Wilhelm Erb's Electrotherapeutics and
Scientific Medicine in 19th Century Germany

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Abstract

Wilhelm Heinrich Erb (1840-1921) was the co-discoverer of the knee jerk response and is often referred to as the German counterpart of the French neurologist Jean Charcot. Erb advocated the use of electricity as a therapeutic agent, particularly in nervous diseases. He belonged to the first generation of German physicians educated in the spirit of Virchow's programme of naturwissenschaftliche Medizin. Among them were his mentor Nikolaus Friedreich, who exerted the most decisive and singular influence upon Erb, Albert Eulenburg, Eduard Hitzig and Hugo von Ziemssen. They were all reputable scientifically minded clinicians with a keen interest in advancing medical therapy and among the most ardent supporters of 'scientific' electrotherapy.

My thesis is not intended to be a comprehensive biographical account of Erb's life but aims to explore the broader reasons for his advocacy of electrotherapy during the first phase (1860-1880) of the implementation of natural scientific medicine in Germany.

Part I portrays the contemporary social, political and institutional context at Heidelberg University located in the German State of Baden where Erb received his medical training and spent almost exclusively his entire professional career.

Part II illustrates the intellectual roots and
epistemological objectives of Rudolf Virchow's concept of *naturwissenschaftliche Medizin*. I emphasize the political and social significance of Virchow's medical reform and its appeal to a generation of medical men raised in the aftermath of the failed 1848 Revolution. Erb is characterised as a "typical child of his time." I also discuss the aesthetic appeal of electricity which helped to promote its medical utilisation.

Part III provides a history of German electrotherapy and investigates the intra-scientific rationale for the momentary enthusiastic employment of medical electricity. It concludes with an analysis of Erb's chief electrotherapeutic publications and actual practice.
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Acknowledgements

It is a pleasure to thank some of the many people who have helped me during the course of my work on this thesis. Above all, my sincere thanks to Professor Bynum who has been a patient and most supportive supervisor.

My research has been made possible thanks to a generous grant from the Wellcome Trust.

I am grateful for the time, friendship and advice from so many students at the Wellcome Institute. I am especially indebted to Katharina Rowold, Carole Reeves and Cornelius Borck.

During my research on this study I have constantly relied upon the following libraries in London: the Wellcome Library for the History of Medicine, the British Museum Library, the library at the Institute of Neurology Queen's Square, the library of the Royal Society of Medicine, the library of the Royal College of Surgeons and the library of the German Historical Institute.

In Germany I visited the Generallandesarchiv Karlsruhe and the University Archive of the University of Heidelberg.

I am grateful to all the library staff for their assistance and kindness. I thank especially Lindsay Lardner at the Wellcome Library for her patience in tracking down material.
I also want to thank Dr Hugh Bostock from the Institute of Neurology at the National Hospital for Neurology at Queen's Square, London for his advice on chapter 8.

Last, but not least, I thank my husband Nicolas for his patience, tolerance and encouragement.
Introduction

This thesis examines the practice of electrotherapy during the early stages of the emergence of naturwissenschaftliche Medizin (natural scientific medicine) in Germany. I have chosen to focus on the early electrotherapeutic publications and practice of Wilhelm Heinrich Erb (1840-1921). Not only has Erb been hailed as Germany's first and foremost neurologist and one of the founding fathers of modern electrotherapy but also as the epitome of a 19th century reputable physician of natural scientific persuasion. However, my thesis is not intended to be a full blown biographical account of Erb's life and career.

Many aspects of Erb's work have already been discussed by medical historians. Erb is often characterised as a gifted nosologist for he unearthed many neurological disease entities. He wrote extensively on muscular dystrophy, spastic spinal paraplegia and was among the first to recognize the relationship between tabes dorsalis and syphilis. He also described the upper brachial plexus lesion and the clinical aspects of 'myasthenia gravis'.

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is probably best known for the discovery of the patellar tendon reflex in 1875. This aspect of his work has already been covered by a medical dissertation.

Less attention has been paid to his ardent advocacy of electrotherapy in clinical medicine and neuropathology. One reason might be that medical electricity never quite rid itself from the less progressive image of mesmerism and animal-magnetism. To be sure during Erb's time the image of medical electricity never quite ceased to be tarnished by the popular perception of electricity as a panacea. This perception was further promoted by advertisements in popular magazines praising the beneficial effects of electrical gadgets like Pulvermacher's electric chain. Erb was anxious to stress that he had "no acquaintance with such things and that they played an unduly prominent part in the jugglery of quacks and charlatans."

Despite some residual misgivings towards medical electricity a significant number of contemporary reputable physicians started to promote electrical medicine. They insisted that electrotherapeutics was a

Inaug.Diss., Ludwigs-Maximilians-Universität München, 1940, pp.5-37; K.Kolle, Grosse Nervenärzte, Stuttgart, Thieme, 1970

3 H.B.Wolf, 'Zur Entdeckung des Patellarsehnenreflexes durch Erb und Westphal', in Rothschuh und Toellner (eds.) Münster'sche Beiträge zur Geschichte und Theorie der Medizin, Nr.11, Münster, 1976

creditable specialty and stressed its scientific character. Among them were Nikolaus Friedreich, Wilhelm Erb, Albert Eulenburg, Eduard Hitzig and Hugo von Ziemssen. They all belonged to Virchow's school of naturwissenschaftliche Medizin. I intend to show that the rising interest in electrotherapeutics was closely linked to the rise of Virchow's programme of naturwissenschaftliche Medizin which aspired to regenerate German medicine. It was closely associated with an optimistic revival of medical therapy, aimed at the demise of therapeutic nihilism, and thus to emancipate the 'Klinik' in the face of a rapidly institutionalising physiology.

One less well known part of Virchow's objective consisted in the activation and renewal of clinical medicine. Thus in 1865 two of Virchow's disciples Ziemssen and Zenker founded the Deutsches Archiv für Klinische Medizin. Interestingly enough between 1865 and 1880 thirty-seven articles concerned with electrotherapy (electricity in medicine) appeared in the Deutsches Archiv für Klinische Medizin compared with twenty-three articles in the Archiv für Psychiatrie und Nervenkrankheiten during the same time span.

This illustrates my principal argument that electrotherapy was in the first place part and parcel of a campaign aimed at revitalising the 'Klinik' and medical therapy by injecting it with a dose of science,
and only in the second place helped to promote clinical neurology by virtue of its primary application and indication in neuro-muscular disorders. This is not to deny electricity's relevance in promoting neuropathology. Erb frequently emphasized the influential role of electrotherapy in the development of neuropathology:

During the fifth and sixth decade significant progress was brought about from an entirely different direction: electrotherapy. Stimulated by the discoveries and progress which the teaching of electricity had experienced during the first decades of our century, physicians turned their attention to the therapeutic employment of this powerful physical agent. Seen against the background of the more recent discoveries in electrophysiology a broad scientific base had come into existence and justified these aspirations...These therapeutic endeavours had to be based on well founded physiological and neuropathological studies, and thus we owe many interesting facts and the subsequent promotion of neuropathology to the efforts of electrotherapists. It is not an exaggeration to say that the majority of German neuropathologists have embarked upon their career coming from electrotherapy. This is a great advantage, for the complete comprehension of neuropathology is not possible without expertise in electrodiagnostic and electrotherapeutic methods.

To my disappointment I have not come across any autobiographical notes, diaries or personal correspondence by Wilhelm Erb. Thus I had to concentrate mainly on archival sources in the University of Heidelberg and the Generallandesarchiv Karlsruhe. Equally frustrating was the fact that no original case histories could be located at the

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5 W.Erb 'Akademische Antrittsrede', in Gesammelte Abhandlungen, Leipzig, Vogel, 1910, p.268
Heidelberg Medizinische Klinik where Professor Erb administered to patients. Relatively little secondary literature exists either. Only few autobiographical accounts by former pupils refer briefly to Wilhelm Erb. These provide only little additional information on his personality and shed no light on his ideas and beliefs other than the repeatedly stated observation that he was pragmatic, a realist, not particularly inspiring, yet characteristic for an entire era in medicine.\(^6\)

Faced with the regrettable lack of direct evidence I decided to portray the environment and Zeitgeist in which Erb was raised and operated. Erb as a teacher and clinician was singularly influenced by the Virchow disciple Nikolaus Friedreich.

Chapter Summary

Chapter 1 consists of a short biography of Wilhelm Erb.

Part I  Heidelberg

Erb received not only his entire medical training but also spent almost his entire professional life at Heidelberg University. Thus Chapters 2 & 3 aim to portray the political and institutional circumstances at Heidelberg University and in the German state of Baden where the university is situated. I believe that the contemporary atmosphere at Heidelberg and in Baden at large ideally presents the contemporary culture and political concerns which occupied the thoughts and shaped the aspirations of so many German physicians during that era.

The main objective of chapter 2 is to clarify how in Baden economic and educational reform, the latter stressing a distinct hands-on approach also in higher education, were linked with liberal political aims of civil servants. I also identify Heidelberg as the hotbed of a specific contemporary movement which aspired to German unification under sole Prussian leadership. Baden's elite and the ruling Grand Duke were quite Prussophile.

Chapter 3 focuses onto the institutional history of Heidelberg University and its medical faculty.

Against the background of the preceding two chapters (2/3) I describe in chapter 4 Erb's attempts
to establish an electrotherapeutic ward at the medical university hospital in Heidelberg between 1872 and 1877. Although the medical faculty did not object and despite the personal support of his mentor Friedreich, personal arguments, petty quarrels and general lack of space in a rapidly expanding university thwarted its successful institution.

Part II Naturwissenschaftliche Medizin: The poetry of reality

The following chapters endeavour to identify the qualities which account for Erb being apparently highly characteristic for an entire epoch in medicine. Contemporaries knew him as a typical representative of naturwissenschaftliche medicine.

Chapter 5 opens with a brief description of the poor state German medicine was perceived to be in during mid-century. Academic physicians were frustrated with a lack of theoretical certainty and the apparent impotence of medical therapy. Having received his medical training during that time of crisis, Rudolf Virchow set out to cure the ailing medicine by attempting to reconcile medical theory and practice. Part and parcel of his programme was to reactivate clinical medicine. Virchow is, of course, well known as the founder of cellular pathology and promoter of pathological anatomy, yet the clinician Virchow has received less attention.
I attempt to trace Virchow's intellectual roots and the wider implications of his claim that the hospital, i.e. clinical medicine, can be regarded as the point of departure of modern medicine. I stress particularly his intellectual debt to Schönlein who initiated the clinical method in German medicine. My decision to elaborate on Schönlein was stimulated by the realisation that he had opened up the 'Klinik' as a shared space for empirical and theoretical knowledge: The composing and comparing act of making a diagnosis was understood to be a substantial ingredient of Schönlein's methodology and became the focus of the clinical enterprise.

The chapter describes how Virchow and his disciples expanded and elaborated this theme. It also surveys the wider political, social and cultural significance and appeal of Virchow's medical reform. I attempt to tie an earlier theme - the almost ubiquitous yearning for national unity in German speaking lands - together with the professionalization of medical expertise throughout German lands (Prussia serves as an example). The remainder of the chapter examines Virchow's recommendations how to transform therapy from an art into the science of healing. His disciples Friedreich and Erb were cautiously optimistic about the potential progress of medical therapy.

Chapter 6 illustrates the arguments made in the preceding chapter through the life of Nikolaus Friedreich. He was a disciple and close friend of Virchow and Erb's mentor.

Chapter 7 attempts a synopsis and synthesis of the aforementioned topics in an effort to place Erb in his time and generation. This chapter also illustrates the wider aesthetic appeal of electricity during the era under consideration.

Part III Electricity and medicine

Chapter 8 follows up Erb's claim that particularly during the first two decades after mid-century electricity had a good chance to become part of viable medicine because of recent electrophysiological discoveries. This chapter attempts to explain contemporary electrophysiological theories which provided a scientific rationale for the therapeutic employment of electricity. It was well understood that electricity was not simply identical with the nervous agent. In the wake of Emil du Bois-Reymond's research the theory of electrotonus enjoyed great popularity.

Chapter 9 introduces the history of German electrotherapy and electrodiagnosis prior to Wilhelm Erb's publications and the last chapter examines Erb's main electrotherapeutic publications, clinical and experimental practice and experiments.
Chapter 1. Wilhelm Erb's Biography

Following the Thirty Years War the Palatine (Pfalz) population had been decimated by battles, famine and disease. Subsequently Kurfürst Karl Ludwig encouraged foreigners, preferably of the same mother tongue, to settle in the Palatine. Attractive concessions were made to accommodate those immigrants. They were spared initially from military service and did not have to pay taxes.

Local historians estimate that by the second half of the seventeenth century nearly forty percent of the local Palatine population was made up of protestant Swiss German immigrants. They had mainly settled in the region Kraichgau.

In the wake of one of these first Swiss German immigration waves Wilhelm Erb's ancestors had come from a small Swiss village Dotnacht near Lake Constance to Wiesloch. Wiesloch is situated twenty kilometres south of the Kurpfalz capital Heidelberg. There Johannes Erb (1669-1723) settled and became a teacher at the local school.

The Erbs remained in Wiesloch where in 1743 Johann Ludwig Erb (1743-1824) was born.\(^1\) He studied theology in Heidelberg. After graduation he went to the Netherlands where he took up an university appointment.

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\(^1\) Johann Ludwig Erb jr. (1743-1824), son of "Schulmeister und herzoglich Pfalz-Zweibrückener Geheimer Kabinettskanzlist" Johann Ludwig Erb sen. (1704-1762). Johann Ludwig Erb jr. was Wilhelm Erb's grandfather.
Having spent nearly twenty years in Holland Johann Ludwig returned to Heidelberg University in 1787 where he taught until his death in 1824 cameral sciences.

Johann Ludwig's first wife died during childbirth. The infant, however, had survived and needed a mother. Therefore Johann Ludwig married his first wife's younger sister. His first born son was named after his godfather the Duke of Pfalz-Zweibrücken, Carl August.

Aged sixteen Carl August Erb (1791-1873) enroled at the Law Faculty and became Privatdozent at the age of twenty one at Göttingen University. Carl August returned later to Heidelberg's university, teaching law and philosophy.

The present family still proudly keeps some memorabilia which date back to Johann Ludwig. Wilhelm's grandfather had enjoyed a good relationship with the local nobility. In 1819 Counsellor Johann Ludwig Erb had received a precious ivory carving with a personal dedication from the local Earl Franz von und zu Erbach.2

Johann Ludwig's second marriage was blessed with eight children. The first child of that marriage - Wilhelm Erb's father - Friedrich (1797-1868) was born in 1797. Unlike his older brother Carl August or his father, Friedrich decided not to take up a university

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2 Erbach, noble dynasty of earls from the 12th century settled in the Odenwald region.
career. He was keen to become a forestry commissioner and was employed as civil servant in Royal Bavaria.

After the collapse of the Napoleonic Empire the Palatine regions left of the Rhine came under Bavarian control. Friedrich Erb was forced to move around to look after the woodlands of the enlarged Royal Bavarian State. In 1831 he was posted to Winnweiler/Pfalz. The new post brought more stability into his life and he could now afford to get married to Amalia Bettinger, the daughter of a counsellor to the Court in Zweibrücken. Amalia died during childbirth three years later. Friedrich Erb married again. His second wife Sophie Hoffmeister (1804-1895) gave birth to three children: Amalia Elise was born in 1839, followed by Wilhelm in 1840 and Karl in 1842.

By the time Wilhelm was born his father was employed as Royal Bavarian District Forestry official. In 1844 Friedrich's superior died and Wilhelm's father was chosen to become his successor. Now, as Forstmeister and Amstvorstand, he received a substantial increase in salary - three and a half times more than he used to earn before plus a free supply of firewood and food for the horses. Furthermore he enjoyed the privilege of a rent free accommodation during his time of service and was given free farming land. His older brother Carl August, the university professor of jurisprudence and philosophy, earned 600 Gulden in 1844. Friedrich had obviously made a smart
decision in entering a non-academic career since he earned the proud sum of 1400 Gulden in the same year, following his promotion.

Erb's father Friedrich was plagued by severe rheumatism and had to take sick leave quite often. Perhaps young Wilhelm considered a medical career having seen his father's life crippled by chronic pain and disability. Friedrich Erb died in 1868.

Wilhelm's mother Sophie enjoyed a long life and spent her old age with Wilhelm's family in Heidelberg. She died aged ninety-one in 1895.

Erb's parents had been comfortably well off and could afford to pay for their sons' education. The oldest daughter Amalia Elise married a Swiss merchant Melchior Imhof and returned with him to Basel.

Wilhelm Erb received his initial education at the local village school and then at a private school, aimed to prepare its pupils for the Gymnasium, under the supervision of the local protestant vicar. Apparently none of his pupils failed to pass the entry exams for the Gymnasium. Wilhelm was sent to the Herzog Wolfgang Gymnasium in Zweibrücken.

Aged seventeen Wilhelm began to read medicine at Heidelberg University in 1857. From there he moved in May 1858 to Erlangen University, where he only spent

one term. The Erlangen Archive has no further records of him other than his entry into the enrolment list.\textsuperscript{4} Subsequently Wilhelm Erb returned to his local university in Heidelberg where he remained as a student under Friedrich Arnold and Nikolaus Friedreich till summer 1861. He spent the final year (1861-1862) at Munich University. During the following two years Erb worked as medical assistant under Nikolaus Friedreich at the "Akademisches Krankenhaus" in Heidelberg. In October 1864 Erb passed at the age of twenty-four the "Medizinische Staatsprüfung" with distinction at Munich University and was awarded his "Promotion" (MD) on 27th October 1864.\textsuperscript{5} Soon afterwards he successfully applied for registration as a medical practitioner in Baden.

Unfortunately no records either about his studies nor his assistantship under Professor Buhl in Munich exist in the local archives. Dr Ludwig Buhl had become Privatdozent at the Munich Medical Faculty in 1847. Three years later he was promoted to Extraordinarius and became in 1858 professor of general pathology and pathological anatomy. Dr Buhl was a renowned and respected representative of that subject at the time.\textsuperscript{6}

\textsuperscript{4} Letter from Prof.Dr.phil. Dr.med.habil.Renate Wittern dated 28th Jan.1994 (Institut für Geschichte der Medizin der Friedrich-Alexander-Universität Erlangen-Nürnberg) and letter from Dr.Hans Otto Keunecke dated 24th Jan.1994 (Universitätsbibliothek Erlangen-Nürnberg)

\textsuperscript{5} Letter from Prof.Dr.Laetitia Boehm (Vorstand des Archivs der Ludwig-Maximilian-Universität München) dated 13th Jan.1994

\textsuperscript{6} Ibid.
In 1866 Wilhelm Erb handed in his successful "Habilitation" at Heidelberg University and was subsequently promoted to Extraordinarius.

In 1872 he married Bertha Karoline Herrman (1848-1873) of Berlin. Bertha died at the age of twenty-five soon after having given birth to their first baby son Hermann in March 1873.

Three years later Wilhelm Erb married Anna Gass (1855-1928), the daughter of an university colleague and professor of theology Friedrich Wilhelm Gass. Wilhelm and Anna had three sons together: Walter was born 1876, Roland in 1879 and Friedrich in 1883. The oldest son Herrmann became a chemist. Walter followed his father's footsteps and studied medicine at Strassburg University. Wilhelm Erb had to mourn the untimely death of three sons. Walter who had already made a name for himself with his experimental research on adrenaline, had died from an infection which he had contracted during his work as a physician 1907 in Strassburg. The oldest son Hermann died suddenly in 1910. His youngest son Friedrich, an engineer with a doctoral degree, fell during the first days of the First World War in a battle near Mühlhausen. Only Roland survived his own father. He had become a lawyer.

The First World War and its consequences distressed Erb very much. Many things which he had found worthwhile and enjoyable in his fatherland prior to the war had lost their appeal and truth.
Wilhelm Erb died in November 1921.
Chapter 2. Heidelberg University - the hotbed of the kleindeutsche national unification movement

General Introduction

Our present concept of nationhood was cultivated during the 19th century often referred to as the "European century of nationbuilding". We are thus inclined to think of nations in terms of geographically defined national territories and tend to assume national institutions that are relatively well integrated and congruent. James Sheehan pointed out that it is, however, anachronistic to apply the same conceptual categories to 18th century German speaking lands.¹

The Germany of 1771 was not the Germany of 1871 in utero; nor can we simply assume that there must be something called 'Germany', a particular territory, a set of ideas and institutions, a cluster of traits and customs.²

Historians have observed that at the beginning of the 19th century many German intellectuals suddenly experienced an identity crisis with respect to their 'nationality'. As to the genesis of this identity crisis historians have suggested as a major cause the collapse of the Holy Roman Empire in the aftermath of the Napoleonic encounter.³


² Ibid., p.5

The collapse of the old Empire had suddenly exposed a bewildering profusion of local divisions, a variety of civil, judicial and fiscal boundaries. Of course, those had existed before, but the previous cameralist rule of the Holy Roman Empire had succeeded in glossing over the political and economical fragmentation. Mack Walker demonstrated how the baroque science of cameralism accepted multiplicity. Its inherent proposition was that the state was the medium of social harmony and was responsible for it, while differentiation was the essence of society itself.¹

Sheehan judged the political role of the Holy Roman Empire similarly:

where the Empire did have a political role to play, this role involved guaranteeing diversity rather than imposing cohesion. The Empire worked best where it unified least, which is why it was most popular among those who benefited from political fragmentation.²

At the turn of the century the atmosphere in German speaking lands is characterised by a yearning for that previous alleged harmony and cohesion, without questioning whether such a blissful state had ever existed. This harking back to a golden past finds its expression in Goethe's admiration of Strassburg's gothic architecture or Herder's medievalism. Another feature of that time is the still cosmopolitan definition of nationality by reference to other

¹ Mack Walker, German Hometowns, Ithaca, N.Y., Cornell University Press, 1971, p.146
² J.Sheehan, op.cit., note 1, p.6
nationalities and Germany's geographical location. In the absence of political institutions Germans had to manufacture their own concept of nationality in their quest for a national identity. They self-consciously invented an imagined national past and idealized future which resulted in a complex web of fact and fiction, still difficult to disentangle today.

The national awakening took place among a relatively limited cultured class, a class once characterised by Mack Walker as the movers and doers. A narrow section of German society had always belonged to a cultural system which was not locked into the necessities of local communities. They came either from the small realm of the aristocracy, the upper ranks of the church, from academic life and the civil service. Their own flexible life style counteracted the inertia of political particularism and fragmentation. Thus they were qualified to exert and implement a unifying and levelling influence upon German society by virtue of their own flexible lifestyle and tolerant cultural outlook.

The civil service had already been organized on the principle of bureaucratic centralization during the eighteenth century. Therefore it lent itself to be a suitable instrument to extend the principle of

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7 M.Walker, op.cit., note 4, p.120 and p.127
bureaucratic centralization across the German countries thus leading to more uniform administrative organization throughout the lands, which would eventually transform the diverse collection of countries into a more homogenous structure - a nation state.

Hegel provided the rationale for such an operation. Under the influence of the French occupation Hegel had developed his ideas of German society.\(^6\) Initially he had divided German society into two main components: a noble upper estate of land owners and army officers, and a lower estate including apparently anybody else. In 1806 he replaced the noble estate with the "general estate" corresponding closely with Walker's movers and doers of the eighteenth century. It was an estate of generalizers dominated by the civil service and university academics and distinguished by its separation from local Bürgers and peasants.\(^7\) Hegel was able to say about this category of the general estate, that although local affairs might be left in local hands, the general will was to be expressed not by public participation but by the civil service. Thus civil servants, mainly in Prussia, arrogated to themselves the mission of representing all the people on the grounds that corporate institutions by their

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\(^6\) Franz Rosenzweig, Hegel und der Staat, 2 vols, Munich, 1920

\(^7\) M.Walker, op. cit., note 4, p.195
manifest nature could not represent all people or join them together.

Apart from the civil service another section from the movers and doers appeared to be suited to initiate national unification: the universities and the "Bildungsbürsrtum" (educated middle classes).

Universities had already been reformed under the influence of Enlightenment ideas during the 18th century. Having had to organize themselves vis-a-vis the strong guilds and local communities they offered a network of communication and movement stretching across the borders and the social restrictions communal life otherwise imposed on its inhabitants. In the eighteenth century German literary culture had extended across territorial boundaries offering an accepted escape from the confines of a small local environment. Yet the society of the educated had guarded their education closely. Gottfried Herder realised that the restricted availability of knowledge had been the chief mark of the old society. Breaking apart this closed and inaccessible world would transform social relations. Herder therefore argued for the wider availability of practical as well theoretical knowledge. Fichte continued the logic of Herder's argument. A state directed education could create a German character. The new university was indeed expected to contribute to the general strengthening of the state as a bastion of
national culture.  

During the first decades of the 19th century civil servants attempted to remove the main obstacles on the path to a unified nation. Thus administrators had to address the contradictions between local communities and the common weal. The political and social life of the many local communities had been ruled for centuries by the traditional rights of corporative guild structures. Thus any attempt to convert local variety into an overall more uniform structure had to target the guilds which kept the local communities with their corporate conceptions of community membership apart from the state. Opening up and directing local communities could only be achieved by enabling the latter to reach beyond the rigid walls fencing them off from each other. Freedom of movement could only be achieved by introducing occupational freedom, i.e. by introducing economical reform which would eventually undermine the antiquated guilds. Baden's history during the early 19th century illustrates very well the struggle between state authority and local autonomy over control of citizenship, which was inseparable from a cluster of controversies over trade regulations.  

Initially the introduction of occupational

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10 Harold James, op. cit., note 3, pp.42-43  
freedom and freedom of personal movement had an undesired destabilising effect for it threatened the social continuity of local communities. Artisans and craftsmen were particularly hard hit by government reforms which destroyed the rules which had hitherto regulated their industry, trade, income and citizenship. Walker observed that during the period in question a significant number of artisans and craftsmen emigrated because they feared poverty in the face of the vast social changes.\(^{12}\)

During the same era, i.e. the 1820's and 1830's, Baden's government founded technical institutes, trade schools and put more emphasis on the so called "Realwissenschaften" and the 'ideology of the practical' in secondary schools. Tuchman's thesis gives a comprehensive account of these developments in Baden's education system.\(^{13}\)

In the light of the aforementioned introduction of economical reform and the deeper political reasons behind it, i.e. the realization of a less divided nation, it becomes clearer how economic and educational reform were linked with the liberal political aims of the civil service.

Tuchman argued that the significant developments which


\(^{13}\) A.Tuchman, Science, Medicine and the State, The Case of Baden 1815-1871, Oxford, Oxford University Press, 1993
altered Baden's economy throughout the 1830's till the 1860's depended on the implementation of government reform designed to improve and modernize the economy:

The abolition of serfdom and the guilds are classical examples of such measures and she continues

But of comparable significance were changes in the educational system that resulted in a greater emphasis on the natural experimental sciences.\(^{14}\)

I agree with her, but would change the emphasis slightly. My review of the historical literature has persuaded me that economic and educational reform were not two distinct steps aimed at achieving political and social integration, but rather educational reform was a corollary to the economic reforms. Without educational reform the immediate less advantageous destabilizing side effects of the economic changes would have affected the petit bourgeoisie even more. This in turn would have increased the threat of popular protest and unrest.

I argue that Baden's government had to resort to educational reform in order to make economic reform work - the latter depended on the former not only in the ideological realm\(^{15}\) but had also a very practical role to play. It acted as a safety net for those who were suddenly propelled by economic reforms beyond the

\(^{14}\) Ibid., pp.5-6

\(^{15}\) Ibid., p.40: Ludwig Winter (1778-1839) head of Baden's Ministry of Interior exclaimed: "Knowledge knows no guilds..only freedom."
sheltered confines of their local communities. The education system had to exert a stabilizing effect which had temporarily been lost in the economic domain.

The contemporary neologism Realschule illustrates my point: In the 1820 "Realgewerbe" had been abolished. This was a heritable property right in the exercise of trade which was an extension of the customary automatic entry into a guild by a master's son. In Baden the abolition of "Realgewerbe" coincided with the introduction of trade schools, Realschulen with their emphasis on a practical hands-on approach. They were targeted at the host of sons of artisans, no longer able to serve an apprenticeship in the traditional guild system. Thus the state not only managed to train the youth for the modern economy it aspired to but also integrated immediately a class of youngsters which would have otherwise been left unoccupied and abandoned. In the long run the direction of change was on the side of the state: "By the middle of the century train stations had replaced city walls."\(^{16}\)

By mid century the struggle for national identity entered its decisive phase. Ideas about national unity and its achievement began to take a more definite shape. Ideas now began to be directed towards the future whereas at the beginning of the century intellectuals appear to pine for the past.

Throughout this period historical projection was

\(^{16}\) J.Sheehan, op.cit., note 11, p.490
used as a synthetic devise to create a certain image of the emerging nation. The ubiquitous yearning for organic wholeness continued to dominate intellectual aspirations. The question of national unity was now, however, moved into the political realm. An abundance of historiographical questions became suddenly unavoidable for those who wanted to define firmer foundations of national identity than eighteenth century evocations of German multiplicity had permitted. Where was the national past? Was it contained in all the scattered German polities of Central Europe with their tangle of interlocked histories? Was there some representative German state whose history might be taken as the source from which a larger nation might develop? What was the relationship between nation and state, between community and society, between "Volk" and nation. What is the state, is it the people or some abstract structure?

