicology: principles and applications, Boca Raton FL, CRC Press

Williams PL (2000), Principles of Toxicology; Environmental and Industrial Applications (2nd edn.), New York NY, Van Nostrand Reinhold

Monographs, textbooks, treatises: sub-disciplines and special topics

Acosta D (ed.) (2001), Cardiovascular Toxicology, Washington DC, Taylor and Francis

Basketter D et. al. (1999), Toxicology of Contact Dermatitis; Allergy, Irritancy and Urticaria, New York NY, Wiley

Chengelis CP et. al. (2001), Regulatory Toxicology, Washington DC, Taylor and Francis
Chiou GCY (ed.), (1999), Ophthalmic Toxicology (2nd edn.), Washington DC, Taylor and Francis

Choy WN (ed.) (2001), Genetic Toxicology and Cancer Risk Assessment, New York NY, Dekker

Peterson ME (2001), Small Animal Toxicology, Philadelphia PA, W.B. Saunders

Dukes MNG (ed.) (1996), Meylers Side Effects of Drugs (13th edn.), Amsterdam, Elsevier

Ellenhorn MJ and Barceloux DG (1997), Ellenhorn's Medical Toxicology: Diagnosis and Treatment of Human Poisoning (2nd edn.), Baltimore, MD, Williams and Wilkins

Ford MD, Delaney KA, Ling LJ and Erickson T (2000), Clinical Toxicology, Philadelphia PA, WB Saunders

Gardiner DE (ed.) (1999), Toxicology of the Lung (3rd edn.), Washington DC, Taylor and Francis

Gilman A, Hardman JG, Lee L (2000), Goodman and Gillman's Pharmacological Basis of Therapeutics (10th edn.) New York NY, McGraw Hill

Goldfrank LR et al. (1994), Goldfrank's Toxicologic Emergencies (5th edn.), Stamford CT, Appleton and Lange

Haddad LM, Shannon MW, Winchester JF (1998), Clinical Management of Poisoning and Drug Overdose (3rd edn.), Philadelphia, PA, WB Saunders

Harvey PW (ed.) (1999), Endocrine and Hormonal Toxicology, New York NY, Wiley

Hodgson E (2001), Introduction to Biochemical Toxicology (3rd edn.), New York NY, Wiley

Humphries DJ (1988), Veterinary Toxicology (3rd edn.), London, Balliere Tindell

Gad SC (2000), In Vitro Toxicology (2nd edn.), Washington DC, Taylor and Francis

Grant WM and Schuman JS, Toxicology of the Eye (4th edn.), Springfield IL, Charles Thomas

Olsen KR et al. (eds.) (1994), Poisoning and drug overdose (2nd edn.), Stamford CT, Appleton and Lange

Peterson ME (2001), Small Animal Toxicology, Philadelphia PA, W.B. Saunders

Roberts R (1999), Apoptosis in Toxicology, Washington DC, Taylor and Francis

Roder J (2000), Veterinary Toxicology, London, Butterworth Heinemann

Thorn I (ed.) (2000), Handbook of Toxicology and Ecotoxicology for the Paper Industry, Oxford, Blackwell

Viccellio P (ed.) (1997), Handbook of emergency toxicology (2nd ed.), Philadelphia PA, Lippincott-Raven

World Health Organisation (1998), IARC Monographs on the Evaluation of Carcinogenic Risk: summarised in Overall evaluation of carcinogenicity – an updating of IARC Monographs Volumes 1-42 Evaluation of Carcinogenic Risk, Geneva, World Health Organisation

Pharmacopias, formularies:

Parfitt K (ed.) (2002), Martindale: the complete drug reference (33rd edn. of Martindale's Extra Pharmacopaeia), London, Pharmaceutical Press

Reviews and summaries of progress:

Journals with a substantial number of reviews in toxicology

Mutation Research

Annual Review of Pharmacology and Toxicology

Environmental Health Perspectives

Critical Reviews in Toxicology

Food and Chemical Toxicology

Primary Resources

Course notes, training materials, syllabi:

Canadian Network of Toxicology Centers, Toxicology Study Guide

<http://www.uoguelph.ca/cntc/educat/guide/study.shtml>

(last visited 15/1/02)

Dundee University, Forensic Medicine courses overview

<http://www.dundee.ac.uk/forensicmedicine>

(last visited 15/1/02)

Edinburgh Centre for Toxicology Introduction to Applied Toxicology, online course

<http://www.bio.hw.ac.uk/edintox/page1.htm>

(last visited 15/1/02)

Hampton-Sydney College, Richmond, VA, Toxic Chemicals in Society syllabus

<http://cator.hsc.edu/~hjsipe/ch105syl.html>

(last visited 13/1/02)

King's College, London University, Lecture notes (overheads) on Marine Toxins, Department of Pharmacology and Therapeutics

<http://www.kcl.ac.uk/depsta/biomedical/pharmacology/jm308/halliday308.htm>

(last visited 15/1/02)

King's College, London University, Part-Time course in Toxicology course outline

http://www.kcl.ac.uk/kis/schools/life_sciences/health/pharmacy/courseinfo/mphil_pgrad/toxicol.html

(last visited 15/1/02)

National Library of Medicine, Washington DC, Tox Tutor toxicology tutorials.

<http://sis.nlm.nih.gov/Tox/ToxTutor.html>

(last visited 27/1/02)

North Carolina Wesleyan College Forensic Toxicology Course Notes.

<http://faculty.ncwc.edu/toconnor/425/425lect14.htm>

(last visited 15/1/02)

Oxford University, Laboratory Medicine Course.

<http://www.ndcb.ox.ac.uk/LMC>

(last visited 15/1/02)

Schonwald S (2001), Medical Toxicology; A Synopsis and Study Guide, Philadelphia PA, Lippincott Williams & Wilkins

Washington University, Home Page for Inhalation Toxicology course

<http://courses.washington.edu/envh514/index.html>

(last visited 15/1/02)

Conference proceedings:

Toxicology for the Next Millennium. Proceedings of a conference, September 20-23, 1999, Warrenton, Virginia, USA. Annals of the New York Academy of Sciences, 2000, 919, ix-xii, 1-324

Can rodent cancer tests predict for human cancers? Proceedings of a toxicology symposium, November 12-13, 1998, Little Rock, AR, Drug metabolism reviews, 2000, 32 (2) 119-266

North American Congress of Clinical Toxicology Annual Meeting – Abstracts, Journal of Toxicology – Clinical Toxicology, 2001, 39(N5), 473-568

Environmental and toxicology assessment of the situation before the 21st century,
Proceedings from the French Society of Toxicology Meeting, October 21-23, 1999, Arachon
(Palais des Congres),– Abstracts. Human and Experimental Toxicology, 2000, 19(8), 473-483

Bushnell PJ (2000), Report of the nineteenth annual meeting of the Behavioral Toxicology
Society, June 24-29, 2000. Neurotoxicology and Teratology, 2001, 23(1), 111-113

Data:

Toxic Release Inventory Data from US Environmental Protection Agency

<http://www.epa.gov/tri>

(last visited 15/1/02)

Diaries, web diaries:

The Poisoned World, National Poison Center, University of Sains, Malaysia.

<http://prn.usm.my/diary>

(last visited 13/1/01)

Journals:

From Science Citation Index Toxicology Grouping

Adverse Drug Reactions and Toxicological Reviews

Alcohol

Annals of Occupational Hygiene

Annual Review of Pharmacology and Toxicology

Aquatic Toxicology

Archiv fur Lebensmittelhygiene

Archives of Environmental Contamination and Toxicology

Archives of Toxicology

Biomarkers

Bulletin of Environmental Contamination and Toxicology

Cell Biology and Toxicology

Chemical Research in Toxicology

Chemical Speciation and Bioavailability

Comparative Biochemistry and Physiology C- Pharmacology, Toxicology and Endocrinology

Critical Reviews in Toxicology

Drug and Chemical Toxicology

Drug Safety

Ecotoxicology

Ecotoxicology and Environmental safety

Environmental and Molecular Mutagenesis

Environmental Carcinogenesis and Ecotoxicology Reviews

Environmental Toxicology and Chemistry

Environmental Toxicology and Pharmacology

Environmental Toxicology and Water Quality

Experimental and Toxicologic Pathology

Fluoride

Food Additives and Contaminants

Food and Agricultural Immunology

Food and Chemical Toxicology

Human and Experimental Toxicology

Immunopharmacology and Immunotoxicology

In vitro Toxicology

Industrial Health

Inhalation Toxicology

International Journal of Toxicology

Japanese Journal of Toxicology and Environmental Health

Journal of Analytical Toxicology

Journal of Applied Toxicology

Journal of Clean Technology, Environmental Toxicology and Occupational Medicine

Journal of Exposure Analysis and Environmental Epidemiology

Journal of Pharmacological and Toxicological Methods

Journal of Toxicology and Environmental Health Part A
Journal of Toxicology and Environmental Health Part B Critical Reviews
Journal of Toxicology - Clinical Toxicology
Journal of Toxicology - Cutaneous and Occular Toxicology
Journal of Toxicology - Toxin Reviews
Marine Environmental Research
Mutation Research - DNA Repair
Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis
Mutation Research - Genetic Toxicology and Environmental Mutagenesis
Mutation Research - Reviews in Mutation Research
Neurotoxicology
Neurotoxicology and Teratology
Pharmacology and Toxicology
Regulatory Toxicology and Pharmacology
Reproductive Toxicology
Teratogenesis, Carcinogenesis and Muraegenesis
Teratology
Therapeutic Drug Monitoring
Toxic Substance Mechanisms
Toxicologic Pathology
Toxicological Sciences (formerly Fundamental and Applied Toxicology)
Toxicology
Toxicology and Applied Pharmacology
Toxicology and Industrial Health
Toxicology in vitro
Toxicology Letters
Toxicology Methods
Toxicon
Veterinary and Human Toxicology
Xenobiotica

From Internet

Anil Aggrawal's Internet Journal of Forensic Medicine
<http://marygoldgupta.freeyellow.com/>
(last visited 24/1/02)

Internet Journal of Medical Toxicology
<http://www.ijmt.net/>
(last visited 24/1/02)

Email lists, newsgroups:

Certified Drug Recognition Experts (DRE's) and Drug-Impaired Driving
LISTSERV@HOME.EASE.LSOFT.COM

Forensic Medicine and Sciences Interest Group (FORENS-L)
MAILSERV@ACC.FAU.EDU

Forensic Toxicology Discussion Group (TIAFT-ML)
info@tiaft.org

The Expert List (Expert-L)
LISTSERV@LISTS.DIGILOGIC.COM

TOXLINK
TOXLINK@uci.edu

European Society of Toxicology in vitro (ESTIV-L)
LISTSERV@NIC.SURFNET.NL

Neurobehavioural Toxicology Discussion List (NBTOX-L)

listserv@listserv.navy.al.wpafb.af.mil

Graduate Student Discussion in Pharmacology and Toxicology (PSST)

psst@net.lut.ac.uk

Society of Environmental Toxicology and Chemistry (Triangle-setac)

majordomo@acpub.duke.edu

American College of Medical Toxicology (ACMTNet)

hmler@pamedsoc.org

Poison Net

listproc@ucdavis.edu

Ecotoxicology-L

listserv@listserv.vt.edu

Occupational and Environmental Medicine List

majordomo@list.mc.duke.edu

ToxList

TOXLIST-request@esc.syrres.com

TOXUPS

samcfadd@access.digex.net

Venom mailing list

majordomo@icomm.ca

Bionet.toxicology

www.bio.net/hypermail/toxicology

(last visited 15/1/02)

Regulations, legislation:

Control of Substances Hazardous to Health (COSHH) regulations 1999, which implement a European Community Council Directive, and are enforced by national legislation; in the UK by the Health and Safety at Work Act (1974)

<http://www.hse.gov.uk/hthdir/noframes/coshh>

(last visited 12/02/02)

Medicines Act (1968) Regulation 3144 (1994) (prescribes procedures for reporting adverse effects of drugs in the UK)

<http://www.mca.gov.uk>

(last visited 12/02/02)

Reports:

US National Toxicology Program Technical Report Series

http://ntp-server.niehs.nih.gov/Main_Pages/NTP_DOCS_PUBS.html

(last visited 12/02/02)

US Environmental Protection Agency R&D Report Series

<http://www.epa.gov/ebtpages/pollutants.html>

(last visited 12/02/02)

PB and AD Report Series from US National Technical Information Service (NTIS)

<http://www.ntis.gov/products>

(last visited 12/02/02)

European Commission Series

<http://dbserver.irptc.unep.ch:8887/metadb/owa/mt.BrowseInventory?iinvid=5221>

(last visited 12/02/02)

TNO BIBRA Toxicity Profiles

http://www.bibra.co.uk/html/toxicity_profiles.html

(last visited 12/02/02)

Progress Report from the Metals/Neurotoxicology Research Core, based at the University of Wisconsin, Milwaukee.

<http://www.niehs.nih.gov/centers/res-core/uwm-res2.htm>

(last visited 15/1/02)

Theses, dissertations:

From Dissertation Abstracts International

<http://library.dialog.com/bluesheets/html/bl0035.html>

Dertinger SD (2001), Influence of aryl hydrocarbon-mediated events on the genotoxicity of cigarette smoke constituents. PhD. University of Rochester, US

Lammon CAB (2001), The effect of dietary protein deficiency and chemically induced methylation inhibition on the developmental toxicity of inorganic arsenic. PhD. University of Alabama, US

George SM (2000), We want to know why our children are sick: A case study exploring toxic waste and health. MA. Boston College, MA

Chapter Six: Appendix

6.6a Query 1 - Contact toxicity of lavender oils in humans

Notes on query definition and relevance judgements

The search was taken to include all contact allergies and dermatitis, and skin sensitivity, whether induced occupationally or otherwise. Definition of relevance was generally straightforward, though in some cases it was necessary to consult the full paper to determine whether data relating to lavender oil was included.

Choice of databases

A range of databases, including Medline, CA Search, Biosis, SciSearch, Food Science and Technology Abstracts, Pascal, CAB, and Life Science Collection, were investigated. However, all except Toxline and Embase gave only a small number of non-unique items, and are therefore not included in the analysis, with the exception of Medline, which is included for comparison with Embase.

Initial search for commercial databases

The initial search logic used for the commercial online databases was:

LAVENDER (w) OIL or RN=8000-28-0

and

(TOXICITY and (SKIN or CONTACT)) or DERMATITIS or ALLERG?

This gave a small number of generally relevant references.

Initial search for TRACE database

The search logic used for the TRACE database was the Registry Number for lavender oil, plus abbreviated keys:

MN	(human)
LO	(local application)
SE	(sensitisation)

Search refinement

The failure analysis indicated a need to expand the substance indication by the addition of terms describing LAVENDER FRAGRANCE; use of broader terms for volatile or essential oils, needed to retrieve some items, gave reduced precision.

A wider set of terms for contact toxicity, e.g. SENSITIZATION and IRRITATION, were found to be needed for good recall, as shown in the final strategy..

Because some of the references retrieved were not descriptive of human toxicity, a profile of terms for this concept were added.

Final set of relevant hits and failure analysis

The final matrix of 22 relevant items is as follows:

Reference	Embase	Medline	Toxline	TRACE
Rademaker, 1994, 58	R	R	R	R
Savova, 1990, 33	R	N	N	R
Hirose, 1989, 81	R	N	S	R
Brandeo, 1986, 249	R	R	R	R
Rudzki, 1981, 167	R	N	N	T
Rudzki, 1977, 115	R	S	S	S,T
Opdyke, 1976, 443	R	N	N	R
Rudzki, 1976, 196	R	S	S	R
Schorr, 1974, 844	R	N	N	R
Rudzki, 1986, 115	N	N	R	T
Cockayne, 1997, 306	R	S	N	R
Katz, 1946, 46-1	N	N	N	R
Katz, 1946, 46-2	N	N	N	R
Le Coulet, 1964, 234	N	N	N	R
Nakayama, 1976, 307	N	N	N	R
Rostron, 1994, 453	N	N	R	R
Schaller, 1995, 143	S	S	S	R
Selvaag, 1995, 354	S	S	S	R
Fernandez, 1996, 184	S	S	S	R
Gossens, 1997, 179	S	S	S	R
Lee, 1990, 137	S	S	S	R
Vente, 1997, 187	S	S	S	R

R=retrieved

N=not present in file

S=not retrieved, no substance indexing

T=not retrieved, no toxic effect indexing

a) For the 18 items present in the three commercial online databases, the performance figures are as follows:

	Embase	Medline	Toxline
Retrieved	10	2	4
Recall (%)	56	11	22
Unique	8	0	2
Total hits	11	2	8
Precision (%)	91	100	50
Recall (idb)	63	18	31

A combination of Embase and Toxline is sufficient to find all the relevant material retrievable from these files, i.e. excluding the 6 items which cannot be found in any commercial database because of lack of indexing of substance. The performance of Embase is particularly good, comparing favourably with Medline in this case.

b) When the references present only in the TRACE database are added, the performance figures for the 22 references and 4 sources are as follows:

	Embase	Medline	Toxline	TRACE
Retrieved	10	2	4	19
Recall (%)	45	9	18	86
Unique	3	0	1	10
Total hits	11	2	8	23
Precision (%)	91	100	50	83
Recall (idb)	63	18	31	86

c) Causes of failure to retrieve relevant items over the 3 commercial databases are these:

- item not present 11
- substance indexing 24
- toxic effect indexing 0

Failures of substance indexing predominate, due largely to records describing data on many substances, which are not indexed individually, with only general terms being applied. Coverage is also a significant factor, largely due to references being in 'obscure' sources, and in one case to a Medline reference almost certainly destined for Toxline being too recent to have appeared there. The profile of toxicity terms used results in no failures in any database for this reason.

d) Causes of failure to retrieve relevant items over the 4 sources are these:

- item not present 29
- substance indexing 25
- toxic effect indexing 3

'Items not present' in the online databases when TRACE's contribution is included are a mix of older pre-online material and items from largely non-journal sources.

Notes on search strategy

The final search strategy used in the commercial databases was:

LAVENDER (w) OIL? or (LAVENDER (w) FRAGRANCE and OIL?) or RN=8000-28-0

and

(TOXICITY and (SKIN or CONTACT)) or DERMATITIS or ALLERG? Or SENSITIVITY or HYPERSENSITIVITY or SENSITIZATION or IRRITAT?

and

HUMAN or HUMANS or MAN or VOLUNTEERS or OCCUPATIONAL or PATIENTS

Little could be done to improve the effectiveness of this strategy. Its only failing was in the substance specification aspect, when records had only general indicators such as 'volatile oils' or 'essential oils', or no useful substance identification at all. To have used these terms would have decreased precision unacceptably, and still would have failed to find all items.

6.6b Query 2 - Toxicity of sage oils

Notes on query definition and relevance judgements

There are, in fact, several species of sage plant (*Salvia*). For this query, oil from any species was considered relevant. In some bibliographic records, it was not clear which form of sage oil was involved. All forms of toxicity to all organisms were included. Relevance judgements were straightforward.

Choice of databases

Five databases were found to be useful:

- Embase
- Medline
- Toxline
- Chemical Abstracts
- Biosis

A sixth, Life Science Collection, was included in the search process, but provided no useful information; it included one relevant item, but this could not be retrieved because of lack of substance indexing.

Initial search for commercial databases

The initial search logic was:

SAGE(w)OIL or SAGE(w)OILS or RN=8016-63-5 or RN=8022-56-8

and

TOXIC? or IRRITA? or MUTAGEN? or CARCINOGEN? or GENOTOX? or
TERATOGEN?

This search logic retrieved 13 items judged relevant from the five databases.

Initial search for TRACE database

The TRACE search logic was:

RN = 8016-63-5 or 8022-56-8 or (sage and oil#)

and

TO (toxicity)

Search refinement

Analysis of records for items present in, but not retrieved from, some of the files indicated that the search strategy needed to be refined to improve recall.

To describe the substances adequately, the term SAGE(w)ESSENTIAL(w)OIL? was added, while DERMATITIS, POISON?, and INTOXICATION were added to specify toxic effect. The search was repeated, and an additional 4 relevant items found. When this was examined, it was evident that the search logic required further extending, to allow for variant substance indexing. The inverted terms OIL?(w)SAGE and OIL?(w)ESSENTIAL(w)SAGE were added, as were terms describing botanical origins: SCLAREOL and (SALVIA and OIL?). This allowed two new relevant references to be retrieved from CA Search; three additional items were also retrieved from CA Search, two from Biosis and one from Medline, but none of these were new to the set as a whole.

Final set of relevant hits and failure analysis

The final matrix of 30 relevant items is as follows:

Reference	Biosis	Medl	Emb	Toxl	CAS	TRACE
Centini,1987,263	N	N	R	N	N	R
Millet,1982,149	N	N	R	N	N	R
Millet,1981,1485	S	R	R	R	N	N
Arditti,1978,371	N	N	R	N	N	R
Ford,1992,115s	R	N	N	R	R	R
BIBRA,1990,4	N	N	N	R	N	R
Zani,1991,237	R	R	R	R	R	N
BIBRA,1996,4	N	N	N	R	N	R
Rudzki,1986,115	S	S	S	R	N	N
Hirayama,1989,363	N	N	N	R	N	N
Ishidate,1984,123	S	N	S	R	R	R
Millet,1980,9	N	S	N	R	R	N
Dury,1986,29	N	N	N	N	R	N
Steinmetz,1980,34	N	N	N	N	R	N
Opdyke,1976,857	N	N	N	N	R	R
Opdyke,1974,897	N	N	N	N	R	R
Opdyke,1974,865	N	N	N	N	R	R
Which, 1990	N	N	N	N	N	R
Tokisk, 1985, 93	N	N	N	N	N	R
Gaworski, 1994, 409	S	S	S	S	R	R
Hachiya, 1987, 269	N	N	N	N	R	R
Heck, 1989, 257	N	N	N	N	N	R
Katz, 1946, 46	N	N	N	N	N	R
Lam, 1991, 660	S	N	N	N	S	R
Salvaag, 1995, 354	S	S	S	S	N	R
Urbach, 1931, 2030	N	N	N	N	N	R
Cockayne,1997,306	N	N	N	N	N	R
Malone,1991,123	R	N	R	N	R	R
Rangelov,1989,34	N	T	N	N	T	R
Rudzki,1976,196	N	S	S	S	N	R

R=retrieved

N=not present in file

S=not retrieved, no substance indexing

T=not retrieved, no toxic effect indexing

a) Performance figures for the set of 24 references present in commercial databases, though not necessarily retrievable from them, is as follows:

Reference	Biosis	Medl	Emb	Toxl	CAS
Retrieved	3	2	6	9	12
Recall (%)	13	8	25	38	50
Unique	0	0	3	4	7
Total hits	11	7	20	29	23
Precision (%)	27	33	30	32	52
Recall (ldb)	33	25	55	75	86

CASearch and Toxline, and to a lesser extent Embase, appear to be the 'best' commercial databases for this search.

To retrieve all 22 references which can be found from commercial databases requires a combination of CASearch, Toxline and Embase. Pairs of databases, for this search, are quite effective, retrieving as follows:

CASearch plus Toxline	17/22
CASearch plus Embase	16/22
Toxline plus Embase	13/22

b) Results including TRACE references (set of 30 retrievable references)

Reference	Biosis	Medl	Emb	Toxl	CAS	TRACE
Retrieved	3	2	6	9	12	22
Recall (%)	10	7	20	30	35	73
Unique incl	0	0	0	1	2	10
Total hits	11	7	20	29	23	26
Precision (%)	27	33	30	32	52	85
Recall (idb)	33	25	55	75	86	100

c) Causes of failure to retrieve relevant items present in any commercial databases are these:

- item not present 100
- substance indexing 25
- toxic effect indexing 2

Coverage is therefore clearly the predominant factor.

d) Causes of failure to retrieve relevant items present over all sources are these:

- item not present 107
- substance indexing 25
- toxic effect indexing 2

Notes on search strategy for commercial databases

The final search strategy used was:

SAGE(w)OIL? or SAGE(w)ESSENTIAL(w)OIL? or OIL?(w)SAGE or
OIL?(w)ESSENTIAL(w)SAGE or SCLAREOL or (SALVIA and OIL?) or RN=8016-63-5
or RN=8022-56-8

and

TOXIC? Or MUTAGEN? or CARCINOGEN? or GENOTOX? or TERATOGEN? or
IRRITA? or DERMATITIS or POISON? or INTOXICATION

The profile of truncated terms performed efficiently in retrieving all toxic effects; no item was missed in any file due to difficulty in retrieving the concept of toxicity. Specification of substance was more difficult, and files such as ChemName and Merck Index were used to check for other potentially useful terms and Registry Numbers. The inclusion of the less specific terms SCLAREOL and OIL? plus SALVIA led to considerable loss of precision, but was necessary for recall, as can be seen by the comparison of relevant / total hits for each database before and after the addition of these terms

	Biosis	Medl	Emb	ToxI	CAS
Before	0/0	1/1	5/5	9/15	6/7
After	3/11	2/6	6/20	9/29	12/23

The precision over the searches as a whole (ignoring overlap of hits between databases) drops from 21/28 (75%) to 32/89 (36%), while, as noted above, no additional relevant material was added to the set. This suggests that there is, in fact, no more to be found, and hence the conclusions on relative databases performance are valid. It is also an illustration of the dilemma facing the searcher; how far should search logic be 'stretched', in the attempt to maximise recall, at the expense of time and resources.

6.6c Query 3 - Acute toxicity of angelica

Notes on query definition and relevance judgements

'Acute toxicity' was taken to mean any harm resulting from a single dose or short-term exposure. It was assumed to relate either to accidental / occupational / clinical trial exposure in humans, accidental exposure in mammals (domestic or farm animals) or toxicity testing in mammals.

This definition proved somewhat imprecise in practice, as it was not clear whether certain effects, contact dermatitis for example, which are usually though not invariably associated with acute exposure, should be specifically included. It was decided to search simply for the 'acute' concept, regardless of type of toxicity.

'Angelica' similarly proved a difficult concept to define with precision, since it does not correspond to a single chemical substance, or group of substances. It is commonly taken to refer to extracts from any parts of any of the umbelliferous plants of the genus *angelica*, though other definitions are more exact; the Merck Index, for example, defining angelica as the fruit or root of the plant species *Angelica archangelica*. There are also specific chemical substances, e.g. angelic acid, angelica lactone and imperatoxin, which are derived from angelica plant sources. Finally angelica extracts form components of a considerable variety of oriental, specifically Chinese and Japanese, medicines, as well as some Western medicines, e.g. Friar's Balsam.

Given the difficulty of making a precise definition, the pragmatic choice was to include any substance noted in the primary document as being derived from any angelica species. Full recall would have required an identification of all substances derived from the genus, and an identification of all medicines from whatever tradition, incorporating them, and inclusion of all these terms in a search strategy.

Relevance judgements, given the pragmatic definitions noted above, were straightforward.

Choice of databases

The final set of databases used was:

- Biosis

- CA Search
- Medline
- Toxline
- Embase

CA Search did not give any useful material with the final search strategy adopted, but has been included for comparison.

A wider variety of databases was initially investigated, including Scisearch and International Pharmaceutical Abstracts, but none added any significant amount of material, nor anything unique.

Initial search for commercial databases

The initial search logic in the commercial online databases was:

ANGELICA

and

TOXICOLOG? or TOXICITY or POISON?

and

ACUTE

Initial search for the TRACE database

The search on the TRACE database used the free-text term ANGELICA? with keywords

MN (human) or MA (mammalian)

and

TO (toxicity)

and

AC (acute)

Search refinement

Failure analysis in the commercial online databases indicated that the term ANGELICAE, used somewhat inconsistently as an alternative to ANGELICA, should be added.

The term ACUTE was not used systematically in indexing. The terms SHORT(w)TERM and INTOXICAT? were therefore added. The term SINGLE in conjunction with DOSE,

ADMINISTRATION etc. was also used, but often in phrases such as 'single and repeated doses', so that a rather imprecise full-text search would have been necessary to include it.

Final set of relevant hits and failure analysis

Results for the 34 references judged relevant was as follows:

Reference	Biosis	CAS	Medl	Embase	ToxI	TRACE
Sethi, 1992, 239	R	S,T	S,T	R	R	N
Zhao, 1994, 71	N	N	R	N	R	N
Li, 1991, 560	N	N	R	N	R	N
Yanagisawa, 1995, 331	N	N	N	R	N	N
Kanitani, 1995, 299	N	N	N	R	N	N
Yoshinaga, 1995, 259	N	N	N	R	N	N
Iijima, 1995, 209	N	N	N	R	N	N
Iijama, 1995, 127	N	N	N	R	N	N
Yanigasawa, 1995, 107	N	N	N	R	N	N
Sanuki, 1986, 581	T	N	N	R	N	N
Ren-Sheng, 1985, 223	S,T	S,T	S,T	R	S,T	N
Chen, 1984, 23	N	N	N	R	N	N
DeJong, 1978, 82	N	N	N	R	N	N
Rudzki, 1976, 100	N	N	S	R	S	N
MBRL, 1992	N	N	N	N	R	N
Anon, 1990, 48	N	N	N	N	N	R
Huber, 1997, 115	T	T	T	T	T	R
IFA, 1997	N	N	N	N	N	R
Kim, 1991, 87	N	N	N	N	N	R
Knudson, 1988, 92	A	N	S	R	N	R
Lee, 1993, 89	A	N	A	A	A	R
Li, 1995, 392	A	N	A	A	A	R
Mei, 1991, 776	A	N	A	A	A	R
Minematsu, 1989, 249	R	N	N	S	N	R
Moran, 1980, 249	S	S	S	S	S	R
Opdyke, 1974, 1005	N	A	N	S,A	N	R
Opdyke, 1975, 723	N	A	N	S,A	N	R
BIBRA, 1993	N	N	N	N	R	R
Rudzki, 1976, 196	N	N	S,A	S,A	S,A	R
Suskind, 1979, 203	S,A	N	S,A	S	S,A	R
Tanaka, 1983, 937	R	N	A	R	A	R
Tanaka, 1971, 1098	T	T	T	T	T	R
Von Skramlik, 1958, 373	N	N	N	N	N	R
Zhongzhu, 1980, 321	N	N	N	N	N	R

R = retrieved

N = not present in file

S = no substance indexing

T = no toxicity indexing

A = no acute indexing

a) For the 29 references present in any commercial online database, though not necessarily retrievable from any, the performance figures were as follows:

	Biosis	CAS	Medl	Embase	Toxline
Retrieved	3	0	2	14	5
Recall (%)	10	0	7	48	17
Unique	1	0	0	12	2
Total hits	3	0	3	27	7
Precision (%)	100	n/a	67	52	71
Recall (idb)	23	0	13	56	29

If, for comparison, the performance figures are calculated against the 19 items which are retrievable from any online database, the recall figures become:

	Biosis	CAS	Medl	Embase	Toxline
Recall (%)	16	0	11	74	26

The good performance of Embase is evident in either case, though it requires three databases (Embase, Toxline and Biosis) for complete recall of the retrievable items. It is noteworthy that CA Search does not provide any useful material for this search; although several items are present, they lack substance or toxicity indexing. This unusually poor performance is due to the search lacking any true chemical substance specification, usually CA Search's strong point.

b) For the total 34 references, the performance figures are as follows:

	Biosis	CAS	Medl	Embase	Toxline	TRACE
Retrieved	3	0	2	14	5	19
Recall (%)	9	0	6	41	15	56
Unique	0	0	0	11	1	15
Total hits	3	0	3	27	7	19
Precision (%)	100	n/a	67	52	71	100
Recall (idb)	23	0	13	56	29	100

The TRACE database appears as slightly superior to the best commercial database, Embase, in terms of recall, and considerably superior for precision. A combination of TRACE and Embase would find 31 out of the 34 items.

c) Reasons for failure among the commercial databases are as follows:

- Item not present

- No substance indexing 24
- No toxicity indexing 17
- No acute indexing 38

The main problem is lack of coverage. This is in part due the 'grey literature' aspect, but also, for this query, particularly to the presence of material from oriental journals covering the medicinal literature of that area. Embase is particularly strong in covering this type of material, and in this search includes a series of 6 papers from the same researchers and published in the same journal (*Japanese Pharmacology and Therapeutics*), which are not included in other services.

The lack of substance indexing is due entirely to the omission of specific substances, rather than to problems with the 'angelica' terminology.

Toxic effect specification was a particular problem in this query, partly due to its complete absence, e.g. in items reviewing all aspects of classes of medicine or cosmetic, and partly due to the difficulties in specifying acute exposure noted earlier.

d) Reasons for failure over all the databases are as follows:

- Item not present 59
- No substance indexing 24
- No toxicity indexing 17
- No acute indexing 38

Notes on search strategy

The search strategy proved reasonably effective, given the difficulty of defining with precision the two concepts involved: angelica and acute toxicity.

As noted above, improved recall could have been obtained by including terms for individual substances which may be derived from angelica plants, and conversely by adding terms for western and oriental medicinal preparations which include it. This, however, would have greatly increased the time and effort required for the search, and would have introduced a good deal of irrelevance.

Inclusion of terms for specific toxic effects which are usually, though not invariably, associated with acute exposure, e.g. contact dermatitis and LD50, could have improved recall, though again with loss of precision. Similarly, ambiguous terms such as 'subchronic' might have given added recall, at the probable expense of precision.

6.6d Query 4 - Carcinogenicity of chloro-cresols

Notes on query definition and relevance judgements

Carcinogenicity was defined as being the occurrence, or otherwise, of tumours in humans or any experimental species, or as other forms of data, such as mutagenicity or epidemiology, where specific conclusions on carcinogenicity were drawn by the authors.

Chloro-cresols were defined as compounds containing a single cresol ring, substituted with between 1 and 4 chlorine atoms; this gives a finite number of compounds, and is therefore not a true substructure search, which would be open-ended. This meant that the search could feasibly be carried out in textual bibliographic databases, the structure search being achieved by use of the words chloro and cresol in various combinations, together with Registry Numbers found from chemical dictionary files. Databases allowing chemical substructure searching would have allowed a more direct approach, but would not necessarily have given greater recall.

Choice of databases

The initial Dialindex search suggested a set of 5 databases as being potentially useful, and these all gave useful material. They were:

- CA Search
- Toxline
- Medline
- Biosis
- Embase

The Chemname and Chemsearch nomenclature databases were also used to find chemical substance search terms.

Initial search for commercial databases

An initial simple search on the commercial online databases relied on a profile of free-text terms:

CHLOROCRESOL? or CHLORO(2W)CRESOL?

and

CARCINOGEN? or TUMORIGEN?

This gave a small set of largely relevant material for the failure analysis.

Initial search for the TRACE database

The TRACE search strategy consisted of a file code for chloro-cresols,

and

CA (carcinogenicity)

Search refinement

The failure analyses indicated that the search logic needed to be extended by improved chemical structure specification - both general and specific - and improved toxic effect specification.

The toxic effect specification was expanded by the addition of the free-text term CANCEROGEN? and the compound term NEOPLASMS—CHEMICALLY INDUCED in Medline and the Toxbib subfile of Toxline.