Faced with such a puzzle of issues some looked to Austria, others to Prussia for salvation. Austria stood for a national experience reminiscent of the old Empire and its particularism. Prussia's potential to unify was identified in its advanced administrative centralization. The *grossdeutsche* solution was advocated by a wide range of supporters scattered all over the political spectrum. The *kleindeutsche* solution had its supporters among the majority of moderate liberals.
The Frankfurt parliament was split between those who advocated a "Great Germany" (Grossdeutschland) and those who favoured a "Little Germany" (Kleindeutschland). The former wished to retain the historical connection between Germany and the Habsburg Empire, while the latter sought to exclude Austria and establish a union under Prussian Hohenzollern leadership. During this period a multitude of German political parties were entangled in a complex web of alliances, antipathies and sympathies.

With the hindsight of today's historical knowledge and experience it is difficult not to view 19th century German history through the perspective of its "Reichsgründung" in 1871 under Prussian leadership:

The major issues in German historiography - the economic foundations of the Reich, the nature of German imperialism, the origins of the world wars, the failure of democracy, and the rise of Nazism - have almost all been seen as national problems, best confronted within the boundaries of the Bismarckian state. Although German historians these days seem to disagree about almost everything, the one thing most of them still accept is the historiographical legitimacy of the settlement of 1871.

This view is particularly hard to avoid since a group of German historians and politicians passionately advocated this version of events prior to its "fulfilment". Their version of German identity and history rested mainly on the fusion of the Prussian and

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18 J. Sheehan, op. cit., note 1, p.3
the German pasts.

During the 1860's Heidelberg University became the hotbed of this so-called "kleindeutsche" historical school. Its main representatives there were Ludwig Häsuer and Heinrich von Treitschke. Ludwig Häsuer advanced throughout the early sixties his kleindeutsche ideas from his academic position. Häsuer was succeeded by the Saxon Heinrich von Treitschke. Treitschke was a zealous convert to the Prussian cause, sometimes too fanatic even for his own comrades-in-arms. In his view only Prussia could dissolve the romantic fairy tale world of particularism and provide the basis for a free unified Germany. Heidelberg has often been identified as a seminal centre for the national unification movement of kleindeutsche persuasion.

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19 J. Sheehan, op. cit., note 11, p. 846; perhaps therein lies a clue to the fact that Naturphilosophie was now vehemently dismissed as obscure particularly by kleindeutsche pro Prussians. Naturalphilosophical rhetoric was thought to be too reminiscent of the former cameral sciences of state management. The latter was designed to accept multiplicity within unity. Both notions were rejected by Kleindeutsche as obscure Austrian attributes.

Politics in Baden and at Heidelberg University 1860-1880

In 1856 the Badenese Grand Duke Friedrich assumed regency on behalf of his mentally ill brother Leopold II. This event is often referred to as the dawn of a new era in Baden's history for Friedrich II was a liberally minded ruler. Friedrich had been educated under the tutelage of the kleindeutsche historians and politicians Häusser and Schlosser at Heidelberg University. It is generally acknowledged that Heidelberg played a decisive and formative role in Friedrich's life. Grand Duke Friedrich was an ardent supporter of the kleindeutsche politics.

In the aftermath of the 1848 Revolution a specific idea of the state's function had gained support among Baden's elite: A practical Hegelianism advocating a powerful and effective state as a major pre-condition for the political and social maturation of the "Bürgertum".

Ludwig Häusser, now having gained a seat in the second chamber of Baden's parliament, was one of the most ardent supporters of this specific blend of Hegelianism. He credited the state with the "divine mission to achieve all high and moral-ethical ends of human life through its prescriptions".  

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21 Ibid., Vol.2, p.163

22 Joseph Becker, 'Der badische Kulturkampf und die Problematik des Liberalismus', in (ed.) Landeszentrale für politische Bildung, Badische Geschichte, Stuttgart,
Comprehensive competence was attributed to a reforming state rather than to the church. This led to a conflict between the Catholic church and conservative Protestants on the one side and the state on the other. Immediate reason for the outbreak of conflict was the question of the supervision of primary schools. Previously the control of primary schools had rested with church officials. Baden's liberal civil servants intended to enfranchise the education system and bring it under state control. After all education was also seen as a unifying and levelling force. Part and parcel of this project was the dissolution of traditional confessional primary schools. Thus they attempted to offset religious division in order to achieve integration by education.\textsuperscript{23} \textit{Wissenschaft} was to become the new religion:

In the shining light of German \textit{Wissenschaft} the mist of confessional prejudice dissolves. But in order to make this light shine brightly, it must also be allowed to shine on the height of political power, and it has to be directed into all layers of society. Science is in its authority equal to religion. As the medieval age managed to secure religious authority and education a beneficial influence onto the higher and lower classes through its ecclesiastical institutions...likewise the new age must be careful to enlighten the peoples' spirit and intellect (Geist) in all respects with the help of scientific institutions.\textsuperscript{24}

\textsuperscript{23} See also Tuchman's thesis that education was understood to be a medium which would eventually create state citizens.

\textsuperscript{24} J C Bluntschli, \textit{Denkwürdiges aus meinem Leben, Nördlingen}, Beck, 1884, Dt.Periode, 1.Hälfte, p.275
Baden's Catholic church was bitterly opposed to the new regulations. The Catholic church enjoyed passionate popular support. This was also a conflict between the Prussophile Protestant elite and the pro Austrian Catholic majority of Baden's peasants and "Kleinbürgertum".25

The ecclesiastical reaction threatened the prestige and power of the state even more, since two thirds of the entire population were Catholic and only one third - which coincided with the dynasty and the majority of higher civil servants - was Protestant.26

Many liberals had come down to earth, depressed by the experience of the failed 1848-9 Revolution. They distanced themselves from their own past in the revolution:

As soon as...the revolution had crushed the ramshackle of a bureaucratic and dynastic regime, Baden turned into a play ground for revolutionary passions,...the masses rebelled, the troops deserted and fled to the rebels, the dynasty fled, the republic was proclaimed. The incompetence of the bureaucracy became apparent as did the political immaturity of the people.27

As to the aims and aspirations of moderate liberals in Baden one of its representatives remarked that the 1848 experience had dampened previous idealistic aspirations. Ideas of freedom and equality akin to French liberalism were now rejected by its former advocates as too abstract, naive and immature.

The aspirations of Badenese Liberalism were indeed

26 J C Bluntschli, op.cit., note 24, Vol.3(2), p.8
27 Ibid., p.7
not as high and its means not as mighty as the ones of French liberalism. It merely aspired to develop Baden into a "Musterstaat" (model state) for other German states, but did not intend to liberate the world or to dominate Europe.\textsuperscript{28}

The idea, however, of a united nation under Prussian leadership persisted. We have seen that a \textit{kleindeutsch} path towards unification was advocated by the majority of Baden's liberal elite in the face of Catholic, pro Austrian, popular opposition. Foreign minister Franz von Roggenbach, a close friend and ally of the Grand Duke, felt that Prussian hegemony was both necessary and justified, if one seriously wanted to advance the national cause. Austria meant to him only obscurity and obstruction on that path to unification.\textsuperscript{29} Baden's geographical position made it vulnerable to French expansion, and perhaps even to Bavarian power lust. Therefore Roggenbach felt that Prussian protection was needed.

Meanwhile Grand Duke Friedrich had married Luise, the daughter of the Prince of Prussia and thus strengthened further the links with the Prussian royal household.

In the politically more mature circles of society the pro Prussian politics found support and understanding. Thus Roggenbach could dare to advance officially the course of the politics, then decried as 'kleindeutsch'.\textsuperscript{30}

\textsuperscript{28} Ibid., p.15

\textsuperscript{29} Ibid., p.18

\textsuperscript{30} Ibid., p.18
Throughout the 1860's and 1870's Baden's inner and foreign politics were dominated by those tricky party-political circumstances. Forced by the complexity of the political situation Baden ended up fighting on the Austrian side against Prussia during the 1866 Austrian-Prussian War, not least to appease the majority of the pro Austrian Catholic population.

Following the Austrian defeat at Königsgrätz (Sadowa) the answer to the German question seemed to be backed up by the logic of events and the formidable power of the Prussian modern state. The kleindeutsche school certainly benefited from the 1866 victory at Königsgrätz (Sadowa). Its prophecies had suddenly become the obvious solution to the German question.

The social life in Heidelberg and at its university mirrored the complex political circumstances of the state of Baden during the 1860's and 1870's. Ewald Hasse gave a vivid description of Heidelberg's "in-crowds and coterie":

Ever since Heidelberg society was renowned for the fact that cliques played a special role there...various more or less different factions opposed each other. There were the determined Ultramontane\textsuperscript{31} and the equally decisive Protestants, the Absolutists and the Liberals, the Particularists, the Grossdeutschen of Prussian and Austrian persuasion. Overt radicals appeared to have vanished after their defeat in 1848. Between all parties attraction and repulsion in all directions took place. For example the orthodox Protestants tended towards the absolutists, but hesitated to join their associates the

\textsuperscript{31} Ultramontane (lat.ultra-montanes=beyond the mountains, in this case the Alps) stands for ultra orthodox catholics closely aligned with the Vatican.
ultramontane pro Austrian Grossdeutsche. However, among the latter group, there existed some which tended to be liberal, even radical, but did not want to have anything to do with the Protestants and despised the pro Prussians. Only a few attempted to stay away from the factionalism and thus risked being judged as spineless and remained without influence. 32

The University was obviously affected by this mind-boggling interplay of personal attractions and repulsions.

Heidelberg has been characterised by contemporaries as somewhat parochial in its general outlook:

In the small and claustrophobic town, everybody knew everybody, one inevitably noticed and criticized one another. There was something narrowminded and petty, yet restless and unnerving in Heidelberg's life, which contrasted with its real splendour and importance. 33

It is not difficult to imagine the whispering behind each others backs in the corridors of office buildings, the University lecture halls during faculty meetings or at professorial dinner parties. Inevitably antipathies, either purely personal or based on opposing political views found often open or disguised expression in university life and influenced policy decisions.

Hitherto the appointment of younger lecturers has always only been accounted for by the ministerial wish to rejuvenate the university's academic staff and to promote the cause of Wissenschaft. However, if one

32 E. Hasse, Erinnerungen aus meinem Leben, Leipzig, 1902, pp.52-53

33 J C Bluntschli, op.cit., note 22, p.24
looks at the events of the New Era through the eyes of a pro-Austrian Catholic university professor one obtains a different interpretation:

During the initial period of Grand Duke Friedrich's regency the climate at Heidelberg University became increasingly politicized in favour of the kleindeutsch historical school. A small group of aged professors watched the new development with abhorrence and sadness. They felt increasingly alienated from the university's life which no longer resembled the comparative peace of the olden days. At the same time Baden's political relationship with the Habsburg Empire deteriorated. At the height of the argument over the supervision of schools, the Bishop of Mainz and the Archbishop of Freiburg turned to Vienna for support. They asked the Austrian Emperor to intervene on behalf of the faithful and good Catholic people of the Black Forest to be protected from such dangerous modern state experiments and the threat to religion.

It was against this background that the Austrian ambassador von Pilat at the Karlsruhe court asked for a secret report to be drawn up by Professor Bähr with the aim "to obtain a better understanding of the Grand

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34 This group consisted of the Catholic monarchist professors Chelius, Rosshirt, Zöpfl and Bähr.

35 They felt justified in doing so, for the Black Forest and the Breisgau had been part of the Austrian Habsburg Empire for centuries till 1805.
Duke's policies" and to receive "a characterization of those who exercise an influence upon the Grand Duke:"

The headquarters of those gentlemen appears to be the University of Heidelberg. The influence of those professors...is so massive, that ministers obey advice from Heidelberg more out of fear than conviction.36

Professor Bähr had once enjoyed a formidable career as a historian of classical philology. He regretted the resurrection of the liberal Gotha party during the New Era. Despite the failed 1848 Revolution Bähr felt that intimate connections with old liberal party political friends had remained and continued to dominate the university. Now, disappointed by the political infighting he had agreed to draw up such an intimidating report. The bottom line of Professor Bähr's brochure is that the Prussian Court was seen as dangerously influential in Karlsruhe and the university as ultimately controlled by the kleindeutsche Gotha party. The appointments of Helmholtz, Friedreich, Kirchhoff, Bunsen, or Weber were judged by him only in political terms and not on the professors' academic merit. He understood these appointments merely as a plot intended to strengthen the kleindeutsche Gotha Party, but not as an educational enhancement of Heidelberg's university:

Needless to say that as a result of all these
appointments...the finances of the university have not improved."

Although the victorious Franco-Prussian war (1871) made factional disputes over the national question irrelevant the atmosphere at Heidelberg University continued to be poisoned. Across all faculties petty quarrels about promotion, remuneration, casting of votes, accountability and honourary titles continued to corrupt the atmosphere:

If Germans are not considerate of the common weal, then professors are on average the most inconsiderate of all beings, for they only think of themselves and their 'coterie' and thus they wipe off their obligation towards the common weal, the state, like dust from their clothes.38

Thus the early 1870's witnessed a major exodus of gifted scholars from Heidelberg: Treitschke, Helmholtz, Kirchhoff and many others.

The seventies have not been lucky ones for Heidelberg. Personal arguments poisoned the atmosphere; some of its best teachers left for Berlin as had once been the case in 1810. But not only for personal reasons: there had been a change in the facts of life. The old German task which could only have been solved from the outside, had been completed; the Empire had been founded and thus the scientific centre of gravity tended to shift towards the capital of the Empire. It was Heidelberg's loss after such a long time of cooperation. Enrolment figures went down, particularly during winter terms the lecture halls

37 Ibid.: "in the medical faculty—after having persuaded Chelius (senior) to retire—-one has ignored his son, a brilliant surgeon, in order to appoint Weber..., who has not been operating for years, as I have been reassured by the medical professors here." (Chelius was a catholic, Weber was a friend of Helmholtz. Helmholtz married the daughter of a Badenese national liberal politician Robert v. Mohl)

38 J C Bluntschli, op.cit., note 22, p.455
remained empty compared with the summer terms. Yet slowly the situation began to improve.39

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39 E. Marcks, op. cit., note 20, Vol. 1, 'Rede auf die Geschichte der Universität Heidelberg in 1903', p. 333
Chapter 3. Institutional History of the Badenese University Heidelberg and its Medical Faculty

General Introduction

Following the collapse of the Holy Roman Empire Napoleon embarked onto a major reorganization of Central Europe. In the wake of this project, designed to create several medium sized states as a protective bufferzone against Prussia and Austria, Baden gained considerably.

The small state Baden, situated on a north-south axis along the Reich's western frontier, had been quite exposed and vulnerable to the expansion of French power after 1793. Baden had a gifted representative in Paris throughout this period, the civil servant Sigismund von Reitzenstein (1766-1847). He negotiated an early peace treaty with France and subsequently Baden was "rewarded" with substantial territorial gains. With its territorial gains Baden also acquired the University of Heidelberg in 1803. Two years later Grand Duke Charles Frederick issued a variety of laws designed to revive the antiquated university.

Initial university reforms in South Germany, notably Baden and Bavaria had the character of an

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1 J. Sheehan, German History 1770-1866, Oxford, Clarendon Press, 1989, p.263: "Under v. Reitzenstein's leadership Baden made the largest gains of any German state, adding the Austrian Breisgau, the principalities of Fürstenberg, Leiningen und Löwenstein - Wertheim, parts of the Palatine and the bishoprics of Strassbourg and Constance, the abbey of St Blasien and the cities of Offenburg, Gengenbach and Zell."
organizational reshuffle, a drive towards greater secularization. The emphasis was put on the university's role as a training ground for future state and ecclesiastical servants. Restructuring the university's institutional framework also involved a correction of the financial situation of the bankrupt university. The state provided it with the financial means for its existence and in return took control in its own hands. Thus the university lost its estates and had to rely on the state's pecuniary provisions. In 1803 the sum of 40 000 fl was provided for the university. The annual budget spent on the university increased steadily and reached 100 000 fl by 1850.

The university's already restricted autonomy was curtailed to some privileges and rights of "corporative self-administration." For example from then on the sovereign took over the rector's office. Control over university affairs was put into the hands of the Ministry of Interior. The pro-rector administered the office on behalf of the sovereign rector.

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magnificentissimus. The prorector's duty was to manage the daily routine of university affairs and to reinforce rules and regulations. He was a member of the faculty elected by the Ordinarien (full professors). Restriction of the university's autonomy was furthermore signified by the abolition of the independent university jurisdiction in 1810. However, rudiments of self-government remained part of the university's administration. The faculties were able to preserve their "corporative rights" in monitoring the studies and examinations.

The statutory provisions of 1805-6 regulated the university's administration until 1918 and some of them even beyond that date: the prorector's term of office was fixed to one year, starting each Tuesday after Easter. The Enger Senat (Closed Senate) the most important decision making organ, consisted at first of nine members, later of six (the prorector, the ex-prorector and the deans of the four faculties). The Enger Senat's term of office lasted one year. One half of its members would be changed each Easter and Michaelmas.

The Grosser Senat (Great Senate), the assembly of all Ordinarien, played only a minor role in the decision making process. Not even protocols of its

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5 Hermann Weisert, *Geschichte der Universität Heidelberg*, Heidelberg, Carl Winkler Verlag, 1983, pp.74-75

6 E.Wolgast, op.cit., note 4, p.3
meetings have been recorded. Its main task was the nomination of the prorector, whose actual appointment was carried out by the Grand Duke. In almost all cases the proposed nominee was appointed. The Enger Senat had more power than the Grosser Senat, being the main channel of communication between government and university.

Another administrative organ gained in independence after 1805: The Bau- und Ökonomiekommission (building and finance commission). It received the right of independent communication with the Ministry of Interior in Karlsruhe, thus being enabled to report to government officials without the Enger Senat's knowledge. Not surprisingly this body would sometimes be used by the Ministry in order to bypass the Enger Senat.

Reitzenstein had not only negotiated a peace treaty with France, he also played an important role in reforming Heidelberg University. Reform was mainly brought about by 'hiring and firing' professors, suited to the needs of the neohumanist civil servants. He managed to fill vacancies with learned young men from Jena, Göttingen and Marburg.

Following the 1805 Pressburg Peace Treaty Baden had also acquired the former Austrian University of Freiburg. From then on the two sister-universities had not only to compete against foreign universities, but also against each other for funds, students and
academic staff.'

During the 1820's and 1830's attractive appointments were made, particularly advantageous for the Philosophical and Medical Faculties. The philosopher Hegel received his first professorship 1816 in Heidelberg.

The anatomist Jacob Fidelis Ackermann (1765-1815) was succeeded by Friedrich Tiedemann (1781-1861). Leopold Gmelin (1788-1853) was given the chair of chemistry in 1814. The appointment of Maximilian Joseph Chelius (1794-1876) to the chair of surgery and ophthalmology had been a fortunate move. He gained a reputation as a highly competent consultant among Europe's nobility and thus enhanced the medical faculty's reputation greatly.

Similarly, Karl Joseph Mittermaier (1787-1867) — the uncle of Richard von Krafft-Ebing — made the Faculty of Law an attraction for students from all over the country. Not surprisingly enrolment figures were boosted.

The introduction of a medical sickness society for students (Akademischer Krankenverein für Studenten) in 1825 may have acted as a further incentive to enrol. Every student had to pay a financial contribution each

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7 Eduard Seidler, Die Medizinische Fakultät der Albert-Ludwigs-Universität Freiburg im Breisgau, Heidelberg, Springer Verlag, 1991, pp.77 ff

8 Reinhard Riese, Die Hochschule auf dem Weg zum wissenschaftlichen Grossbetrieb, Stuttgart, Klett Verlag, 1977, p.27
term. In return he was entitled to free outpatient treatment, if hospital admission was required he would have to pay only half of the total costs.9

During almost the entire 19th century Heidelberg's University was dominated by its flourishing Law Faculty. At times every eighth law student in Germany was enroled at Heidelberg.10 The law faculty remained - with few interruptions - the largest faculty till the beginning of the twentieth century.11

From 1840 Ludwig Häusser (1818-67) taught history at Heidelberg and Georg Gottfried Gervinus (1805-71) became honorary professor for history and history of literature in 1844.

In the same year the Medical Faculty was substantially promoted by the appointment of two young promising scientists Karl Pfeuffer (1806-69) and Jacob Henle (1809-85). The story of their struggle and successes in the scientific community is well documented in Tuchman's book.12

These new appointments not only improved the university's standing in the world of learning, they also had a significant impact in the world of politics.

9 E.Wolgast, op.cit., note 4, p.8
10 R. Riese, op. cit., note 8, p.27
11 E.Wolgast, op.cit., note 4, p.24
The majority of the newly appointed professors were supporters of the liberal "Gotha" party. During the 1840's Heidelberg University came to be seen in the public eye as the flagship of the so-called "south-west German liberalism". The mouthpiece of this movement was the newspaper Deutsche Zeitung (The German News) which had been founded by Gervinus, Mittermaier and Häusser. Mittermaier and Gervinus also happened to be members of the Frankfurt National Assembly. In the ante-parliament (Vorparlament) Heidelberg's university was represented with a total of eight professors.\(^\text{13}\)

Following the suppression of the 1848/9 Revolution a short period of reaction prevailed in Baden. Then universities were seen as breeding grounds for subversive elements and regarded with suspicion. Some heads had to roll at Heidelberg University, particularly amongst its most outspoken liberals who had supported the revolution.

The passions had been exhausted in the aftermath of the revolution, although the turbulence and repercussions of this period were still trembling under the surface. Men of strictly conservative convictions had come to power, among them not only orthodox Catholics, but also numerous moderates of all political persuasions, who felt still shaken by the shock of the revolution.\(^\text{14}\)

Contemporary accounts describe considerable disharmony among Heidelberg's professorate between 1850 and 1880. The university suffered from a climate of

\(^\text{13}\) E.Wolgast, op.cit., note 4, p.11

increasing tension among its members. In 1873 the anatomist Karl Gegenbaur (1826-1903) found the medical faculty in such a state of disarray that he alluded to it as a "difficulty rather than a faculty".\textsuperscript{15}

Traditional university histories identify the period 1850-1890 as a time of increasing specialization, predominantly in the natural sciences and medicine. This coincided with rising numbers of students. At the same time no adequate and corresponding increase in teaching personnel can be discerned. Not surprisingly this led to some professors feeling overburdened in their teaching duties and dissatisfied students accordingly. The distinctions between disciplines previously clearly defined became blurred or overlapped with others as we will later see with the example of medical disciplines. Eventually more academic staff had to be recruited. But the younger generation of lecturers was not necessarily given the sort of promotion they had expected or felt entitled to. The vexed question of the "Nichtordinarien" troubled faculty members and politicians. Particularly throughout the second half of the nineteenth century an increase of appointed permanent teaching personnel in medicine and the natural sciences was achieved by increasing the number of so called "etatmässige Extraordinarien." This meant

\textsuperscript{15} Karl Gegenbaur, \textit{Erlebtes und Erstrebtes}, Leipzig, Engelmann Verlag, 1901, p.104
that generally the number of "Nichtordinarien" rose. At this point an explanation of the customary German terminology is in place:

The body of academic staff consisted of "Ordinarien" (regular full professors) and "Nichtordinarien" (non regular full professors). Perhaps it is helpful to think of an Ordinarius as an 'ordained' professor, i.e. a professor having been given full rights of status and remuneration in the fraternity of his colleagues. This status offered a variety of privileges: the right to sit and vote in the faculty meetings and thus participation in faculty politics, the right to regulate examinations and subsequently the possibility to build up one's own circle of students. Naturally to become an "Ordinarius" was the ultimate ambition of every university lecturer.

Any academic activity be it in the humanities, natural sciences or medicine having been given an "Ordinariat" (full chair) was thus integrated into the accepted curriculum and had been properly institutionalized. I have already mentioned that the university was financed by a state budget. Every year a sum was designated for the university's needs, including salaries and state pensions. An 'ordained' full professor was also an appointed civil servant under an oath of loyalty to the state. In return the

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16 E.Wolgast, op.cit., note 4, p.3
state was obliged to provide for him throughout his career and old age. Thus by increasing the numbers of "Ordinarien" a considerable strain was put upon the treasury. Facing a growing demand for teachers the problem was bypassed in establishing more non-regular teaching posts, i.e. "Extraordinarien" who received smaller remuneration, and "Privatdozenten" with no state remuneration.

During the 1860's a further distinction was made between "real" or "budgeted Extraordinarien", receiving a fixed state salary and so called "non-budgeted Extraordinarien". The latter were Privatdozenten, having been given only the title in appreciation of their work.

Once the 1850's reaction had loosened its tight grip upon public life a liberal group of professors attempted to reform the university's institutional framework. The aim was to increase the autonomy of the Grosser and Enger Senat. These efforts met with only little enthusiasm from the Ministry of Interior in Karlsruhe. Only few minor amendments were made and the constitution of the Enger Senat was slightly altered. The most pressing problem of the Nichtordinarien's representation in the university was not solved. They remained excluded from advisory committees and did not receive any rights to participate in the decision making process.¹⁷ In 1909 the "Nichtordinarien" teamed

¹⁷ Ibid., p.13
up and formed a pressure group. Two years later they achieved that "budgeted Extraordinarien" were allowed to vote in faculty meetings, provided they represented an independent discipline. All "Nichtordinarien" had to be informed about decisions being taken and were given the right to make proposals.\(^8\)

The Medical Faculty and University Hospitals in Heidelberg

Historians have observed at Heidelberg University a swift process of differentiation in the theoretical medical disciplines, whereas the clinical specialities appear to lag somewhat behind. Between 1850 and 1892 the number of independent chairs rose from one (anatomy) to a total of five (1892) in the theoretical medical disciplines. During the same period only two clinical specialities gained a full chair ("Ordinariat"): psychiatry (1878) and ophthalmology (1868). After 1878 no clinical discipline was to receive an "Ordinariat" for forty years.

Initially four classical "Ordinariate" existed in the Medical Faculty: anatomy, and the three clinical disciplines medicine, obstetrics & gynaecology, surgery & ophthalmology. During the first half of the century physiology and pathological anatomy were institutionally linked with anatomy.\(^9\)

\(^{18}\) Ibid., p.21

\(^{19}\) R.Riese, op.cit., note 8, p.113
From 1844-1850 a temporary "Ordinariat" in pathological anatomy and physiology was created for Jacob Henle. From 1852 pathological anatomy was taught by the "Ordinarius" of Medicine (Pathological Anatomy and Therapy) and a separate "Ordinariat" for Experimental Physiology was created in 1858 for Helmholtz. At that time Heidelberg was the thirteenth university out of twenty six in the German speaking lands with a separate chair for physiology.\textsuperscript{20} Pathological anatomy eventually gained recognition as an independent Ordinariat in 1870.\textsuperscript{21} Pharmacology was institutionalized with an independent chair in 1890, followed two years later by hygiene. The latter had been taught since 1866 in tandem with forensic medicine by professor Franz Knauff.

The comparative delay in creating a similar adequate number of chairs in the clinical disciplines is generally attributed by historians to the reluctance of clinical directors to share their patients and research-material. In the clinical disciplines directorship of an institute or hospital was held in "Personalunion" with at least a budgeted professorate. Holding an "Ordinariat" in the clinical subjects meant also an additional income from patient fees for the

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clinical director.

It had been noted that the philosophical faculty generally responded generously to the demands of newly emerging disciplines. Here the elders tried to get their younger colleagues rather sooner than later at least budgeted status and thereby enhanced their chances of establishing an independent chair.

Things appear to be different at the medical faculty during the same period, which was dominated by rivalry and competition. The medical faculty tended not to support demands for chairs or clinical representation in the new disciplines. The government acted on the whole more open-minded, but was often limited in setting up new institutions by financial constraints.²²

Towards the end of the nineteenth century the existence of independent disciplines became more accepted. A flood of requests to establish "extraordinary" and "ordinary" chairs at Heidelberg University set in. Their representatives received in most cases only the status of "etatmässiger Extraordinarius" (budgeted Extraordinarius) without their own institutional base. Parallel with these events Heidelberg established its own natural scientific/mathematical faculty separated from the

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²² E.Wolgast, op. cit., see note 4, p.19 and R.Riese, op.cit., note 8, p.112
philosophical faculty.  

After 1890 specialised departments in dermatology and venerology, neurology, dental surgery and orthopaedics evolved in either the Surgical or the Medical University Hospital. Their existence and survival depended on the good will of the clinical director of the respective hospital where they had found shelter. In 1914 neurology received a "Lehrstuhl" (chair) at Heidelberg University.

One of the oldest hospitals in Heidelberg was a Leprosarium founded by Ludwig (1410-1436) which was located in Schlierbach and dissolved in March 1741. All its assets were distributed among the hospitals of the three ecclesiastical communities (Catholic, Reformed, Lutheran) which had been established in the meantime and continued to exist alongside each other well into the 20th century.