The generic specification of compound type was extended with the additional terms:

CHLOROMETHYLPHENOL?
CHLORO(2W)METHYLPHENOL?
METHYLCHLOROPHENOL?
METHYL(W)CHLOROPHENOL?

It also became clear that good recall would require the specification of individual substances by CA Registry Numbers. To identify these, the nomenclature files CHEMSEARCH and CHEMNAME - both available on Dialog - were consulted. CHEMSEARCH includes all 16 million substances in the CA Registry File, while CHEMNAME includes the smaller set of compounds indexed more than once in the CA bibliographic files.

The nomenclature files were searched both by synonym and by structural features - molecular formula, ring size and composition, etc. - to ensure good coverage. Of the relevant compounds identified, 44 were mentioned at least once in Chemical Abstracts during the relevant time period. In order to select those likely to be of sufficient commercial significance to have been tested for toxicity - and to simulate 'realistic' searcher behaviour - the 15 compounds occurring more than 10 times in Chemical Abstracts were chosen. Had the full set of substances been used, including those not mentioned in the secondary source, the search would have been equivalent to a 'true' substructure search.

Final set of relevant hits and failure analysis

The set of 24 relevant references is as follows:

Reference	CAS	Toxline	Medl	Biosis	Embase	TRACE
Sakamoto, 1986, 3030	R	N	N	N	N	T
Persson, 1990, 20	N	R	N	N	N	N
Bayer, 1992	N	R	N	N	N	N
Kauppinen, 1994, 262	S	R	S	S	S	R
Bueno, 1993, 289	N	R	N	S	S	R
Abrams, 1991, 463	N	R	S	S	N	S,T
GDCH, 1989	N	R	N	S	N	N
Sims, 1987, 601	S	R	N	S	N	N
Lynge, 1985, 259	N	R	R	R	R	N
Larsen, 1982, 127	N	R	N	N	N	N
Lynge, 1987, 427	N	R	R	R	R	N
BUA, 1993-1	N	N	N	N	N	R
BUA, 1993-2	N	N	N	N	N	R
CIR, 1995-2	N	N	N	N	N	R
COLIPA, 1983	N	N	N	N	N	R
CIREP, 1997	N	N	N	N	R	R
DF, 1991	N	N	N	N	N	R
BIBRA, 1992	N	R	N	N	N	R
Kogevinas, 1995, 396	N	N	S	N	S	R
Kogevinas, 1997, 1061	N	S	S	N	S	R
Lundberg, 1992, 24	N	N	N	N	N	R
Mesquita, 1993, 289	N	N	N	N	N	R
VCI, 1994	N	N	N	N	N	R

R=retrieved

N=not present in file

S=not retrieved, no substance indexing

T=not retrieved, no toxic effect indexing

a) For the 15 references present in any commercial online database, the performance figures were as follows:

	CAS	Toxline	Medl	Biosis	Embase
Retrieved	1	11	2	2	3
Recall (%)	7	73	13	13	20
Unique	1	9	0	0	1
Total hits	4	15	2	2	9
Precision (%)	25	73	100	100	33
Recall (idb)	33	92	33	29	43

The particularly good performance of Toxline for this query is notable, though CA Search and Biosis also give unique items.

b) For the total 24 references, the performance figures are as follows:

	CAS	Toxline	Medl	Biosis	Embase	TRACE
Retrieved	1	11	2	2	3	14
Recall (%)	4	46	8	8	12	58
Unique	1	6	0	0	0	10
Total hits	4	15	2	2	9	22
Precision (%)	25	73	100	100	33	64
Recall (idb)	33	92	33	29	43	88

The TRACE database gives best overall recall, whereas Toxline gives greater precision. Overall a combination of the in-house and commercial sources is necessary to give acceptable recall. A combination of Toxline and TRACE finds all except 1 relevant item.

c) The reasons for failure to retrieve, for the 15 references in commercial databases, are:

- Item not present 40
- No substance indexing 16

In this query, specification of toxic effect did not cause any loss of retrieval, in commercial databases.

d) The reasons for failure to retrieve over all the databases are these:

- Item not present 47
- No substance indexing 17
- No toxic effect indexing 2

Notes on search strategy

The final search strategy was:

CHLOROCRESOL? or CHLORO(2W)CRESOL? or
CHLOROMETHYLPHENOL? or CHLORO(2W)METHYLPHENOL? or
METHYLCHLOROPHENOL? or METHYL(W)CHLOROPHENOL? or
[set of 15 Registry Numbers]
and
CARCINOGEN? or TUMORIGEN? or CANCEROGEN? or
NEOPLASMS—CHEMICALLY INDUCED

No improvements in the toxic effect specification for recall could be seen. If human cancers had been the focus of the search, additional precision from the databases with MeSH headings might have been obtained by the addition of terms for SARCOMA-- and LYMPHOMA-- CHEMICALLY INDUCED.

This strategy was successful in retrieving all the records which had detailed substance indexing. Additional recall would be achievable only by using more general terms for substance - e.g. CHLOROPHENOLS.

It was notable that in several cases recall was reliant on use of specific substance Registry Number identification, since there was no feasible generic substance description provided. Registry Numbers are not applied consistently: in one record, the BIOSIS subfile in Toxline provided more Registry Numbers than the corresponding Chemical Abstracts record. Although Registry Numbers are provided in all the databases used for this query, their use is still very limited in some cases: for example, of the 15 numbers used in these searches, only 3 were present in Medline. As noted above, because this search involved a finite set of compounds which could be sought in the nomenclature files by molecular formula and similar descriptors, the text databases allow as good a search to be done as would be possible in substructure searchable files.

6.6e Query 5 - Teratogenicity of formaldehyde, papers published in 1995, 1996 or 1997.

Notes on query definition and relevance judgements

The time period restriction was made to control the number of potentially relevant references. Although teratogenicity refers specifically to malformations in an organism resulting from exposure to a toxin, the broader concept of reproductive toxicity, and the concept of embryotoxicity, were included in order to avoid losses due to incorrect indexing.

References specifying mixtures or resins were not considered relevant.

Choice of databases

Databases found to be useful were:

- Biosis
- Life Science Collection
- Medline
- Embase
- Toxline
- CA Search
- Occupational Safety and Health
- SciSearch

Of others tried, NTIS, SEDbase and Pollution Abstracts produced no relevant material, Enviroline contained one relevant item but it was not retrievable due to lack of substance indexing, and CAB had one relevant, and retrievable, item, and one irretrievable because of lack of indexing of teratogenic effect.

Initial search for commercial databases

The initial search strategy used was:

FORMALDEHYDE/DE, TI or RN=50-00-0

and

TERATOGEN? Or EMBRYOTOX? Or REPRODUCT?
plus the year limitation.

The term FORMALDEHYDE was limited to title and descriptor, since initial scoping searches had indicated that its occurrence in abstracts etc. led to irrelevance.

Initial search for the TRACE database

The TRACE strategy consisted of the registry number for formaldehyde

and

RE (reproductive effects)

and

year limitation

Search refinement

The failure analysis indicated the need to search for FORMALDEYDE in record elements other than title and descriptor for best recall. When this was done, one additional relevant item was found.

Final set of relevant hits and failure analysis

The final matrix of 37 relevant items is as follows:

Reference	Biosis	LifeSci	Medl	Emb	Toxl	CAS	OSH	SciS	TRACE
Odeigah,1997,141	R	R	R	R	R	T	N	R	R
Magras, 1996, 197	R	N	R	N	R	N	N	R	N
Senich...,1996,108	R	N	R	N	R	R	N	N	N
Kersmaekers,1995,325	R	R	R	R	R	S	S	R	R
McDiarmid,1995,829	S	N	S	N	S	N	R	S	N
Ahlborg,1995,957	S	S	S	S	R	N	R	N	N
Sanotskii,1997,17	S	N	S	N	R	R	N	N	N
Contreras,1995,163	N	N	N	N	R	N	N	N	N
Harris,1995,162	N	N	N	N	R	N	N	N	N
Ruehl,1995,335	S	N	N	N	R	N	N	N	N
Passman,1996,69	N	N	N	N	N	R	N	T	N
Petrelli,1996,110	N	N	R	R	R	N	N	N	N
PTCN, 1996, 13	N	N	N	N	N	N	N	N	R
FedReg, 1997, 55818	N	N	N	N	N	N	N	N	R
ATSDR, 1997	N	N	N	N	N	N	N	N	R
Barbaud, 1995,253	S,T	N	S,T	N	S,T	N	N	S,T	R
CIR, 1995, 204	N	T	N	T	T	T	T	T	R
DECOS, 1997	N	N	N	N	N	N	N	N	R
DoE, 1995, 79	N	N	N	N	N	N	N	N	R
DoE, 1995, 577	N	N	N	N	N	N	N	N	R
Dulskiene, 1996, 25	N	N	N	N	N	N	N	N	R
FedReg, 1998	N	N	N	N	N	N	N	N	R
EC, 1997, 212	N	N	N	N	N	S	N	N	R
Gephart, 1995, 1052	N	N	N	N	N	N	N	N	R
Hall, 1995, 281	S,T	S,T	S,T	T	S,T	S,T	N	S,T	R
HSE, 1996, 315	N	N	N	N	S	N	N	N	R
IARC, 1995, 405	T	N	N	N	R	N	N	N	R
PharmTher, 1996, 1	S,T	N	S,T	T	S,T	S,T	N	N	R
MRC, 1996, 381	N	N	N	N	N	N	N	N	R
NOHSC, 1997, 15	N	N	N	N	N	N	N	N	R
Pauste..., 1997, 217	T	T	T	T	T	T	N	T	R
Rodford, 1997, 281	S,T	N	N	S,T	S,T	S,T	N	N	R
SCF, 1995, 80	N	N	N	N	N	N	N	N	R
WHO, 1996, 473	S,T	N	N	N	S,T	N	N	N	R
WHO, 1996, 22	N	N	N	N	N	N	N	N	R
Witschi, 1997, 29	S	N	S	S	S	S	N	S	R
WorkAust, 1997, 7	N	N	N	N	N	N	N	N	R

R=retrieved

N=not present in file

S=not retrieved, no substance indexing

T=not retrieved, no toxic effect indexing

a) Performance figures for the set of 23 items retrieved from any of the commercial databases were as follows:

	Biosis	LifeSci	Medl	Emb	ToxI	CAS	OSH	SciS
Retrieved	4	2	5	3	11	3	2	3
Recall (%)	17	9	22	13	48	13	9	13
Unique	0	0	0	0	4	1	1	0
Total hits	48	5	10	10	61	6	5	12
Precision (%)	8	40	50	30	18	50	40	25
Recall (idb)	25	33	38	30	52	25	50	30

The overall superiority of the Toxline file, particularly in finding unique references, is evident. The best pair of databases is Toxline plus OSH or CAS, finding 12/13 relevant items.

b) Performance figures including the references present only in the TRACE database are as follows:

	Biosis	LifeSci	Medl	Emb	ToxI	CAS	OSH	SciS	TRACE
Retrieved	4	2	5	3	11	3	2	3	27
Recall (%)	11	5	14	8	30	8	5	8	73
Unique	0	0	0	0	3	1	1	0	24
Total hits	48	5	10	10	61	6	5	12	27
Precision (%)	8	40	50	30	18	50	40	25	100
Recall (idb)	25	33	38	30	52	25	50	30	100

c) Causes of failure to retrieve the 23 items retrievable from any commercial databases are these:

- item not present 91
- substance indexing 41
- toxic effect indexing 38

Coverage is therefore clearly the predominant factor. Failures in substance indexing generally occur with articles reviewing lists of compounds, which are not exhaustively indexed. Failures due to toxicity indexing become increasingly significant as the more 'difficult' material, not found in any database, are included in the analysis.

d) Causes of failure to retrieve items over all the databases are these:

- item not present 101
- substance indexing 41
- toxic effect indexing 38

Notes on search strategy

The final search strategy used was:

FORMALDEHYDE or RN=50-00-0

and

TERATOGEN? Or EMBRYOTOX? Or REPRODUCT?

plus the year limitation.

The term REPRODUCT? led to some lack of precision, since it retrieved toxic effects other than teratogenicity, e.g. cancers of the reproductive system; however, omitting it led to recall failures. Also, as noted above, greater precision was obtained by restricting the term FORMALDEHYDE to the title or abstract, but at the cost of recall. This is seen by the comparison of relevant / total hits for each database with the more restricted (TI and DE only) and fuller strategy.

	Biosis	LifeSci	Medl	Emb	ToxI	CAS	OSH	SciS
Restricted	4/12	1/1	3/7	3/8	11/47	3/6	2/4	2/5
Full	4/48	2/5	5/10	3/10	11/61	3/6	2/5	3/12

The search as a whole, over all databases, only gained one extra relevant item, by the adoption of the fuller strategy. Note the particular drop in precision, for little gain in recall, with Biosis (in which FORMALDEHYDE is frequently specified as a reagent in the abstract).

Apart from these factors, the search strategy was straightforward to construct and use.

6.6f Query 6 - Exotoxicity of ethylene glycol, papers published in 1990 - 1997

Notes on query definition and relevance judgements

The time period restriction was chosen to control the number of potentially relevant documents. Ecotoxicity was taken to mean any effect on the general environment, and species within it; excluding toxicity testing and epidemiological studies in humans. Relevance was sometimes difficult to judge because of this rather diffuse concept.

Choice of databases

A wide variety of databases appeared at first to provide information relevant to this query. Ultimately 5 were included in the final analyses:

- Biosis
- CAsSearch
- IAC Prompt
- Embase
- Toxline

Other databases which, though they provided some information, were not included in the final analyses because they provided relatively little additional material, and nothing unique, were CAB, Pollution Abstracts, NTIS and ABI/Inform and (from a different perspective) Magazine Index.

Initial search for commercial databases

The initial search strategy was:

ETHYLENE(w)GLYCOL or RN=107-21-1

and

ECOTOXIC? or ENVIRONMENTAL(w)TOXIC?

and

time period indicator

This produced 14 items judged relevant.

Initial search for the TRACE database

The TRACE strategy consisted of the registry number for ethylene glycol

and

EA environmental aspects

and

time period indicator

Search refinement

One improvement indicated by the failure analysis was the possible use of more general free-text terms, including wide proximity searching, for ecotoxicity, such as ECOLOGY, AQUATIC(2N)TOXIC?, ENVIRONMENT?(2w)TOXIC?, ENVIRONMENTAL(W)PROTECTION, ENVIRONMENTAL(W)POLLUTANT?, ENVIRONMENTAL(W)FATE, SOIL(W)POLLUT? And WATER(W)POLLUT?. However, this led to very high numbers of irrelevant hits. The only terms which provided useful material without an unacceptable loss of precision were ENVIRONMENTAL(w)HAZARD?, AQUATIC(w)TOXIC? and ENVIRONMENTAL(W)POLLUTANT, and these were incorporated into the final search logic. Conversely some items could only have been retrieved by use of a profile of individual species names. Use of concept codes and section headings did not give much increase in retrieval without considerable loss of relevance.

Alternative forms of chemical substance terms, e.g. 2-methoxyethanol, used in some relevant items, were also used, but produced no additional, relevant references.

It was notable that EMBASE used the 'drug toxicity' indicator for this kind of environmental material.

Final set of relevant hits and failure analysis

The final matrix of 42 relevant items is as follows:

Reference	Biosis	IAC	CAS	Toxl	Embase	TRACE
Horetskii,1995,419	R	N	N	R	N	N
Siljeholm,1997,S27	S	N	R	R	S	N
Chester,1996,191	N	N	R	N	N	N
Calleja,1994,173	S	N	R	S	R	N
van Leewen,1992,267	S	N	R	R	S	R
Anon,1991,N/A	N	R	N	N	N	N
Kahru,1996,147	S	N	T	T	R	N
Calleja,1994,69	S	N	T	R	R	N
Bantle,1991,549	N	N	S,T	R	N	N
Calleja,1994,923	S	N	N	R	S	R
Klaassen,1990,1615	S	N	N	R	N	N
Hall,1991,193	R	N	N	R	N	N
Verhaar,1992,471	S	N	R	R	S	N
Anon,1994,1	N	N	N	R	N	N
Philip,1995	S	N	N	R	N	N
Lilius,1994,47	S	N	E	R	E	R
Lilius,1995,299	S	N	E	R	R	R
Nielsen,1993	N	N	N	R	N	R
ATSDR,1993	N	N	N	N	N	R
Fed Reg,1996,25873	N	N	N	N	N	R
BUA,1991	N	N	N	R	N	R
Calleja,1993,330	N	N	N	N	N	R
CEC,1991	N	N	N	N	N	R
Dobson,1991,64	N	N	N	N	N	R
DOE,1995	N	N	N	N	N	R
DOE,1995	N	N	N	N	N	R
EPA,1991	N	N	N	N	N	R
EPA,1997	N	N	N	N	N	R
Greig-Smith,1991	N	N	N	N	N	R
Halle,1991,338	N	N	N	N	N	R
Hartwell,1995,1357	S	N	E	E	E	R
Howard,1990	N	N	N	N	N	R
Howard,1991	N	N	N	N	N	R
JETOC,1992	N	N	N	E	N	R
Lewan,1992,297	N	N	N	N	N	R
Pedersen,1997,1	N	N	N	N	N	R
Pillard,1995,311	E	N	E	E	E	R
Ren,1996,63	E	N	E	E	E	R
RCEM,1996	N	N	N	N	N	R
Sax,1990	N	N	N	N	N	R
Scow,1990	N	N	N	N	N	R
VCI,1992	N	N	N	N	N	R

R=retrieved

N=not present in file

S=not retrieved, no substance indexing

T=not retrieved, no toxic effect indexing

E=not retrieved, no environmental indexing

a) For the 23 items present in any of the commercial online databases, of which 4 were considered not retrievable by any sensible search logic, the performance figures are as follows:

	Biosis	IAC	CAS	ToxI	Embase
Retrieved	2	1	5	15	4
Recall (%)	9	4	22	65	17
Unique	0	1	1	8	1
Total hits	11	5	8	41	6
Precision (%)	18	20	63	37	67
Recall (ldb)	13	100	38	71	33

Toxline gives clearly the best performance of any single database, but there is a considerable spread in retrieval, with four databases needed for complete retrieval. A single unique (and apparently useful) reference is given by IAC Prompt, a business database which might not have been an obvious choice for a search of this kind. Precision is relatively high for CASearch and Embase. (It is worth noting that before the addition of the extra terms from the failure analysis both these databases gave 100% precision; loss of precision was countered by the addition only one, non-unique, reference in each database.)

b) For the 42 references retrieved from all sources, including the TRACE database, the performance figures are as follows:

	Biosis	IAC	CAS	ToxI	Embase	TRACE
Retrieved	2	1	5	15	4	29
Recall (%)	5	2	12	36	10	69
Unique	0	1	1	3	1	23
Total hits	11	5	8	41	6	30
Precision (%)	18	20	63	37	67	97
Recall (ldb)	13	100	38	71	33	100

c) Causes of failure to retrieve relevant items over all commercial databases are these:

- item not present 46
- substance indexing 18
- toxic effect indexing 4
- environmental indexing 14

While coverage is the predominant factor (particularly in view of the inclusion of the IAC database, which would not be expected to cover scientific material to any

extent), substance indexing poses a problem in this case. This is largely due to documents dealing with large numbers of substances, without individual indexing. The difficulties with definition of the 'environmental' aspect have already been noted.

d) Causes of failure to retrieve relevant items over all the databases are these:

- item not present 59
- substance indexing 18
- toxic effect indexing 4
- environmental indexing 14

Notes on search strategy

The final search strategy was that used from the first:

ETHYLENE(w)GLYCOL or RN=107-21-1
and

ECOTOXIC? or ENVIRONMENTAL(w)TOXIC? or ENVIRONMENTAL(w)HAZARD? or
AQUATIC(w)TOXIC? or ENVIRONMENTAL(W)POLLUTANT

and

time period indicator

Its deficiencies are those noted above; an inability to identify all the ecotoxicity material without an impractical level of irrelevance. In fact, this is less of a problem for retrieval than substance identification, but this, as noted above, is a problem of indexing, which cannot be overcome by any practicable search strategy.