Around 1600 the Medical Faculty made the first attempts to convert the university's Nosocomium into an institution for practical bedside teaching. Until then it had been customary to take medical students into the homes of the sick and to instruct them there.  

In 1766 a school for midwives had been founded in nearby Mannheim, initiated by Princess Elizabeth Auguste. In 1805 the school of midwifery was

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23 R.Riese, ibid., p.112

24 Anon., Illustrierte Festchronik der V. Säkularfeier der Universität Heidelberg, 1886
transferred from Mannheim to Heidelberg into the Dominican cloister and thus the first "stationary" inpatient hospital of Heidelberg's University was founded. In the same year a medical Poliklinik was introduced, aimed at the instruction of medical students in conjunction with home-visits conducted by the medical students throughout the town.\textsuperscript{25}

The Poliklinik or so called town-clinic has the aim to introduce young doctors into the practice, not just in the artificial environment of a hospital where the recognition of each individual disease picture is distorted by the confluence of varied disease pictures of patients living together; but it is aimed at instructing the beginners at the various bedsides in a spacious, sprawling town to demonstrate them the forms of diseases in their different exactly defined circumstances and to show them the patients themselves in their varied conditions of civic life, surrounded by anxious parents and children...in short to introduce them to the specific conditions of their career they are just about to enter.\textsuperscript{26}

The students would on return from their home visits report back to their teachers. This exercise was often accompanied by a case presentation, provided the patient was fit enough to attend. It took another ten years (1815) until an actual inpatient facility (Hospitalklinik) was opened in the same building. In 1818 Chelius inaugurated a surgical ward there, too.

\textsuperscript{25} Hufeland coined the term Poliklinik. His definition indicates that this medical facility was specifically set up to be a "city-clinic". (gr.polis= city, town) D.Jetter, 'Die ersten Universitätskliniken westdeutscher Staaten', \textit{Dtach.med.Wschr.}, Jahrg.87, Nr.40, 5.Okt. 1962, pp.2037-2043

\textsuperscript{26} Eberhard Stübler, \textit{Geschichte der medizinischen Fakultät Heidelberg 1386-1925}, Heidelberg, C.Winter, 1926, p.200
Soon the building was no longer spacious enough to accommodate three inpatient wards (hospitals, also referred to as Klinik) and the anatomical theatre. In the same year the three clinical institutions moved into an old army barrack Marstall.\(^{27}\) The anatomical theatre remained in the Dominican cloister. Space in the new Marstall building was divided between the surgical, obstetrical and medical wards. The medical ward was initially given the entire first and some parts of the second floor, a total of twenty eight rooms with the same number of beds. A further two rooms were reserved for patients with eye diseases.

The Poliklinik was attached to the medical ward/hospital whereas the surgical ward had its own outpatient department. During 1819 a total of 352 patients had attended the Medical Klinik\(^{28}\) and 152 patients had been admitted to the Surgical Klinik which was under the direction of Professor Chelius. He remained in charge till 1864, which meant that he singlehandedly conducted the administration of the surgical and ophthalmological hospital for forty six years. During his time in office he had witnessed the coming and going of six physicians directing the

\(^{27}\) Also referred to as Weinbrennerbau

\(^{28}\) "Klinik" the term was introduced into the German language in the 13th century from 1.clinice = art of healing bedridden diseased people 2.kline (Greek) bed, stretcher and 3.klinein (Greek) to lean over, also used in German in the sense of "institution aimed at the instruction in the art of healing."
neighbouring medical hospital.\textsuperscript{29}

The medical hospital (also referred to as Klinik) remained in the same building, but experienced a less continuous history than the adjacent surgical hospital. Space continued to be a problem and subsequently the obstetrical ward was moved to the West Wing of the Marstall building in 1830. Fourteen years later it moved back again into the main Marstall building, after the latter had been vacated by the medical and surgical wards. They had been moved (1844) to the Jesuitenkollegium. The West Wing of the Marstall was eventually sold off to accommodate offices for the department of customs and excise.

In 1844 Pfeuffer followed a call to Heidelberg and was given the Ordinariat in pathology and therapy (= medicine). He demanded the direction of his own medical hospital and therefore a second one had to be established in addition to the existing one directed by Puchelt. Pfeuffer's medical hospital was now referred to as Medizinische Klinik II. It provided initially sixteen beds. Pfeuffer's new institution was intended to be an university facility and thus entirely funded and maintained by the state. Puchelt's Medizinische Klinik I maintained the character of a civilian-urban institution and the town remained responsible for its

\textsuperscript{29} They were Conradi, Sebastian, Puchelt, Pfeuffer, Hasse and Duchek.
upkeep. The latter was also nicknamed the servants' hospital (Gesindespital).

For the purpose of conducting the Poliklinik the town was divided into two districts, one to be looked after by Puchelt, the other by the newcomer Pfeuffer. Since Puchelt was a blind old man, increasingly unable to fulfil his commitments, Pfeuffer was practically directing the Medizinische Klinik I and II plus the entire Poliklinik. His successor Ewald Hasse entered into the same working conditions. Following Puchelt's death in 1856 Ewald Hasse left utterly frustrated with the confused and unsatisfactory administration of the medical institutions. Subsequently a thorough revision of the situation was undertaken. Medizinische Klinik I and II were amalgamated with the surgical hospital under one administrative management. All three hospitals combined were subsumed under the heading "Akademisches Krankenhaus" in 1856. From then on the university was responsible for the financial management of the hospital and the upkeep of the building itself. This marked its gradual shift from an urban into a university institution. Thus the academic hospital gradually lost its function as a medical institution for the urban poor. The municipal council had to pay the fees for this category of patients once they had been admitted. A hospital commission was established

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30 R.Riese, op.cit., note 8, p.226
31 E.Hasse, op.cit., note 14, p.250
directly responsible to the Ministry of Interior in Karlsruhe. This commission was supposed to supervise administrative and financial matters. It consisted of the clinical directors of the hospitals, a third independent professor (from the faculty of law or national economics), the university magistrate, the university treasurer and two members, selected by the municipal council.

Following Puchelt's death the two medical inpatient facilities (Med.Klinik I & II) were united under the clinical direction of Adalbert Duchek (1824-1882). He taught general pathology, therapeutics and pathological anatomy in Heidelberg, whilst offering practical exercises in microscopy. His major interest was devoted to pathological anatomy. Duchek spent only a brief period in Heidelberg and chose to follow a call to Vienna where he succeeded Skoda in 1858.

By then Badenese government officials felt that the medical faculty needed an injection of younger blood and more administrative stability. Karlsruhe decided to emancipate the Poliklinik "aimed at the care of the town's poor population" from the medical hospital. In 1856 Privatdozent Theodor Dusch (1824-1890) was promoted (a.o.) Professor and clinical director of the Poliklinik. However, government ministers had not sought the medical faculty's approval or rather had acted against it. Inevitably relations

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32 E.Stübler, op. cit., note 26, p.313
between government and Heidelberg's medical faculty were initially strained. At that time the medical faculty consisted predominantly of older and politically conservative members, who objected to Dusch's promotion mainly on political grounds. Theodor Dusch was the son of Baden's former liberal foreign minister Alexander Dusch. His father had been in office from 1844-49 and belonged to the liberal circle "Museum" surrounding Häsßer, Jolly, Bunsen and Hasse. Even after more likeminded liberal professors had arrived in the medical faculty Theodor Dusch's presence continued to cause tension within the faculty. Friedreich, himself a professed liberal, allegedly opposed him quite often. Perhaps Dusch's personality was partly responsible for the antipathies he aroused. Local historians hinted that he had an "exuberant and boisterous temper, which conflicted particularly in his youth with the discipline of the faculty".

In Easter 1858 Duchek left for Vienna, angry that he had not been entrusted with the combined direction of Medical Klinik and Poliklinik. He was succeeded by Nikolaus Friedreich (1825-1882).

Once more the question of the distribution of rooms and responsibilities in the "Akademisches Krankenhaus" led to some discussion. Some problems were

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33 R. Riese, op. cit., note 8, p. 119

34 Philipp Bamberger, '100 Jahre Pädiatrie in Heidelberg', *Ruperto Carola*, 1960, Vol. 27/28, 1960, p. 175
solved in 1866 when Julius Arnold was officially registered to teach pathological anatomy. Prior to Arnold's appointment dissections and teaching in pathology had rotated between the clinical directors of the medical and surgical hospitals.

Medical and surgical beds were evenly distributed through the main section in the Jesuitenkollegium. An adjoining building housed the mortuary, the dissection hall and from 1857 on its second floor the Poliklinik. In 1866 Arnold's pathological anatomical institute moved into its attic.

After 46 years of duty Professor Chelius retired and a successor had to be found. Initially it was difficult to find a suitable replacement and Friedreich, Lange and Fehr had to share the direction of the surgical hospital in addition to their own establishments during the winter term 1864/65. Eventually the surgeon Karl Otto Weber (1827-1867) was called to Heidelberg, having been highly recommended by Helmholtz who had met Weber in Bonn and subsequently held him in high esteem. Unfortunately Weber's career was cut short by his sudden untimely death from diphtheria in June 1867. Weber's main contribution during his short period of activity at Heidelberg lies in his immense efforts to improve the hospital facilities. Immediately after assuming office (1865) Weber succeeded in persuading the government of the urgent necessity of building a new hospital. Karlsruhe
responded swiftly. In October 1867 a commission was appointed consisting of Friedreich, Helmholtz and Weber's successor Simon. Their task was to identify the most suitable and up-to-date architecture for the future academic hospital.

The government had bought land from the city of Heidelberg, which was located between Bergheimer Strasse and the river Neckar. This area was the intended location for the new hospital. The commission was joined by Professor Knauff who spent considerable time and effort on research and foreign travel, visiting different types of hospitals abroad. It was decided that the new building ought to be of a "mixed architectural system", i.e. consisting of pavilions (medicine) and corridors (surgery). In autumn 1869 the first excavations began.

The Franco-Prussian War caused considerable delay in the building works. The new academic hospital was ready for operation in October 1876. The project had swallowed the princely sum of 1 840 000 Marks which had entirely been borne by the state of Baden. Some of the new facilities, such as laundry, machine room, the "ice house", pharmacy and the workshops had to be shared with neighbouring institutes, i.e. lunatic asylum, botanical gardens and the women's hospital.

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35 Otto Becker, Festschrift zur 500 Jahrfeier der Universität Heidelberg, 1886 in Nr.3 p.48 f/Nr 11 p.185

Professor Friedreich remained in charge of the Medizinische Klinik (in the Akademische Krankenhaus) till his death in 1882.

Thomas Henkelmann has identified three mechanisms in the institutionalization of new clinical facilities in Heidelberg.37

During midcentury the paediatric and ophthalmological hospitals emerged from private clinics, partly financed by charities and inaugurated mostly by Privatdozenten. Otology and its sister discipline laryngology took their beginnings from outpatient departments.

The third path of institutionalization is still thought to be customary today. In this case the clinical director leaves the direction of a comparatively specialized subdepartment in his institute to a reliable and "deserving" assistant. This latter case can be illustrated with the example of dermatology, neurology or orthopaedics at Heidelberg University.

Riese identified two different, temporarily distinct modes in which independent "Spezialkliniken" emerged in Heidelberg.

Until 1900 they mostly developed from Privatkliniken which had been directed by Privatdozenten and were initially intended for clinical instruction. From 1890 onwards the establishment of Spezialkliniken

took a structurally different route which is still common today. In the traditional general medical or surgical hospital specialized departments were established under the immediate direction of an assistant...whereas the director maintained overall command. Provided continuity of personnel was preserved the department could achieve some stability. The respective assistant would then receive official registration to teach and a professorial title. As soon as the award of a budgeted Extraordinariat followed the separation from the general hospital as Spezialklinik was complete.38

Before focusing attention on Erb's attempts to establish an electrotherapeutic ward at the "Akademisches Krankenhaus", we need to look at the ongoing events during the period 1860-1880:

I have already discussed the lack of enthusiasm with which Theodor Dusch's promotion was greeted in 1856. Directorship of the Poliklinik was associated with the obligation to teach pathology. Dusch, however, also decided to teach paediatric medicine, previously taught by Posselt. Dusch was genuinely interested in children's welfare. He actively raised funds for a small charitable institution intended to care for sick children. Thanks to his family connections and his own efforts he succeeded in raising funds, particularly among Baden's upper classes. Following a generous donation from the English Countess Jenison Walworth he was able to rent a small flat in town and opened a private paediatric clinic in July 1860. Meanwhile he attracted an increasing number of patients into his

38 R.Riese, op.cit., note 8, pp.231-237
flourishing (medical) Poliklinik. Within ten years the number of patients attending had doubled. Hence the faculty was forced to consent to a higher budget for the Poliklinik in 1866. Only a few years previously Friedreich and Chelius had disapproved of a higher subsidy for Dusch's clinic. They felt it would only help to increase competition between their own outpatient departments and the Poliklinik.

During the same period Dusch's father Alexander actively campaigned for his son's career, asking the Badenese government for his promotion to full professor. Though the ministry was inclined to grant his wishes, they did not want to tread on toes at Heidelberg University and remained passive. Grand Duchess Luise, however, was pleased to become the patron of Dusch's private clinic.

In 1868 Theodor Dusch published a successful textbook in cardiology and was busy raising funds and organizing bazaars for his charity. Slowly the tide turned in his favour at the medical faculty. Helmholtz had always been very supportive and was now joined by Arnold, Lange and Simon. The latter even collected signatures from students and colleagues expressing approval of Dusch's clinical abilities and popularity. Eventually in 1870 Dusch was made full professor in pathology. Nine years later he was elected prorector. In 1880 the Grand Duke ennobled him to Counsellor Theodor von Dusch. However, his private clinic was
still struggling to survive on donations, though it was used by the university for clinical instruction. The medical faculty did not have the slightest intention to promote the small paediatric hospital. Only in 1922 was the paediatric clinic converted into a state institution and linked to the academic hospital.\(^39\)

One cannot but agree with Riese's assessment of the entire episode. He felt that the arguments surrounding Theodor Dusch's appointment did not throw a particularly good light on the medical faculty's conduct during the 1850's and 1860's.\(^40\)

Another young colleague suffered a strikingly similar fate. Chelius's assistant Jacob Herrman Knapp (1832-1911) had completed his habilitation in ophthalmology in 1859. Two years later Knapp set up a private ophthalmological clinic with twenty-two beds. Despite Chelius' misgivings the faculty approved of a government grant of over 500 fl towards Knapp's private clinic. Karlsruhe officials felt their subsidy was justified in view of the "inherent drive of modern medicine towards specialization".\(^41\) Knapp's clinic continued to be financed from donations and state subsidies, which eventually reached 30 000 fl per

\(^39\) E.Stübler, op.cit., note 26, p.279 and pp.293-299 and pp.324-326; R.Riese, op.cit., note 8, pp.120-122 and pp.128-129

\(^40\) R.Riese, ibid., p.121

\(^41\) Ibid., p.122
annum. Following Chelius' retirement Knapp was appointed extraordinary professor. The faculty remained ambiguous and hesitant towards his demands for a proper full "Ordinariat". In 1866 Knapp demanded full recognition for a subject which had already been described by Wunderlich in 1841 as a fully established speciality. He asked for an adequately salaried professoriate and the direction of an ophthalmological hospital combined with a full (ordinary) chair in ophthalmology "since he realized that one always remained in the wrong as long as one did not have a seat in the faculty". Furthermore he wanted the expansion of his hospital with a seat and vote in the hospital commission. The faculty refused despite Helmholtz's efforts to calm the mood. Knapp felt so frustrated that he emigrated to the United States of America, where he gained fame and recognition.42

A year later the very faculty that had refused to support an ordinary full chair for Knapp gave its blessing to exactly the same demands by Otto Becker (1828-1890). Becker had been called from Vienna to the university with the intention of giving him only an extra-ordinary professorate and the directorate of Knapp's private eye-clinic. Becker somehow managed to

42 Knapp edited the Archives of Ophthalmology and was the founder of the "New York Ophthalmic and Aural Institute". R. Riese, op.cit., note 8, p.124 and Birgit Hessler, 'Die Gründung der ersten Augenklinik in Heidelberg durch Jakob Herrmann Knapp', MD, University of Heidelberg, 1969
sway the medical faculty in his favour by pointing out that he was accustomed to the Austrian tradition of full "Ordinariate" in ophthalmology.\textsuperscript{43} Becker also negotiated successfully the construction of a new eye-hospital according to his plans, which was completed in 1877.\textsuperscript{44}


\textsuperscript{44} R.Riese, op.cit., note 8, pp.124 ff. and E.Stübler, op.cit., note 26, p.322
Chapter 4. Erb's attempts to establish an electrotherapeutic ward

Erb's interest in electrotherapy had been kindled by his tutor Friedreich and by the common contemporary medical practice of treating nervous diseases with the galvanic current.¹ Between the years 1862 and 1865 Friedreich had entrusted his young assistant with the conduction of localized faradisation on patients suffering from "muscular atrophy and other nervous disorders."²

Archive material suggests that Wilhelm Erb first requested the creation of an electrotherapeutic ward in summer 1872. According to university histories he began to teach electrotherapy in June 1873.³

I was unable to find any of his first petitions. However, a protocol of a faculty meeting from 27th/28th November 1872 sheds more light onto the affair. The faculty had convened following a request made by Professor Dr Erb regarding the establishment of an electrotherapeutic ward. Discussion among the faculty members resulted in


² W. Erb, 'Was wir erstreben, Gedanken über die Weiterentwicklung der deutschen Nervenpathologie', Neurologisches Centralblatt, 1914, pp. 1170-1180, p. 1170

³ H. Weisert, Zeittafel zur Geschichte der Universitat Heidelberg, Heidelberg, C. Winkler Verlag, 1986, p. 31
unanimous support of Erb's application at the Ministry of Interior. Only one reservation was expressed: the faculty was keen to emphasize that its approval was given only in consideration of Erb's professional interests, his personal integrity and scientific reputation. Professor Erb had already demonstrated scholarly competence in a series of scientific publications on medical electricity. He also enjoyed the undivided approval of students attending his electrotherapeutic courses.¹

The faculty insisted that in the event of Erb leaving the university the ward had to be closed. The subsequent discussions focused mainly on the question of the location of the ward. Building works for the future "Akademisches Krankenhaus" were in progress and:

The majority of faculty members felt...that one ought to try whether one was not able to gain some rooms in the new hospital building. Only in the event that rooms could not be made available should one request at the Ministry of Interior the erection of a new building...possibly following the building of the future eye hospital.²

Only three faculty members, Simon, Kühne and Dusch, favoured the immediate construction of an entirely new building for Erb's electrotherapeutic ward. Simon was eager to stress that he did not envisage the possibility of his sparing any space in the new

¹ UA HD Dekanat Friedreich, Eingabe an den Engeren Senat, p.147

² UA HD H-III-81 Dekanat Friedreich 1872/73 Protokoll der Fakultätssitzung 27./28.November 1872
surgical hospital.

Irrespective of Erb's specific request regarding the installation of an electrotherapeutic ward "the faculty agreed unanimously to ask for the Ministry's approval granting Erb official registration to teach electrotherapy and that he should be given an adequate salary to do so."®

Subsequently the District Building Commission had been asked for advice regarding the technical aspects of the localization of the planned electrotherapeutic ward. Meanwhile the future eye hospital had also been considered as a potential location. Its director Otto Becker disapproved vehemently of such a move. He wanted to be the one and only master in the house.® Professor Becker was known to be an extremely wilful and determined person better not to be argued with. Anecdotal evidence suggests that he had once smashed a window with his bare fists during a dinner party at his home, complaining that the room temperature was too high. He repeatedly submitted petitions to the District Building Commission and the Ministry of Interior during the long debate surrounding the location of Erb's ward. He always expressed his fierce opposition to the installation of such an institution in the premises of

® UA HD: H-III-81 Dekanat Friedreich 1872/73, p.13 and pp.147-151

his hospital.

In March 1873 the District Building Commission delivered its report to the Medical Faculty. It had examined four different approaches by which the installation of an electrotherapeutic ward at the eye hospital could proceed. The report dismissed the option of admitting Erb's patients onto an ophthalmological ward for this would probably result in the loss of its children's ward and posed generally too many architectural problems. Becker, however, did not object to handing over "only one room for the installation of apparatus and a further room intended for outpatient treatment". Only a few months later Becker withdrew his concession.

Friedreich's support was more dependable and consistent. He reassured the Ministry of Interior that he would be happy to accommodate twelve electrotherapeutic beds in the new "Medizinische Klinik". Furthermore he would also be able to provide the necessary space for apparatus and outpatient treatment. Karlsruhe felt that this option was the most appropriate answer to the problem.

In August 1874 the Ministry granted Erb a yearly budget of 250 Gulden which was intended to finance his electrotherapeutic courses. But no agreement on the actual location of an electrotherapeutic inpatient

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8 Bericht der Bezirks-Bauinspektion Heidelberg, Akten UA HD Medicinalanstalten Elektrotherapeutische Station 1873-77, 558/IV 3c, Nr 155
facility nor any arrangement by which it was to be achieved had been reached. In October 1876 the new Akademisches Krankenhaus was opened, but Erb was still without his desired ward.

Four years after his initial application, in December 1876, Erb turned once more to the medical faculty. He felt entitled to raise this matter again "now that the new hospital building was already in operation". "After consultation with the director of the medical hospital, Privy Councillor Friedreich, who continued to support the applicant with undiminished benevolence" Erb submitted a draft of regulations designed to "achieve his aims as satisfactorily as possible":

Draft of a statute regarding the establishment of an Electrotherapeutic Ward at the Academic Hospital Heidelberg:

§ 1 the "Elektrotherapeutische Station" at the Academic Hospital consists
a. of a 12 bedded patient department with six beds in a female ward and six beds in a male ward located in the Pavilion of the Medizinische Klinik.
b. and a further room to accommodate outpatients, the teaching of electrotherapeutic courses and the conduction of scientific examinations....and an administrative facility ("electrifying room") together with the right to use the waiting room for patients
awaiting electric treatment.

§ 2 This ward will be under the direction of Professor Dr Erb as long as he teaches at the local university. In the event of his departure from Heidelberg, the right of disposal over the ward will be returned to the Medical Klinik.

§ 3 Five out of twelve beds ought to be available for patients from the Medical Klinik which are intended for electrical treatment. So long as these five beds are not taken up by patients from the Medical Klinik the right of disposal and authority over these beds rests with Professor Erb.

§ 4 The remaining seven beds are at the free disposal of Professor Erb regarding the accommodation of his patients awaiting electrical treatment (under the regulations and rules of the academic hospital regarding admissions.)

§ 5 The patients of the Medical Klinik under the care of the Electrotherapeutic Ward will remain in financial clearing unit with the medical Klinik.

§ 6 The inpatients of the Electrotherapeutic Ward will receive their treatment plan from Professor Erb, their histories will be taken by the assistants or will be continued in the case of referral from the Medical Klinik; the case histories of patients from the Medical Klinik will be returned on discharge or referral of its patients.

§ 7 In the interest of scientific instruction and
research it appears to be useful to grant Professor Erb the possibility of admitting patients free of charge. Therefore he will be entrusted with a budget which allows him the free admission of three patients, each of them for 300 days per year. This budget allows for payment of their fees to the Academic Hospital.

§ 8 The budget will be calculated as follows:

a. three free admission on 300 days each 900 days of inpatient episodes at 2 Marks per day 1800 Marks

b. yearly salary of an assistant 350 Marks

c. maintenance and repair of apparatus, instruction, teaching material and remuneration of additional duties yearly 350 Marks.

Total Sum: 2500 Marks

§ 9 Professor Erb is also obliged to treat patients from other hospitals who are not inpatients on the electrotherapeutic ward, provided the consultants of those hospitals wish so and consider it to be appropriate.

Erb was at pains to justify paragraph 7 and 8 for both paragraphs required the admission of a defined patient clientele free of charge:

It is well known that the daily costs in the Academic Hospital (2 Mark per day) are not affordable for poor or less well off patients. The sick who require electric treatment are mostly chronically ill patients. Because of their long lasting chronic ailments they have become invalids and thus they are unable to work. Especially those patients find a long hospital admission hard to afford. It is also known that the communities or whoever is responsible for the care
of such people...are only prepared to pay the fees once the patients have become entirely helpless and impoverished. However, experience teaches that just those patients (suffering from chronic neuroses and diseases of the spinal cord) are usually only in the early disease stages receptive to some hope and cure, whereas in the later stages they are almost all beyond any help. The recognition and treatment of those early disease stages is of paramount interest to prospective physicians. Particularly in those cases therapeutic experiments promise the best success.⁹

The faculty, however, did object to Paragraph 2 of Erb's provisional draft:

Although the faculty unanimously...supported the establishment of an electrotherapeutic ward under the supervision of Professor Dr Erb..., paragraph 2 met with considerable resistance.¹⁰

The main objection was based on fears that in the event of Erb leaving his post the director of the medical clinic would be landed with additional obligations and inconveniences. Yet the actual director of the medical clinic, Professor Friedreich, remained silent and did not express any such reservations. The decision to reject paragraph 2 was accepted with Friedreich having abstained from the vote.

Herewith a substantial part of the statute which granted Erb too much independence was refused and considered not to be acceptable in that form.¹¹

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⁹ Brief W.Erb an die hochlöbliche medizinische Fakultät der Universität Heidelberg, 16.Dezember 1876, in UA HD Akten der med.Fak.1876/77 I; H-III-111/86 (Dekanat Dusch)

¹⁰ Protokoll der Sitzung der Med.Fak. am 22.Dezember 1876 in Akten der Med.Fak. 1876/77 UA HD H-III-111/86

¹¹ Ibid.
The dean's (Theodor Dusch) application to ask for financial support on behalf of Professor Erb "to safeguard during the tenure of his lectureship his activities" and "to provide him with the financial means to establish an electrotherapeutic ward in order to secure him a safe and lasting initiative" was accepted without further qualifications.\textsuperscript{12}

Thus Erb was forced to reconsider the wording of his draft, particularly the troublesome Paragraph 2. After consultation with Friedreich who did not appear to be bothered with that particular paragraph and its dreaded consequences Erb approached the dean again:

Since Professor Friedreich agrees with the medical faculty's proposal I am happy to do so as well. On further reflection I feel that I can also achieve in that way what I mainly aspire to: namely a relatively secure working environment and material for my courses and scientific research. Therefore I do agree, if the medical faculty modifies my proposal to the effect that I will be given a specified sum (of money) by the government, whereas the accommodation of my patients in...the medical clinic will be left to mutual agreement between Privy Councillor Friedreich and me. I leave it up to the faculty whether it would not be appropriate to somewhat increase the yearly budget of 2500 Marks I initially asked for.\textsuperscript{13}

On this occasion the dean Professor Dusch and the medical faculty warmly supported Erb's adjusted request. An application was submitted to the "Enger Senat" with the reference "that Erb has earned himself

\textsuperscript{12} Protokoll der Sitzung der Med.Fak.22nd December 1876 in Akten der Med.Fak. 1876/77 UA Hd H-III-111/86

\textsuperscript{13} Ibid.
a honourable place in "Wissenschaft" with his research on nervous diseases and electrotherapy and that he had exercised over the years a successful teaching career at the university."\(^{14}\)

A yearly subsidy of 3000 Marks was requested to pay for patient care, teaching facilities, electrical apparatus and a salary for one assistant. Karlsruhe responded with an increase of the yearly budget from 430 Marks to 1500 Marks apologising that "a further increase during this year is not planned, since the present budget is already exceeded. However, one shall feel free to make an appropriate application next year."\(^{15}\)

One would assume that the matter was resolved more or less to the satisfaction of everybody involved. Erb and Friedreich drafted a sort of "private contract" between themselves. This agreement was meant to regulate the constitution of the electrotherapeutic ward housed under the roof of Friedreich's Medizinische Klinik.

In May 1877 the faculty met to discuss the edition of the university's directory (Adressbuch) which listed all institutions and lecturers.\(^{16}\)

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\(^{14}\) Ibid.

\(^{15}\) Abschrift, Karlsruhe, den 17ten Februar 1877, Ministerium des Innren, No.2784 in Akten der Med.Fak.1877 (Dekanat Dusch)

\(^{16}\) UA HD Akten der med.Fak.1876-77 I,Dusch; H-III-111/86 pp.87-89
The private contract between Friedreich and Erb had been sent to the Ministry of Interior awaiting final approval. Now Theodor Dusch consulted the faculty:

So far the electrotherapeutic ward and the Institute for Forensic Medicine have not been listed in the directory. Recently doubts had been raised concerning the terminology used to describe the status of the institution for otology and its director. Therefore I ask you to consider whether and how the above institutions shall be listed in the directory.\(^1\)

He received the following replies:

ad 3) Since the electrotherapeutic ward and the Inst.f.Forensic Medicine belong to facilities intended for study and research....it seems to be in order to grant them as well a place in the directory.I can not discern ..an essential difference between the term "under the conduction of.." (Leitung) or alternatively "directorship" (Direktion).  
Lange, Gegenbaur

ad 3) may I suggest following the reservations having been expressed recently against the usage of the term "director" ...to say simply "Institute."
Kühne

ad 3) may I say that at present an electrotherapeutic ward does not yet exist, since its statute...still remains with the Ministry...awaiting ratification. As long as ministerial approval of the contract has not been received...listing of the ward in the directory is not yet permissible. I agree that the Electrotherapeutic Ward shall be entered into the directory in the form suggested by Kühne...On that occasion I would like to add, that my second thoughts regarding the Electric Institute have been made known to the two last voting colleagues and I believe...that their vote could have been modified, provided the dean Herr Dusch would have taken care that the voting procedure should have taken place in an order according to age.  
Friedreich

ad 3) I agree that the Inst.f.Forensic Medicine and Otology shall be listed in the form suggested by Kühne.  
Arnold

\(^{17}\) Ibid.
ad 3) I agree with my colleague Arnold.
Czerny

ad 3) as long as...the contract has not been ratified by the Ministry any entry of the Electrotherapeutic Ward into the directory cannot take place...I agree with Professor Kühne.
Delffs

ad 3) have read it.
Becker

Finally Dusch advised the university secretary that the following entries into the university's directory could be made:

Forensic medicine and otology could be listed as institutes. However, since the statute regarding the electrotherapeutic ward has not yet been approved, this facility did not qualify to be listed in the directory. Should, however, the approval of the statute arrive within the next few days prior to its printing, Erb's institute could be entered into the directory under the same heading which had been used to define the other two institutions.¹⁸

Two years later Wilhelm Erb received a call to Leipzig University. He was asked to become (a.o.) Professor of Special Pathology and Hygiene and was promised the directorship of the Poliklinik. It was a tempting offer. Although Erb was extremely fond of his beloved Heidelberg he could not resist:

I do not conceal the fact that I leave Heidelberg University with a sad heart...and I nearly refused the promising and tempting call to Leipzig; the very thought, however, of the discouraging attitude which the medical faculty took towards this very question and the unpleasant prospect of a long succession of adversities (Widerwärtigkeiten) which my remaining here would provoke under the present circumstances,

¹⁸ Theodor Dusch an das Universitätssekretariat 29th May 1877, H-III-111/86 pp.87-89
urged me to leave.\textsuperscript{19}

\textsuperscript{19} GLA KA Personalakte Erb GLA 235/1936, Brief an den Präsidenten des Grossherz.Ministeriums des Inneren in Karlsruhe, verfasst in Heidelberg, den 3.Dezember 1879
Chapter 5. The German school of "Naturwissenschaftliche Medizin": Scientia est Potentia

Only thee whose ultimate aim is to cure deserves to be called a physician. (Virchow, 1846)

A German medical practitioner would have been only too conscious of the sorry state of his trade during the 1840's. Physicians were used to be the laughing stock of party conversations, depicted as quarrelling incompetent quacks in caricatures or as fraudulent imposters in the literature.

The general uncertainty of medicine and the lack of faith in medical ability and skill are so commonplace nowadays that almost every contemporary novel seems to depict the physician as playing a miserable role.¹

Serious academic physicians wrestled with methodological questions in an attempt to better the situation. How was the salvation of medicine to be sought? Should the approach be empirical or rational and how to employ a hypothesis in scientific medical inquiries? Such methodological confusion and uncertainty resulted in an equal measure of chaos in medicine's practical application - in the art of healing.

Historians are still horrified by the disarray of confused therapeutic measures of a 'pre-scientific' era in medicine, i.e. Boillaud's vampirism, the Parisian alkaloid therapy, Hahnemann's homeopathy and above all

the consequences of polypharmazy.\textsuperscript{2}

It is beyond doubt that many clinical teachers and practising physicians do more harm than good by resorting to too large a number of drugs altering them too frequently.\textsuperscript{3}

No wonder that under such circumstances "many patients resorted to religion or charlatans and the more intelligent part of the population would construct their own individual therapeutic systems."\textsuperscript{4}

The therapeutic shortcomings of practical medicine were generally recognised and several attempts were undertaken to remedy medicine's sad condition. A considerable number of medical periodicals set up during the early 1840's bear witness to that reform movement.

During that era two important journals dedicated to medical reform were inaugurated: the Zeitschrift für rationelle Medicin founded by Karl Pfeuffer (1806-1869) and Jacob Henle (1809-1885) and the Archiv für physiologische Heilkunde set up by Carl August Wunderlich (1815-1877), Wilhelm Roser (1817-1888) and Wilhelm Griesinger (1817-1869).\textsuperscript{5}

\textsuperscript{2} Fr.Krause, 'R.Virchow und die heutige Klinik', Virchows Archiv, 1921, Vol.235, pp.298-328, p.326

\textsuperscript{3} R.Virchow, op.cit., note 1, p.16

\textsuperscript{4} Ibid.

\textsuperscript{5} J.Bleker, 'Biedermeiermedizin-Medizin der Biedermeier? Tendenzen, Probleme, Widersprüche 1830-1850', Medizinhistorisches Journal, 1988, Vol.23, pp.5-22, p.16; C.Huerkamp, Der Aufstieg der Ärzte im
It was generally felt that a substantial change for the better could be brought about only by combining physiology and pathological anatomy with the aid of experiment.¹

During the 1830's a shift from natural philosophy towards natural history and natural science had already occurred with Johann Lucas Schönlein (1793-1864).⁷ His programme, the so-called "Naturhistorische Medizin", put a strong emphasis on nosology and the introduction of natural scientific methods into clinical medicine.⁸

After careful analysis of primary sources and secondary literature I came to the conclusion that it is important to say a few words about Schönlein and his movement. Hess noted that it is commonplace in the historiography of medicine to argue that any decisive breakthrough of clinical medicine with its vast progress in medical diagnosis happened only with the

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¹  H.P. Schmiedebach, 'Pathologie bei Virchow und Traube', in Die Experimentalisierung des Lebens (eds Rheinberger/Hagner), Berlin, Akademie Verlag, 1993, p.128


⁸  Disciples of Schönlein were: Canstatt, Fuchs, Eisenmann, Siebert, Marcus, Mohr and Pfeuffer.
The development of the "natural scientific school of German medicine" owes in actual fact a great deal to natural historical medicine as proposed by Schönlein. Virchow seldom acknowledged explicitly his intellectual predecessors. Perceptive contemporaries, however, did. Johann Gottfried Eisenmann once portrayed Schönlein as *John the Baptist* in relation to Virchow. A discussion of Virchow's concept of natural scientific medicine will demonstrate that Eisenmann's bold statement contains a kernel of truth.

Nikolaus Friedreich, too, recognized Schönlein's beneficial influence on German medicine:

> Schönlein...succeeded to break the natural philosophical bonds and established an empirical foundation for medicine again, for without the latter no real progress and no prevailing gain would have been possible.\(^9\)

Johanna Bleker's work has corrected a great many misconceptions regarding Schönlein and the "Naturhistorische Schule". The latter has often been confounded with Karl Stark's parasite theory of

\(^9\) V. Hess, 'Von der semiotischen zur diagnostischen Medizin-die Entstehung der klinischen Methode zwischen 1750 und 1850', *Abhandlungen zur Geschichte der Medizin und der Naturwissenschaften*, Heft 66, p.297; Hess argues that the role of diagnosis is central to the modern clinical method and action.


disease. Bleker demonstrated that Stark's (1787-1845) ideas were wrongly labelled as 'natural historical' and belong more properly to the speculative views espoused by romantic authors, such as Dietrich C.Kieser (1779-1862). Their methodology was quite different from the programme elaborated by Schönlein.

Schönlein's method sought to distinguish pathognomonic symptoms and signs of bedside phenomena and compare them employing a retrospective 'historical', i.e. genetic, view of their development. The aim, of course, was to arrive at so called 'natural' systems of disease classification. The way to proceed, stressed by Schönlein, was thought to be strictly empirical and implied the optimistic view that such observations and comparisons were conducted without any a-priori prejudices and would therefore successfully uncover the true genetic relationships between nosological entities.12

Wunderlich, a proponent of the physiological medical programme of the 1840's, frequently opposed Schönlein and considered him to be too empirical and rejected his disease concept as ontological. Wunderlich's rhetoric is probably partly responsible for some of the misconceptions still dominating the history of the "Naturhistorische Schule" which Bleker

attempted to correct. The essential difference between adherents of the natural historical school and its opponents consisted in a controversy over method, i.e. whether special pathology was to be informed primarily by physiology, i.e. theory, or by clinical observation and experience. Wunderlich and Roser demanded that physiology informed medical practice whereas Schönlein and supporters turned the tables:

The teaching of the Klinik... has to choose the bedside as its principal standpoint, from where she surveys all other branches of science approving of what serves her end, the cure. All rays of science converge in her (the Klinik's) centre.

According to Bleker there is no firm historical evidence that Schönlein held any parasitic theories of disease. He admitted an ontological notion of disease for methodological purposes. This manoeuvre enabled him to observe aided by his empirical-analytical method a disease as an object - as an "ens sui generis" - and thus permitted the definition of disease entities so that they could be handled at the bedside.

Volker Hess has confirmed Bleker's thesis in an excellent study on the emergence of the clinical method between 1750 and 1850. He also demonstrates

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14 V. Hess, op. cit., see note 9, p. 268 from A. Siebert, Technik der medicinischen Diagnostik, 1844, Vol.1, Erlangen

15 J. Bleker, op. cit., note 12, pp. 62-64 and p. 41
conclusively that Schönlein's phenomenological description of disease was being augmented by a physiological notion of disease as a process.¹⁶

The natural historical method allowed for a wide employment of empirical observation and theoretical considerations:

The phenomenological disease picture could be related to pathological post mortem examinations, the results of percussion and auscultation, chemical and microscopical examinations and theoretical explanations offered by the sciences of pathology and physiology. The nosological depiction of disease offered a shared space for empirical and theoretical knowledge.¹⁷

Thanks to Schönlein the previously neglected and ridiculed methods of percussion and auscultation, chemical analysis and microscopical examination were introduced into practical clinical medicine.¹⁸

Hess also maintains that the natural historical method, as understood and practised by Schönlein and his disciples became the foundation of the clinical method as such between 1820 and 1840. Making a diagnosis was understood to be a substantial part of that natural historical method, aiming to define nosological disease entities. As a consequence, Hess argues, diagnosis became the focus of the physician's clinical acumen and his main clinical activity, whereas


¹⁷ V.Hess, op.cit., note 9, p.298

¹⁸ N.Friedreich, op.cit., note 11, p.13.
previously prognosis had dominated his clinical venture.  

Albert Eulenburg's assessment (1876) of Schonlein's historical relevance for German medicine confirms Hess's thesis:

The main emphasis of his historical importance lies in his method...which was based on the exact observation of nature, induction and the meticulous use of auxiliary sciences; a method which gradually drew upon all available physico-chemical methods of examination, percussion and auscultation, the microscope etc. and thus rebuilt the medical Klinik on new grounds or so to speak truly inaugurated her. Hence one would actually be justified in referring to Schonlein's school as the clinical one per se and describe her simultaneously as the starting point of all future clinical directions, as their common source.  

Admittedly Schonlein did not succeed in ridding his method from the odour of ontology. Wunderlich continued to dismiss his natural historical method as not completely liberated from natural philosophy and insisted that diseases should not be differentiated phenomenologically but ideally by their aetiology.  

Despite the multifarious disputes and perhaps deliberate misunderstanding between all parties involved, the fight against dogma, exclusive medical systems and an ontological notion of disease had been declared. Even Wunderlich, a critic of Schonlein, did not oppose the "vital core" of Schonlein's teachings and "its positive effect upon the clinical side of

19 V.Hess, op.cit., note 9, p.286
20 A.Eulenburg, op.cit., note 2, p.4 and p.8
21 Ibid., p.5
medicine." Wunderlich accepted the clinical orientation of Schönlein's school and cultivated it himself carefully.\textsuperscript{22} The importance of physiology had widely been accepted. Yet the gap between medical theory and practice was difficult to close; on the contrary it appeared to widen:

The gap between science and practice is a comparatively recent phenomenon; our century and our fatherland managed to produce it. After all medicine was not to be left unaffected by this internal disorder which has torn apart all sections of German life?\textsuperscript{23}

That was basically the atmosphere in which Rudolf Virchow undertook his own medical training and made his first pronouncements on the natural scientific method and medical therapy in 1847.\textsuperscript{24} Virchow did not suddenly suggest the introduction of an unprecedented epistemology into medicine nor did he reject old principles completely.\textsuperscript{25} In matters of scientific method Virchow abhorred exclusive narrow systems and attempted to mediate between empiricism and

\textsuperscript{22} Ibid., p.5


\textsuperscript{24} Virchow's important and only lecture on medical therapy was held on 20th Dec 1847 at the 'Jahressitzung der Gesellschaft für wissenschaftliche Medicin zu Berlin' and published later as 'Die naturwissenschaftliche Methode und die Standpunkte in der Therapie', Archiv f.Path.\& Anat.\& und Physiologie und Klin.Med., Vol.2 (Heft 1) 1849, pp.3-37

rationalism, between experience and theory. The same applied to his approach towards medical therapy. Virchow attempted to keep a balance between reductionism and holism. He, like Schönlein, preferred an active optimistic approach, attempting to rationalize the therapeutic operation by keeping it preferably local whilst respecting the patient's own individual constitution and circumstances. Indeed the very mystery of individuality excluded the possibility of a purely rational exercise of the art of healing solely based on exact research. His friend and disciple Friedreich argued that

\textit{Individualisation at the bedside is the sign of a thinking physician.}\footnote{R.Virchow, op.cit., note 23, pp.8-9}

Virchow opposed any relapse into the crude empiricism of the old days nor did he favour Wunderlich's "hyperrationalism", which "only bred scepticism and thus led to therapeutic nihilism."\footnote{G.P.Sacharoff, 'Rudolf Virchow und die Russische Medizin', \textit{Virchows Archiv}, 1921, Vol.235, pp.368-9, pp.373-4} The latter attitude had been promoted by the Vienna School of Medicine, according to Virchow.\footnote{A.Eulenburg, op.cit., note 2, p.23}

Virchow succeeded in providing his colleagues


\textit{N.Friedreich, op.cit., note 11, p.18}

with a clear and comprehensible synthesis of numerous principles of desirable scientific conduct, which had previously often been perceived as contradictory. Thus by mediating between theory and practice Virchow restored physicians' crippled self-confidence. His attempts at reconciliating theory and practice seem simple common sense to the modern observer.

Seen in the light of the contemporary context Virchow's strategy acquires further relevance. The 1840's were not merely about methodological reform of medicine but also about wider political and social reform and ultimately about constructing national union in one shape or another. The point that Virchow conceived of medicine as a social science at its core, ultimately as true anthropology does not need to be reiterated. Indeed he preached the gospel of medicine as an utopian programme holding the key to human and cultural progress and society's advancement. If the

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30 E.Ackerknecht, op.cit., note 26, p.52: "Virchow was perhaps not even conscious of the fact that he was affected by Hegel's invention of dialectics. Neither his style...nor his continual operating with antithesis (science-practice, vitalism-mechanism, humoralism-solidism, localism-holism) that are resolved by his synthesis (cellular pathology, pathological physiology) leaves any doubt."

31 Ibid., p.140: "the other basic slogan of the German revolution of 1848, 'National Unity', was no less meaningful to the reformers. Dr Alexander Pagenstecher...submitted to the Frankfurt parliament bills that were the logical application of this general theme to medical reform and found general approval."

physician's task was to cure not only individuals' but also society's ills then he personally had to be at ease with himself, his task and above all with his own profession. How could national unity be brought about if the nation's healers were not united themselves? One of the most important demands of the medical reform movement was a unique and united medical profession and degree, and the abolition of the medieval subdivision of the medical occupation into different classes and casts with different rights and privileges. Prussia had, for instance, at the time still three classes of physicians and two classes of surgeons.\footnote{33}

Virchow, son of a Pomeranian farmer, was a leading voice in the medical and political reform movement of 1848.\footnote{34} Virchow's intra-scientific mediation between theory and practice, between rationalism and empiricism partly symbolized a certain development which had already taken place in the medical 'marketplace' and expressed partly an expert demand for further future homogenisation and unification of the medical profession. The underlying intention of those experts, i.e. university trained physicians, was ultimately to transform the medical market into a level-playing field.

Claudia Huerkamp and Thomas Broman have studied

\footnote{33}{E.Ackerknecht, op.cit., note 26, p.140}

\footnote{34}{Ibid., p.44}
the professionalisation of medical expertise in Prussia during the first half of the 19th century. They have demonstrated that during the latter half of the 18th and first half of the 19th century the traditional hierarchy of multiple subdivision of healers had gradually been eroded by a complex process in Prussia and other German states.

Whereas many urban dwellers usually enjoyed an organised sophisticated medical system, often established since medieval times, the rural population suffered from a considerable lack of medical attention and care. Huerkamp discovered towards the end of the 18th century an increasing interest by university educated physicians to expand their sphere of action into the countryside. They sought increasingly control over the inferior casts of healers (barber surgeons) and attempted to influence the implementation of health policies and their political administration. Their action corresponded initially with the state's interest in expanding its bureaucracy over a web of diverse and incoherent regional corporations and guilds. Reaching out into the rural areas of Prussia necessitated a host of complex changes in education, jurisdiction and the medical system. Prussia's enlightened absolutist monarch regarded the health of its citizens as a


36 C.Huerkamp, op.cit., note 5, p.42
necessary prerequisite for the entire commonwealth of the nation. In order to improve citizens' wellbeing the state was interested in preparing its population for an enlightened rational and health conscious conduct.\(^{37}\) Thus the rural medical infrastructure needed to be improved by increasing the number of available medical personnel and by educating the often quite ignorant and superstitious peasants. This was to be accomplished by supervising medical education in state institutions, thus ensuring that highly qualified personnel familiar with the authority's policies and intentions were able to implement the desired reform.

Initially this was attempted by creating a semi-professional class of medical practitioner, "Wundarzt erster Klasse", trained in semi-academic medico-surgical teaching institutes. This solution was introduced in 1825. On the one hand the creation of another type of practitioner appeared to divide the medical profession even further. Yet on the other hand the urban learned physicians were still mainly "medici puri", pure medical physicians of the older generation, unwilling to diminish their prestige by associating themselves with inferior barber surgeons treating the poorer uneducated rural population.\(^{38}\)

The creation of medico-surgical schools (mediko-chirurgische Lehranstalten) around 1825 symbolized the

\(^{37}\) Ibid.

\(^{38}\) Ibid., pp.45-59
beginning convergence of medical and surgical training, an initial timid integration of learned and practical medicine.\textsuperscript{39} These schools were aimed at training "Wundärzte" of lower middle class descent for the medical care of the poorer population. In Bavaria similar developments had taken place a few years earlier. Here semi-academic "Landarztschulen" had been introduced to train "Landärzte" (country-doctors), a medical occupation which historians have likened to the French "officiers de santé".\textsuperscript{40} Simultaneously a Prussian law passed in 1825 not only prescribed medical knowledge for "Wundärzte erster Klasse", trained in medico-surgical schools, but also a surgical exam for medical university students. The university students could then choose between a final qualification (Approbation) as 'medici puri' or, provided they wanted to apply their acquired surgical knowledge and training as well, as "Mediko-Chirurgen". One can easily discern a primary streamlining of surgical and medical education into one united professional training.

From the 1830's onwards a combination of diverse social, political and economic factors led to an increasing number of medical university students take the final qualifications as "Medikochirurg". They

\textsuperscript{39} Medico-surgical schools were founded in Münster in 1822, in Breslau in 1823, in Magdeburg in 1827 and in Greifswald in 1831.

\textsuperscript{40} R. Heller, 'Officiers de Santé: The second-class doctors of 19th century France', \textit{Medical History}, 1978, Vol.22, pp.25-43
preferred to set up their medical practices in towns, which was socially more acceptable and prestigious and, of course, also more lucrative. Despite government intervention the majority of semi-academic "Wundärzte" tended to settle in towns as well, thereby increasing the number of medical practitioners in urban areas. The initial aim to ensure better medical care for the countryside was thus not achieved for there less well qualified "Wundärzte" of the second order and other inferior practitioners continued to operate. Eventually competition and rivalry among academic and semi-academic medical practitioners soared in the towns and forced academic physicians to acquire surgical (practical) knowledge in order to be able to compete with younger university trained "Medikochirurgen" and semi-academic "Wundärzte" swamping the medical marketplace. At the same time learned physicians tried to discredit their semi-academic rivals as a 'sort of mixture' or 'dangerous compromise'. Interestingly enough the argument that Wundärzte were "only trained for practical routine but not able to individualize in every single case - the mark of a genuine medical practitioner - which made them particularly prone to cause damage" was frequently being resorted to."

Later Virchow and his disciples would use the same argument. In Virchow's view the ability to individualize at the bedside singled out the genuine

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41 C.Huerkamp, op.cit., note 5, p.55
natural scientific physician.

During the 1830's and 1840's the rising number of various types of medical practitioners in Prussian towns and elsewhere in Germany led to increasing competition and rising unemployment amongst urban doctors whereas the rural population still lacked the desired medical care. Academic physicians had gradually accepted the necessity for an hands-on approach to their patients in order to be able to compete with their semi-academic colleagues. Simultaneously the concept of practical knowledge was actively promoted by the respective government think-tanks. This principle gained in popularity and was integrated into the university curriculum. Arleen Tuchman's monograph illustrates the complexity of that particular process and its manifold causes comprehensively.\textsuperscript{42}

The 1825 legislation in Prussia suggests a first timid convergence of practical and theoretical knowledge. Legislation was also introduced to secure better medical care in the rural areas. The latter goal, however, had not been achieved because of an unwillingness of semi-academic physicians to practice there. The medical occupation was still divided in classes of differently qualified medical practitioners and increasingly at odds with itself.\textsuperscript{43}

\textsuperscript{42} A.Tuchman, \textit{Science, Medicine and the State in Germany, The Case of Baden, 1815-1871}, Oxford, Oxford University Press, 1993

\textsuperscript{43} C.Huerkamp, op.cit., note 5, pp.53 ff
Events eventually led to the rise of the 1848 medical reform movement which insisted on a comprehensive reorganisation of the entire medical system. On the one hand physicians objected to government interferences in medical matters demanding self-rule; on the other hand academic physicians relied on state intervention in order to abolish the lower medical occupations, amend medical university education and implement public health reforms."

The ideal of the traditional learned physician had gradually altered some of its scientific and social attributes and had assimilated the idea of a 'hands-on approach' towards patients. Yet, at the same time academic physicians were interested in keeping the upper hand against the rising competition of semi-academic practitioners. Therefore academic physicians had to "mix with the ordinary people" if they wanted to retain control and a decent income and above all keep their patients. It is noteworthy that historians observed during the same period the emergence of a new ideal type of academic physician/medical practitioner: the 'all-round practitioner' and ideal 'country doctor' (Landarzt) devoted to his patients prepared to visit them day and night not withstanding adverse weather

conditions. The new ideal "Arzt" defined himself increasingly by his vocation and practice rather than lifestyle and association with the upper social class."

Between 1849 and 1852 the medico-surgical schools in Breslau, Magdeburg, Greifswald and Münster were closed down and the diverse categories of semi-academic medical practitioners were abolished. In Prussia from October 1852 only one category of university trained physician combining the previous classes of "praktischer Arzt, Wundarzt and Geburtshelfer" was qualified to practice medicine."

The prevailing contemporary perception of the academic physician was that he was seen to be learned but clumsy whereas the practitioner was often thought to be ignorant but appreciated as capable."

Virchow differentiated between the scientific part of medicine based on physiology striving to become eventually pathological physiology proper and its non-scientific component, practical medicine. Contrary to contemporary customs he did not discriminate against either of them, rather he questioned the apotheosis of Wissenschaft as expressed in the then fashionable motto knowledge for its own sake, "a remnant from times of great philosophical confusion which had developed

45 C.Huerkamp, op.cit., note 5, pp.58-59
46 Ibid.
47 R.Virchow, op.cit., note 23, p.5
particularly well in Germany eventually damaging the reputation of medicine". Virchow referred to the humanistic ideal of "Wissenschaft" and rejected it as inhumane and too esoteric. Science for its own sake really had to be science for the sake of mankind:

If a scientifically minded human being happens to be a physician then it is only proper that his science involves a relationship towards its own end, the end of medicine being the restoration of health."

Virchow demanded that absolute Wissenschaft should give up its pretensions and "mix with ordinary people". This clearly signalled a dismissal of the romantic notion of Genius but also legitimated, as I have tried to demonstrate, the perceived need of academic physicians for social and economic reasons to expand their patient clientele. This was not merely an altruistic idea, for simultaneously this notion supported the state's desire to reach the rural population with improved medical care - one strategy amongst many others to unite the many diverse regional institutions.

According to Virchow the aim of scientific medicine included the examination of altered vital organic conditions:

The objects of scientific medicine are the altered conditions under which the diseased body suffers, the definition of those deviations which life endures in disease and finally its objective rests in the search for agents which dissolve those abnormal conditions."

The edifice of Virchow's scientific medicine -

" Ibid., p.7.

" Ibid., p.4
pathological physiology - required several well built foundations on which it would finally be able to rest. The crucial substructure had to contain sound knowledge of physiology, i.e. the knowledge of the normal vital functions. Scientific medicine as such involved two integral parts: pathology which examined the altered vital conditions and therapy which sought to find the agents which would alleviate those altered vital conditions or sustain normal vital functions.

Practical medicine thus was never, "not even in the hands of the most gifted masters", scientific medicine as such, but merely its application. The scientific practitioner, however, was unlike the "medical adventurer" well qualified since he could rely on the achievements of scientific medicine. This was considered a valuable asset which secured him a proper base for his practical operations.\(^5^0\)

The grand design of the palace (Residenz) of scientific medicine, i.e. pathological physiology, consisted of many building blocks; its ultimate purpose was aimed at medical therapy.\(^5^1\) Admittedly the realization of this vast project was still far from being fulfilled but that should not deter any scientifically minded physician from joining the collective effort to erect the edifice of scientific

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\(^{50}\) Ibid., p.4; Fr.Krause, op.cit., note 2, pp.326-327

\(^{51}\) E.Ackerknecht claimed that Virchow's therapeutic ideas never developed beyond the generalizing stage, op.cit., note 26, pp.58-59
medicine.

This time of unrest will eventually pass and soon everybody will realize that only calm, industrious and slow efforts, the faithful labour of observation and experiment will be of lasting value. Pathological physiology will...develop, not as a result of the efforts of few highly strung individuals but as a consequence of the labours of many investigators.\(^{52}\)

How exactly, in Virchow's opinion, was the erection of this grand structure to be brought about?

Let us determine how natural science as such is being made in order to realize the possibility of constructing medical natural science and in particular medical therapy.\(^{53}\)

Virchow insisted that the actual method of research and study was the essential and distinct mark of natural science. The latter always naturally evolved having passed through the stages of natural philosophy and natural history. Virchow gave several definitions of his so called natural scientific method in medicine, including this classic one:

The natural scientific method, incidentally the only method in existence...enables us to formulate natural scientific questions. Everybody capable of posing such a question is a Naturforscher. The natural scientific question is the logical hypothesis which proceeds from a known law with analogy and induction; the answer is provided by the experiment which is dictated by the question itself. Such a hypothesis is the result of a deliberate calculation with facts, which requires a broad knowledge of the facts; an experiment is a logical and necessary, entirely cognizant action aimed at a certain end. Every individual who knows the facts and is able to think correctly is thus able to force nature into answering a question, provided he has the material to furnish the experiment. The study of nature thus requires factual knowledge,

\(^{52}\) R.Virchow, op.cit., note 23, p.19

\(^{53}\) R.Virchow, op.cit., note 1, p.6
logical reflection and material; these three components joined together methodically produce natural science.\textsuperscript{54}

Philosophically speaking Virchow was and remained a sensualist. He started from the assumption which since Locke, Condillac and Cabanis has guided so many medical scientists that sense impressions are the primary elements of mental life.\textsuperscript{55} Factual information had to be based on historically secured knowledge; only what was known historically was known exactly. All knowledge depended on sensual observation.

This general programme translated thus into medical science: scientifically qualified questions which would eventually help to construct pathological physiology were to be received partly from pathological anatomy partly from practical medicine. The answers were partly provided by clinical observations at the bedside and partly from animal experimentation.\textsuperscript{56}

Virchow's guidelines for the implementation of natural scientific medicine mediated between the opposing positions once taken by Wunderlich, Henle and Schönlein.\textsuperscript{57}

\textsuperscript{54} Ibid., pp.7-8; A.Bauer, op.cit., note 7, pp.49-50; R.Virchow, op.cit., note 23, p.17

\textsuperscript{55} E.Ackerknecht, op.cit., note 26, p.49

\textsuperscript{56} R.Virchow, op.cit., note 23, p.17

\textsuperscript{57} E.Ackerknecht, op.cit., note 26, p.53: "Virchow felt that the notion of 'pathological physiology' also separated him from the 'physiological medicine'of Wunderlich and Griesinger and the 'rational medicine'of Henle and Pfeuffer. He was closer to the truth when he occasionally admitted that no difference of principle
In 1862 Professor Friedreich acknowledged the groundwork which had already been done by Schönlein, preparing the way for the advent of natural scientific medicine:

The natural historical school managed to get rid of the old and brought a certain provisional order into the mass of accumulated material, it prepared the mind to get used to unprejudiced observation of nature; current medicine considers it as its task to go further and not to be satisfied with a knowledge of the disease progress and symptoms...but aspires to comprehend the essential character of disease and its intimate causes.\(^58\)

Virchow assigned theory and practice a place in the edifice of medicine without getting involved in any major epistemological discussion about their primacy or superiority. His approach was quite pragmatic which prompted a clinician in 1921 to celebrate Virchow as the founder of the "modern pragmatic clinical period."\(^59\)

Pathological anatomy, Virchow's favourite discipline, was established between 1849 and 1876 at every German speaking university; physiology emancipated itself from anatomy - the last German university to receive its own 'Ordinariat' in physiology was Giessen in 1891.\(^60\)

Virchow envisaged distinctly democratic rules existed between the three groups."