It was also noted that the chemical fragmentation terminology used by Biosis caused additional lack of precision with this strategy, since diethylene glycol would be fragmented into di and ethylene, giving a match to the strategy above.

6.6g Query 7 - Aquatic toxicity of propoxur

Notes on query definition and relevance judgements

'Aquatic toxicity' was intended to encompass toxic effects of any kind on aquatic organisms, including fish, and to include both observations in the field and laboratory testing.

Choice of databases

7 databases were used in the final analyses:

- CAB
- CA Search
- Water Resources Abstracts
- Pollution Abstracts
- Life Science Collection
- Biosis
- Toxline

Initial search for commercial databases

The initial search statement was:

PROPOXUR OR RN=114-26-1

and

TOXICITY OR MORTALITY OR SAFETY

and

AQUATIC OR WATER OR FISH OR FISHES

Initial search for the TRACE database

The TRACE strategy consisted of:

Registry number

and

EA (environmental aspects)

Search refinement

An initial failure analysis indicated the need to improve the search logic for all three concepts within the search. The trade name BAYGON was added to the substance identification, since it was, in some records, the only substance identifier. POISON?

and SUBLETHAL? were added to the terms for toxic effect. The 'aquatic' concept was improved by the addition of several terms for freshwater, and by the term AMPHIBIAN?. The more general term 'water' caused retrieval of much irrelevant material, and had to be discarded.

This revised search logic was used in a further series of searches, which produced new material, which was in turn subjected to a failure analysis. This revealed the necessity for further augmentation of the 'aquatic' concept by the inclusion of terms reflecting particularly relevant fish species, and also more general terms for water pollution, though the latter led to some loss of precision. A revised search strategy led to no new relevant items.

Final set of relevant hits

The final matrix of 75 relevant items is as follows:

Reference	CAB	CAS	Water	Pollut	LifeSci	Biosis	Toxline	TRACE
Raj,1988,25	R	R	N	N	N	R	R	N
Liong,1988,147	R	N	N	N	N	N	N	N
Ku,1981,1	R	N	N	N	N	N	N	N
Assoc,1982,238	R	N	N	F	N	F	R	N
Colquhoun,1980,32	R	N	N	R	N	R	R	N
Muirhead,1973,479	R	N	N	N	N	S	R	N
Chen,1971,28	R	R	S	N	N	N	R	N
Katoka,1992,17	N	R	N	N	N	N	N	N
Heungens,1987,631	R	R	N	N	N	S	R	N
Areekul,1986,164	N	R	N	N	N	N	N	N
Yoshioka,1986,195	N	R	N	S	S	S	R	R
Tanaka,1984,1306	N	R	N	N	N	N	N	N
Lakota,1981,183	N	R	N	N	N	R	N	N
Nishiuchi,1981,31	N	R	N	N	N	N	N	R
Bogacka,1980,151	N	R	N	N	N	N	R	N
Lakota,1979,186	N	R	N	N	N	N	N	N
Nishiuchi,1979,178	N	R	N	N	N	N	N	N
Nishiuchi,1979,172	N	R	N	N	N	N	N	R
Nishiuchi,1979,166	N	R	N	N	N	N	N	N
Nishiuchi,1979,119	N	R	N	N	N	N	N	N
Nishiuchi,1979,36	N	R	N	N	N	N	N	N
Imada,1976,43	N	R	N	N	N	N	N	N
Groba,1979,33	N	R	N	N	N	N	R	N
Lakota,1978,197	N	R	N	N	N	R	T	N
Nishiuchi,1978,145	N	R	N	N	N	N	N	N
Nishiuchi,1977,108	N	R	N	N	N	N	N	N
Lejczak,1977,583	N	R	N	N	N	R	R	N
Baba,1977,51	N	R	N	N	N	N	R	N
Baba,1976,80	N	R	N	N	N	N	N	N
Alabaster,1969,29	N	R	S	N	N	N	N	R
Sievers,1995,9	N	N	R	R	N	N	N	N
Strickman,1985,133	R	R	R	N	N	S	R	N
Cain,1984,571	T,F	F	R	N	N	T,F	T,F	N
Singh,1984,63	N	F	N	R	R	N	N	N
Srivastava,1982,31	N	N	N	N	R	R	R	N
Singh,1992,189	T	F	N	F,T	F,T	R	T	N
Federle,1976,19	N	F	N	N	N	R	R	N
Estenik,1975,81	N	N	N	N	N	T	R	N
Sangha,1972,4650	N	S,F,T	N	N	N	N	R	N
Mel'nik,1993,117	S,F	N	N	N	N	S	R	N
Landa,1988	N	S	N	N	N	S	R	N
Holck,1987,407	F	F	N	F	F	F	R	N
Strickman,1985,NTIS	N	N	N	N	N	N	R	N
Singh,1991,121	R	N	N	F	R	N	N	N
Djuangsih,1993,283	N	R	S	S	S	S	S	N
Glierberman,1984,72	N	R	N	N	N	N	S	N
Nishiuchi,1983,228	N	R	N	N	N	N	N	N
Nishiuchi,1982,172	N	R	N	N	N	N	N	N
Nishiuchi,1979,48	N	R	N	N	N	N	N	N

Nishiuchi, 1979, 42	N	R	N	N	N	N	N	N
Nishiuchi, 1977, 140	N	R	N	N	N	N	N	N
Guilbault, 1972, 235	N	R	S	N	N	N	N	N
Singh, 1982, 115	N	F	N	N	R	N	N	N
Singh, 1997, 357	N	N	N	N	N	R	N	N
Boumaiza, 1979, 307	S	F	N	N	N	N	R	N
Kuhr, 1980, 251	N	S,F	N	N	N	S,F	R	N
Pentani, 1997, 963	S	R	N	N	N	S	S	R
Fisher, 1993, 1307	S	R	S	S	S	S	R	R
Kallander, 1997, 29	R	R	N	N	N	F	F	R
Butler, 1964, 5	N	N	N	N	N	N	N	R
CEC, 1991	N	N	N	N	N	N	N	R
EPA, 1991	N	N	N	N	N	N	N	R
Geiger, 1988	N	N	N	N	N	N	N	R
Johnson, 1979	S	N	N	N	N	N	N	R
Kemp, 1973	N	N	S	N	N	N	N	R
Kline, 1987, 539	N	N	S	N	N	S	S	R
Lundbergh, 1995, 56	N	N	N	N	N	N	N	R
MAFF, 1986	N	N	N	N	N	N	N	R
Pickering, 1989, 998	S	N	S	N	N	S	S	R
Roush, 1985, 667	N	S	N	N	N	S	S	R
Sanders, 1972	N	N	N	N	N	N	N	R
Sax, 1990, 42	N	N	N	N	N	N	N	R
Spehar, 1981, 1028	N	S	S	S	N	N	S	R
Vittozzi, 1991, 167	S	S	S	N	N	N	N	R
Willis, 1982, 267	N	S,T	N	N	N	S	T	R

R=retrieved

N=not present in file

S=not retrieved, no substance indexing

T=not retrieved, no toxic effect indexing

F=not retrieved, no fish/aquatic indexing

a) Performance figures for the 67 relevant items present in the commercial databases, though not necessarily retrievable from any, are as follows:

	CAB	CAS	Water	Pollut	LifeSci	Biosis	Toxline
Retrieved	10	37	3	3	4	9	23
Recall (%)	15	55	4	4	6	13	34
Unique	2	24	1	0	1	2	8
Total hits	30	46	6	8	12	13	58
Precision (%)	33	80	50	38	33	69	40
Recall (idb)	48	73	23	27	44	32	66

The particularly good performance, in terms both of recall and of unique items found, from CA Search is partly due to its (largely exclusive) coverage of a series of papers by a single author (Nishiuchi). Retrieval is otherwise quite spread, with the combination of 6 databases required to give complete recall.

b) Performance figures for the set of 75 items, including those retrieved only by TRACE, are as follows:

	CAB	CAS	Water	Pollut	LifeSci	Biosis	Toxline	TRACE
Retrieved	10	37	3	3	4	9	23	23
Recall (%)	13	49	4	4	5	12	31	31
Unique	2	20	1	0	1	2	8	16
Total hits	30	46	6	8	12	13	58	36
Precision (%)	33	80	50	38	33	69	40	64
Recall (idb)	48	73	23	27	44	32	66	100

In this case, both recall and precision from the TRACE database are bettered by those from commercial databases. The low recall from TRACE in this instance is a reflection of the dates of coverage, as items are included only from 1987 onwards. This search retrieves a significant body of material from earlier dates. The wide coverage of the commercial databases is seen to be useful in this query.

c) Causes of failure to retrieve relevant items over all commercial databases are these:

- item not present 292
- substance indexing 52
- toxic effect indexing 11
- fish/aquatic indexing 25

Coverage is by far the dominant factor, other retrieval failures being distributed among the three indexing concepts, though lack of substance indexing is more significant than the other two factors.

Failures due to substance indexing are those with documents dealing with tests of large numbers of substances which are not indexed individually, being covered by general terms such as 'pesticides'. Problems with toxic effect indexing were due to the use of very general terms such as 'effect', 'health', or 'quality'. These two problems could only be overcome by the use of a search strategy of such generality as to be impractical. Difficulties in retrieving the aquatic concept were largely due to the use of very specific terms, such as 'crayfish' or 'tadpoles', in databases which provided no hierarchical organism indexing; this problem could only have been overcome by the heroic expedient of including the species name of every aquatic species likely to be mentioned.

d) Causes of failure to retrieve relevant items over all the databases are these:

- item not present 344
- substance indexing 52
- toxic effect indexing 11
- fish/aquatic indexing 25

Notes on search strategy

The final search strategy was:

PROPOXUR or BAYGON or RN=114-26-1

and

TOXIC? or MORTALITY or LETHAL? or SUBLETHAL? or POISON? or SAFETY

and

FISH or FISHES or AQUATIC or AMPHIBIAN? or STREAM? or POND? or RIVER? or
FRESHWATER or FRESH(W)WATER or WATER(W)POLLUTION or
WATER(W)POLLUTANT? or OSTEICHTHYES or MALACOSTRACA or BC=FISH or
BC=FISHES or BC=OSTEICHTHYES or BC=MALACOSTRACA

For this search, in addition to the file-specific use of Registry Numbers for substance identification, Biosystematic Codes for fish species names were required.

The difficulty in adequately covering the concept of the aquatic environment is clearly shown by the lengthy profile of terms needed to encompass it; even this was not fully adequate as noted above.

6.6h Query 8 - Cases of chloracne due to exposure to dioxins

Notes on query definition and relevance judgements

The query implied exposure of humans, occupational or accidental, and required discussion, comparison or counting of individual cases. General discussions of mechanism, safety precautions etc., and simple statements of chloracne as a result of dioxin exposure, were not regarded as relevant.

Choice of databases

A wide selection of databases as initially tested, as Dialindex searches had indicated that they should produce useful material. Life Science Collection, CAB Health, Scisearch, Enviroline and Pollution Abstracts all gave some useful material, but in small quantity, and with nothing unique.

The final set of databases used was

- Biosis
- Embase
- CA Search
- Toxline
- Medline

Initial search for the commercial databases

The initial search logic for the commercial online databases was:

DIOXIN or RN=1746-01-6

and

TOXICITY or POISON?

and

CHLORACNE

and

CASE or CASES

and

date limitation

It was thought necessary to include the 'toxicity' concept to keep precision by restricting the scope to the specific exposure of humans to the substance. However,

the 'human' concept was not explicitly included: while it would have been simple to add this term to databases such as Medline, which tag the HUMAN concept, in other sources it would have been necessary to construct a profile of free-text terms - worker, occupation, etc. - with consequent complication of search logic and risk of loss of recall.

Initial search for the TRACE database

The search logic for the TRACE database was:

T1309 or T1383C (substance codes for dioxin)

and

TO (toxicity)

and

MN (human)

and

CHLORACNE or SKIN (free text terms)

Search refinement

The failure analyses indicated some refinements necessary in all aspects of the search, to increase recall.

The substance term DIOXIN was truncated to allow for items indexed only with the generic form of the term, and the synonym TCDD was added.

Specification of the toxicity concept was broadened by addition of the term ADVERSE EFFECTS, used as alternative to TOXICITY or POISONING in MeSH-indexed files, and by the concept code 22506 (Environmental and Industrial Toxicology) for Biosis; this last was necessary to get reasonable retrieval from Biosis, as 10 relevant items with this code assigned did not have any term indicating toxicity in title, abstract or keywording.

The MeSH term ACNE VULGARIS - CHEMICALLY INDUCED was added as an alternative to the more specific CHLORACNE.

Several terms were added as an alternative to CASE / CASES: INCIDENCE, EPIDEMIOLOG?, MEDICAL(w)RECORDS, COHORT, and FOLLOW(w)UP.

Final set of relevant hits

The final matrix of 38 relevant items is as follows:

Reference	Biosis	Emb	CAS	Medl	Toxi	TRACE
Needham, 1997, 225	R	R	N	C	N	A
Neuberger, 1997, 431	R	N	N	N	N	N
Assenato, 1989, 119	R	R	N	R	R	R
McConell, 1993, 699	C	R	C	C	R	R
Demers, 1993, 855	N	R	N	N	N	N
Schechter, 1992, 702	R	R	C	R	R	A
Bertazzi, 1992, 118	R	R	N	R	R	A
Schechter, 1991, 1921	A,C	R	A,C	N	A,C	N
Gawkrodger, 1991, 73	N	R	N	N	N	N
Bond, 1990, 423	N	R	N	R	R	R
O'Malley, 1990, 411	R	R	N	R	R	R
Rodriguez, 1991, 311	C	C	N	R	R	R
Neuberger, 1991, 325	R	T,C	C	R	R	S
Bertazzi, 1991, 5	R	T	C	R	R	N
IPCS/WHO, 1989, 409	N	N	N	N	R	C
Jansing, 1994, 91	R	R	N	R	R	N
Zober, 1994, 479	R	R	N	R	R	A
Zober, 1990, 139	R	R	N	R	R	A
Bond, 1989, 771	R	R	N	R	R	R
Bond, 1989, 121	R	R	N	R	R	A
Haring, 1997, 241	C	R	N	C	N	A
Coenraads, 1994, 569	N	R	N	N	C	N
Zober, 1997,249	A	R	A	A	N	N
Ott, 1993, 1	R	R	A,C	R	R	A
Collins, 1993, 7	N	R	N	R	R	A
Gough, 1991, 129	S	R	C	R	R	C
Lilienfeld, 1989,28	A	R	N	A	A	C
Caputo, 1988, 812	A	R	N	R	R	A
Guo, 1996, 223	N	N	R	N	N	N
Cheng, 1993, 81	R	T	N	R	R	A
Manz, 1991, 959	R	T	A,C	R	R	A
Mocarelli, 1991, 357	R	C	A,C	R	R	A
Barbieri, 1988, 29	C	C	N	R	R	A
ECETOC, 1992, 91	N	N	A,C	N	R	C
Anon, 1989, 329	C	N	N	C	C	R
Carpenter, 1991, 817	N ¹	N ¹	N ¹	N ¹	N ¹	R
Cheng, 1990, 300	C	N	N	N	C	R
DVA, 1991	N	N	N	N	N	R

¹ this is a letter to the editor; of the commercial databases, it is present only in SciSearch, though not retrievable, because it lacks any 'dioxin' indexing.