\(^58\) N.Friedreich, op.cit., note 11, p.15

\(^59\) Fr.Krause, op.cit., note 2, p.326

according to which the natural scientific method should be implemented. The metaphor of a building site, i.e. the erection of the edifice of scientific medicine, which required shared responsibilities and collective action was frequently invoked. Simultaneously the scientific method was of universal character. Members of the scientific community were encouraged to share their burden in a united effort, yet at the same time they had to "enter the battleground and account for their action." Thus by discussing and comparing one's own research and actively seeking to involve likeminded colleagues the great task could be mastered. This had several advantages, for the shared ambition gave the scientific community a common goal, their cooperation safeguarded against individuals monopolizing their knowledge and perhaps attempting to construct medical systems. At times this could also be pretty uncomfortable. A frank and public exchange over one individual's findings and claims could provoke arguments and occasional criticism and even personal conflict:

This is about crushing illusions with unforgiving criticism even if individuals may be hurt by it.

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61 H.P.Schmiedebach, op.cit., note 6, p.128; J.Bleker, 'Biedermeiermedizin', Medizinhistorisches Journal, 1988, Vol.23, p.13. Bleker pointed out that already the method and supporters of the naturhistorische Schule were regarded as democratic!

62 R.Virchow, 'Cellular-Pathologie', Virchows Archiv, 1855, Vol.8, p.3

63 Ibid., p.4
Simultaneously the single individual researcher was protected against getting lost in the isolation which the technicalities of scientific investigations often required. This was a painful and positively unexciting process demanding reserve and strict selfdiscipline:

One has to practice steady investigation, apt reasoning and unpretentious conclusions.

Contemporary literature reveals that the medical community felt greatly inspired by being united by a common goal - the construction of the edifice of new German medicine. In the eyes of contemporary physicians ideological fragmentation, professional estrangement, theoretical confusion and dogmatism were perceived to have been almost completely eradicated:

Thus it happens that today's principal German clinicians cannot be divided any more by their different affiliations; all forces have united on the broad grounds of exact research.

This sentiment inevitably struck a cord with the

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64 R.Virchow, op.cit., note 23, p.8: "man muss erkennen..., dass jetzt nicht die Zeit der Systeme ist, sondern die Zeit der Detailuntersuchungen. In den letzteren liegt eine...Gefahr des Zurückfallens in einen rohen Empirismus, allein diese Gefahr existiert nur solange, als man aus einzelnen Detailuntersuchungen willkürlich allgemeine Schlüsse zieht."

65 R.Virchow, op.cit., note 62, p.3


67 A.Eulenburg, op.cit., note 2, p.5; Lebert, Handbuch der praktischen Medizin, Tübingen, 1871, p.2
majority of German physicians, associated with national liberalism, yearning for German national unity.

During the same period one observes among clinicians a curious sort of sober disciplined collective action which expressed itself in the growing practice of simply gathering clinical case histories, *Kasuistiken*, in medical journals. The community of scientific medical practitioners was united in accumulating and evaluating facts. Physicians managed to form a constructive assembly whereas politicians still failed to do the same.

Michael Hagner has argued that neurophysiologists like Moritz Schiff had questioned the scientific dignity of casuistries. 68 Bettina Wahrig-Schmidt's assertion that "the Kasuistik was a prominent descriptive technique resorted to by clinical medicine" corresponds with my own observations regarding the era under review. Wahrig-Schmidt argues that the casuistry was employed and understood by clinicians as a "guarantee of the authenticity of the facts" and protected its author from the "suspicion of careless and hasty generalizations." 69


69 B.Wahrig-Schmidt, F.Hildebrandt, 'Pathologische Erythrocytendeformation', op.cit., note 68, p.79; Wahrig Schmidt observes that the Kasuistik was particularly popular in nephrology. This applies also to respiratory medicine, cardiology and neurology as Friedreich's own practice illustrates.
I repeatedly noted the absence of any ambitious claims with which these case histories would be submitted. They are strikingly modest and restrained in their scientific aspirations; they are simply part of a Baconian enterprise of compiling facts and data:

The period of collecting and confirming the facts won't be over for a long time, many separate building blocks still lie around scattered in isolation waiting to be assembled. But the foundations of the new house of scientific medicine...have been realised.70

Hagner and Wahrig-Schmidt's observations appear to contradict each other. They do not; they depict merely some of the residual antipathies between rationalists (i.e. physiologists) and empiricists (clinical practitioners). Friedreich reconciled the apparent antithesis between physiology and bedside-medicine (i.e the Klinik) in Virchowian style and endorsed the Kasuistik:

The careful clinical observation of individual cases of disease does often cast more light onto the physiological functions of organs; in conjunction with other cases of similar kind it occasionally closes a gap which still consists in our knowledge of disease processes. Thus the cultivation of clinical casuistry becomes an important aid in the construction of the physiology of the diseased body. So-called 'nice cases' are not merely curiosities, but provided each of them is observed accurately it is of lasting value for scientific medicine, even if it only serves to confirm known facts or to open up new enquiries. Finally a carefully evaluated Kasuistik provides us with a useful basis for medical statistics.71

His pupil Wilhelm Erb routinely scrutinized the

70 N.Friedreich, op.cit., note 11, pp.16-17
71 Ibid., pp.18-19
bulk of his clinical case histories. His publications are of the Kasuistik style, paradigmatic for the naturwissenschaftliche Klinik. Invariably his articles concluded with the simple wish "that co-researchers might have been stimulated by my account to report similar cases, which have been observed exactly and have been treated consistently."

By 1855 Virchow claimed confidently that the new improved method had gathered momentum. He observed that the previous turmoil in medicine had calmed down and was looking forward to the future:

Where the prospect of better times achieved through the combined efforts of an increasing number of hands appeared to be secured. Some of the old trouble makers had confessed their sins promising to better their ways; others had silently converted and demonstrated with their work that they had accepted the new direction.

And he continued:

Only the younger generation will eventually convey the full importance of the present reform.


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73 R. Virchow, op. cit., note 62, pp. 4-5

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b. The role of medical diagnosis and therapy in "naturwissenschaftliche Medizin"

While many historians see Virchow's success reflected in the speedy institutionalisation of pathological anatomy throughout Germany they tend to deny his impact upon actual medical practice and therapy. Ackerknecht argued that Virchow's therapeutic ideas never developed beyond the generalizing stage. He perceived Virchow's general programme as too wide to be fully realized "even by a man of such breadth and dynamism." Krause argued in a similar vein: "that the one sided pathological anatomical trend Virchow included was unproductive in medical therapy."

Admittedly Virchow's immediate therapeutic suggestions appear from today's perspective as comparatively insignificant.

In 1847 Virchow had expressed sympathy with the disaffected medical practitioner Rademacher, who had campaigned for a radical Neo-Paracelsian empiricism in therapy.

I openly admit that I see in Rademacher's work the beginning of a reform which will finally result in switching from the present standpoint of rationalism or physiology to empiricism in therapy.

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76 E.Ackerknecht, op.cit., note 26, p.58
77 Fr.Krause, op.cit., note 2, p.327
78 Keim, 'Vier Jahrzehnte innerer Therapie', Berliner Klin.Wochenschrift, 1887, Nr.16, p.295
79 R.Virchow, op.cit., note 1, p.23
This was not intended to be a condemnation of physiology per se. Virchow referred to Wunderlich's programme of 'physiologische Heilkunde' which he perceived as too rational and sceptical. In his eyes such an attitude only tended to paralyse medical therapy. Virchow soon reconciled himself with Wunderlich's programme, however, and admitted that "the latest brochure, published by the physiologische Heilkunde agreed essentially with his own opinion."®

Virchow merely intended to rehabilitate empiricism as the legitimate departure into natural science. He had realized that at a given stage of science, therapeutics had to be developed primarily out of a direct therapeutic experience, had to be empirical.® It may suffice to stress once more that Virchow never advertised any crude unrefined brand of empiricism.®

Careful analysis of Virchow's early publications in his Archiv (1847 and 1855) soon reveals that he wanted to reassure medical practitioners and clinicians that "they had every right to consider their own experiences as positive" and should not feel ashamed to "disclose them openly."® Virchow also vehemently

® R. Virchow, op. cit., note 23, p.8; E. Ackerknecht, op. cit., note 26, p.53


® G. P. Sacharoff, op. cit., note 28, p. 368

® R. Virchow, op. cit., note 23, p. 23
opposed so called "therapeutic experiments", i.e. the blind and wild application of drugs until one would eventually find an effective substance.

In my view Virchow made indirectly a lasting influence upon medical therapy in gently reconciling theory and practice. His guiding slogan was *Scientia est potentia*. He managed to instil hospital physicians (clinicians) with an optimism which made them feel that their task - once perceived to be hopeless and doomed to fail - was worthwhile:

Even if the dissection halls are now fuller than ever, if pathological anatomy gains more and more ground at universities and in hospitals, even if the microscope gains in popularity as an indispensable tool in the hands of physicians, nevertheless only sheer ignorance or blindness could still insist that nowadays medical practice is exhausted in the dissection rooms, that pathological anatomy dominates medicine suppressing it rather than serving her, that the essential end of medical action is being forgotten over the occupation with the microscope. No longer do doctors pass each other with a conspiratory arrogant smile. And should they pause on their way in order to discuss the 'cell', for their practice does not kill their grasp of theory - so be it. They shall hardly forget the sick whom they have been sent for.\

In 1865 Zenker and Ziemssen inaugurated the medical journal *Deutsches Archiv für Klinische Medicin*:

Contemplating the present state of affairs it is obvious that the reign of pessimism is over. Everywhere we detect physicians realizing that they

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84 The original text uses the term 'Augurenlächeln'. G. Bächmann, *Geflügelte Worte*, Frankfurt/Main, Ullstein, 1986, p.313: This term was first used in Cicero's manuscript "De divinatione" (II,24,51) referring to a remark by Cato. 'Augurenlächeln' describes a presumptuous grin exchanged between conspiring insiders.

ought to be and can be the assistants of suffering humans.\textsuperscript{86}

Virchow's natural scientific method instructed physicians to focus their attention, to be methodical and to "think microscopically". This mental act of concentration tamed one's own imaginations and vanity and thus taught self discipline. The same restraint and discipline had to be exercised in medical therapy. This translated itself into the following three principles of therapy: Combined endeavour to enlarge the means of medication, localized and precise (specific) application of therapeutic agents and definition of their indication.\textsuperscript{87}

As a consequence of new insight into pathological processes we see everywhere fresh therapeutic endeavour, partly on novel grounds, which define new indications. In order to suffice they carefully assess and test the results and open up new avenues.\textsuperscript{88}

Contrary to orthodox historical opinion the pathological anatomical orientation was perceived as beneficial and productive for medical diagnosis and therapy by contemporary clinicians:

Within a few decades pathological anatomy has inaugurated such a knowledge of the material organic alteration which - even if still far from perfection - leaves everything behind which had been investigated in the preceding centuries. The knowledge of anatomical alteration (which we know

\textsuperscript{86} Ibid., p.7

\textsuperscript{87} A.Eulenburg, op.cit., note 2, p.25

\textsuperscript{88} F.Zenker & H.v.Ziemssen, op.cit., note 66, p.7
from post mortem examination) prompted such a strong desire to make them accessible to the physician's eye also in the living body. Such diagnostic aspiration knew well how to develop satisfactorily the necessary tools. Physical diagnostics, percussion and auscultation, developed alongside pathological anatomy - likewise the physician's mind did not rest till it found new ways to direct light to the inner organs thus making them accessible to the doctor's senses. This aspiration was crowned with ample success. What the eye can discern can now be reached by the hand to fight against disease on the spot where formerly the medical art only managed to cope via deceptive excursions with illusory media of illusive effects. What the hand can not reach physical technology is able to unravel with new methods. The triumphs of gynaecology since it based its diagnosis on the examination with eye and hand, the booming laryngoscopy with its therapeutic successes...speak volumes of the development of our science.99

Contemporary literature celebrated the successful development of clinical diagnostics. Particularly the introduction of optic devices like the laryngoscope or the ophthalmoscope received proud and frequent praise:

Everywhere where the mirror used as diagnostic aid has cast its rays the perfected examination method has been succeeded by a localising method of cure.90

The emergence of local therapy - mostly surgical - was perceived as a direct result from the general introduction of the vaginal speculum into gynaecology and from the application of the laryngoscope and rhinoscope in the local treatment of diseases of the upper respiratory tract. Suddenly also the local treatment of organic regions which had so far been inaccessible even by the aided eye was pushed forward

99 Ibid., pp.9-10
90 Ibid.
with "instrumental methods" of considerable innovative character:

Independently of optic appliances the local treatment of such bodily regions which are not accessible by direct ocular examination...tries to reach diseased tissues as directly as possible with the aid of other artifice and instruments. In many cases they are very successful. Today liquid substances can be directed to the deepest branches of the trachea or even the lung after having been vaporized by apparatus with compression-pumps and having been inhaled through mouth pieces. The same method of inhalation is successfully utilized in local therapy of afflictions of the left heart.\(^91\)

Such tangible advances motivated the physicians immensely and restored their lost faith in their capabilities. They suddenly felt a reassuring sense of vocation.

Concrete results were generated, numerous enough to elate the previously depressed spirits. The joys of success motivated active intervention and an expansion of research into every direction.\(^92\)

It was not so much the recently acquired pathological anatomical knowledge per se, as Zenker and Ziemssen claimed, which was responsible for the rapid growth of physical diagnostics, but rather the anatomical thought process by which it was motivated: "Where is the seat of the disease?"

Simultaneously Virchow had rehabilitated the role of empiricism and clinical bedside observation as

\(^91\) H.Immermann, 'Ueber die therapeutischen Bestrebungen der heutigen inneren Medicin', Dt.Archiv für Klin.Med., 1871, Vol.9, pp.247-273, pp.258-9; Following the invention of a transportable 'pulverisateur' by Sales-Giron in 1858 the inhalation of remedial vapours was introduced into the treatment of respiratory disorders.

\(^92\) F.Zenker & H.v.Ziemssen, op.cit., note 66, p.10
legitimate aids "which are available to scientific medicine in the construction and refurbishment of its new edifice." As an immediate consequence the clinical investigation of disease was strongly encouraged and thus diagnostic clinical medicine began to flourish. But it should be remembered that the idea of diagnosis as an important element of clinical medicine had already been introduced by Schöllein.

By claiming that the recent accumulation of pathological anatomical knowledge had encouraged the growth and advance of diagnostic aspirations Zenker and Ziemssen gave the impression as if diagnostic action was a mere result of improved pathological knowledge, which had been generated thanks to the natural scientific method. The original intention of Schöllein, however, was to make the "composing and comparing act" of forming a diagnosis a crucial part of the clinical method. Virchow never mentioned that the contemporary "breakthrough" of the diagnostic approach towards disease was conceptually indebted to the natural-historical method. Hess argued that this was a deliberate strategy designed to question the

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93 N. Friedreich, op. cit., note 11, p. 17


methodological independence of the 'Klinik'.

Previous citations of Virchow should have made it clear that he did not assign any methodological primacy either to practical medicine, i.e. the Klinik, or to theory. Indeed he insisted that practical medicine was never, not even in the hands of the most gifted master, scientific medicine, but merely its application. For the scientific clinician the achievements of scientific medicine are the basis of his operations. According to Virchow clinical practice is kept in the hands of Wissenschaft: "Scientia est potentia".

I do not intend to dwell here on the rapid advance of medical diagnostic methods and the development of a host of diagnostic apparatus after the 1850's. These themes have already enjoyed a considerable amount of attention by medical historians.


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95 Schönlein's school maintained the methodological autonomy of the Klinik: "All rays of science converge in her centre". See also footnote 12 of this chapter.

96 V. Hess, op. cit., note 9, pp. 288-289

Reiser argues it was in the 19th century that "objective" diagnostic technologies were developed in earnest. The stethoscope permitted the detection of pathology by sound. The ophthalmoscope and laryngoscope permitted the visual exploration of the body's interior without the surgical penetration of its surface. The microscope revealed a cellular universe in which the microscopic causes of many diseases could be located. The development of the manometer, the sphygmograph, electrocardiograph and thermometer permitted the translation of physiological actions into the quantifiable language of machines." With the introduction of mechanical measuring instruments such as the sphygmometer, spirometer and thermometer many 19th century physicians recommended that the principal measures of disease should not be defects in the body architecture but changes in essential body functions, such as breathing, blood circulation and temperature. By mid century, physicians were firmly attached to getting numerical measures of physiological processes." The introduction of the thermometer especially encouraged the belief that the physiological


forces expressing health and disease could be precisely measured. Where the anatomical perspective asked "Where is the lesion?" this functional perspective led physicians to ask "What can the organ do?" and to expect a precise numerical answer to the question. Reiser also argues that in the 20th century the vast increase in knowledge of the human body made possible through these diagnostic technologies resulted in medical specialization and the concomitant centralization of medical diagnosis and therapy in hospitals.

Friedreich was convinced that his friend and mentor Virchow was "ultimately responsible for medicine's transformation into "naturwissenschaftliche Medizin". Friedreich was instrumental in conveying Virchow's message to his pupil Erb. He maintained that the exercise of the correct method was crucially important in establishing medicine proper:

Virchow repeatedly insists on the application of the exact method of natural sciences to medicine...he demands secured and complete premises and facts, which had been accumulated by sense observation, by post mortem examinations and experiment, confirmed by reliable witnesses. In order to prove not only the validity of the facts but also the reliability of the witnesses Virchow maintained that frank criticism was indispensable. The latter had to be based on repeated personal observation, had to advance empirically and not rationally (raisonnerend) and its aims above all had to be as radical as possible.

Friedreich also invoked Virchow's architectural

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100 N.Friedreich, op.cit., note 11, p.16
101 Ibid., p.16
metaphor of the edifice of scientific medicine which was about to be constructed by the medical community. Friedreich's future edifice of scientific medicine rested on four pillars. The first basic pillar was considered to be clinical observation and the clinical investigation of individual disease processes. Clinical bedside medicine relied upon observation, *individualization* at the bedside, the communal cultivation of clinical casuistry and the systematic application and elaboration of all available methods of physical and chemical examination.¹⁰²

To clinical observation a second essential building block was added: pathological anatomy and histology. The microscope played a crucial role in pathological anatomical research:

Pathological anatomy demonstrates organic and histological alterations in different stages of the disease and provides us in conjunction with clinical observation with an insight into morbid disturbances as they evolve as organic processes. Admittedly there exists a certain number of diseases without manifest anatomical alterations, occasionally we yearn to detect alterations being unable to demonstrate them in the corpse which would indicate the cause of death. Does that, however, not justify the conclusion that such diseases, such deaths are not produced by some material substratum? Are we not compelled to believe that in such cases exist subtle molecular organic and histological alterations which are presently inaccessible to the scalpel, even to the eye aided by the microscope? The history of pathological anatomy illustrates that the microscope managed to disclose organic alterations which had so far been missed by the knife and the naked eye; without doubt eventually the progress of pathological histology and improved instruments will succeed in penetrating the most refined molecular organic and histological alterations and thus the

¹⁰² Ibid., pp.16-21
category of so called functional diseases will increasingly be limited.\textsuperscript{103}

Friedreich's optimism appeared fully justified in view of the recent advances and the formulation of the cell-theory:

Every day brings new results; but also new questions and problems whose solution is quite essential not only for the pathologist but also the physiologist. Admittedly the subtle and final chemical and physical processes within the cell...are still not revealed; but the path which will ultimately lead to the goal has been opened up. Investigations have been moved by the microscope to the cells, the smallest anatomical units and the very workshops of that mechanism, where ultimately morbid and healthy life is being produced.\textsuperscript{104}

The third pillar supporting the edifice of scientific medicine was the "path of the experiment". The animal experiment was suited to fill the information gaps which had still been left open by clinical observation.

The pathological experiment allows us to produce arbitrarily alterations in animals, allows us to demonstrate a specific phenomenon in its dependence on a specific condition and allows us...to observe specific results produced by that condition. The pathological experiment offers us the advantage...of manufacturing the morbid conditions in a simple manner, to interrupt, to modify and to vary the latter and thus we gain easier insight in the relationship between cause and effect than facilitated at the bedside or dissection hall. Disease is an experiment put on show by nature, but its conditions are often so complicated that it is almost impossible to achieve the correct insight into the laws of morbid disturbances without the comparison and illumination of the experiment.\textsuperscript{105}

Like Virchow Friedreich insisted that the ultimate end of medicine was the cure of the sick:

\textsuperscript{103} Ibid., p.22
\textsuperscript{104} Ibid., p.25
\textsuperscript{105} Ibid., pp.26-27
The ideal aim of pathological physiology was the complete prevention of disease: Genuine medicine would not be satisfied in making brilliant diagnoses or be exhausted in research; true medicine was aimed at 'healing' and would not remain in the grip of therapeutic scepticism or nihilism.\textsuperscript{106}

Friedreich could not deny that "irrespective of its progress contemporary medicine was still pretty impotent in dealing with a great number of disease processes". On the other hand he cautiously claimed that pathological anatomy had already made positive contributions towards therapy, putting it on a safer footing.

Medicine's "future task" was generally perceived to be the "encouragement of the construction of rational therapy, the reconciliation and synthesis of pathology and therapy", in other words to "transform therapy from an art or mere routine into the science of healing".\textsuperscript{107}

How should the physician act once faced with a disease whose cause could not be removed, where the disease could not be forced to retreat or when morbid side effects persisted even when the original cause had been eliminated? How should one actually proceed, bearing in mind that Virchow had condemned therapeutic experiments by trial and error?

Friedreich did not hesitate to assert that the physicians' task remained, even when confronted with

\textsuperscript{106} Ibid., p.28
\textsuperscript{107} A.Eulenburg, op.cit., note 2, p.24
seemingly hopeless cases, "in searching for remedies which offered the chance of eradicating disease". A responsible physician would always seek to alleviate suffering:

Therapy is wholly justified and even obliged to search empirically for remedies and cures if the causation of disease is still obscure and theory cannot indicate any potentially effective remedial action. I do not suppose that therapy should just come to a standstill until research has entirely clarified the nature of all diseases, until perfect pathological physiology has lifted the last remaining veil which still hides the subtle mechanisms of disease? Many of the best remedies have been found in a purely empirical manner. Nobody would seriously criticize medicine for resorting to agents from which she knows that they are effective although she cannot explain why this is the case. A scientific physician resorts to quinine when attempting to cure a patient suffering from intermittent fever, even when he still does not know the exact mode of its action. Can one really condemn medicine's aspiration to search for effective remedies against old and new diseases or dismiss it even as unscientific?\(^{108}\)

Friedreich was convinced that no reputable physician would make such assertions, provided of course "scientific physicians would not rely on unrefined therapeutic empiricism which dared to employ willy nilly entirely unknown agents in diseases of equal uncertain nature". Empirical therapy striving to enlarge the number of available remedies was not allowed to leave the basis of certain knowledge.

One particular type of therapeutic experiment was deemed to be acceptable: Provided some analogies and positive experiences indicated a potential beneficial effect of the agent in question and provided previous

\(^{108}\) N.Friedreich, op.cit., note 11, p.33
experiments with healthy and diseased animals had been performed, the application of a comparatively unknown remedy was allowed.

It's a different kind of thing with...remedies, acquired through thought and experience. They are almost always derived from an analogy; One knew for example from experience that ergotamin stopped some forms of uterine bleeding and subsequently it was employed in haemorrhages of other organs as well.\textsuperscript{109}

Friedreich was convinced that this was the correct practice which vindicated the empirical development of therapy. Such was his conviction that he envied coming generations of physicians who would be able to enjoy the privilege of witnessing the fulfilment of those philosophical words:
"Scientia est potentia!"\textsuperscript{110}

So far I have tried to demonstrate that the inauguration of rational therapy was understood to be intimately related to physiological research, pathological anatomy, experimental pathology, aetiology and diagnostic improvements by contemporary physicians.\textsuperscript{111}

In 1876 Albert Eulenburg, then Professor of Medicine at Greifswald University, contemplated the "vast therapeutic advances during the course of the present century." He put the "present advantages of modern therapy" down to three major points: Firstly the

\textsuperscript{109} Dr Keim, op.cit., note 78, p.334

\textsuperscript{110} N.Friedreich, op.cit., note 18, pp.32-35

\textsuperscript{111} H.Immermann, op.cit., note 91, pp.253-254
enhancement of the 'Materia Medica' and its liberation from excess baggage; secondly the more defined application of remedies as a result of improved understanding of their indications and better knowledge of drugs. The first was considered to be a direct result of scientific pathology, the latter was put down to the progress of experimental pharmacology\textsuperscript{112} and thirdly the more localised application of treatments.\textsuperscript{113}

Many contemporaries argued that there were indeed encouraging signs of progress in the present state of therapy. But they also admitted that the ideal rational therapy seemed still a long way off.\textsuperscript{114} On the other hand recent developments in organic and inorganic chemistry were quite promising and had "transformed the available sources of medication considerably".\textsuperscript{115} For example quinine replaced 'Chinarinde' in the treatment of intermittent fever. It had also been observed in laboratories that solutions of quinine had actually halted fermentation and killed low organic life forms, i.e. fungi. Thus physicians wondered whether quinine could be employed in diseases which were thought to be

\textsuperscript{112} Ibid., "Purely speculative remedies are not being employed any more only by Romantics, by those lacking any judgement or blindly searching for solutions for they've reached the end of their tether."

\textsuperscript{113} A.Eulenburg, op.cit., note 2, p.25

\textsuperscript{114} Ibid., p.32

\textsuperscript{115} Ibid., pp.251-253
the result of some form of harmful fermentation in the human body?\footnote{116}

Apart from the introduction of pharmaceutical products "a wide range of 'non-pharmaceutical treatments'- some of which almost developed into disciplines in their own right" was being introduced into therapy.\footnote{117} Among them were electrotherapy, balneotherapy, hydrotherapy, kinesiotherapy (gymnastics), aerotherapy, climatotherapy and dietary therapy.

The integrity of the new naturwissenschaftliche method permitted the scientific physician also to utilize therapies previously decried as 'unscientific' or associated with quackery:

New avenues have been opened up for therapeutic research whereby treatments which originate from crude empiricism...have been utilised for science...provided they are being employed sensibly and are being subjected to methodical research by intellects trained in the new spirit of exactitude. The splendid development of electrotherapy and the emergence of scientific hydrotherapy are very telling examples.\footnote{118} (my emphasis)

It was considered as real progress that therapeutic indications began to be defined more clearly and above all were limited to specific cases. For example in the past the diagnosis of pneumonia had inevitably prompted an endless and lethal succession of

\footnote{116} Ibid., pp.252-253
\footnote{117} A.Eulenburg, op.cit., note 2, p.27
\footnote{118} Zenker & Ziemssen, op.cit., note 66, p.11
venesections. Now it was strictly contraindicated. Instead the systematic application of ice was encouraged to combat pyrexia, usually a symptom in pneumonia which according to latest pathological research was thought to pose a greater danger to the organism than the congestion of the lungs.\textsuperscript{119}

Ludwig Traube had experimentally investigated the effects of digitalis. Its influence upon the vagal nerve was elucidated and further indications for its application were defined, i.e. its use in chronic heart disease.

Binz investigated the probable antiseptic side effects of quinine which would help to destroy the organic 'carriers' of putrefaction and fermentation.\textsuperscript{120} Therapeutic experiments were conducted to clarify the potential benefits of electricity in treating muscular and nervous diseases.\textsuperscript{121}

With the departure from humoralism and the growing tendency to infer disease primarily from local alterations of tissue - a perspective which had been encouraged by pathological anatomy and by Virchow's cellular pathology - therapy began to be directed at the seat of the disease ('sedes morbi' or 'locus

\textsuperscript{119} A.Eulenburg, op.cit., note 2, p.29

\textsuperscript{120} Ibid., p.29

\textsuperscript{121} Ibid., p.31
affectus'), thus became local therapy.\textsuperscript{122}

Simultaneously medical therapy acquired a more \textit{surgical} character.\textsuperscript{123} This point has already been illustrated by the introduction of diagnostic optic appliances into gynaecology or laryngoscopy.