R = retrieved
 N = not in database
 S = no substance indexing
 T = no general toxicity indexing
 C = no 'case' indexing
 A = no chloracne indexing

a) For the 36 references present in any commercial online database, though not necessarily retrievable from any, the performance figures were as follows:

	Biosis	Emb	CAS	Medl	ToxI
Retrieved	17	23	1	21	24
Recall (%)	47	64	3	58	67
Unique	1	7	1	0	1
Total hits	24	35	1	32	62
Precision (%)	71	66	100	66	39
Recall (idb)	61	77	8	78	83

b) For the total 38 references, the performance figures are as follows:

	Biosis	Emb	CAS	Medl	ToxI	TRACE
Retrieved	17	23	1	21	24	10
Recall (%)	45	61	3	55	63	26
Unique	1	7	1	0	1	4
Total hits	24	35	1	32	62	11
Precision (%)	71	66	100	66	39	91
Recall (idb)	61	77	8	78	83	34

c) Reasons for failure among the commercial databases are as follows:

- Coverage 64
- Substance indexing 1
- Toxicity indexing 4
- Case indexing 29
- Chloracne indexing 14

CA Search, which provides a single unique item with 100% precision, appears to be very different in retrieval performance from the others. However, causes of failure, expressed as percentages, are very similar, with and without CA Search:

	with CAS	without CAS
Overage	57	53
Substance indexing	1	1
Toxicity indexing	4	6
Case indexing	26	28
Chloracne indexing	13	11

Coverage is the predominant factor. Problems with 'case' indexing and chloracne indexing follow in order. General toxicity and substance indexing pose little problem.

d) Causes for failure to retrieve relevant items over all databases are as follows:

• Coverage	73
• Substance indexing	2
• Toxicity indexing	4
• Case indexing	33
• Chloracne indexing	28

Notes on search strategy

The final search strategy used was:

DIOXIN? or TCDD or RN=1746-01-6

and

TOXICITY or POISON? or TOXICOLOG? or ADVERSE(w)EFFECTS or CC=22506

and

CHLORACNE or ACNE VULGARIS - CHEMICALLY INDUCED

and

CASE or CASES or INCIDENCE or EPIDEMIOLOG? or MEDICAL(w)RECORDS or COHORT or FOLLOW(w)UP

and

date limitation

The major limitation with the search logic is with the concept of 'case report'. The set of terms used gave reasonably good precision, with the inevitable failures in free text, such as 'in any case . . .'. While this concept could be omitted entirely, it would lead to greatly reduced precision. A compromise would have been to use CASE? within two or three words of CHLORACNE; this would however have reduced recall to a considerable extent; and recall is the greater problem in this search.

The only way to have increased recall significantly by modifying the CASE terms would have been by the inclusion of a profile of terms indicated this concept, e.g.

MEDICAL EXAMINATIONS
MEDICAL STUDY
CLINICAL STUDY
HISTORY or HISTORIES
SUBJECTS

and so on. These are by no means precise, and would increase recall only slightly at the expense of a considerable drop of precision.

The CHLORACNE concept again caused problems of recall, though not of precision. Some small gains in recall could have been made by including such variant forms as ACNEIC LESION (Biosis) and ACNE, CHLOR (CA Search).

Slightly increased retrieval across the databases - though adding no new items to the set - could have been gained by omitting the TOXICITY concept; again at the expense of precision.

Substance specification could not reasonably be improved, since the only item missed for this reason used only the term PESTICIDES.

6.6i Query 9 - Evidence of mortality in humans due to occupational exposure to styrene, documents published in 1995,1996 or 1997.

Notes on query definition and relevance judgements

An initial exploratory query, encompassing all harmful effects resulting from occupational exposure to styrene, generated too large a number of references, of varied nature, for careful analysis. The query was therefore refined to include the specific concept of evidence of human mortality. Any mention of mortality in populations occupationally exposed to styrene, as well as hard data on mortality rates, was judged relevant.

Choice of databases

A wide variety of databases were included in initial searches, as likely to be useful. Finally searching was concentrated on the six shown below. Other databases which produced some useful material, though no unique references, were CA Search, Enviroline, Pollution Abstracts, Environmental Bibliography, Cancerline, Embase and Occupational Safety and Health. The main six resources were:

- Biosis
- Life Science Collection
- Toxline
- Medline
- Healthstar
- Pascal

Initial search for the commercial databases

The initial search logic was:

STYRENE or RN=100-42-5

and

OCCUPATIONAL(w)EXPOSURE

and

MORTALITY

and

year restrictions

The term DEATH as an alternative to MORTALITY was found to produce too much irrelevance.

Initial search for the TRACE database

The TRACE search strategy consisted of:

the registry number

and

TO (toxicity)

MN (man)

OC (occupational exposure)

Specification of mortality is not possible, hence the relatively low precision from the TRACE database in this search.

Search refinement

Analysis of items judged relevant showed that, while the terms for substance specification and for mortality were adequate, additional terms for the concept of 'occupational exposure' were needed for good recall. Use of the uncoordinated term OCCUPTIONAL conversely led to poor precision. Eventually a profile of Ored terms was needed:

OCCUPATIONAL(w)EXPOSURE?
EXPOSURE? and INDUSTRY and WORKERS
OCCUPATIONAL(w)MEDICINE
OCCUPATIONAL(w)HEALTH
OCCUPATIONAL(w)DISEASE?

This still failed to identify every relevant item in the six sources being studied, but omission of this concept, use of broad concept codes / section headings, or inclusion simply of 'human' led to very poor precision.

Final set of relevant hits and failure analysis

The final matrix of 12 relevant items is as follows:

Reference	Biosis	LSC	Medl	HStar	ToxI	Pascal	TRACE
Welp,1996,623	R	N	O	N	R	R	R
Welp,1996,223	R	R	O	O	R	R	R
Welp,1996,499	R	R	R	R	R	R	R
Kolstad,1995,320	R	R	R	R	R	R	R
Cantor,1995,336	R	R	R	R	R	R	R
Delzell,1996,182	O	R	O	O	R	R	S
Macaluso,1996,190	O	R	R	R	R	R	R
Sans, 1995, 217	S	S	S	S	S	S	R
Selensky, 1995, 385	S	S	S	S	S	N	R
Anon, 1995, 20	N	N	N	N	N	N	R
Anon, 1996, 4	N	N	N	N	N	N	R
DECOS, 1997, 47	N	N	N	N	N	N	R

R=retrieved

N=not present in file

O=not retrieved, no indexing for occupational exposure

S=not retrieved, no substance indexing

a) For the 9 references present in the online databases, the performance figures are as follows:

	Biosis	LSC	Medl	HStar	ToxI	Pascal
Retrieved	5	6	4	4	7	7
Recall (%)	56	67	44	44	78	78
Unique	0	0	0	0	0	0
Total hits	7	6	7	7	20	7
Precision (%)	71	100	57	57	35	100
Recall (idb)	56	75	44	50	78	87

Precision figures are high. Toxline precision appears low, as noted earlier, since the same item is retrieved from several sub-files, but only counted as retrieved once. All online files give relatively high recall.

If only the 9 items retrieved from any online database are considered, both Toxline and Pascal provide 100% recall, and Pascal combines this with 100% precision.

b) The TRACE search gave 61 references, of which 11 were judged relevant, compared with 7 relevant items from the commercial databases; 6 of the 7 are in the TRACE set.

Including the TRACE results, the performance figures for the set of 12 items are:

	Biosis	LSC	Medl	HStar	ToxI	Pascal	TRACE
Retrieved	5	6	4	4	7	7	11
Recall (%)	42	50	33	33	58	58	92
Unique	0	0	0	0	0	0	5
Total hits	7	6	7	7	20	7	61
Precision (%)	71	100	57	57	35	100	18
Recall (idb)	56	75	44	50	78	87	92

c) Causes of failure to retrieve relevant items from commercial databases, are these:

- item not present 20
- substance indexing 11
- occupational exposure indexing 7

Unusually, failures in indexing exceed coverage as the reason for lack of retrieval; of course, the findings would be different if the several other databases which produced a very small amount material had been included in the analysis.

Lack of substance indexing and terms for the 'occupational exposure' concept are both causes of failure to retrieve relevant items; the 'mortality' concept presented no problem.

d) Causes of failure to retrieve relevant items over all databases are these:

- item not present 3
- substance indexing 12
- occupational exposure indexing 7

Notes on search strategy

The final search strategy was:

STYRENE or RN=100-42-5

and

OCCUPATIONAL(w)EXPOSURE? or (EXPOSURE? and INDUSTRY and WORKERS) or
OCCUPATIONAL(w)MEDICINE or OCCUPATIONAL(w)HEALTH or
OCCUPATIONAL(w)DISEASE?

and

MORTALITY

and

time period restriction

The simplicity of the search statements for the concepts of substance and toxic effect, by comparison with the complexity of that required for the occupational exposure is notable.

6.6j Query 10 - Acute effects of inhalation of toluene, items published in 1995, 1996 or 1997.

Notes on query definition and relevance judgements

It was assumed that this query implied toxicity in humans (accidental exposure or clinical study) or in mammalian species (accidental or experimental exposure).

The difficulties of specifying 'acute toxicity' have been noted above (angelica query). In this case, since the inhalation route was specified, effects such as dermatitis were not under consideration.

Relevance judgements were mostly straightforward, though in some cases there was scope for debate as to what constituted 'acute' toxicity.

Choice of databases

Dialindex searches, and initial exploratory searches, suggested that 6 databases might prove useful, and these were all carried through into the final searches.

The databases used were:

- Biosis
- Toxline
- Medline
- Life Science Collection
- Embase
- CA Search

Initial search for commercial databases

The initial search strategy used in the commercial databases was:

TOLUENE or RN=108-88-3
and

TOXICITY or TOXICOLOG? or POISON?

and

INHALATION

and

ACUTE or SHORT(w)TERM or INTOXICAT?

and

date limitation

Initial search for the TRACE database

The TRACE strategy consisted of:

the registry number
and
TO (toxicity)
AC (acute)
HA (inhalation)

Search refinement

The failure analysis revealed, more than in any other test query, multiple failures to retrieve items, due to the lack of appropriate indexing for two, three or even all four concepts, of those sought.

The failure analysis indicated a loss of recall due to lack of 'inhalation' specification; a series of free-text terms (INHALED, INHALANT, INHALING)) were added to improve recall. Other terms possibly useful in increasing recall - AIR POLLUTION, AIR POLLUTANT?, AIR LEVELS, VAPOR, VAPOUR, LUNG, RESPIRATORY, etc. - proved to generate too much irrelevant material to be feasibly added to the search strategy. They might have proved useful for a more restricted search, e.g. for human occupational exposure.

For Biosis, the concept codes 22502 (toxicology – general methods and experimental toxicology) and 22506 (environmental and industrial toxicology) were added, enabling the retrieval of 3 documents which did not have clear toxicology indexing.

Final set of relevant hlts and failure analysis

The final matrix of 38 relevant items is as follows:

Reference	Biosis	Toxl	Medl	LSC	Emb	CAS	TRACE
Fertikova, 1997,20	R	R	R	N	N	N	N
Tan, 1997, 138	R	R	R	N	N	N	N
Carder, 1997, 117	N	R	R	N	R	N	N
Frantik, 1996, 226	N	R	R	N	R	R	N
Ashikaga, 1995, 443	N	R	R	N	I	N	N
Stengard, 1995, 261	R	R	T	N	R	I,A	N
Pelekis, 1997, 79	A	A	A	R	A	A,I	R
Rahill, 1996, 640	R	A	A	R	T,A	A	R
Anon, 1997, 44	N	N	N	N	R	N	N
Dietert, 1996, 633	S,I,A	S	S	S	R	S,I,A	N
ATSDR, 1996	N	N	N	N	N	N	R
Cary, 1997, 455	A,I	A,I	A,I	N	A,I	A,I	R
CSA, 1996, 420	N	N	S,T,A,I	N	N	N	R
Craig, 1995, 919	S,A,I	S,A,I	N	N	A,I	S,A,I	R
DeJongh, 1996, 260	A	A	A,T	A,T	A	A,I	R
DF, 1996	N	N	N	N	N	N	R
DOE 1995	N	N	N	N	N	N	R
DOE 1995G	N	N	N	N	N	N	R
ECETOX, 1996	N	I	N	N	N	S,A,I	R
Edling, 1997, 171	I	I	I	I	I	I	R
EC, 1997, 212	N	N	N	N	N	S,A	R
FDA, 1997, 24302	N	N	N	N	N	N	R
FDA, 1997, 67377	N	N	N	N	N	N	R
Greenberg, 1997,1	A	A	A	A	A	A,I	R
Holmen, 1997, 317	N	N	N	N	N	N	R
HSE, 1996	N	A,I	N	N	N	N	R
Hutcheson, 1996, 85	A,I	A,I	A,I	N	A,I	S,A,I	R
ICH, 1996, 209	N	N	N	N	N	N	R
Manning, 1995, 59	A,I	A,I	A,I	A,I	A,I	A,I	R
Mujiser, 1996, 455	A,I	A,I	A,I,T	N	A,I	A,I	R
Niklasson, 1995, 351	I	I	I	I	I	A,I	R
NOHSC, 1997	N	N	N	N	N	N	R
Storrery, 1996, 471	I	I	I,T	N	S,I	I	R
Uaki, 1995, 229	A,I	A,I	A,I	A,I,T	A,I,T	A,I	R
Wang, 1996, 239	A,I	A,I	A,I,T	N	A,I	A,I	R
WHO,1996, 473	S,T,I,A	S,T,A,I	N	N	N	N	R
WHO, 1996, 22	N	N	N	N	N	N	R
WILKINS-HAUG, 1997,145	A,I	A,I	A,I	N	A,I	A,I	R

R = retrieved

N= not present in database

S = no substance indexing

T = no toxicity indexing

I = no inhalation indexing

A = no 'acute' indexing

a) For the 28 references present in any commercial online database, though not necessarily retrievable from any, the performance figures were as follows:

	Biosis	Toxl	Medl	LSC	Emb	CAS
Retrieved	4	6	5	2	6	1
Recall (%)	14	21	18	7	21	4
Unique	0	0	0	1	2	0
Total hits	11	25	13	3	17	1
Precision (%)	36	24	38	67	35	100
Recall (idb)	20	24	23	22	29	5

No database performs well in recall terms, Biosis, Medline, Toxline and Embase being roughly equal.

Precision is generally poor, though CAsEarch achieves 100%. Embase and LSc provide unique references.

b) For the total 38 references, the performance figures are as follows:

	Biosis	Toxl	Medl	LSC	Emb	CAS	TRACE
Retrieved	4	6	5	2	6	1	30
Recall (%)	11	16	13	5	16	3	79
Unique	0	0	0	0	2	0	28
Total hits	11	25	13	3	17	1	32
Precision (%)	36	24	38	67	35	100	94
Recall (idb)	20	24	23	22	29	5	100

The TRACE database's 79% recall is far in advance of any commercial database's performance.

c) Reasons for failure among the commercial databases are as follows:

- not present in database 110
- no substance indexing 15
- no toxicity indexing 12
- no inhalation indexing 71
- no 'acute' indexing 72

Coverage is the major reason for failure in retrieval, but the problems with specification of 'inhalation' and 'acute' concepts are clear, and outweigh those associated with the substance and toxicity components.

d) Reasons for failure over all databases are as follows:

- not present in database 118
- no substance indexing 15
- no toxicity indexing 12
- no inhalation indexing 71
- no 'acute' indexing 72

Notes on search strategy

The final search strategy was:

TOLUENE or RN=108-88-3

and

TOXICITY or TOXICOLOG? or POISON? or Biosis cc=22501 or cc=22506 [cc only for Biosis]

and

INHALATION or INHALANT or INHALED or INHALING

and

ACUTE or SHORT(w)TERM or INTOXICAT?

and

date limitation

It is clear that retrieval is in many respects poor, and the strategy could have been augmented in various way to improve recall for the toxicity and inhalation concepts.

- For the toxicity concept, the MeSH term ADVERSE EFFECTS, and one or more Biosis concept codes could have been added.
- For the inhalation concept, terms such as AIR POLLUTION, AIR POLLUTANTS, AIR LEVELS, VAPOUR, VAPOR, RESPIRATORY, AEROSOL, BREATH, ATMOSPHERE etc. could have been added. Inhalation is implied by phrases such as 'solvent exposure' or by phrases such as 'parts per million', but these, while they may be understood in the text by someone with reasonable subject knowledge, are not easy to incorporate in a search strategy.

However, as the failure analysis showed, these additions would have improved recall only slightly (particularly given the large incidence of failure for retrieve items for 2, 3 or even 4 reasons) at the expense of a considerable drop in precision.

The substance concept could not really be improved, recall failures being due to lack of any specific substance identification. The acute concept was largely implicit; the only change which could have been brought about was to add very general terms such as SINGLE, which would have added slightly to recall, but greatly reduced precision.

It seems inevitably, therefore, that this type of search in the commercial databases will be characterised by relatively poor precision, due to lack of consistent indexing for route of administration, and type of exposure, with long sets of items to be examined for relevance.

6.10a Databank evaluation

The following databanks were investigated:

- **RTECS Registry of Toxic Effects of Chemical Substances**
A comprehensive database of 'basic toxicity information' for over 100,000 compounds.
- **CHEMTOX**
A comprehensive collection of data on 6,500 'regulated toxic and hazardous substances'
- **DOSE Directory of Substances and Effects**
A compilation of essential data on 4,000 substances, providing a guide to 'their impact on humans, animals and the environment'
- **PFF Pesticide Fact File**
Provides information on the active components of agrochemical products
- **Merck Index**
A one-volume encyclopaedia of chemicals, drugs and biologicals, corresponding to the printed Merck Index
- **Beilstein**
Extensive collection of data on organic compounds, corresponding to the printed Beilstein Handbook
- **CHDC Chapman and Hall Chemical Database**
Source database for chemical identification and properties, including hazards and toxicity, corresponding to several printed chemical dictionaries
- **HSDB Hazardous Substances Databank**

Results are presented below in terms of: coverage; toxicity data present; extent of data; and usefulness of data.

Coverage: presence of a record for the substance in each source was as follows:

	RTECS	CHEMTOX	DOSE	PFF	Merck	Beil	CHDC	HSDB
lavender oil	P	-	-	-	-	-	-	-
sage oil	P	-	-	-	-	-	-	-
formaldehyde	P	P	P	-	P	P	P	P
ethylene glycol	P	P	P	-	P	P	P	P
propoxur	P	P	P	P	P	P	P	P
styrene	P	P	P	-	P	P	P	P
toluene	P	P	P	-	P	P	P	P
angelica	P	-	-	-	P	-	-	P
chlorocresol	P	P	P	-	-	P	P	P
dioxin	P	P	P	-	P	P	P	P

P = substance present in databank - = not present

As might be expected, the Pesticide Fact File has an entry only for propoxur, the one substance in the list marketed as a pesticide. RTECS is the only source to have entries for all 10 substances, and is the only one to include lavender oil or sage oil; HSDB includes the remaining eight substances. The other four files each have information

on seven compounds: Merck Index omits the chlorocresol, CHEMTOX, DOSE and CHDB omit angelica.

Toxicology data was present as shown.

	RTECS	CHEMTOX	DOSE	PFF	Merck	Beil	CHDC	HSDB
lavender oil	T	-	-	-	-	-	-	-
sage oil	T	-	-	-	-	-	-	-
formaldehyde	T	T	T	-	N	N	N	T
ethylene glycol	N	N	T	-	N	N	N	T
propoxur	N	N	T	T	N	N	N	T
styrene	N	T	T	-	N	N	N	T
toluene	T	T	T	-	N	N	T	T
angelica	T	-	-	-	N	-	-	N
chlorocresol	T	T	T	-	-	N	N	T
dioxin	N	T	T	-	T	N	T	T

T = substance present in databank, with relevant toxicology data

N = substance present in databank, but without relevant toxicology data

- = substance not present

In deciding whether relevant information was present, there were two possible points of doubt. For ethylene glycol, where evidence of ecotoxicity was being sought, CHEMTOX noted that the substance was listed as an 'environmental hazard'. For toluene, where acute inhalation toxicity data was being sought, the Merck Index provided a reference to a report of the acute toxicity of toluene. Although these two entries arguably provide some information, it was considered that it was not sufficient to be directly useful, and they have therefore been recorded as not providing relevant information.

With exception of PFF, which includes only one substance and provides relevant information for it, DOSE is the only databank to provide relevant information for all the substances it covers. HSDB provides information for 7/8, omitting acute toxicity data for angelica oil, CHEMTOX provides information for 5/7, missing the eco- and aquatic toxicity aspects, while RTECS, perhaps reflecting its 'basic toxicity' remit, provides relevant information for only 6/10.

The three 'chemical' files - CHDB, Merck, and Beilstein - perform relatively poorly in this respect, providing relevant information on only 2, 1 and 0 substances, out of 7 included in each case. This reflects their strong emphasis on laboratory and process chemistry, and on hazards and toxic effects directly associated with this. Thus CHDB includes information on chloracne as an acute effect of dioxin, as does Merck, and

also on acute toxicity of toluene inhalation - as noted above, Merck also has a reference to this.

Extent of information was assessed only for those four databanks which gave relevant information for more than half the queries: RTECS, CHEMTOX, DOSE, and HSDB.

For each of these sources, and for each query, an attempt was made to indicate the number of relevant 'information items'; numerical values, statements of toxic effect, etc.. While this is far from exact, and requires judgement as to what, for instance, is a separate statement, it gives a good indication of the extent of information provided.

For comparison, the number of bibliographic references found for the corresponding query in the earlier evaluation is also given. This is again far from exact, since the queries have been modified in some cases, as noted above, and the bibliographic searches had time period restrictions which are not a consideration for the databanks. Nonetheless, it gives a general impression of the relative amount of information.

	RTECS	CHEMTOX	DOSE	HSDB	bibl refs
lavender oil	1	-	-	-	22
sage oil	5	-	-	-	30
formaldehyde	21	11	2	3	37
ethylene glycol	N	N	12	10	42
propoxur	N	N	12	12	75
styrene	N	1	1	7	12
toluene	16	6	2	4	38
angelica	1	-	-	N	34
chlorocresol	7	2	2	3	24
dioxin	N	1	1	12	38

It is obvious that there is a wide variety in the extent of information available in each databank, across the queries. It is also evident that the amount of information to be found from these sources is much less than that from the bibliographic databases.

While it may be argued that the databanks provide selected and summarised information, and conciseness may be a virtue, it seems clear that the primary literature, accessible through bibliographic databases, will provide a much richer set of information, and that databanks can be used on as a convenient access to a summary of some of it.

Usefulness of information was assessed only for those four databanks which gave relevant information for more than half the queries: RTECS, CHEMTOX, DOSE, and HSDB.

RTECS provides highly structured, summarised and coded data, with literature references, under headings such as 'irritation data', and 'mutation data'. For example, an entry for sage oil under the 'toxicity effects data' reads:

orl rat LD50 2600 mg/kg FCTXAV 12,987, 1974

This can be 'translated' as:

route of administration:	oral
species:	rat
toxic effect:	lethal dose 50%
dose:	2600 mg/kg
journal reference:	Food and Cosmetics Toxicology, 1974, vol 12, p987

(the journal coden and full title are given at the end of the record)

This databank gives a rapid overview of the toxic effects produced, with numerical data, and allows consistent and complete access back to the primary literature.

There is no form of discussion or other form of context setting.

CHEMTOX contains a compilation of information from diverse sources and in varying styles of presentation, including some in RTECS format. As an example, the following information appeared in various places in the record for formaldehyde:

EPA SUPERFUND - Environmental Protection Agency
SARA 312 Categories

....
Chronic toxicity: reproductive toxin.

Reproductive Toxicity
orl-rat TDLo:168 mg/kg (1-21D preg) GISAAA 55(3),89,90

EFFECTS ON EMBRYO OR FETUS
Fetotoxicity(except death,e.g.,stunted fetus)

SPECIFIC DEVELOPMENTAL ABNORMALITIES
Craniofacial(including nose and tongue)

SPECIFIC DEVELOPMENTAL ABNORMALITIES
Musculoskeletal system
ipr-mus TDLo:240 mg/kg (7-14D preg) TJADAB 30(1),34A,84

There is a great deal of information present, including regulatory, legislative, safety precautions first aid instructions, etc., as well as toxicology itself. However, it is not

integrated, nor is any interpretative overview given. Links to the primary literature, i.e. the original sources for the statements made, are not always clear. While useful information is present, this source is likely to be of more use for regulatory and legislative information than for scientific toxicology.

DOSE records are carefully structured and integrated, with clear access to the original reference, and are presented in a more 'readable' format than RTECS or CHEMTOX, e.g. part of the record for formaldehyde:

TERATOGENICITY AND REPRODUCTIVE EFFECTS: Mice receiving up to 185 mg kg⁻¹ on days 6-15 of gestation showed no embryotoxic or teratogenic effect (21). Mice receiving the compound intravenously (100 microl of 37% formaldehyde solution) on day 16 of pregnancy developed foetuses that 24 days later demonstrated chromosome aberrations in cultured liver cells (22).

- ..
21. Tobe, M. et al Toxicology 1989, 56(1), 79-86.
22. Okui, T. et al Hokkaidoritsu Eisei Kenkyushoho 1989, (39), 110-12 (Japan.) (Chem. Abstr. 110, 210416b).

and for ethylene glycol:

ECOTOXICITY:

FISH TOXICITY: LC50 (14 day) guppy 8850 mg l⁻¹ (1). LC50 (96 hr) bluegill sunfish, rainbow trout, goldfish 27,500-41,000 mg l⁻¹ (2-4).

INVERTEBRATE and MICROBIAL TOXICITY: LC50 (96 hr) crayfish 91,400 mg l⁻¹ (2). EC50 (30 min) Photobacterium phosphoreum 620 ppm Microtox test (5). LC50 (48 hr) Daphnia magna 46,300 mg l⁻¹ (6). LC50 (48 hr) Ceriodaphnia dubia 25,800 mg l⁻¹ at 20 Deg C and 10,000 mg l⁻¹ at 24 Deg C (6).

BIOACCUMULATION: Bioconcentration factor in golden ide 10, and for Chlorella fusca 190 (7).

.....
.....

ENVIRONMENTAL FATE:

DEGRADATION: Biodegraded in aerobic systems using activated sludge and soil inocula. Degradation is almost complete in environmental conditions in <1-4 days (8). Completely degraded at a concentration of 2500 mg l⁻¹ within 12 days by methanogenic bacteria isolated from activated sludge (9). ThOD 1.26 mg l⁻¹ O₂; BOD(20) 0.36 mg l⁻¹ O₂ at 10 mg l⁻¹; BOD(20) 0.91 mg l⁻¹ O₂ at 10 mg l⁻¹ (10,11).

ABIOTIC REMOVAL: Reaction with photochemically produced hydroxyl radicals in the atmosphere, t_{1/2} (est.) approx. 24 hr (8,12). Treatment of water with ozone yields glycoaldehyde, glyoxal, glyoxalic acid and formaldehyde (13).

ABSORPTION: Adsorption by activated carbon 0.0136 g g⁻¹ carbon (14).

OTHER COMMENTS: Environmental fate reviewed (8).

HSDB contains summaries and extracts from a variety of sources, both standard texts and data compilations and journal articles, e.g. for styrene:

- Human Toxicity Excerpts - HTOX -

An elevated incidence of hematopoietic and lymphatic cancer has been reported for workers in the styrene-butadiene rubber industry. ... 10 yr mortality history of 6678 male rubber workers /were examined/. ... The age-related mortality rate due to lymphatic and hematopoietic cancer was reported to be 4.4 times higher for workers with 2 yr of experience and 5.6 times higher for workers with 5 yr of experience compared to the general population. For lymphatic leukemia, the age-adjusted mortality rate in the synthetics plant workers was 2.9 times higher for workers with 2 yr of experience and 3.7 times higher for workers with 5 yr of experience, compared to the general study population. ****PEER REVIEWED**** (McMichael AJ et al; J Occup Med 18: 178-85 (1976)).

and propoxur:

- Ecotoxicity Values - ETXV -

TLm *Pimephales promelas* (fathead minnow) 53.6 mg/l/48 hr (soft diluted water) /Conditions of bioassay not specified/ ****PEER REVIEWED**** (Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1056).

- Ecotoxicity Values - ETXV -

TLm *Artemia salina* (Brine shrimp) 68 mg/l/24 hr; 52 mg/l/48 hr /Conditions of bioassay not specified/ ****PEER REVIEWED**** (Price KS et al; J Water Pollut Control Fed 46 (1): 63-77 (1974)).

- Ecotoxicity Values - ETXV -

TLm *Carassius auratus* (goldfish) 64.7 mg/l/96 hr in water hardness of 20 mg/l calcium carbonate /Static bioassay/ ****PEER REVIEWED**** (Pickering QH, Henderson C; J Water Pollut Control Fed 38: 1419-29 (1966)).

- Ecotoxicity Values - ETXV -

TLm *Lebistes reticulatus* (guppy) 74.8 mg/l/96 hr in water hardness of 20 mg/l calcium carbonate /Static bioassay/ ****PEER REVIEWED**** (Pickering QH, Henderson C; J Water Pollut Control Fed 38: 1419-29 (1966)).

- Ecotoxicity Values - ETXV -

TLm *Lepomis macrochirus* (bluegill) 25.1 mg/l/96 hr in water hardness of 20 mg/l calcium carbonate /Static bioassay/ ****PEER REVIEWED**** (Pickering QH, Henderson C; J Water Pollut Control Fed 38: 1419-29 (1966)).

- Ecotoxicity Values - ETXV -

TLm *Pimephales promelas* (fathead minnow) 46.4 mg/l/96 hr in water hardness 20 mg/l calcium carbonate /Static bioassay/ ****PEER REVIEWED**** (Pickering QH, Henderson C; J Water Pollut Control Fed 38: 1419-29 (1966)).

- Ecotoxicity Values - ETXV -

LC50 *Cyprinodon variegatus* (sheepshead minnow) 9.1 mg/l/96 hr, ambient salinity from 10-30 parts per trillion and temp from 25-31 deg C /Static bioassay/ ****PEER REVIEWED**** (Heitmuller PT et al; Bull Environ Contam Toxicol 27 (5): 596-604 (1981)).

- Ecotoxicity Values - ETXV -

LD50 *Carassius auratus* (goldfish) 26 mg/l/24 hr /Conditions of

bioassay not specified/ ****PEER REVIEWED**** (Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1057).

- Ecotoxicity Values - ETXV -

TLM Pimephales promelas (fathead minnow) 62.8 mg/l/24 hr (hard diluted water) /Conditions of bioassay not specified/ ****PEER REVIEWED****

(Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1056).

- Ecotoxicity Values - ETXV -

TLM Pimephales promelas (fathead minnow) 59.3 mg/l/96 hr (hard diluted water) /Conditions of bioassay not specified/ ****PEER REVIEWED****

(Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1056).

All four databanks provide summarised access to information from varied sources.

RTECS presents data in a standardised manner, but loses all comment and

contextualisation. DOSE presents the most integrated and easily comprehended

form. HSDB and CHEMTOX present information in a variety of formats.

Any of these databanks could serve to answer straightforward queries themselves,

although in many cases it would be necessary to go back to the primary source to

gain fuller information. This would not always be possible from CHEMTOX, where links

to the primary literature are not clearly given. The other three databases provide such

links systematically, citing a variety of sources (including each other). HSDB is

particularly strong at giving extracts from standard texts and handbooks, and could

serve as a surrogate for a collection of these. The other sources emphasise the journal

literature. Perhaps more usually, they could be used a starting point, to get a rapid

assessment of what information may be available.

There is also the question of the validity and reliability of information in these sources.

Problems here may range from simply questions of accuracy, which may due to mis-

transcribing of values from the primary literature (anecdotal evidence suggests that

wrongly placed decimal points are not unknown), to problems of valid statements

taken out of their full context, and hence perhaps misinterpreted. This is another

argument for using such sources as a starting point, and relying on the primary

literature for definitive values and opinions.

It is evident from the results, that several of factual databanks can provide useful

toxicological information.

6.10b Grey Literature Evaluation

Lavender oil search

OSH 1 item, judged relevant
CSN 1 item, judged relevant
FR 2 items, judged not relevant
NTIS 2 items, 1 judged relevant, 1 not relevant

Sage oil search

OSH 1 item, judged relevant
CSN 1 item, judged relevant
FR 4 items, judged not relevant
NTIS 1 item, judged relevant

Formaldehyde search

OSH 5 items, 2 judged relevant
CSN 2 items, 1 judged relevant, 1 not relevant
FR 12 items, 2 judged possibly relevant, 10 not relevant
NTIS 4 items, judged not relevant

Toluene search

OSH 1 item, judged not relevant
CSN 1 item judged relevant
FR 36 items, 2 judged possibly relevant, 34 not relevant
NTIS 1 item, judged not relevant

Angelica search

OSH 2 items, 1 judged relevant, 1 not relevant
CSN 1 item, judged relevant
FR 9 items, judged not relevant
NTIS 3 items, 1 judged relevant, 2 not relevant

6.10c Citation Searching

Example 1

Libretto SE (1994)(Glaxo Group Research, Ware), A review of the toxicology of salbutamol (albuterol), Archives of Toxicology, 68(4), 213-216

This paper reviews the published literature on the toxicity of a single compound, which is used medicinally. It was therefore used as the starting point for the search 'toxicity of salbutamol', for papers published in 1995, 1996, 1997 or 1998.

It was cited by 5 papers during this time period. Two of these references were relevant, one was of peripheral relevance (discussing toxicity testing methodology), and two were of no apparent relevance.

A subject search was carried out on Scisearch, using the simple search logic (SALBUTAMOL or ALBUTEROL) and TOXIC? and (date range). This gave 32 items, 22 of which were determined to be relevant, 3 of peripheral relevance, and 7 irrelevant (because the toxicity was associated with another compound, though salbutamol was mentioned). The two relevant and one peripheral items from the citation search were retrieved by this strategy.

In this example, citation searching did not provide any unique references not found from the subject search, which provided 22 relevant items, as against 2 from citation search. Precision of citation and subject search were 40% and 69% respectively.

Example 2

Alison MR and Sarraf CE (Royal Postgraduate Medical School, London) (1995), Apoptosis - regulation and relevance to toxicology, Human and Experimental Toxicology, 14(3), 234-247

This paper reviews the concept of apoptosis - programmed cell death - and its relations to toxicity, carcinogenicity, mutagenicity, etc. It was therefore used as the starting point for a search on the concept of apoptosis, and any relation to toxicology.

A citation search was carried out on this publication; on a point of practicality, it is worth noting the need to EXPAND the cited reference, to allow for variant forms of citation (Brown (1998), Bawden (1999)):

E4 27 CR=ALISON MR, 1995, V14, P234, HUM EXP TOXICOL
E5 2 CR=ALISON MR, 1995, V14, P234, HUMAN EXP TOXICOL

It was cited by 29 publications during 1996, 1997 or 1998. 18 of these were judged relevant; the remainder were discussions of aspects of apoptosis with no evident relevance to toxicology.

A subject search used the logic:

(APOPTOSIS or APOPTOTIC or PROGRAMMED(w)CELL(w)DEATH) and TOXIC? and
(date range)

This gave a total of 1711 items.