Drug therapy had to concede many of its privileges to the electric and galvanic current, to gynaecology and otology, to climato- and balneotherapy, to hydrotherapy, to active and passive gymnastics, to diet, to inhalations and various injections and above all to surgery - once the cinderella of therapy! Now seated on the throne of asepsis she courageously attacks with the knife the beast of disease hidden in its cave; medicine, however, sat in front of that cave for ages and tried to lure the beast out of all bodily orifices with all kinds of pharmacological baits - but the beast never left! Now even scabies and nasal polyps belong to medical therapy.\textsuperscript{124}

The principle of localised treatment in electrotherapy was frequently endorsed by the leading authorities in that field, i.e. Erb, Eulenburg and Ziemssen.\textsuperscript{125}

Bearing in mind that Virchow had always abhorred a narrow perspective, local treatment was not advocated as the exclusive therapeutic approach, albeit a preferred one.

It would be too one sided...to expect progress merely by advocating local therapy as the one and only method. Despite the knowledge of the local derivation of disease as a consequence of diagnostic examination methods, its local treatment is not always possible - and the local and surgical

\textsuperscript{122} Ibid., pp.30-32

\textsuperscript{123} H.Immermann, op.cit., note 91, p.260

\textsuperscript{124} Dr Keim, op.cit., note 78, p.333

\textsuperscript{125} H.Immerman, op.cit., note 91, p.259
treatment in internal disease will always have its limits, there exist quite a few disease processes which either affect many or all parts of the organism and whose localisation is unknown to us.\textsuperscript{126}

Adherents of local therapy admitted "that the scientific physician could also achieve results without actual medication or even outside local therapy." For example they stressed the fact that diet (or climate) had a rightful place in therapy.\textsuperscript{127} Thus:

Modern therapy began to tackle the scientific justification of...other therapeutic approaches which might forceful retune (energisch umstimmen) the organism and the exploitation of physical agents. Of course the physiological effects of the aforementioned therapies had to be tested prior to their application or they were only employed provided their probable positive effect had previously been observed empirically.\textsuperscript{128}

Occasionally Wilhelm Erb attempted to explain the observed therapeutic benefits of electricity with its likely ability to retune the entire organism.

"Naturwisenschaftliche Medizin" was not only about its contents, but also about conduct. The point that Virchow conceived of medicine as a social science at its core, ultimately as true anthropology, has already been mentioned. Virchow preached the gospel of medicine as an utopian programme holding the key to human progress and society's advancement.\textsuperscript{129}

\textsuperscript{126} Ibid., pp.260-261

\textsuperscript{127} Ibid., p.251 & p.261

\textsuperscript{128} Ibid.

\textsuperscript{129} E.Ackerknecht, op.cit., see note 26, p.46. Virchow adopted for example the slogan:"medicine is a social science, and politics nothing else but medicine on
Emil du Bois-Reymond judged the entire role of "Naturwissenschaft" in a similar vein:

Natural science is the absolute organ of culture, the history of the natural sciences is the very history of mankind.\textsuperscript{130}

Natural scientific medicine thus perceived was not only about cultural improvement but also about cultivation. It was paramount for members of the medical community to be seen to engage in that process. On the one hand that tended to be expressed as involvement in public health medicine. Many academic physicians participated in local politics, too. Essentially, however, they were required to cultivate science as such: they had to demonstrate that they understood the natural scientific method which required above all patience, perseverance, self-discipline and restraint:

\textit{In the strict scientific realm the sphere of our action should not expand into infinity. For in proper restriction lies...a substantial part of our energy.}\textsuperscript{131}

I have read a considerable amount of primary sources from the era under investigation. Whenever one opens a contemporary medical journal, associated with natural scientific medicine, one cannot help but notice the sudden increase in tables, graphs and meticulous listings of all sorts of data when compared with the a large scale" from Salomon Neumann.

\textsuperscript{130} Emil du Bois-Reymond, \textit{Culturgeschichte und Naturwissenschaft}, Leipzig, Veit & Comp, 1878, p.34

\textsuperscript{131} F.Zenker & H.V.Ziemssen, op.cit., note 66, p.2
era between 1820-1850. It is quite tiresome to read those and undoubtedly it must have been extremely tedious and time consuming to produce these statistics and endless tables. It certainly must have required patience and concentration not only from the reader but also from the scientific author to write these articles.

The majority of clinical research publications are notably of the Kasuistik type. I have already mentioned their two-fold significance - firstly as a guarantee of the authenticity of the gathered facts, secondly as an expression of the collective and shared act of compiling 'hard' facts.

A number of questions...can only be solved through the collection of as many observations and Kasuistikten as possible.132

Simultaneously the scientific community was encouraged to act in a democratic and undogmatic fashion:

Clinical science has to be aware that she receives inspiration from all sister disciplines. Though she should focus on the more obvious tasks at home which require all her attention. Thus in accordance with the correct principle of the division of labour she will reach out for the sister's hand or offer her own help, yet independently she pursues her own goal.133

The rhetoric resorted to in scientific publications is conspicuously sober and unpretentious thus seemingly expressing modesty, honesty, accuracy and "common sense". The new era was about fact not


133 F.Zenker & H.v. Ziemssen, op.cit., note 66, p.2
fiction, about the poetry of reality. Nebulous phrases and speculation were dismissed as the linguistic marks of Romantic excesses.\textsuperscript{134}

It remains to make many observations, conscientiously and unbiased by preconceptions, before we can arrive at a final solution of a problem.\textsuperscript{135}

I noted a marked rhetorical difference between early 19th century publications and the articles published in medical journals after the mid-century. Contemporary scientists observed a contrast, too: "Times are different and so are the methods by which one serves the entirety." Their rebellious and ingenious predecessors, Andreas Röschlaub, Lorenz Oken or Johannes Müller, had their glorious names written down in big "letters in the annals of science" for they had "torn down the moribund structures" of the ailing old medicine.\textsuperscript{136}

But current times were not "revolutionary" - on the contrary rather "peaceful and calm", to put it bluntly less exciting, less extreme and less captivating - well not romantic at all! The accumulation of facts and their repeated analysis were hardly exciting, nor was there much fame to be

\textsuperscript{134} Ibid., p.3

\textsuperscript{135} W.Erb, Electrotherapeutics, London, Smith Elder & Co, 1887, p.259

\textsuperscript{136} Reference to Röschlaub as "Barrikadenkämpfer"in H.Rohlfs, Umrisse zur Kritik der neueren deutschen Medizin, München, 1851, p.24; J.H.Baas, Grundriss der Geschichte der Medizin und des Heilenden Standes 1876, Stuttgart, Enke, p.673
sought:

Times of fight and victory are usually followed by peace and calm development. Now it is the time to preserve the field...to plough every year new furrows into the prepared ground, to reap rich harvests. History tends to ignore such ages. Their unassuming quiet action, however, safeguarded history's course and steady progress. But it is only through those quiet periods that we appreciate former times of struggle.  

Browsing through programmatic primary literature one cannot help noticing the frequent employment of agricultural metaphors of cultivation. Physicians likened themselves remarkably often to farmers cultivating the soil of medicine, sowing the seeds of science, watching the steady growth of leafy blossoming trees, i.e. results, eventually yielding a rich rewarding harvest. On the one hand that exemplifies the contemporary historiography of science which understood science to be a steady process of organic growth to perfection. Thus the progress of science itself was often described with botanical metaphors.

On the other hand the ideal "Arzt" began to be increasingly characterized by the "country doctor". It is probably not mere coincidence that academic physicians began to resort to such rural and agrarian metaphors when alluding to their own occupation. After all academic medicine had began to "mix with ordinary people" and began slowly to expand its influence beyond urban universities. This might also partly account for the current rehabilitation by academic physicians of

137 Ibid., p.4
folk medicine, i.e. water-cures as inaugurated by Priessnitz.  

Likewise farming metaphors timidly suggested that one did not have to be any longer exceptionally gifted to train as a medical student. Provided he was prepared to work hard an ordinary young man could make it as well. Extraordinary Genius was not required, but what mattered was methodical work, industry, honesty and hard labour:

Here even the average (mediocrity) finds its fair share, provided one works hard and earnestly seeks truth.

Scientific medicine was part and parcel of all natural sciences which were in the eyes of many contemporary scientists literally about utilising nature. Again agricultural metaphors were ideally suited to convey the utilitarian interpretation of natural science:

Under natural science we understand not only the sum of all knowledge of inorganic and organic nature, its products, properties and laws, but also the conscious insight into the method, which helps to enlarge that knowledge and the simultaneous application of natural science to serve the ends of technology, navigation, medicine and so forth; in short the deliberate exploitation and utilisation of nature by man in order to increase his power, his comfort and pleasure.

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138 A. Eulenburg, op. cit., note 2, p. 27; the layman Vincenz Priessnitz had inaugurated cold water cures; the latter were introduced into scientific therapy by Winternitz and Runge.

139 Emil du Bois-Reymond, Culturgeschichte und Naturwissenschaft, 1878, Leipzig, Veit & Comp, p. 38, first published as a speech in 1877 in Dt. Rundschau, Novemberheft.

140 Ibid.
Emil du Bois-Reymond's definition of "Naturwissenschaft" has almost religious connotations. It recalls the biblical words in Genesis where man is called upon by God to go forth, multiply and conquer the earth.

In that context medical equipment acquired a further meaning as utensils of culture and cultivation. They were the very "ploughs" with which the physician cultivated medicine according to the rules laid out by Virchow. In the case of electrophysiology the development of complicated apparatus required not only theoretical knowledge but also practical skill and experience. Many scientists therefore needed the assistance of craftsmen in order to build the complicated machinery they wanted for their laboratory experiments. Thus in the conception of many medical apparatus theory and practice merged through an act of democratic cooperation between scientist and craftsman. The actual operation of medical devices required perhaps only modest technical knowledge and skill in the case of electrotherapy.

It has often been claimed that the machine had deflected the physician's attention from the patient to its objective mechanical performance in the form of sounds or signs: for example the motion of blood became visible through the sphygmograph's measurement of the

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141 Emil du Bois-Reymond mentioned the help and assistance provided by the mechanic Sauerwald.
pulse. As a result, it is argued, the patient's subjective voice was silenced. The patient was controlled by the machine, sometimes even became an object him- or herself. For example in the case of electrotherapy, the patient's body was being inserted between two electrodes, acting as a galvanometer or electrical conductor.

Electrotherapeutics consists simply in placing the human body-usually a part of it only-into the external circuit of an electrical current.\textsuperscript{142}

I would never go as far as to argue that the patient was entirely lost or forgotten, as some historians do. After all, according to Friedreich, individualization at the bedside was still considered the distinct mark of a thinking physician. But there is certainly evidence that the patient's individual account and his own perception of disease became less relevant.

I am not aware that historians have actually looked at the impact of the new technology on physicians' own experience. I feel that technological innovations restrained not only the patient but often also the physician. For example Erb and many of his fellow electrotherapists often stressed that they had to master many difficulties in producing the galvanic reaction of the acoustic nerve. It was indeed considered a highly delicate and difficult operation which required utmost resilience, patience and self-

\textsuperscript{142} W.Erb, op.cit., note 132, p. 23
discipline on the parts of both the experimenter and patient:

Only with perseverance, patience and self-sacrifice on part of the subject... and in the experimenter... is it usually possible to obtain the acoustic reaction in many individuals.\textsuperscript{143}

Erb admitted that he had to repeat his galvanic examinations over and over again:

I did gain even more competence and dexterity in ascertaining the galvanic reaction following months and months of intense occupation with that matter.\textsuperscript{144}

Like ploughing a field, the cultivation of science, the operation of novel medical technology required hard labour, a certain degree of discipline and was at times also quite repetitive. Not only the patient but also the physician was harnessed to the machine.

\textsuperscript{143} Ibid., p.136 & p.145

\textsuperscript{144} Ibid.
Chapter 6. Biography of Nikolaus Friedreich

The most important and lasting influence upon the young student Erb was undoubtedly exerted by his mentor Professor Nikolaus Friedreich. Contemporary assessments of Friedreich express an almost religious admiration of his brilliant clinical skills and good character. The terms blessed and chosen for example are frequently resorted to.

Nikolaus Friedreich (1825-1882) was the descendant of a famous German family of physicians: "Devotion and genuine talent for medicine had been passed on through three generations in Friedreich's family."¹ Friedreich's grandfather Johannes Nikolaus Antonius Matthias (1761-1836) had published the first accurate clinical description of a case of peripheral facial paralysis 'De paralysi musculorum faciei rheumatica' in 1797.² His son Johann Baptist, Friedreich's father, is probably better known to medical historians. Johann Baptist Friedreich's (1796-1862) main interests were forensic medicine and the pathology and therapy of psychiatric diseases.³

His son Nikolaus was born on 31st July 1825 in Würzburg where he spent his entire youth and


² A translation of his work can be found in Edinburgh Annals of Medicine, 1801, Vol.5, article 13, pp.214-226

³ A.Hirsch, Biographisches Lexikon, Berlin, Urban und Schwarzenberg, 1930, p.624
adolescence. Nikolaus received his gymnasium education in the Bavarian towns of Straubing and Ansbach. Having decided to follow the family tradition Nikolaus Friedreich enrolled in medicine 1844 at Würzburg University. After six years of training mainly spent in Würzburg, but interrupted by a six month period in 1847 at Heidelberg University under Henle, he graduated in 1850 from Würzburg University with an MD. Already as a medical student he excelled with the successful solution to a prize question in botany during his philosophical biennium which earned him in later years an honourary doctorate in philosophy. In 1848 he and his friend Karl Gegenbaur published an anatomical paper 'Ueber den Schädel des Axolotl'.

Among Friedreich's teachers at Würzburg University Koelliker, Rinecker and Marcus are thought to have been most influential during his early formative years. A year prior to his final examination Friedreich worked as junior medical assistant under Professor Marcus at the Juliushospital. Following his finals he continued to work as first medical assistant under Marcus who was by then totally blind and thus utterly dependent on the diagnostic skills of his junior staff. One suspects that the unfortunate disability of his teacher had forced the young medical

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apprentice to develop his own clinical skills and diagnostic abilities to such excellency:

There was no greater master in the technique of physical examination. Nobody reached his perfection in the art of percussion, there wasn't any better percussion hammer or plessimeter other than Friedreich's finger. Even from the biggest patient he succeeded in teasing out the percussion sounds so that they were quite easily audible.  

In 1849 Rudolf Virchow received the first chair in pathological anatomy in German speaking lands. This chair was created especially for him at Würzburg University. Friedreich's colleagues and disciples, Dr Kussmaul and Dr Weil, agreed that Virchow's influence upon Friedreich was the most significant and determining one in his medical career:

when Friedreich was just about to reach the conclusion of his medical studies, Virchow came in 1849 to Würzburg and exerted immediately the greatest influence upon him. Without ever having been his medical assistant Friedreich soon developed a close relationship with him (Virchow). Throughout his entire life he was and remained one of his most devoted and enthusiastic disciples.  

Wilhelm Erb suggested that Friedreich's universal education in pathological anatomy and his particular preference for that branch of medical science can be traced back to Virchow's influence and teachings.  

Under the immediate influence of Virchow the young Friedreich had at first seriously considered a career exclusively in pathological anatomy.

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5 A.Kussmaul, op.cit., note 1, p.204
6 Ibid., p.196
7 W.Erb, op.cit., note 4, pp.163-164.
In 1853 Friedreich completed his Habilitationsschrift on "Geschwülste innerhalb der Schädelhöhle" (On tumours of the inner cavity of the skull) and was appointed Privatdozent in special pathology and therapy.

Suddenly in 1856 Virchow received a call to Berlin, and a suitable candidate for the vacant post in pathological anatomy had to be found. Virchow expressed the wish, that the government ought to fill the vacancy with one of his disciples, who familiar with his own teachings would be able to continue his work in the same spirit as he had previously done. He recommended Friedreich as the most suited personality to the medical faculty. In 1857 the Royal Bavarian Government appointed Friedreich as Professor Extraordinarius in pathological anatomy and made him in fact Virchow's successor.

Friedreich had to prove constantly to his students in the lecture hall and to colleagues in the mortuary during public post mortem examinations that he was a worthy successor. Initially these tiresome ordeals appeared to threaten Friedreich's strength; however, he passed the many tests and tribulations and emerged victoriously. He was able to prove that he not only operated with "skill and fortune" at the bedside

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© A.Kussmaul, op.cit., note 1, p.197
but also in the dissecting theatre and with the microscope in the laboratory.\textsuperscript{10}

Aged thirty-two the young scientist and physician took over the direction of Heidelberg's medical hospital and was appointed Professor for special pathology and therapy at the University. Friedreich's move to the Badenese university has often been interpreted as his eventually realizing his due potential and vocation as a clinician:

There he reached his goal towards which his genuine ambition and desire had always been directed; he had considered the anatomical position only as the transitional stage to the clinical one, and indeed, according to his entire nature Friedreich was the born clinician, chosen unlike many.\textsuperscript{11}

Among the medical students at Heidelberg University eagerly awaiting Friedreich's first lectures and demonstrations was Wilhelm Erb. He once gave a vivid account of his training under Friedreich:

He (Friedreich) took over a clinical department in the third floor of the old "Seminar" which consisted initially of seven, later of eight beds - the rooms were just about big enough - and two clinical assistants, relatively few nursing staff; there was also a prospering "Ambulatorium" with an assistant living in town who was also responsible for the direction of the facilities for dermatology and venereal diseases, which were housed in a room in the fourth floor but under the auspices of the medical "Klinik". This "Ambulatorium" was often used for clinical teaching. There were only few students, during the first semester only seven attended the "Klinik"; for a number of years there were hardly more than ten to eighteen students attending the "Klinik" (in winter 1862/63 twenty; during the seventies forty to forty three as

\textsuperscript{10} Ibid., p.198

\textsuperscript{11} Ibid., p.198
maximum); that was probably less stimulating for the teacher, yet for us apprentices (I had joined them Easter 1860) that proved to be useful, since we were called upon frequently and enjoyed the teacher's immediate input upon our studies and exercises. Friedreich's clinical teaching method was particularly advantageous for beginners. He ascertained with greatest care the patient's history, followed by a very accurate and total physical examination, which had to be performed by the student (Praktikant) under the teacher's guidance and control; then the diagnosis in all its aspects was being considered; we were often most impressed by Friedreich's trained and practical eye; his therapy was simple, but well considered, free from nihilism based on therapeutic optimism and was - once decided upon - carried out consistently and without frequent changes. A particular feature [of his procedure] was the constant attention to the single case presently under consideration; rarely generalizations or summaries were made. The students were given an excellent education, since they were often called upon and had to examine the patients themselves; thus Friedreich's Klinik became very popular and was scarcely missed out. The post mortems were also carried out by him with Virchowian diligence and were submitted to thorough criticism.¹²

Friedreich's teaching activities were not restricted to the Klinik, which was held for nine hours each week. He also lectured on special pathology and therapy (medicine), general pathology and diagnostics. Only in 1866 was pathological anatomy delegated to Arnold, following Friedreich's suggestion. Till then dissections had also been performed by him fairly regularly. In other words during his first eight years at Heidelberg University Friedreich had developed an active teaching life and held more or less two professorial posts in one.

Friedreich and Arnold (jr) cooperated closely and

¹² W.Erb, op.cit., note 4, pp.164-165
Friedreich continued to be involved in teaching pathological-histological courses and setting up a collection of pathological anatomical material. When Erb started in 1862 as Friedreich's assistant one of his first tasks was the labelling of the various specimens which were housed in a dark cellar.\textsuperscript{13}

Besides being an university teacher (Klinik Ambulatorium, lectures, dissection) Friedreich was also the clinical director and chief physician at the local medical hospital:

Whenever possible, he did a daily ward round (Visite) covering the entire department, mostly also on Sundays and extended it often over the usual time span, totally unaware of himself and unconcerned about his own needs. He cultivated especially physical diagnostics and relied a lot on his junior staff with wardwork. But also patient care in its narrower sense, the whole conduct and direction of the wards, the supervision and training of assistants and nursing staff were of immediate concern to him, the direction of the "Heidelberger medizinische Klinik" was and remained always exemplary. Yet Friedreich generated a particularly beautiful and far reaching impact upon his disciples... He was strict with them and demanded ability, dedication and a strong sense of duty. He was little inclined to grant time off, but it was also a pleasure to work under him. He supported his assistants in their scientific work, but granted them independence so that they did not have to work merely for him. That was something which he did not like at all. He was pleased with their successes and results and would encourage them to persevere. Often he would discuss not only his own but also their work.\textsuperscript{14}

Likewise Friedreich patiently supervised his students at the bedside discussing the patient examination and findings. He put a particularly strong emphasis on

\textsuperscript{13} Ibid., p.166

\textsuperscript{14} Ibid., p.167
diagnostic questions, percussion and auscultation, the venous pulse curve, the microscopy of sputa and so forth. He did it to such an extent that even his assistants thought Friedreich was at times overdoing it a bit.\textsuperscript{15}

Nikolaus Friedreich also participated actively in the administrative and political life of the university as a member of the medical faculty. Having experienced himself the inertia of academic institutions in earlier years at Würzburg and the inability of the older generation to give way to younger colleagues, he was particularly concerned with the welfare of younger scientists and the respective disciplines which they represented or attempted to advance. Thanks to Friedreich's influence a professorate for pathological anatomy was created at Heidelberg in 1866; but he was also actively engaged in the creation of a professorate for ophthalmology. The establishment of special teaching posts (Lehrauftrag) in physical diagnostics, electrotherapy, forensic medicine and hygiene, dermatology and "syphilodology" can be traced back to his spirited and relentless initiative, not to speak of his and Otto Weber's robust campaign for the erection of a new Akademisches Krankenhaus. The latter project was eventually completed in 1876. Friedreich pushed for the creation of a psychiatric hospital and chair in psychiatry withstanding numerous hindrances. He was one

\textsuperscript{15} Ibid., p.170
of the leading faculty members and "despite the odd outbursts of odious opposition he managed to represent medicine (Innere Medizin) and the Klinik with dignity for almost a quarter of a century at Heidelberg University".\textsuperscript{16}

One should assume that the busy life of university professor, physician, clinical director and faculty member should have left no time at all for any substantial production of medical research. That was not so! Friedreich was a truly learned man, even a bookish person. He had a lifelong passion for books, so that a certain sum of money was put aside every year to keep his valuable collection updated. A large portion of his library consisted of neurological literature. Friedreich's former library is now housed as a separate collection in Heidelberg's University Library, the "Bibliotheka Friedreichiana".\textsuperscript{17}

Friedreich was a relentless researcher and a prolific writer. During his Würzburg period under Virchow he published mainly anatomical and pathological anatomical work. This branch of medicine remained a life long interest. His contributions to pathology and pathological anatomy were mostly of the Kasuistik type, then gaining in popularity among clinicians. The

\textsuperscript{16} Ibid., p.169

\textsuperscript{17} Ibid., pp. 169-170; A.Kussmaul, op.cit., note 1, pp.194-195
greater part of his publications dealt with \textit{physikalische Diagnostik} which overlapped with his clinical interest in cardiovascular and respiratory diseases. Many of these publications are excellent pieces of \textit{semiotic} character.

He made his most "brilliant contributions", however, in his favourite field of nervous and muscular diseases.\textsuperscript{18} Already his "Habilitation" covered a neurological theme. It was an attempt to relate clinical symptoms to the anatomical seat and distribution of cerebral tumours prior to the introduction of diagnostic aids like the ophthalmoscope. Soon after his arrival in Heidelberg Professor Friedreich began to publish those papers which procured him "neurological fame".\textsuperscript{19}

For Friedreich Heidelberg's \textit{genius loci} was the ideal breeding ground naturally suited to nurture the growth of neurology:

My clinical activity at a location where nature had created such a peculiar contrast between the beauty spots along the banks of two converging rivers and the most hideous forms of numerous and widespread goitre, cretinism, progressive muscular atrophies and various forms of central paralyses, offered me such opportunities to observe chronic forms of spinal diseases, which I would have hardly enjoyed at any other place in such favourable circumstances and in such abundance.\textsuperscript{20}

In 1863 Friedreich's famous study 'Ueber

\textsuperscript{18} A.Hirsch, op.cit., note 3, p.625

\textsuperscript{19} P.Vogel, 'Die Heidelberger Neurologische Schule', \textit{Heidelberger Jahrbuch}, 1970, Vol.14, pp.73-84, p.74

\textsuperscript{20} Ibid., p.75
degenerative Atrophie der spinalen Hinterstränge' appeared in Virchow's Archiv.²¹ This work intended to define more precise pathological anatomical criteria for the differentiation of spinal diseases.

Friedreich opened his study with a critique of previous observations and descriptions of what was then called grey degeneration in the posterior spinal cord; he insisted on the necessity of microscopical examinations which would eventually help to put the pathology of the spinal cord on a solid foundation. He felt dissatisfied with the vague nosological notion of tabes dorsalis which was to him merely a symptomatological disease picture which could be resolved anatomically into many different diseases.

The study was based on six clinical case histories which described two sets of three siblings. All patients presented with almost monotonous regularity similar symptoms: the onset of motor disturbances during puberty, progressing slowly from the lower to the upper extremities, finally involving disturbances of speech. Friedreich concluded that it was not so much a disturbance of the action of singular muscle groups but rather the harmony of their coordinated action was affected. The principle of this type of disturbance was later named ataxia by Duchenne.

de Boulogne. Friedreich adopted the same term a little later, but not yet in his 1863 publication. Less constant symptoms among his patients were nystagmus, vertigo and spinal deformities.

Three out of the six patients had died and were also submitted to a post mortem examination. The striking feature of the corresponding pathological anatomical findings in a postmortem revealed a degenerative atrophy of the spinal posterior cord extending over the entire length of the cord but particularly well expressed in the lumbar portion. Despite the marked degeneration and atrophy of the spinal posterior cord all the patients had had an intact sense of touch and muscle sense during life. Therefore Friedreich concluded that Bell's postulate about the sensory nature of the spinal posterior root did not apply to the spinal posterior cord. The spinal posterior cord, however, had to play an important part in the association and coordination of movement.22

Thirteen years (1876) later Friedreich published another study: 'Ueber Ataxie mit besonderer Berücksichtigung der hereditären Formen' which was based on four additional case histories and basically confirmed his 1863 findings.23 Friedreich clearly distinguished his new disease picture from the disease

22 A good summary of his 1863 paper can be found in P.Vogel, op.cit., note 19.

23 N.Friedreich, in Virchows Archiv, 1876, Vol.68, pp.145-245
by then conventionally identified as tabes - the so-called *Ataxie locomotrice progressive Duchenne* - and from another disease referred to as "Multiple Sklerose". Now Friedreich used the term hereditary ataxia.

In 1873 Friedreich published a comprehensive monograph *Ueber progressive Muskelatrophie, Über wahre und falsche Muskelatrophie*. This monograph:

is based on a large number of his own clinical observations and post mortem findings taking into account the contemporary medical literature discussing relevant questions in nerve physiology and pathology with a great measure of precision, dialectic and learnedness. It (the monograph) discusses the entire question of trophoneurotic effects and its surrounding theories; it delivers a complete treatise on the so called muscular pseudohypertrophy. The author does not neglect the close relationship of the latter with muscular atrophy; finally he also considers genuine muscular atrophy and progressive bulbar paralysis...In this work Friedreich inaugurates and justifies the opinion that progressive muscular atrophy is nothing other than a chronic inflammation of the muscles (*Myositis interstitialis chronica*), in other words a genuine myopathy. He maintains that the nervous system or any of its components (peripheral nerves, sympathetic, spinal cord) has no role whatsoever in its genesis (origin); its involvement is only of secondary nature. Thus he disputed Charcot's teachings which were opposed to his own and had come to fruition in the 1860's. Charcot and his followers claimed that progressive muscular atrophy was a disease of the nervous system, principally of the spinal cord (grey anterior columns).

Within a few years of his arrival at Heidelberg

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24 N.Friedreich, *Ueber progressive Muskelatrophie*, Berlin, Hirschwald, 1873

25 W.Erb, op.cit., note 4, pp.179-180; A.Kussmaul, op.cit., note 1, p.203 (Charcot maintained that progressive muscular atrophy was of neuropathic nature whereas Friedreich thought it to be of a myopathic nature)
Friedreich had initiated a formidable private practice (Consiliarpraxis) which prospered and flourished throughout his entire life. Prior to the advent of railways Chelius and Nägele had already attracted a substantial number of patients from all over the world to Heidelberg, which was often referred to as the Grand Hotel at the European Road. "With the introduction of the steam engine into the transport system consultations were made even easier for dignitaries living further abroad. The immediate consequence was that the endless stream of those seeking Friedreich's advice was much bigger than in the past.""26

Friedreich was so dedicated to his patients that he still received them during the last weeks of his life, knowing that he suffered from a fatal disease. In 1879 Friedreich began to suffer from symptoms which he himself diagnosed as signs of a developing aortic aneurism. He soldiered on anxious to hide his deteriorating health from his wife Josephine. On 6 July 1882 he died from a ruptured thoracic aneurism.