In order to reduce this to a manageable level, these were restricted to those with the term TOXIC? in the title. This gave 200 items. Titles of 50 were scanned, and all seemed relevant. This set was further reduced to those with APOPTO? also in the title. There were 40 of these, and from examination of the abstract all seemed relevant.

It seems clear that in this case the subject search is superior to the citation search, in producing a much larger set of material, with a higher degree of relevance.

The citation search would have some value in quickly producing an 'overview collection' of material on the general topic of apoptosis, in which each item had some connection to the paper relating to toxicology; though the original article would have to be examined in each case to see what this connection was. For the purpose of 'straightforward' retrieval, however, subject searching seems much more effective in this case.

Example 3

Sherman JD (Alexandria VA) (1995), Organophosphate pesticides - neurological and respiratory toxicity, *Toxicology and Industrial Health*, 11(1), 33-39

This paper was chosen as representative of toxicology of a group of compounds.

The search was first carried out taking the query to be simply 'toxicity of organophosphate pesticides', ignoring the specific form of toxicity specified in the original paper.

A citation search was carried out on the original publication, again noting variant form of citation

5 CR=SHERMAN JD, 1995, V11, P33, TOXICOL IND HEALTH
1 CR=SHERMAN JD, 1995, V11, P33, TOXICOL IND HLTH

6 items cite it during the relevant time period. 5 of these were judged relevant; 2 of these are letters, one referring to the original paper, the second a reply by Sherman. The initial letter, in fact, contains severe criticisms of the detail and presentation of data in Sherman's original paper, suggesting that it '..puts the reader in the frustrating situation of not knowing either what was done, or how it was done .. makes it impossible for the reader to ascertain the validity of the author's conclusions'. Specific examples of this are given, under six main headings, including lack of detail on how the study sample was chosen, how they were exposed to the pesticide, and how the symptoms described were defined and identified. Sherman's reply answers some of the points, indicates where further detailed data may be found, and cites additional literature references in support. This information would be of use to anyone intending to use Sherman's original work for any purpose.

These letters are typical of the kind of material it may be valuable to know about, yet difficult to identify, other than by citation searching, because of the disinclination of some secondary services to cover letters and similar material. SciSearch does usually include letters, but often provides little in the way of access points, lacking useful title terms and indexing, as in these examples:

Untitled
Maurissen JPJ
Toxicology and Industrial Health, 1997, 13(1), 91-93

Untitled - Reply
Sherman JD
Toxicology and Industrial Health, 1997, 13(1), 95-97

A rather general subject search strategy was constructed:

(ORGANOPHOSPORUS or ORGANOPHOSPHATE?) and PESTICID? And TOXIC?
and date range

to obtain full recall from SciSearch, it would be necessary to include terms for individual compounds and specific forms of toxicity; one of the advantages of citation searching is that the need for construction of complex strategies is removed.

This strategy retrieves 158 items, although these are very varied, most seem relevant to the topic. The analysis was not pursued further, since it again clear that subject searching produces much higher recall than citation searching, even with a clearly sub-optimal search strategy.

Considering more specifically the form of toxicity - neurotoxicity and respiratory toxicity - the citation search itself does not alter. Two of the citing references judged relevant are now judged irrelevant, since they deal with other forms of toxicity.

The subject search was revised, including the terms NEUROTOX?, NEUROL?, NERVE, INHALATION, LUNG, and RESPIRATORY. Again, a wider profile of terms could have been used for maximal recall. This search retrieved 37 items. 30 of these were judged relevant. They did not include the two letters noted above, since they are recorded simply as 'untitled' and have no subject indexing.

In this example, citation searching provided 3 relevant items, including the two letters which could not be found by subject search, as against 30 from a subject search of the same database. Precision of citation and subject searching was 50% and 81% respectively.

In order to test whether the two letters would be retrievable by subject searching on other databases - since if they would not, this would be a clear advantage for citation searching - an author search was carried out on Medline, Toxline, Chemical Abstracts, Biosis, Life Science Collection, Occupational Health and Safety, and Embase.

Maurissen's original comment, though not Sherman's reply, is included in Medline, and reproduced in the equivalent section of Toxline. The Medline editors have given the letter a meaningful title, and it has sufficient subject indexing terms for its retrieval. Both letters, comment and reply, are included within a single Embase record: this is not given a title, being simply recorded as 'letter to the editor', but there is sufficient subject indexing for effective retrieval by any reasonable search logic.

The records are shown below:

Medline

Organophosphate pesticides--neurological and respiratory toxicity
[letter; comment]

Maurissen JP

Toxicol Ind Health (UNITED STATES) Jan-Feb 1997 , 13 (1) p91-3, 95-7,

Comment on Toxicol Ind Health 1995 Jan-Feb;11(1):33-9

Document type: COMMENT; LETTER

Tags: Human

Descriptors: *Insecticides, Organophosphate--Adverse Effects--AE;

*Nervous System--Drug Effects--DE; *Research Design; *Respiratory System

--Drug Effects--DE; Environmental Illness--Etiology--ET

CAS Registry No.: 0 (Insecticides, Organophosphate)

Toxline

02114111 Subfile: TOXBIB-97-253513

Organophosphate pesticides--neurological and respiratory toxicity
[letter; comment]

Maurissen JP

Source: Toxicol Ind Health; VOL 13, ISS 1, 1997, P91-3, 95-7 ISSN:

Comment on Toxicol Ind Health 1995 Jan-Feb;11(1):33-9

Document Type: COMMENT; LETTER

Tags: Human

Descriptors/Keywords: *Insecticides, Organophosphate--Adverse Effects--AE

; *Nervous System--Drug Effects--DE; *Research Design; *Respiratory System

--Drug Effects--DE; Environmental Illness--Etiology--ET

CAS Registry No.: 0 (Insecticides, Organophosphate)

Embase

Letter to the editor

Maurissen J.P.J. ; Sherman J.D.

Toxicology and Industrial Health (TOXICOL. IND. HEALTH) (United States)

1997, 13/1 (91-93+95-97)

DOCUMENT TYPE: Journal; Letter

DRUG DESCRIPTORS:

*organophosphate pesticide--drug toxicity--to

MEDICAL DESCRIPTORS:

*lung toxicity; *neurotoxicity

human; letter; methodology; occupational exposure; symptomatology

SECTION HEADINGS:

035 Occupational Health and Industrial Medicine

052 Toxicology

It is therefore possible to find these items without using citation searching. However, only Embase, of all the databases tried, gives full details of the two letters, indicating the value of citation searching in this particular case.

Example 4

Clewell HJ (1993), Coupling of computer modeling with in-vitro methodologies to reduce animal usage in toxicity testing, *Toxicology Letters*, 68(1/2), 101-117

This was taken as a starting point for search on a complex topic: the use of *in vitro* parameters in physiologically-based pharmacokinetic (PBPK) modelling in toxicity and risk assessment, with specific reference to reduction in the use of animals in testing.

The article is cited by 9 items between 1994 and 1998. 8 were judged relevant against the main definition, though they did not make explicit reference to reduction of animal usage.

Two of the nine items were reviews, one by the original author:

Clewell HJ (1995), The application of physiologically-based pharmacokinetic modeling in human health risk assessment of hazardous substances, *Toxicology Letters*, 79(1/3), 207-217

Anderson ME (1995), Development of physiologically-based pharmacokinetic and physiologically-based pharmacodynamic models for applications in toxicology and risk assessment, *Toxicology Letters*, 79(1-3), 35-44

These are suitable for use as starting points for further citation searches, in an iterative process (Bawden 2001). When this is done, 3 citations are found to the first article and 1 to the second; none of the 4 cite the original Clewell 1993 article. However, none of the 4 was judged relevant to the original query, since they did not deal with use of *in vitro* parameters; an example of how precision falls away with increasing iteration from an original cited article.

The subject search logic was rather more complex than used in the other three examples; though not as complex as it could have been for maximal recall. It was:

```
in(w)vitro or invitro
and
pbpk or physiologically(w)based(w)pharmacokinetic?
and
model? or simulat?
```

and
toxic? or risk(w)assessment
and
date range

This gave 132 references, including all of the 9 found by citation search. They were not analysed in detail, but from titles alone it was clear that a majority were relevant, i.e. the subject search had found considerably more material than the citation search.

In order to try to simulate the precision of the citation search, the subject search was refined; it was obvious how this would best be done, and several approaches were tried. By insisting on 'toxic?' or 'risk?' being in the title, and the use of the acronym PBPK (common use of 'jargon' of this sort being a good way of identifying closely related material, the output was reduced to 16 references. 11 of these were judged relevant; the others, though dealing with the correct general area, did not address the specific use of *in vitro* parameters. 4 of these were in the set found from citation searching.

Alternative refinements of the search, using two terms to reflect explicitly the aspect of reduction in animal use, or to specific use of *in vitro* parameters gave little or no useful material.

Based on the combined sets of 8 and 11 relevant items (with 4 in common) found by citation and refined subject searching respectively, the figures are:

	recall	precision
citation (single search)	8/15 = 53%	8/9 = 89%
citation (with iteration)	8/15 = 53%	8/13 = 62%
subject	11/15 = 73%	11/16 = 69%

Citation searching, based on the single starting reference, gives better precision than the refined subject search, but still gives poorer recall, while it is clear that the broader subject search will find a much greater volume of relevant material. When an additional iteration is performed in the citation search, recall does not increase, while precision falls below that of the subject search.

Example 5

H Spliid and J Torslov (Technical University of Denmark) (1994), Statistical analysis of joint toxicity in biological growth experiments, *Ecotoxicology and Environmental Safety*, 28(2), 181-192

This paper was taken as the starting point for a search on methods for statistical analysis of experiments on joint toxicity, i.e. the toxicity caused by a mixture of toxic substances. It might be expected that this search would show advantages for citation searching, as its value for retrieving information on statistical techniques has been demonstrated (Bawden 1984).

In fact this paper has only been cited twice; one of these references was judged relevant.

A subject search was then carried out, for papers published between 1995 and 1998, using the terms:

JOINT(w)TOXIC? or MIXTURE(2w)TOXIC?
and
ANALYS? or STATISTIC?

This gave 10 items, 4 of which were judged relevant; the others, though they mentioned statistical significance, gave no substantive discussion of the methods used. One of these four was the single relevant item found by citation searching.

Citation searching here gave slightly higher precision (1/2 compared with 4/10), but poorer recall (1 useful item compared with 4), and no unique references.

Example 6

LW Hall and RD Anderson (University of Maryland) (1995), The influence of salinity on the toxicity of various classes of chemicals to aquatic biota, *Critical Reviews in Toxicology*, 25(4), 281-346

This review was used as a starting point for a search on influence of salinity on toxicity in the aquatic environment.

It was cited 5 times, all the citing articles being published in 1997 or 1998. 4 of these articles were judged relevant.

An equivalent subject search was conducted, using the terms:

TOXIC? and (SALINITY or SALINITIES) and AQUATIC

The output was initially restricted to the years 1997 and 1998, to give as clear a comparison as possible with citation searching. 11 references were retrieved, of which 3 were judged relevant; the others either mentioned a salinity level in an aquatic toxicity test, but gave no comparison at various salinities, or discussed the toxicity of saline itself.

The subject search did not retrieve any of the 4 references found from citation searching; nor were any of the 3 subject search items found in the citation search, though ironically one of the latter is by the same authors (Hall and Anderson) as the original 'seed' paper; an illustration of the unreliability of citation practice.

In this case, the citation search performed better than the subject search, figures being:

	recall	precision
citation	4/7 = 57%	4/5 = 80%
subject	3/7 = 43%	3/11 = 27%

When the time period was altered to the 'standard' form used in these examples, i.e. including articles published in 1996, the subject search retrieved 11 more references. None of these were judged relevant, however. Inclusion of these reduces the precision of the subject search to 3/22, i.e. 14%.

In this case, the citation search is superior to subject searching in terms of both recall and precision. It is difficult to see how the subject search could be significantly improved in either respect, without unacceptably reducing the other.

Chapter Seven: Appendix

7.2.a Library of Congress Subject Headings, 23rd edition, 1999. Entries relevant to toxicology

Toxicology

[RA 1190-RA 1270]

- UF Chemicals - Toxicology
- BT Medicine
 - Pharmacology
- RT Poisoning
 - Poisons
- SA subdivision Toxicology under Individual chemicals and other Substances for works on their Poisonous effects on human Beings or animals eg. Copper - Toxicology
- NT Analytical toxicology
 - Aviation toxicology
 - Behavioural toxicology
 - Biological toxicology
 - Cardiovascular toxicology
 - Dematotoxicology
 - Developmental toxicology
 - Endocrine toxicology
 - Environmental toxicology
 - Forensic toxicology
 - Genetic toxicology
 - Hepatotoxicology
 - Immunotoxicology
 - Industrial toxicology
 - Molecular toxicology
 - Nephrotoxicology
 - Ocular toxicology
 - Pediatric toxicology
 - Poison control centers
 - Poisoning accidental
 - Poisonous plants - Toxicology
 - Pulmonary toxicology
 - Radiography in toxicology
 - Reproductive toxicology
 - Toxicity, Effect of temperature on
 - Toxicological chemistry
 - Toxicological emergencies
 - Veterinary toxicology
- Animal models
 - [RA 1199.4.A54]
- BT Animal models in research
 - Toxicology experimental
- Dose-response relationship
 - [RA 1199.4.D66]
- UF Poisons - Dose-response Relationship
 - (former heading)
- BT Dose-response relationship
 - (Biochemistry)
- Genetic aspects
 - USE Genetic toxicology
- Jurisprudence
 - USE Forensic toxicology
- Statistical methods
 - [RA 1199.4.573]
- Testing
 - USE Toxicity testing

7.2.b Bliss's Bibliographic Classification, 2nd Edition, entries relevant to toxicology

HSQ	Poisoning, intoxication
	<i>Treatment</i>
GKB	Antidotes
GKC	Mechanical
GKD	Chemical
GKF	Physiological
H	<i>Pathology</i>
HJV	Toxicity
HO	Toxaemia
KV	Toxic shock
Q	Poisons, toxicology
QR	<i>by origin</i>
QRS	Toxic irritants
QS	Poisonous plants
QT	Fungi
QV	Individual fungi, A/Z
QW	Other lower plants, A/Z by Latin name
QX	Higher plants
QY	Individual higher plants, A/Z by Latin name
R	Poisonous animals, venoms
RQ	Bites and stings
RR	Marine animals
RS	Land animals
RT	Invertebrates
RV	Annelida
RW	Leeches
RX	Aracnida
RY	Scorpions
SA	Spiders
..	
SM	Other invertebrates A/Z
SN	Vertebrates
SO	Reptilia
SP	Snake bites
SQ	Other vertebrates A/Z
ST	Autointoxication
	(Drug toxicology, side effects - cross referenced to HNV)
	(Food poisoning - cross referenced)
	Industrial and other products - created by adding to HSQ the letters following C in CT - CY chemicals facet, e.g. HSQ WOC for pesticide poisoning
HSR	B Chemical warfare agents
BQ	Ordeal poisons
BR	Weapons poisons
C	Criminally administered poisons
	<i>by effect</i>
DTJ	systemic poisons
DUC	vessicants
DWE	lacrimators, toxic gases, smokes
DWG	lung irritants
	<i>by state or constitution</i>
	created by adding to HSR letters F/Y following HC, e.g.

GV	gas poisoning
HT	alkalis
HU	acids
	<i>by element or compound</i>
I	inorganic poisons
IEG	inert gas narcosis
IJC	carbon monoxide poisoning
..	...
NZ	other substances, A/Z
O	organic poisons
OEY	toxins

7.2.b Bliss's Bibliographic Classification, 2nd Edition, entry for food poisoning

HSS		Food poisoning
HSS	Q	<i>state of food</i>
		these are created by adding notation from the HKH section, e.g.
HSS	Q PJ	Raw foods
...		...
HSS	Q PYM	Preserved foods
HSS	Q PYT	tinned, canned
....		
		<i>form or constitution of food</i>
HSS	S	Bacterial food poisoning
	SR	Salmonella food poisoning
	...	
	SV	Other bacteria, A/Z
	T	Fungi
	TR	claviceps purpurea, ergotism
	TS	mushrooms, toadstools
	TV	other fungi, A/Z
	VB	Higher plants
	VC	epidemic dropsy (mustard)
	VE	(blighia sapiala) Ackee
	..	
	VV	Other plants, A/Z by Latin name
	WB	Animals
	WD	ptomaine poisoning
	WF	shellfish
	WH	fish
	WK	poultry
	WM	meat
	WP	other animals, A/Z

7.4.a EMTREE Thesaurus, 1998, terms beginning with the stem 'toxic'

Toxic epidermal necrolysis	<i>see under</i> Bullous skin disease Histopathologic skin reaction Intoxication
Toxic gas	D5.80.85
Toxic goiter	<i>see under</i> Goiter Hyperthyroidism
Toxic hepatitis	<i>see under</i> Hepatitis Intoxication
Toxicity	C6.880.880
Toxicity and intoxication	C6.880 <i>see also</i> Toxicology
Toxicity testing	E1.880
Toxic megacolon	<i>see under</i> Colitis Intoxication
Toxic oil syndrome	<i>see under</i> Intoxication
Toxicokinetics	<i>see under</i> Xenobiotic metabolism
Toxicological parameters	E8.880
Toxicology	Q1.880 <i>see also</i> Toxicity and intoxication
Toxicosis	<i>use</i> Intoxication
Toxic oxygen	<i>use</i> Oxygen poisoning
Toxic shock syndrome	<i>see under</i> Bacterial infection Shock
Toxic substance	D5.80

Note the use of the '80' and '880' notation to identify toxicology concepts in various facets, i.e. part of the classification system.

7.4.b EMTREE Thesaurus, listing for toxic effects in subfacet C6 - physical disease by etiology and pathogenesis

C6.880	Toxicity and intoxication
C6.880.455	Intoxication
	Alcohol cardiomyopathy
	Alcohol intoxication
	Alcohol withdrawal
	Alloxan diabetes mellitus
	Argyria
	Body burden
	Botulism
	Cadmium poisoning
	Carbon monoxide intoxication
	Cyanide poisoning
	Digitalis intoxication
	Drug intoxication
	Drug overdose
	Drunkenness
	Endotoxemia
	Envenomation
	Ergotism
	Fluorosis
	Food poisoning
	Gas poisoning
	Halothane liver injury
	Hangover
	Heavy metal poisoning
	Hepatic coma
	Iron overload
	Lathyrism
	Lead poisoning
	Mercurialism
	Methanol poisoning
	Minamata disease
	Mushroom poisoning
	Oxygen poisoning
	Paraquat poisoning
	Plant intoxication
	Retinol intoxication
	Toxaemia
	Toxic epidermal necrolysis
	Toxic hepatitis
	Toxic megacolon
	Toxic oil syndrome
	Vitamin D intoxication
	Water intoxication
	Withdrawal syndrome
	Yusho disease
C6.880.880	Toxicity
	Acute toxicity
	Blood toxicity
	Bone marrow toxicity
	Brain toxicity
	Cardiotoxicity
	Chronic toxicity
	Delayed neurotoxicity
	Ecotoxicity
	Effluent toxicity
	Embryotoxicity
	Eye toxicity
	Fetotoxicity
	Gastrointestinal toxicity
	Genotoxicity
	Immunotoxicity
	LD 50
	Lethal dose
	Liver toxicity

C6.880.880.230

Lung toxicity
Lymphocytotoxicity
Multiple chemical sensitivity
Nephrotoxicity
Neurotoxicity
Ototoxicity
Oxygen toxicity
Phototoxicity
Phytotoxicity
Reproductive toxicity
Skin toxicity
Teratogenicity
Drug toxicity
 Drug carcinogenicity
 Drug cytotoxicity

7.4.c EMTREE Thesaurus 'Toxic substances' occur in the D5 sub-facet - environmental, industrial and domestic chemicals

D5.80	Toxic substance	- Capsaicin - Cigarette smoke - Cigarette smoke condensate - Clastogen - Dimethyl sulfate - Hemolysin - Industrial toxic substance - Irritant agent 4 o methylphorbol 13 acetate 12 myristate 4alpha phorbol didecanoate - Tobacco smoke
D5.80.20	Carcinogen	- N acetoxyl n (2 fluorenyl)acetamide .. - Asbestos - Asbestos fiber .. 48 specific substances .. - Tumor promoter
D5.80.20.180	Cocarcinogen	1,4 bis (3,5, dichloro 2 pyridyloxy)benzene .. 13 specific substances
D5.80.50	Mutagenic agent	3 amino 1,4dimethyl 5h pyrido[4,3 b]indole .. 10 specific substances .. - chemical mutagen - environmental mutagen - promutagen ..
D5.80.70	Poison	- Cyanide - Environmental poison - Fluoroacetic acid - Polybrominated dibenzodioxin - Polybrominated dibenzofuran - Polychlorinated dibenzodioxin - Polychlorinated dibenzofuran - Potassium cyanide - Sodium cyanide - Strychnine 2,3,7,8 tetrachlorodibenzofuran 2,3,7,8 tetrachlorodibenzo para dioxin
D5.80.75	Pyrogen	- Endogenous pyrogen - Eticholanolone
D5.80.85	Teratogenic agent	6 aminonocotinamide - Chemical teratogen 2,3,7,8, tetrachlorodibenzo para dioxin
D5.80.85	Toxic gas	- Chemical warfare agent - Hydrogen cyanide - Hydrogen sulfide - Lewisite - Mustard gas - Phosgene
D5.80.85.610	Nerve gas	- Sarin 3 specific examples

D5.80.85.750		Riot control agent 2 chlorobenzylidenemalononitrile Phenacyl chloride Tear gas
D5.80.90	Toxin	Alpha toxin Cardiotoxin Hormonotoxin Immunotoxin Skin toxin Uremic toxin Xomazyme
D5.80.90.80		Bacterial toxin Anthrax toxin .. <i>88 specific examples</i> ..
D5.80.90.200		Cytotoxin Cytotoxic factor 4 ipomeanol Lymphotoxin Tumor necrosis factor Verotoxin
D5.80.90.260		Endotoxin Escherichia coli endotoxin Salmonella endotoxin
D5.80.90.265		Enterotoxin Escherichia coli enterotoxin .. <i>4 specific examples</i>
D5.80.90.270		Exotoxin Pseudomonas exotoxin
D5.80.90.520		Marine toxins Anatoxin .. <i>41 specific examples</i>
D5.80.80.590		Mycotoxin Aflatoxicol .. <i>63 specific examples</i>
D5.80.90.610		Neurotoxin 2 amino 3 methylaminopropionic acid .. <i>28 specific examples</i>
D5.80.90.690		Plant toxin Atractyloside .. <i>33 specific examples</i>
D5.80.95	Venom	coelenterate venom <i>4 specific examples</i>
D5.80.95.50		Amphibian venom Batrachotoxin <i>11 specific examples</i>
D5.80.95.60		Arthropod venom Omega agatoxin iva .. <i>14 specific examples</i>
D5.80.95.440		Spider venom Insect venom Ant venom Apamin .. <i>11 specific examples</i>
D5.80.95.300		Fish venom Stonefish venom
D5.80.95.560		Mollusc venom Snail venom
D5.80.95.820		Snake venom Albolabrin

..
25 specific examples
..
Viper venom

7.4.d Derwent Drug File Thesaurus, 1995, terms relevant to toxicology

TOX.

SN	toxic/toxicity. Term used for studies of toxic effects in animals, e.g. LD50, mutagenesis, teratogenesis
Use for	TOXIC TOXICITY
NT	LD10 LD50 LD90 LD100

LD10, LD50, LD90, LD100

SN	concentration of substance killing 10%, 50%, 90%, 100% of animals tested
BT	TOX.

INTOXICATION

Use for	TOXICOSIS POISONING
NT	15 specific syndromes, e.g. ERGOTISM, BOTULISM, TOX.OIL SYNDROME, STAGGERS and SLOBBERS (the last two being veterinary terms)
RT	ALCOHOLISM HYPERVITAMINOSIS THYROTOXICOSIS ADDICTION

CYTOTOX.

SN	cytotoxicity

ANTIDOTES

SN	An agent administered to prevent or counteract the action of a poison or of drug intoxication.
NT	61 named compounds

TOXINS

RT	ZOOTOXINS PHYTOTOXINS

ZOOTOXINS

PHYTOTOXINS

TERATOGEN

SN	compound which induces malformation of the embryo
Use for	EMBRYOTOX.

TERATOGENESIS

SN	malformation of the embryo
RT	CONGENITAL DISEASE

MUTAGEN

SN	compound which induces gene mutation
RT	CARCINOGEN COCARCINOGEN

CARCINOGEN

SN	Activity of a compound which induces tumor formation
RT	COCARCINOGEN MUTAGEN

COCARCINOGEN

SN	Activity of a compound which does not induce tumor formation on its own, but which enhances the carcinogenic activity of another compound or which, when combined with another inert compound induces tumor formation
RT	CARCINOGEN MUTAGEN

CARCINOGENESIS
CARCONOEMBRYONIC

7.4.e DHSS-Data Thesaurus, terms judged to be relevant to toxicology

TOXICITY

BT	POISONING
RT	POISONING
	TOXIC SHOCK
	TOXICITY STUDIES

TOXICITY STUDIES

NT	ACUTE TOXICITY STUDIES
	ALLERGY AND IRRITANCY STUDIES
	CELL TRANSFORMATION ASSAYS
	DOMINANT LETHAL STUDIES
	GENOTOXIC STUDIES
	LONG TERM STUDIES
	REPRODUCTIVE TOXICITY STUDIES
	SUBACUTE TOXICITY TESTS
RT	TOXICOLOGY

TOXICOLOGY

NT	DRUG TOXICOLOGY
RT	POISONING
	POISONS

TOXIC SHOCK

Use for	Shock, toxic
	Toxaemia, traumatic
BT	POISONING
RT	TOXICITY

TOXINS

BT	ANTIGENS
NT	ENDOTOXINS
	MYCOTOXINS

ACUTE TOXICITY STUDIES

SN	Anything up to 28 days
UF	Lethal concentration 50 determination
	Lethal dose 50 determination
	Limit tests
BT	TOXICITY STUDIES

ALLERGY AND IRRITANCY STUDIES

BT	TOXICITY STUDIES

CELL TRANSFORMATION ASSAYS

BT	TOXICITY STUDIES

DOMINANT LETHAL STUDIES

BT	TOXICITY STUDIES

GENOTOXIC STUDIES

BT	TOXICITY STUDIES
NT	DNA DAMAGE ASSAYS
	MUTAGENICITY TESTS

LONG TERM STUDIES

Use for	CHRONIC TOXICITY STUDIES
	LIFE TIME STUDIES
BT	TOXICITY STUDIES

REPRODUCTIVE TOXICITY STUDIES

BT	TOXICITY STUDIES
NT	FERTILITY STUDIES
	FOETOTOXICITY STUDIES
	MULTI-GENERATION STUDIES

FERTILITY STUDIES

BT	REPRODUCTIVE TOXICITY STUDIES

FOETOTOXICITY STUDIES

Use for Specific locus tests
Teratogenicity studies
BT REPRODUCTIVE TOXICITY STUDIES

MULTI-GENERATION STUDIES

BT REPRODUCTIVE TOXICITY STUDIES

SUBACUTE TOXICITY TESTS

SN Studies ranging from 28 to 90 days
BT TOXICITY STUDIES

DNA DAMAGE ASSAYS

BT GENOTOXIC STUDIES
NT CYTOGENETIC ANALYSIS
DNA MODIFICATION ASSAYS
DNA REPAIR ASSAYS
SISTER CHROMATID EXCHANGE

MUTAGENICITY TESTS

BT GENOTOXIC STUDIES
NT HOST MEDIATED ASSAYS
RT GENETIC ENGINEERING
GENETICS
MUTATION

MUTAGENESIS

BT SYMPTOMS (DISEASE)
RT MUTAGENS

MUTAGENS

BT POLLUTANTS
RT MUTAGENESIS
MUTATION

MUTATION

BT GENETIC VARIANCE
RT GENETICS
MUTAGENICITY TESTS
MUTAGENS

CYTOGENETIC ANALYSIS

Use for Heritable translocation assays
Micronucleus tests
Nondisjunction assays
BT DNA DAMAGE TESTS

DNA MODIFICATION ASSAYS

SN Covalent modification of DNA by xenobiotics
BT DNA DAMAGE ASSAYS

DNA REPAIR ASSAYS

Use for Unscheduled DNA synthesis
BT DNA DAMAGE ASSAYS

SISTER CHROMATID EXCHANGE

BT DNA DAMAGE ASSAYS

DRUG TOXICOLOGY

BT TOXICOLOGY
RT DRUG ADVERSE REACTIONS
DRUG SIDE EFFECTS

DRUG ADVERSE REACTIONS

Use for ADVERSE REACTIONS (DRUGS)
BT ADVERSE REACTIONS (MEDICAL TREATMENT)
DRUG SIDE EFFECTS
NT DRUG HYPERSENSITIVITY
RT DRUG ANTAGONISM
DRUG INCOMPATIBILITY

	DRUG TOXICOLOGY
DRUG SIDE EFFECTS	
BT	SIDE EFFECTS (MEDICAL TREATMENT)
NT	DRUG ADVERSE REACTIONS
RT	DRUG THERAPY
	DRUG TOXICOLOGY
POISONING	
Use for	INTOXICATION
BT	ACCIDENTS
NT	ACID POISONING
	FLUOROSIS
	FOOD POISONING
	GAS POISONING
	HEPATOTOXICITY
	METAL POISONING
	TOXAEMIA
	TOXIC SHOCK
	TOXICITY
RT	ANTIDOTES
	POISON CENTRES
	POISON CONTROL
	POISONS
	TOXICITY
	TOXICOLOGY
POISONS	
BT	CHEMICAL HAZARDS
	DANGEROUS MATERIALS
NT	ARSENIC
	PESTICIDES
	POISONOUS PLANTS
	STRYCHNINE
RT	MEDICAL JURISPRUDENCE
	POISON CONTROL
	POISONING
	TOXICOLOGY
ACID POISONING	
BT	POISONING
FLUOROSIS	
BT	POISONING
RT	FLUORIDES
FOOD POISONING	
BT	DISASTERS
	ERGOTISM
	FOOD HAZARDS
	POISONING
NT	ERGOTISM
	MUSHROOM POISONING
	SALMONELLA FOOD POISONING
	TOXIC OIL SYNDROME
	YUSHO
RT	CONTAMINATION
	FOOD ADULTERATION
	FOOD HYGIENE
	FOOD SPOILAGE
GAS POISONING	
BT	POISONING
NT	WAR GAS POISONING
HEPATOTOXICITY	
Use for	Liver toxicity
	Toxic hepatitis
BT	LIVER DISEASES
	POISONING

METAL POISONING

BT	POISONING
NT	CADMIUM POISONING
	LEAD POISONING
	MERCURY POISONING
	SILVER POISONING
	VANADIUM POISONING

TOXAEMIA

BT	POISONING
NT	PREGNANCY TOXAEMIAS

POISON CENTRES

Use for	Poison control centres
	Poisoning treatment centres
BT	CLINICS
RT	POISON CONTROL
	POISONING

POISON CONTROL

BT	PREVENTIVE MEDICINE
RT	POISON CENTRES
	POISONING
	POISONS

ANTIGENS

BT	IMMUNOLOGIC FACTORS
NT	RHESUS FACTOR
	TOXINS
RT	IMMUNITY
	VACCINES

POISONOUS PLANTS

Use for	Plants (poisonous)
BT	DANGEROUS MATERIALS
	PLANTS
	POISONS
NT	BRACKEN

POLLUTANTS

BT	DANGEROUS MATERIALS
NT	AIRBOURNE INFECTIONS
	ASHES
	DIRT
	EXHAUST GASES
	FERTILISERS
	MUTAGENS
	ODOURS
	RADIOACTIVE WASTES
RT	AGRICULTURAL CHEMICALS
	AIR POLLUTION
	CHEMICAL HAZARDS
	CONTAMINANTS
	POLLUTION
	WASTES

CHEMICAL HAZARDS

BT	DANGEROUS MATERIALS
	ENVIROMENTAL HAZARDS
	HEALTH HAZARDS
NT	GAS HAZARDS
	OIL HAZARDS
	POISONS
RT	ASBESTOS
	CHEMICAL BIOLOGY WARFARE
	CHEMICALS
	POLLUTANTS

DANGEROUS MATERIALS

BT	HEALTH HAZARDS
	MATERIALS

NT	AEROSOLS ASBESTOS CHEMICAL HAZARDS DANGEROUS MATERIALS TRANSPORT DUST EXPLOSIVES FIREWORKS FLAMMABLE MATERIALS POISONOUS PLANTS POISONS POLLUTANTS RADIOACTIVE MATERIALS SMOKE
RT	CHEMICAL BIOLOGY WARFARE DANGEROUS ENVIRONMENTS SAFE HANDLING SAFE STORAGE
TERATOGENS	
RT	CONGENITAL DISORDERS DRUG INDUCED TERATISMS
CARCINOGENS	
RT	CANCER CARCINOGENICITY
CARCINOGENICITY	
SN	Relating to the ability of a stimulus to cause the formation of tumours
RT	CARCINOGENS CARCINOMAS

7.4.f CAB Thesaurus, 1999, toxicology-related terms

TOXICOLOGY		
NT		TOXIC SUBSTANCES
RT		TOXICITY
		TOXINS
		PESTICIDAL PROPERTIES
TOXIC SUBSTANCES		
uf		POISONS
BT		TOXICOLOGY
NT		FISH POISONS
		CARCINOGENS
		TERATOGENS
		plus numerous specific and generic toxic substances, e.g.
		AFLATOXINS, BENZENE, PENICILLIC ACID, POLYBROMINATED BIPHENYLS
RT		RESIDUES
		PESTICIDES
		POISONING
		POISONOUS PLANTS
		POLLUTION
		POLLUTANTS
TOXICITY		
NT		CYTOTOXICITY
		DRUG TOXICITY
		ONCOGENICITY
		PHOTOTOXICITY
		PHYTOTOXICITY
		SOIL TOXICITY
RT		ALLELOPATHY
		LETHAL DOSE
		PATHEOGENICITY
		POISONING
		TOXIC SUBSTANCES
		TOXICOLOGY
		TOXINS
POISONING		
NT		FOOD POISONING
RT		DISEASES
		POISONOUS PLANTS
		POISONOUS WEEDS
		POLLUTION
		TOXIC SUBSTANCES
POISONOUS PLANTS		
uf		TOXIC PLANTS
NT		POISONOUS WEEDS
		POISONOUS FUNGI
		plus numerous specific examples of poisonous plants by botanical name, e.g.
		DAPHNE MEZEREUM, PRUNUS LAUROCERASUS
RT		FOOD POISONING
		PLANTS
		POISONING
		TOXIC SUBSTANCES
POLLUTION		
NT		AIR POLLUTION
		WATER POLLUTION
RT		CONTAMINATION
		ENVIRONMENTAL IMPACT
		ENVIRONMENTAL POLICY
		POISONING
		POLLUTANTS
		POLLUTION CONTROL
		TOXIC SUBSTANCES