26 A.Kussmaul, op.cit., note 1, p.205
Chapter 7. Zeitgeist and Electrotherapy 1850-1880

From a forester's hut in the Black Forest to the chair of neurology in Heidelberg is a long path, but one which Wilhelm Erb plodded with taciturn brilliance...Of his antecedents nothing is known except that his father was a woodsman.¹

This biographical account was most certainly designed to evoke feelings of admiration and awe in the reader. Its authors, however, were mistaken. For one thing Erb's antecedents are not shrouded in the darkness of the Black Forest. His family history can be traced back as far as to his ancestor Johannes Erb who lived from 1669 to 1723. Erb's childhood, while not indulgent, was not as poor and underprivileged as one would imagine a child growing up in a forester's hut.

On the contrary Wilhelm Heinrich Erb's persona can firmly be located in the German Bildungsbürgertum. Many aspects of Erb's medical practice ideally illustrate the mentality and culture which surrounded and carried the German Bildungsbürgertum during the mid 19th century. James Sheehan has analyzed the social mores of that particular section of German society. He identified three aspects of modern culture associated with the Bürgertum: natural science, literary realism and national consciousness.² Natural science and

¹ A.Torkildsen & Th.Erickson, 'Wilhelm Erb 1840-1921', Neurological Biographies and Addresses, 1936, Foundation Volume, Oxford University Press, pp.114-119, p.114

national consciousness play a great role in Erb's life.

My thesis will be less concerned with the aspects of literary realism other than perhaps referring to contemporary examples of that specific brand of German literature for illustrative purposes. Instead of choosing literary realism as one feature of an emerging modern *bürgerliche* culture I prefer to depict realism as a prevalent aesthetic and epistemological strategy in German bourgeoisie culture during that period, bearing in mind that natural science and the arts were being considered essential components of that culture. Closer inspection reveals that realism became simply the *bürgerliche* world view during the 1850's and 1860's and that this extended also into the political sphere. Incidentally the term *Realpolitik* was also coined during that era (1853) by August Ludwig von Rochau. The opening lines of Rochau's *Principles of Realpolitik* are often taken as a kind of epigraph for the post-revolutionary era:

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5 Rochau's personal transformation from student rebel to political exile to support of Bismarck's Reich illustrates a generational shift from opposition to reconciliation. W.Smith, *Politics and the Sciences of Culture in Germany 1840-1920*, Oxford, Oxford University Press, 1991, pp.3-298, p.39
The discussion of the question, who should rule...belongs in the realm of philosophical speculations; the practical question only has to do with the simple fact that it is power alone which can rule.*

A glance at contemporary popular literature, political pamphlets and scientific treatise reveals that natural science, an ideology of realism and a growing sense of national consciousness among the emerging middle class were intermingled in a perplexing multitude of combinations. In 1858 - ten years after the failed 1848 revolution - an anonymous publicist put it simply in a nutshell:

Our nation of forty million dreamers and idealists has learned a good deal in the hard school of reality, and it has also fortunately forgotten some things. Above all, it has become more practical. Romanticism and sentimentality, transcendental philosophy and supranaturalism have now withdrawn from the public life of our people into private life. For realism and steam, machines and industrial exhibitions, the natural sciences and practical interests fill now the great market place of life and work at the humming loom of our time.? The failed 1848 revolution is customarily portrayed as a kind of watershed in German history.

Within the new materialistic Weltanschauung that arose in the 1850's - the decade of hardened perceptions that followed the failed revolution of 1848 - natural science invariably served as the consecrating element. Filling the vacuum left by the abandonment of both idealism and the prospect of constitutional politics, natural science in the new world view carried out a dual function: it provided the economically reinvigorated middle class with positive, factual knowledge tailored to a new, practical agenda; it also served as an emblem in a

* J.Sheehan, op.cit., note 2 , p.853

new form of political conflict, the struggle by the same Bildungsbürgertum to attain dominance through cultural representations.

It has to be pointed out, however, that sentiments of what Lenoir characterised as a moderate liberal programme had already been expressed prior to the 1848 revolution. He has examined popular German literature designated for the educated public published in the 1830's and 1840's. Among them were Brockhaus' Conversationslexikon and articles in the Deutsche Vierteljahresschrift. This literature advocated for example an alliance between Bildungsbürgertum and the entrepreneurial groups in order to bring about the desired transformation of society:

The values essential to this alliance were a commitment to the creation of a unified German state, in which the talent, industry and initiative were protected, rewarded and recognised as the sources of future wellbeing of the body politic.

Lenoir also confirms an observation already made by other historians, i.e. the centrality of economic reform to the moderate liberal national programme. Within this programme German unity was best achieved by economic reform and the pursuit of material

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*T. Lenoir, 'Laboratories, medicine and public life', in Cunningham and Williams (eds), The Laboratory Revolution in Medicine, Cambridge, Cambridge University Press, 1992, p. 41
interest. Various articles in the Brockhaus on trade and industry resounded with the message that the unification of Germany would be effected through the expansion of industry and improved communication:

The state should support industrial growth through the construction of railways, improved roads and waterways, and improvements in communication, such as telegraphs, the postal system and newspapers. The minutiae of that economic reform were subject to debate. But it was universally agreed that the best way to ensure a prosperous and socially just future was to protect industry and remove any obstacle to the full development of the capacities of the productive middle classes, the agents of historical change. The latter were, according to Lenoir, the new breed of academics representing the most progressive disciplines such as political economy and the natural sciences, and, within the natural sciences of the 1840's, the most progressive disciplines of chemistry, physics and physiology.

Lenoir concludes that eventually the aftermath of the failed 1848 Revolution had brought about much of what the writers of the Brockhaus and the Vierteljahresschrift articles had been attempting to achieve. The ensuing decades were set upon rejecting idealism and embracing a realism guided by the pursuit

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10 Ibid., p.31
11 Ibid., pp.28-29
12 Ibid., p.30; T.Hamerow, op.cit., note 7, p.153
of material interest as the path towards solving the political and social questions of Germany.\(^3\) This world view also fostered an epistemological realism in science which emphasized the hands-on basis of scientific cognition.

Robert Brain's study on the German family magazine *Westermann's Monatshefte* which was founded in the 1850's confirms Lenoir's conclusions. Arleen Tuchman's thesis describes the historical circumstances in 19th century Germany which brought together the new scientific method, i.e. an hands-on approach, natural sciences and political liberalism.\(^4\) Her findings are in accord with the aforementioned conclusions.

Historians acknowledge that a growing national consciousness was almost universally present in every member of *bürgerliche* society.\(^5\) One of the most cherished and elusive aims of the middle classes was the quest for a unified German nation.\(^6\) This applies also to Wilhelm Erb who was an ardent supporter of Bismarck, because he had managed to bring about German unification. Also Erb's attendance at

\(^{13}\) T.Lenoir, ibid., p.70; to be sure the new emerging ideology attempted to unite the best features of idealism and materialism in a common-sense realism.

\(^{14}\) A.Tuchman, 'Science, medicine and the state; the institutionalisation of scientific medicine at the University of Heidelberg', Ph.D.thesis, University of Wisconsin, 1985

\(^{15}\) Th.Hamerow, op.cit., note 7, p.144

\(^{16}\) R.Brain, op.cit., note 8, p.367
Heidelberg University coincided with the rise of the kleindeutsche historical school at the university which undoubtedly helped to foster his pro Prussian political leanings.17

Erb epitomised many aspects of the culture of Bürgerlichkeit. Victor von Weizsäcker hit the nail on its head when he portrayed Erb as: "rich in personality and yet highly characteristic for an entire epoch in medicine...a typical representative of a specific age."18

Erb's scientific method was an expression of the realism which pervaded all spheres of life:

Wilhelm Erb's passion was a passionless empiricism, his conscience was the conscience of facts, his confession was realism. To him truth was not the transcendent, but only the visible.19

Similarly Alfred Hoche remembered his teacher Erb "not as a sparkling personality", but as someone who was infused with genuine, deep and intelligent willpower:

As a young assistant and lecturer he embarked upon the task of serving neurology not by constructing speculative though intellectual theories...Erb was neither inclined nor skilled in that respect; but he was equipped with the necessary ability i.e. a sharp discerning eye for the factual and essential, a self-less and incorruptible sense for truth, a pedantic insistence on examination, enormous industry and will-power, which could neither be

17 E.Gass, Aus meinen Erinnerungen, p.44 (undated): The sister of Wilhelm Erb's second wife Anna (nee Gass) recollects in her personal memoirs how she and Anna Erb visited Bismarck in Kissingen during the late 1890's. Professor Erb always kept a bust of Bismarck in his study.

18 V.v.Weizsäcker, op.cit., note 3, p.1595

19 Ibid., p.1595
broken by resistance nor fatigue. The analysis of nature's experiments with the nervous system in the shape of complicated and baffling disease pictures was the ideal task destined for his character.20

James Sheehan once gave an excellent analysis of the basic virtues of Bürgerlichkeit: independence and discipline-sometimes fused as self-discipline:

Independence (Selbstständigkeit)...the liberal's favourite criterion for active political participation, was both a material and spiritual condition: it required sufficient property to be free from social constraints and financial dependence, as well as sufficient moral substance to be free from irrational desire and unwholesome drives. But independence was only one side of the bürgerlich social ideal no less important was a man's willingness to subject himself to social discipline, obey legitimate authority, and adopt sensible opinions. In the culture of Bürgerlichkeit, the ideal self was supposed to be autonomous but not autarkic, free but not isolated, independent but not without sustaining bonds.21

Erb's colleagues and pupils frequently refer to both bourgeois social ideals, independence and self-discipline, as the hallmarks of Erb's character:22

He trusted man's ability and duty to be independent and to develop in his inner self the forces which maintain an equilibrium even in the face of a turbulent fate.23


21 J.Sheehan, op.cit., note 2, pp.798-799

22 S.E.D.Shortt, 'Physicians, Science and Status: Issues of the Professionalization of Anglo-American Medicine in the 19th Century', Medical History, 1983, Vol.27, pp.51-68. Shortt argues on p.51 that: "to the earnest Victorian...the attainment of professional status was intimately linked to the possession of character...signifying a range of enduring credentials such as mental initiative, self-reliance and usefulness."

23 V.v.Weiszäcker, op.cit., note 3, p.1595
Equally Erb's voluntary retirement in 1907 was judged to be proof of the fact that Erb was not ruled by the indiscriminate forces of fate but that he commanded his own life.²⁴

Sheehan identified the pocket-watch as the perfect emblem of self-hood in a bürgerliche society for it captures "so nicely its specific blend of autonomy and discipline."²⁵

Owning a watch was a sign of autonomy since it implied a kind of power over time that dependent people could not enjoy, but it also suggested the owner's voluntary conformity to the authority of schedules and timetables. To be on time, to save time, and to spend it wisely were all, important bürgerlich virtues.²⁶

Of course Professor Erb owned a pocket-watch, in his case a silver one dangling from a chain. It is also striking that almost every obituary mentions Erb's punctuality and economic use of time. Max Nonne remembered that his boss would always appear on the dot for the daily ward round and nobody was left waiting and hanging around:

Erb was a hero of labour; he was only able to fulfil the immense self-expectations by brilliantly organising his daily work load. As he hated nothing more than being kept waiting he was always on time, thanks to the punctuality of our master we assistants were able to dispose over our own time and did not have to waste any time idly waiting -

²⁴ Ibid., p.1595
²⁵ J.Sheehan, op.cit., note 2, p.799
even for us the hour had sixty minutes.\textsuperscript{27}

The same applied to Erb's use of his leisure time or as the Germans would say \textit{Freizeit} (time off, free time) which was incidentally also a \textit{bürgerlich} neologism. It indicated that free time belonged to the individual and was the earned right to rest after hard work. Free time itself was to be spent sensibly, preferably not with the excessive intake of alcohol. Instead an educational visit to the museum, zoo and library or recreational leisure activities like sport were highly recommended, for they were also aimed at self-education and self-improvement.\textsuperscript{28}

Erb appreciated his deserved time off: "A life which consists only of work is not a fulfilled life either" he warned his pupil Nonne. Erb gave the following fatherly advice to Nonne on his departure: "Be quick in your work and allow yourself some swift amusement". Erb loved to spend his summer vacation in the fashionable spas or went ice-skating in the Black Forest during winter. But to be sure "he usually returned with one or more manuscripts ready for publication."\textsuperscript{29}

Historians have established that natural science became an inextricable part of the middle-class domain

\textsuperscript{27} M.Nonne, 'Wilhelm Erb', in K.Kolle (ed) \textit{Grosse Nervenärzte}, Stuttgart, Thieme, 1970, pp.68-80, p.78

\textsuperscript{28} J.Sheehan, op.cit., note 2, p.800

\textsuperscript{29} A.Torkildson & Th.Erickson, op.cit., note 1, p.118
of culture during that era. Particularly during the initial phase of industrialization (1848-1871) natural science was not only about its products and results but equally about its symbolic and aesthetic appeal to the general public at large. Hamerow argued that "it was symptomatic of an early stage of German industrialization that before 1871 the most important area of investment was not production but transportation". A relatively high value was assigned to the means of communication and transportation: the triad of railroad, steamship, telegraph was evoked time and again as representative of industrial progress.

Correspondingly natural science was considered first the conceptual (and pedagogical) vehicle of change which would then in the near future deliver the goods. In order to bring about that transformation one had to be seen to participate in the practice of natural science. Thus the cultivation of natural scientific activity as such was a paramount prerequisite to social and political progress. Science became a code-word for methodology and a vehicle for social mobility.

30 Th.Hamerow, op.cit., note 7, p.24


32 S.E.D.Shortt, op.cit., note 21, p.62
Nicholas Jardine has recently recommended that historians of science should focus more on the aesthetics of scientific practice. In Jardine's historiographical proposal "two sorts of incitement to human action play central roles - rhetorical incitement and aesthetic incitement."³³

Aesthetic incitement...includes the whole range of ways in which perceptible things - gestures, words, representations, instruments, preparations, displays and demonstrations - move persons through their appeal to the senses, the imagination and the emotion...Aesthetic incitement is...doubly social, social in the sense that it presupposes and works through social conventions for the staging and demonstration of things, their illustration and representation, and social in the sense that the modes of aesthetic response are...socially instilled dispositions. But there again more is involved than the blind play of social conventions and dispositions. Aesthetic appeal and response depend upon the powers and appearances of the things themselves.³⁴

The railway was one of those "powerful perceptible things" which conveyed a host of meanings and aesthetic incitements. Its actual and metaphorical importance did not escape the contemporary educated public. Wilhelm Raabe, the author of the novel Guttmanns Reisen (1891), admitted that the plot of his story would have been unimaginable without the railway and thus the train-station. The romance is set in the 1860's, a period which was dominated by political aspirations to

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³⁴ Ibid., p.322
national unification. *Guttmanns Reisen* (Guttmann's travels) is basically a love story culminating in the engagement of a South German *Fraulein* Clothilde Blume with the North German Wilhelm Guttmann:

Without the route to the railway station the entire story would not have taken place. How could the German people possibly come to an adequate understanding...how else could the two young people of the same mohtertongue both descending from German tribes possibly meet each other? How would it have been possible to emerge from the entire unholy confusion as one heart and soul, as one flesh - other than through the route to the railway station?\(^{35}\)

*Kleindeutsche* historiography deliberately supported the image of the railways as a means to German unification. As it was the function of the rail to overcome natural resistances and obstacles it would conquer the obstacles in the way of economical union by facilitating the unimpeded and speedy circulation of goods and commodities. Wolfgang Schivelbusch argued that the railway system was also envisaged as one great machine covering the land drawing together the various geographical parts and its people.\(^{36}\) Schivelbusch further observed that the telegraph became an integral element of the railway machine ensemble:

In order to guarantee the proper functioning of this machine, juridical and politico - economic regulations had to be revised, but technological improvements proved equally necessary. The most important technological addition to the railways was


\(^{36}\) W.Schivelbusch, op.cit., note 31, p.29
the electrically operated telegraph system.\textsuperscript{37}

The electrical telegraph was of great importance for the technical operation of the railway. Max Maria von Weber\textsuperscript{38}, a railroad expert, observed that without the telegraph the railway would be like an organism without nervous system:

As a muscle of a human body without the nerve flashing through it would be a mere lifeless hunk of flesh, so would the flying muscles that Watt's and Stephenson's inventions have lent to humanity be only half as capable of winging their way, if they were not animated by the guiding thought imperiously flashing through the nerves of the telegraph wires.\textsuperscript{39}

The association of electrical telegraphs with the nervous system was commonplace in physiology. The interchange of biological and technological images flourished in an environment bent on the pursuit of material interests and a hands-on approach to scientific cognition. Technology and machines acted as mediators and generators of scientific, technological and cultural practices:\textsuperscript{40}

The nervous system can be compared to the telegraph

\textsuperscript{37} Ibid., p.29

\textsuperscript{38} Max Maria von Weber was the son of the famous composer of the opera 'Der Freischütz' Karl Maria von Weber.

\textsuperscript{39} Ibid., p.30; Schivelbusch quoted that passage from D.Sternberger, \textit{Panorama of the Nineteenth Century}, Oxford, 1978; Sternberger quoted M.v.Weber while discussing the mutual influence exercised by technological and organic metaphors in the nineteenth century.

\textsuperscript{40} N.Wise, 'Mediating Machines', \textit{Science in Context}, 1988, Vol.2 (1), pp.77-113
system stretching across the state. The cellular nervous elements stand for the apparatus while the fibrous elements play the role of the wires which transmit the impulses from the centre to the periphery and vice versa from the periphery towards the centre. The brain and spinal cord have to be regarded as the big telegraph stations in the capital and the ganglia dispersed over the different parts of the body are the stations in smaller locations.\(^{41}\)

Thus electricity was frequently associated with improved means of communication and transportation.

Adolf Kussmaul observed that "with the introduction of the steam engine into the transport system consultations were made even easier for dignitaries living further afield "which resulted in an endless stream of patients seeking initially Friedreich's and later Erb's medical advice."\(^{42}\)

Having undertaken their journey to Heidelberg from as far abroad as Russia, as for instance in the case of the composer Michael Skriabin, the patient would encounter sensations (and aesthetic incitements) in Erb's consulting rooms which were not entirely dissimilar to those visual and physical impressions experienced throughout his railway journey.

During the nineteenth century the train was frequently described as a projectile by virtue of its velocity. The passenger who sat inside the 'projectile' ceased to be a traveller and became, as noted in


another popular metaphor of the century, a mere parcel:  

For the duration of such transportation one ceases to be a person and becomes an object, a piece of freight.

Similarly the passenger's perception of the passing panorama was affected by the velocity and the linearity with which the train traversed the landscape. This led the traveller to develop a sort of panoramic perception:

Panoramic perception, in contrast to traditional perception, no longer belonged to the same space as the perceived objects: the traveller saw the objects, landscapes, etc through the apparatus which moved him through the world. That machine and the motion it created became integrated into his visual perception: thus he could only see things in motion.

Victor Hugo described the view from a train window:

The flowers by the side of the road are no longer flowers but flecks, or rather streaks...there are no longer any points, everything becomes a streak.

Thus the patient receiving electrotherapy in Erb's Praxis was perhaps not surprised to discover himself once more being transformed into "a living appendage to

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43 W.Schivelbusch, op.cit., note 31, p.54
45 Ibid., p.55
the machine", for "electrotherapy consisted simply in placing the human body into the external circuit of an electrical current." Similarly the professor would sometimes record the actions of the patient's muscles with a myograph. The graph which recorded the patient's muscular movements displayed an image or panorama which again was not dissimilar to the "streaks" which had passed the passenger's eye at the train window.

Soraya de Chadarevian's paper on "the graphical method and discipline" reconstructs the network of investigative, disciplinary, institutional and cultural relations which favoured the method of curves in German physiology. Thus in Erb's consulting room patient and physician re-enacted an experience which was already familiar from daily life in the modern world of an industrializing state.

The paraphernalia of an electrifying room and electricity itself certainly also had their aesthetic appeal - they were related to the mechanisms of modern traffic and improved unimpeded communication which held the promise of uniting the nation:

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47 W. Schivelbusch, p. 120; the phrase "living appendage to the machine" is borrowed from Karl Marx. (Das Kapital).


The notion that communication, exchange, motion bring to humanity enlightenment and progress, and that isolation and disconnection are the obstacles to be overcome on this course, is as old as the modern age. The bourgeois cultural development of the last three centuries can be seen as closely connected with the actual development of traffic.\textsuperscript{50}

Cultural and social historians have frequently demonstrated how the nineteenth century bourgeois saw the well-being and vitality of its social institutions as dependent on a healthy circulation or metabolism of values and goods. In pre-1871 Germany the middle classes tended to advocate a prudent laissez-fair approach to the economy.

The circulation metaphor illustrates the biologisation of social and economic processes and conversely, the influence of underlying social conditions on biophysical notions.\textsuperscript{51}

Electricity had proved to be so beneficial in running the railways that contemporaries identified the electrically operated telegraph with the nervous system of an organism. Conversely electricity was perceived to be a beneficial stimulus in managing the nervous system successfully. This becomes particularly apparent in the electric treatment of paralysis. There electricity was supposed to facilitate the unhindered journey of the nervous impulse along the nervous track.

\textsuperscript{50} W.Schivelbusch, op.cit., note 31, p.197

\textsuperscript{51} Ibid., p.195; Ch.Hill, 'William Harvey and the Idea of Monarchy', \textit{Past and Present}, 1964, No.27, pp.54-72
A hindrance in the motor conduction, which cannot be overcome by the will, may perhaps be conquered by a stronger, artificial stimulation, and the way thus made clear for voluntary action. Hence, if we allow the electric irritation to act energetically above the seat of the lesion the hindrance may perhaps be removed that way.\textsuperscript{52}

Erb extended his analogy which also demonstrates that he perceived of electricity as a fluid-like agent:

A very fair comparison would be that of a water pipe in which the current is stopped by some hindrance...which weakens or completely prevents the flow. The simplest remedy for this is to wash away the hindrance by a stronger current of water, under higher pressure and so make the course free again.\textsuperscript{53}

I have attempted to demonstrate the aesthetic appeal of electricity to patient and physician against the complex background of the prevailing Zeitgeist. I believe that the extra-scientific rationale of electricity's use in medical therapy can be attributed to its aesthetic attraction in a bürgerliche culture.

The employment of medical electricity had become more regulated, domesticated and less dramatic as opposed to the spectacular public displays of electricity during the previous century. Nevertheless, electricity still retained some of its more thrilling and extraordinary aspects. Among his patients Professor Erb was also known as the great magician.\textsuperscript{54}

\textsuperscript{52} W.Erb, op.cit., note 48, p.430

\textsuperscript{53} Ibid., p.431

Chapter 8. The context of contemporary electrophysiology

The mode by which nerves mediate between organs fascinated the enquiring minds of natural philosophers since antiquity. At times this mediation process was conceptualized akin to the motion of bell ropes. Others likened that process to the conduction of subtle fluids, so called nervous spirits, through hollow nerve pipes. Albrecht von Haller's *Elementa physiologiae corporis humani* (1762) provides an interesting contemporary discussion of similar considerations.¹

It has also been well documented that during the late eighteenth and early nineteenth century the nervous system assumed a predominant position in physiological writings. Then natural philosophers felt compelled to investigate the possible mediating function of the nervous system after Cartesian teachings had just opened up that mysterious gap between mind and body. It was assumed that the nervous system provided the integrating mechanism for the body and thus became the common matrix for philosophical, psychological and physiological inquiries. In conjunction with those efforts to elucidate the nervous functions and the action of the soul a debate began concerning electricity's role in medicine and physiology.

According to Haller's and du Bois-Reymond's historical accounts the mathematician Hausen (1693-1743) first suggested in 1743 that electricity might be the nervous principle. At that time electricity also began first to play a role as a stimulus in neurophysiological experimentation.

Already ancient philosophers had understood vitality as being expressed in movement and sensation. The eighteenth century preoccupation with the nervous system put a new emphasis on sensation and sensibility within the context of the emerging sensualist epistemology. Suddenly also the concept of the reactive organism was investigated and the interface between animal organism and environment came under scrutiny: the concept of a "stimulus" evolved. Previously the organism was conceived of as embraced by atmospheric and cosmic influences. Now these diffuse affections became narrowly defined as stimuli in the laboratories of natural philosophers like von Haller or Baglivi. The latter had coined the term "stimulus" without providing its exact definition.²


³ Hans Jürgen Möller demonstrated that Haller used the term stimulus or synonymously irritamentum in his work Elementa physiologicæ (1766) only in the context of muscular activity and its causation. H.J.Möller, Die Begriffe Reizbarkeit und Reiz, Konstanz und Wandel ihres Bedeutungsgehalts, Stuttgart, Fischer, 1975
Haller mentioned various stimuli which evoked a muscular response such as: poison, alcohol, cold and heat, pricks with a scalpel. The most effective stimulus, according to him, was the electrical spark. Haller's experiments puzzled his colleagues and continue to irritate medical historians. His definition of irritability, excitability, elasticity and contractility caused confusion of terminology and bewilderment among physiologists regarding the distribution of devolved animating properties. Soon some natural philosophers tried to restore the concept of a monolithic order within the body. Haller's attempted localization of animating properties in consigned areas of the body was considered by some as too materialistic. Subsequently Haller's opponents subsumed all bodily expressions under either the concept of irritability or sensibility as modifications of the same vital force.

Brigitte Lohff has persuasively argued that seen against that background Galvani's (1791) discovery of animal electricity - be it by chance or design - had a special role to play.¹ An all pervading animal electricity, provided it could be demonstrated, offered them an excellent explanation for an integrating vital force thus restoring ontological harmony within the

body. Hence Haller's opponents claimed identity between nervous force and electricity.

Haller himself had pondered the mechanism of nervous activity and had considered the possibility that the nervous agent was electricity. He felt, however, that his experiments had proven that ligated nerves were hindered in their interaction with the muscles. Since electricity could not be arrested by such ligatures he could not see how electricity could be an effective nervous agent. Speculations that the nervous principle might be identical with electricity continued and led to a host of experiments being performed on nerves. Yet despite these attempts no single galvanic effect had been made known which would have justified it to imply electromotor action proper to the nerve.

Exactly hundred years after the idea of the electrical nature of the nervous principle had first been expressed, du Bois-Reymond discovered a fact which appeared to justify such an assumption. In spring 1840 Johannes Müller had asked du Bois-Reymond to follow up Matteucci's experiments on the "frog current" and the

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6 Ibid., p.144

7 Ibid., (Vol.2) chapter 5, p.185
question of the possible electrical nature of the nervous principle. The prehistory to du Bois-Reymond's own experiments has been described by himself so completely that it is still regarded by medical historians as unsurpassed.

Throughout his career du Bois-Reymond concentrated on the development and refinement of two types of instruments: electrodes for conducting weak bioelectric currents without distortion and devices for detecting and amplifying those currents. One of the major complications of early electrophysiological investigations was the polarization of the electrodes used (that is the progressive change in their electric properties). Assisted by Helmholtz he eventually designed non-polarizable electrodes (zinc amalgam electrodes) which were to remain in use with only minor modifications till 1940.

A study by Geddes and Hoff provides further elucidation on the historical interrelation of electrophysiology and electromechanics.

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8 T.Lenoir, 'Models and instruments in the development of electrophysiology, 1845-1912', HSPS, 1986, Vol.17, pp.1-54, p.4


excellent study on 'models and instruments in the
development of electrophysiology between 1845 and 1912' provides also good illustrations and explanations.

In 1843 Emil du Bois-Reymond announced that he had demonstrated the "frog-current", which had first been detected by Nobili. With his new sensitive "astatic galvanometer" du Bois-Reymond confirmed the presence of a continuous weak current flowing between the nose and tail of the frog. Though it has now been demonstrated that this is an artifact and may have no physiological significance at all, it became a central component of du Bois-Reymond's later theorizing.\textsuperscript{11}

Then he examined the large sciatic nerve and the gastrocnemius and sartorius muscles of the frog and detected two phenomena exactly parallel to his "frog-current". He called them the "muscle current" and "nerve current" and considered them to be fundamental phenomena of neurophysiology.\textsuperscript{12} He showed that in both muscles and in nerve segments a current flows from the exterior surface to the axial cross section of nerve or muscle fibre in such a way that the muscle or nerve is positively charged along its surface and negatively

\textsuperscript{11} T.Lenoir, op.cit., note 8, p.7

\textsuperscript{12} E.du Bois-Reymond, op.cit., note 2, 1848, Vol.1, p.501
charged at the cross section.\textsuperscript{13}

Prior to du Bois-Reymond's investigation of the nervous principle three theories regarding its nature were held.

First, electricity was said to be identical with the fluid thought to be the nerve's conducting agent, so that it was solely responsible for nerve action.\textsuperscript{14} Johannes Müller, du Bois-Reymond's mentor, had rejected the 'hypothesis of identity' and adhered to the second theory, which claimed that there were no electrical currents in nerves and that conduction took place by means of a nervous principle as yet unknown. Electricity was merely regarded to be an irritant that set in motion the conduction process just as in the case of mechanical or chemical stimulation. Müller differentiated meticulously between the \textit{physics of the nerve} and the \textit{nervous principle} which underlies and facilitates the nerve's action. He repeatedly stated in his \textit{Handbuch} that the nature of the nervous principle was still unknown and that it was the physiologist's

\textsuperscript{13} T.Lenoir, op.cit., note 8, p.8 and figure 3; Ludimar Hermann emphasized in his \textit{Handbuch der Physiologie} (1879) that the transverse section was actually an artefact, since all these experiments had been conducted on dissected motor nerves of frogs. It still needed to be demonstrated whether the natural transverse section of the living intact nerve was also negative with respect to the nerve's surface.

first and foremost task to investigate the expressions of that principle without necessarily having to know its precise nature.\textsuperscript{15}

The third theory was that there existed an underlying conduction process in the nerve, again unidentified, but which was accompanied by an electrical signal.\textsuperscript{16} Du Bois-Reymond adhered to the hypothesis of identity in 1848.

In 1850 Helmholtz started to measure the speed of nerve conduction (velocity of the nervous impulse) experimentally with the aid of two methods. He experimented with the motor nerves of frogs, later also with human sensory and motor nerves. The first method relied on the help of the 'Myographion', the second was performed with the aid of the 'galvanometric method of Pouillet.'\textsuperscript{17} Having applied both methods to measure the speed of the nervous conduction process of an excitation, Helmholtz obtained with the myographion a speed of 27.25 metres/second and with the second method 26.40 metres/second.

One can conclude from these figures that this

\textsuperscript{15} Brigitte Lohff, 'Johannes Müller und die Nervenphysiologie', in Ernst Florey und Olaf Breidbach (eds), Das Gehirn-Organ der Seele?: Zur Ideengeschichte der Neurobiologie, Berlin, Akademie Verlag, 1993

\textsuperscript{16} E.Clarke and S.Jacyna, op.cit., note 14, pp.208-211

\textsuperscript{17} Claude Servais Mathias Pouillet (1790-1868) French physicist who was successively Professor of Physics at the École Polytechnique, and in the Faculty of Science, and Director of the National Conservatory of Arts & Crafts.
conduction process proceeds extraordinarily slowly as compared to the speed with which electrical processes propagate themselves.\textsuperscript{18}

Thus du Bois-Reymond's concept of the identity of the nervous agent with electricity was disproved. But he was already moving towards the third proposition, for he had suspected that the electrical signals he could detect in a nerve were the external manifestations of an underlying, yet unknown, conduction mechanism.\textsuperscript{19}

Du Bois-Reymond succeeded in demonstrating the existence of electrical currents in animal tissues which pass from their natural surface through a circuit to their transverse section. The latter was artificially obtained by cutting the nerve. By further reducing the length of the respective piece of tissue (muscles or nerves) he observed that each shortened tissue fragment exhibited the same regularities of voltage distribution as the longer ones. This reminded him of the similar behaviour of magnets which after having been broken off into smaller fragments point with their poles in the same direction as prior to their reduction. In the case of the magnets Ampere had concluded that they consisted of minute molecular magnets or magnetic molecules.

Subsequently du Bois-Reymond relied on an analog

\textsuperscript{18} Ernst Brücke, \textit{Vorlesungen über Physiologie}, Vol.2, Wien, Braumüller, 1887, p.14

\textsuperscript{19} E.Clark and S.Jacyna, \textit{op.cit.}, note 14, p.211
model to interpret nerve and muscle action in terms of Ampere's theory of magnetism. Du Bois-Reymond resorted to a "molecular theory of animal electrical currents", which implied the pre-existence of electromotor corpuscles in muscles and nerves. He assumed that each muscle or nerve fibre consisted on a microscopic level of series of "peripolar-electrical molecules", each of which had an electro-positive (Zn-like) equator and two electro-negative (Cu-like) poles. His initial experimental findings appeared to confirm such a working hypothesis. Du Bois-Reymond took his hypothesis very seriously and was unable to abandon it. Later he would adjust his theory in order to save the appearances but never renounced the pre-existence of electrical currents in nerves or muscles nor his claim that all electrical phenomena exhibited by nerves (and muscles) were owing to their electromotive molecules.  

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20 Ibid., p.210; H.Boruttau, op.cit., note 9, p.34
The fundamental characteristics of nerve phenomena

Among the elementary organs of the animal, none is substantially of such a specific animal nature as the nerve and the nerve cell. For all other tissues, be they connective, contractile or secretory have an equivalent representative in the plant. The essential property of the nervous system consists in the production of functional interconnections independent of direct contiguity or of the flow of liquids, whereas the plant does not possess any chain of organs beyond those. (Ludimar Hermann)

Excitability had long been accepted as the pre-eminent attribute of nervous tissue. Contemporary physiology dealt mainly with three different aspects of the physiological phenomena exhibited by the nerve: "excitability", "conductivity" and the "state of excitation" (often only referred to as excitation). A tissue was said to be excitable if it responded by the development of specific changes to local action of external change in its immediate environment. The altered condition thus produced was termed "the excitatory state", whilst the external agent which had evoked this was termed the "stimulus" or "exciting cause".\(^\text{21}\)

The nervous state of excitation was defined as the condition inaugurating a conduction process in the nerve. Initially the precise relation between the two nervous attributes of excitability and conductibility was far from clear. Du Bois-Reymond's research helped to explicate that the two nervous attributes "excitability" and "conductivity" were two distinct

conditions, though intimately related to each other.

Two fundamental physiological facts were generally accepted though not easily accounted for by contemporary physiologists:

It was a well known fact that when a particular group of nerve fibres were excited, the excitatory state thus evoked was propagated along the excited fibres and their branches only. This was generally referred to as the law of isolated conduction.\(^{22}\) (Gesetz der isolierten Leitung)

Around 1850 it began to transpire that if a nerve fibre was stimulated in the course of its continuity the excitatory state was transmitted along both its peripheral and its central portions. The property possessed by the nerve was thus recognized as one of conductivity in both directions. (das doppelsinnige Leitungsvermögen der Nerven)

In accordance with the accepted dichotomy between the sensory and the motor nervous system physiologists had assumed unidirectional conductivity of the afferent and efferent nervous fibres. Du Bois-Reymond took the view that this assumption was only on first sight simple and obvious. After further consideration it posed a real problem: How should one conceive of a mechanism which would allow the nerve to conduct in one direction only. Already Schwann and Bidder had assumed

\(^{22}\) J.Müller, Handbuch der Physiologie, Vol.1, 4.Auflage, Coblenz, 1844, p.585; L.Hermann, op.cit., note 5, p.6
bidirectional conductivity of all nervous fibres but had not succeeded in providing convincing experimental proof.

Du Bois-Reymond succeeded in demonstrating the electrical change accompanying the development of the excitatory state in the nerve (the negative variation of the nervous current) at both the central and the peripheral transverse section of the nerve. Thus he had delivered final experimental evidence of conductivity in both directions along the nerve fibre.

Physiologists also differentiated between normal physiological and artificial excitation, the latter being defined as an artificially evoked state of excitation which can be set in motion at any place along the nerve. Normal physiological excitation was regarded as a process which could only be started either from the sensory or central organs.

The fact that a nerve could be stimulated anywhere along its course and thus a state of excitation be evoked was taken as further evidence against the conduction of a material messenger along the nerve. Whereas it could be envisaged that a substance could be sent along the nerve originating from the central or sensory organs it was thought to be unlikely that the same could happen anywhere along the nerve.

Therefore it is more likely that the nervous

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23 L.Hermann, op.cit., note 5, p.10

24 Ibid., p.105
conduction consists of the propagation of an alteration.  

Artificially induced "states of excitation" were regarded "as the only sound experimental medium and therefore the best investigative tool to become acquainted with the nervous properties."  

Among the range of available modes of nervous stimulation electrical stimulation was generally considered to be the most convenient method for experimental purposes:  

The electrical stimulus is that principally employed on account of the ease with which it can be applied to a definite region of the nerve, the facilities its employment offers for graduating the intensity of the stimulus, and the comparatively small amount of injury it causes in the tissue subjected to its action.  

Physiologists did not solely investigate muscular responses to stimulation. They concentrated their inquiries on the nervous excitability itself wondering whether the latter experienced any alterations under the impact of stimuli. The term excitability was used to refer to the possession by living nerve of a capability to respond with a definite change to the action of an external agent. Every external agent which was capable of evoking such a response was considered an efficient or adequate stimulus.  

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25 Ibid., p.8  
26 Ibid., p.27  
27 Francis Gotch, op.cit., note 21, p.459  
28 Ibid., p.459
Initially the excitability of nervous tissue was measured in terms of the intensity of the minimal efficient stimulus. The index of a nerve response to a stimulus was an indirect index - the muscular contraction.

An indirect index is afforded by the propagation of the excitatory change from the seat of the local stimulus to such a peripheral organ as a muscle, a contraction of which is evoked on arrival of the transmitted nerve effect.\(^{29}\)

The preferred method of applying an artificial stimulus to the nerve was electrical stimulation of motor frog nerves with the galvanic current.\(^{30}\) It was felt that the latter was easier to be understood in its operations than faradic currents.\(^{31}\)

It is a fact which can be demonstrated at any moment that the motor nerves of man and the vertebrates (either laid bare or left in situ) can be excited by the application of electrical currents (faradic or galvanic), and that this excitation is manifested by a muscular contraction in the muscle supplied by the excited nerve.\(^{32}\)

It was also understood that the excitation of a

\(^{29}\) Ibid., p.459

\(^{30}\) It was customary to differentiate between different types of electricity according to the mode of their production or the technical means by which one could obtain electrical currents. Therefore one distinguished between static (friction) electricity and circulatory electricity or the electrical current. The latter was again divided into galvanic currents obtained with batteries (constant currents, contact electricity) as opposed to induction currents, obtained by induction (faradic, induced or interrupted induction currents).

\(^{31}\) W.Erb, Handbuch der Elektrotherapie, Leipzig, Vogel, 1882, p.72

\(^{32}\) Ibid., p.71
nerve with an external stimulus was favoured by two sets of conditions. One of these was the physiological property of the nerve itself—its excitability; the other was the character of the exciting cause and the parameters controlling it. One of the advantages of electrical stimulation was thought to be the comparative ease with which it could be controlled and exploited in laboratories.

It had long been observed by experimental physiologists, that stimulation of the nerve occurred at the make and the break of a continuous (galvanic) current. The general "law of nervous excitation with the electrical current" had been formulated by du Bois-Reymond in 1845:

It is not the absolute degree of the density of the current at any certain moment which acts as an excitant to the motor nerves, but only the change in its degree from one moment to another; i.e. it is only variations in the density which excite, and their actions are the more intense the greater their amplitude in a unit of time; or their amplitude being equal, the more rapidly they occur; most intense, therefore, upon sudden closure and opening of the current.

Du Bois-Reymond's law indicated that it is the increase or the decrease, the onset or the cessation, of the flow of a current, and not its maintenance, which determines its exciting efficiency; the second

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33 The terms "make" and "break" are used to designate the acts by which the current is caused to flow through the body or conductor (make or closure) and caused to cease (break or opening).

proposition implies that in proportion as the onset or cessation is more rapidly effected, the exciting efficiency is increased.

This law remained without modification until the 1890's, when the employment of high-frequency currents and condenser discharges by D'Arsonal and others led to the recognition of the fact that the current intensity must exceed a certain minimum value and that it must act for a certain minimum length of time for contractions to occur.\textsuperscript{35}

A third factor and its possible influence upon nervous excitability was frequently investigated - that is the direction of the excitating electrical current. Du Bois-Reymond managed to demonstrate the so-called 'negative deflection' (negative Schwankung) of the alleged muscle- and nerve current. He succeeded in establishing that in the case of galvanic stimulation (i.e with a constant current) the current derived between longitudinal- and transverse nerve section experienced an increase or decrease in the deflection of the galvanometer needle according to whether the constant current flowed in the same or in the opposite direction to that of the assumed pre-existent nerve current. The observed effect lasted as long as the stimulating constant current was passing through the nerve.\textsuperscript{36} Having ensured beforehand that the

\textsuperscript{35} Ch.Susskind & M.Rowbottom, op.cit., note 9, p.96

\textsuperscript{36} T.Lenoir, op.cit., note 8, p.9
(excitatory) constant current had no direct effect on the galvanometer circuit it appeared to be evident that the constant current had induced a change in the resting electrical state of the nerve. It had brought into existence another electromotive force. His finding of the negative deflection was thought to be proof of the physiological activity of excitable tissue. The state which a nerve appeared to assume whilst being permeated by a constant current was called Electrotonus. 37

The nerve was said to be in the positive phase of the electrotonic state when there was an apparent increase in the nerve current, and in the negative phase when there was a decrease.

In order to account for the negative deflection and the electrotonic state on the basis of his molecular theory du Bois-Reymond abandoned the existence of peripolar molecules. He had postulated at first that each molecule had two negative poles and a positive equatorial region. He felt that the observations were better accounted for by postulating dipolar molecules that were arranged in pairs in the resting muscle and nerve, giving a peripolar

arrangement that could not be separated mechanically. For a nerve in the electrotonic state he supposed that there was a rearrangement of the molecules - a form of polarization. He argued that a nerve is a moist conductor and therefore when a current flows through it electrolysis is induced, which begins with the polarization of the electropositive and electronegative elements of the electrolyte (the voltaic-pile like polarization of the nerve-elements). He thought that this change from the natural to the dipolar arrangement induces a disturbance of equilibrium that manifests as either a muscular contraction or sensation (e.g. of pain) in the animate organism. Equally on breaking the circuit he supposed that there occurred again a disturbance of equilibrium as the natural condition was resumed.

The alteration of the resting nerve current brought about by the constant current (stimulus) reminded him of the induction caused by a magnet (or electrical conductor) in an adjacent conductor. Du Bois-Reymond expanded on the analogy with induction and concluded:

Indeed, if we expand on the comparison of induction and nervous excitation, then it becomes clear that the voltaic-pile like polarization of nerves induced by electrical currents corresponds exactly to

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38 For an illustration of this model see Bence Jones, On Animal Electricity: Being An Abstract Of The Discoveries of Emil du Bois-Reymond, 1852 in Ch. Susskind and M. Rowbottom, op. cit., note 9, p. 98

Faraday's electrotonic state of matter.  

Then du Bois-Reymond started to investigate the electromotive changes evoked by excitation in the nerve. He connected an excised nerve to a high resistance galvanometer by longitudinal and cross sectional contacts and stimulated the distal portion remote from these contacts by a rapid series of excitations. He introduced the phrase "tetanizing" the nerve by using the rapid make and break of a continuous current (or the alternating current of an induction coil) for the stimulation of the nerve in such a way that tetanus (spasm) of the muscle occurred. A fall in the resting potential difference was subsequently observed, which on cessation of the stimulation passed away. Such a decline was considered by Du Bois-Reymond the 'excitatory negative variation', the term negative being used in its algebraic sense. The same result was obtained when the nerve's distal portion was excited by chemical or mechanical stimuli.  

Du Bois-Reymond's experiments had made it plausible that the negative variation was the electrical expression of excitatory changes in the nerves. It also became clear that this electrical

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41 Ibid., Vol.2, p.473; A good English account is in Schäfer, op.cit., note 21, p.524

42 There is an excellent German account in L. Hermann, op.cit., note 5, Vol.2, pp.150-152
change was a concomitant of the real excitatory process, but the two were not strictly identical. There was no need to postulate a special nervous force; nor was the excitation travelling along the nerve transmitted like an electrical current is transmitted along a conducting wire.

Emil du Bois-Reymond had also hinted at the possible involvement of chemical action, when he suspected "that electrical excitation is nothing more than a stage in the process of electrolysis." 43

Eduard Pflüger (1829-1910), one of du Bois-Reymond's pupils, spent much time and effort in investigating the physiology of electrotonus. He intended not only to explore the alterations of the nerve's physiological properties during the passage of a constant current along a short length of the nerve but also the "modifications of nervous excitability" following the application of a constant current.

As early as 1830 Nobili had reported a puzzling observation. Some of his frog muscle preparations had suddenly started to twitch. These tetanic contractions could be arrested after the application of constant (galvanic) currents. Valentin was the first to investigate these phenomena systematically. According to Pflüger, Valentin's most important experiment was as

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44 Eduard Pflüger, Untersuchungen über die Physiologie des Elektrotonus, Berlin, Hirschwald, 1859
follows:

Having applied a pair of electrodes (constant current) to the N.ischiadicus right above the knee, he used a second pair of electrodes inflicting a stimulus to the ischiadicus in the pelvic region. Every time he applied the stimulus above the nervous portion, through which a constant current was passing, the response to the stimulus, the muscular contraction, appeared weakened. The constant current passing through the nerve below the stimulus appeared to block the conduction of the nervous excitation process. Valentin found this only to be the case when the constant current was of ascending direction. Eckard continued the same research which was finally perfected by Pflüger, using non polarizable electrodes and employing the myograph in order to measure the extent of muscular responses to the stimulus.

He stimulated a frog nerve (motor nerve) at various points along its length - either above or below the section of the nerve through which a constant current was passing. We have to bear in mind that the nervous portion in the circuit of a constant current was assumed to be in the electrotonic state, i.e.polarized.

Imagine a frog nerve prepared and laid bare with the gastrocnemius muscle still attached to it. Then two electrodes were placed along the nerve, so that the

45 E.Brücke, op.cit., note 18, pp.28-29
46 E.Pflüger, op.cit., note 41, pp.102-110
current was thought to pass between them in ascending (centripetal) direction. Electrophysiologists assumed that the constant current flows from the positive (anode) to the negative (cathode) pole. Hence in this particular experimental setting the cathode was attached to the nerve more centrally (further away from the muscle) whereas the anode was placed distally in closer vicinity to the muscle. Pflüger termed the nervous section between the polarizing electrodes the intrapolar one, whereas the parts on either sides of the electrodes were called the extrapolar sections. The central extrapolar nervous fragment was termed centripolar or suprapolar, the extrapolar fragment between lower electrode and muscle was termed myopolar or infrapolar. During the passage of a weak polarizing continuous current between the electrodes, Pflüger observed decreased excitability in the myopolar section and increased excitability in the suprapolar section, e.g. the myographion must have registered a weaker muscular response to the same stimulus applied in the myopolar fragment or a stronger muscular response to an equally strong stimulus applied in the suprapolar region. Pflüger introduced the term "anelectrotonus" for the "decreased" state of excitability near the anode, "catelectrotonus" for the state of "increased" excitability near the cathode. Pflüger repeated these experiments with weak, moderate and stronger polarizing

"7 L. Hermann, op. cit., note 5, p. 43
ascending and descending currents.

Diagram

The horizontal line represented the nerve, e the position of the Anode, e' the position of the cathode. The parts of the curve below the line indicated diminished excitability; those above the line, increased excitability. The curves a (-), b (---) c (• •) were obtained with polarizing currents of low, medium and high intensity respectively.
The excitant effects produced by making and breaking the circuits of galvanic currents of various strengths, and also by changing the direction of the applied constant current presented many conflicting results. Much time and labour had been devoted to discovering the relations between these differences and the stimuli."

Pflüger was the first to give an accurate and scientific formula of these phenomena (Pflüger's law of contractions)."

He had designed many of his experiments constantly bearing in mind that he actually wanted to find a formula which would explain under which circumstances muscular contraction would occur as soon as a galvanic current of varying strength and direction (descending or ascending) was being passed through the nerve."

Pflüger had concluded that muscular contraction always occurred only once caused either by the development of 'Katelectrotonus' or the cessation of 'Anelectrotonus'. However, the process of a disappearing 'Katelectrotonus' would not cause muscular contractions nor would the development of an 'Anelectrotonus'. In other words as soon as excitability is suddenly increased, contraction occurs;

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48 Early researchers concerned with those questions were Pfaff, Ritter, Schiff, Marianni and others.

49 W.Erb, op.cit. note 31, p.72

50 E.Brücke, op.cit., note 18, p.31; E.Pflüger, op.cit., note 41, 'Vorrede', p.4
a state of increased excitability returning to the norm does not cause any contractions to occur. A depression of excitability does not appear to be cause for any contractions to occur, only as soon as the process of depression ceases i.e. as soon as the molecules assume their normal position, muscular contraction occurs.\textsuperscript{51}

In summary Pflüger concluded:

1. With \textit{weak currents}, in either direction, contraction occurs on closure alone, but none is produced on opening; the contraction is somewhat stronger on closure of the ascending than of the descending current (rationale: the rise of catelectrotonus is a more effective stimulus than the return of anelectrotonus to normal).

2. With \textit{moderate currents}, contractions occur on opening and closing both directions, but the former are always weaker than the latter.

3. With \textit{very strong currents}, contraction occurs only on opening, none on closure of the ascending current; only on closure, none on opening of the descending current (rationale: the state of an anelectrotonus acts as a block and prevents the impulse from passing to the muscle).\textsuperscript{52}

\textsuperscript{51} E.Brücke op.cit., note 18, p.31; Ch.Susskind & M.Rowbottom, op.cit., note 9, p.99

\textsuperscript{52} A very good explanation can be found in Schäfer, op.cit., note 21, pp.503-504 and W.Erb, op.cit., note 31, p.73. Many of Pflüger's and other early investigators' experiments were on nerves that were not in a healthy condition and depolarized. Frankenhauser was one of the first to show that anode break excitation is seen only in
Pflüger's law of contraction

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Closure (Make)

Anodic fall of excitability (i.e. greater stability of molecular equilibrium), established instantaneously, increasing slowly to a maximum, declining slowly

Cathodic rise of excitability (less stable molecular equilibrium)

established instantaneously, increasing rapidly to a maximum, subsiding quickly

Cessation (Break)

Anodic rise of excitability (rebound to lessened stability), established instantaneously, increasing and subsiding slowly

Cathodic fall of excitability (rebound to greater stability), established instantaneously, subsiding rapidly

In 1868 Ludimar Hermann (1838-1914), also a disciple of du Bois-Reymond, succeeded in providing sound evidence that:

a muscle removed from a living animal with greatest care, appears...currentless when one leads off from the longitudinal surface and from the tendon.\(^{53}\)

Hermann's experiments undermined du Bois Reymond's doctrine of the pre-existence of the muscle and nerve current. He established that potentials arose only at the interface between injured (as the excised and dissected nerves were indeed) and normal tissue. He therefore introduced the term injury current and demarcation potential. Hermann concluded that "a resting nerve current could only be demonstrated at the artificial cross-section".\(^{54}\) In 1879 Hermann advanced his so called core conduction theory (*Kernleiter-theory*) of the propagation of the negative variation (termed by Hermann action current) along the nerve.\(^{55}\)

Ten years earlier Julius Bernstein (1839-1917) had succeeded in charting the time course of the negative variation at du Bois-Reymond's request. He had shown that the "negative variation" was conducted at

\(^{53}\) J.Bernstein, *Elektrobiologie*, Braunschweig, Vieweg, 1912, pp.8-9


\(^{55}\) Ch.Susskind & M.Rowbottom, op.cit., note 9, p.101; core conduction theory: the nerve is likened to a cable with a conducting core separated from a conducting medium by a boundary of high resistance and some capacitance.
the same rate as the nerve impulse, which made it very likely for them to be identical. In 1902 Bernstein proposed the membrane theory of nervous excitation.56

Investigations relating to the phenomena of excited nerves and muscles and the propagation of the nerve impulse continued to flourish and gradually the present concept of nervous function evolved.

The nerve impulse is not an electric current flowing down the length of the fibre in the way that electricity passes down a wire, but is a progression of ionic changes whose electrical signs constitute the action potential. The energy for the transmission of the impulse comes from the nerve itself and not from the stimulus.57

I did not intend to defend a thesis in this chapter. It merely outlines the main developments in contemporary electrophysiology which provided the context for Erb's first electrotherapeutic publications between 1867 and 1875. During that period Emil du Bois-Reymond was one of the leading German electrophysiologists.

Work in electrophysiology dates from the publication of Galvani's work on decapitated frogs in 1791 and the ensuing debate with Volta over the nature

56 Ibid., p.101: "according to this theory the semipermeable membrane surrounding the cell on excitation becomes permeable to sodium ions which enter the cell from the surrounding tissue fluid and so give rise to the state of polarization on the surface of the cell."

of 'animal electricity'. These initial investigations were deepened and extended by Humboldt, Ritter, Nobili, Matteucci and others. Their results were qualitative and phenomenological.

Timothy Lenoir has demonstrated that the research conducted by du Bois-Reymond and Helmholtz which began around 1845 was guided by the aim of formulating a quantitative theory of nerve and muscle action with exact measurements. Emil du Bois-Reymond's formative hypotheses were all guided by the search for analogies between bioelectric currents and the conceptual models developed by Faraday and Ampere. His initial concepts derived directly from the instrumentation used by Faraday in investigating induced currents.58 Timothy Lenoir explored the interdependence of experimentation, instrumentation and conceptual models during this period as illustrated by du Bois Reymond's research:

du Bois-Reymond's models were not only conceptual models, dependent on the syntax and conceptual elements of a better known system; they were also physical models. Du Bois-Reymond's instrumentation prevented him from exploring the properties of nerves and muscles at the microscopic level. But the drive to construct an explanatory model for the phenomena carried beyond the macro level. No matter how finely he sectioned muscle and nerve segments, the nerve and muscle currents always behaved in the same way. To go beyond segments to individual muscle fibres...du Bois-Reymond showed, by experimenting on his models composed of unit voltaic cells, a similarity between his model and the physiological system he was investigating.59

58 T.Lenoir, op.cit., note 8, pp.48-49
59 Ibid., pp.52-53
The electrophysiology of electrotonus is still of interest to neurophysiologists today. A recent analysis of older and modern electrophysiological research has been undertaken by Baker and his colleagues. They confirm that the changes in potential (electrotonus) and excitability occurring at cathode and anode are now appreciated to be very complicated, depending as they do on many different voltage dependent ion channels at the nodes of Ranvier and under the myelin sheath.

The task of 19th century electrophysiology was double. It included the study of living tissues as sources of electricity; and the study of electricity as a means of influencing the functions and of modifying the excitability of those tissues. The discovery of the constant current and the early history of this manifestation of electrical force were bound up with the first electrophysiological problem and task; the era under du Bois-Reymond and his disciples was entirely concerned with the latter. The fact that contemporary scientific electrophysiology tangibly demonstrated the altered nervous properties under the influence of electrical stimulation provided a welcome rationale for the therapeutic use of electricity.

Chapter 9. Short History of Electrotherapy and Electrodiagnosis in German Medicine

A complete history of medical electrotherapy would have to begin with the ancient physicians who used to treat their patients with shocks discharged by electrical fish to remedy gout and paralysis.

The first major technological impulse to the medical application of electricity was released by the Leyden jar. The development of the first electrical condenser in 1745 had made it suddenly possible to produce electricity artificially in sufficient quantities.

Christian Kratzenstein (1723-1795) was the first physician in Germany to employ static or frictional electricity for medical purposes. He was also responsible for the publication of one of the first books on the uses of electricity in medicine in 1745. The common electrical machine (Elektrisiermaschine) was used by De Haen, Kratzenstein and Krüger in Germany; by Jallabert, Sigaud de la Fond, Bertholon and Mauduyt in France. Static electricity was thought to enhance the vital powers and was subsequently recommended for the treatment of a variety of ailments such as paralysis, poor vision, deafness, chorea, epilepsy and even for

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the rescue from apparent death.  

At the turn of the century (1800) different methods were employed in the use of frictional electricity. The most popular was the electrical bath, drawing sparks and shocks from the Leyden jar.  

Traditional histories of science celebrate Galvani's account of his research experiments between 1781 and 1791 as the beginning of a new era in the science of electricity. Medical historians have adopted the same chronology and subsequently divide the history of electrotherapy into pre-galvanic and galvanic periods.

But it was only after Galvani's celebrated discovery in 1786 (1791) that electrotherapy received a major and lasting impulse; thus a new epoch was entered upon, of which the initial period extended over the first twenty or thirty years of this century. However, only the discovery of the Voltaic Pile in 1800 bestowed Galvani's discovery with its true value and thus established its practical utility.

Following Galvani's discovery and the construction of the Voltaic Pile contemporary physicians focused their attention on the curative properties of the new form of dynamic electricity which was then regarded as the true medical electricity and

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3 Ch. Susskind & M. Rowbottom, *Electricity and Medicine, History of their Interaction*, San Francisco, San Francisco Press, 1984, Chapter 2


used almost exclusively substituting the use of static electricity.® Alexander von Humboldt, Pfaff and Reil recommended the use of galvanism (constant, battery current) for the cure of hemiplegia, rheumatism, paralysis and amaurosis. In 1801 the first systematical treatise on the remedial powers of galvanism was published by Karl Grappengiesser (1773-1813) in Berlin.™

Contemplating the fate of electrotherapy during those early decades of the nineteenth century, Wilhelm Erb observed that "electrotherapy did not enjoy any lasting progress". Erb put it down to the fact that the maintenance of the apparatus was too costly and cumbersome, knowledge of the disease processes was still poor and above all that quacks discredited electrotherapy, confounding galvanism with animal magnetism and mesmerism.®

On the basis of Oerstedt's experiments during the 1820's and subsequent research, a new type of electrical generator independent of friction electricity or electrochemical batteries was developed. In 1831 Faraday had discovered mutual induction and a

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® J. Althaus, op. cit., note 1, p. 180

™ Ch. Susskind & M. Rowbottom, op. cit., note 3, pp. 38-47 and pp. 50-52; J. Althaus, op. cit., note 1, p. 182; W. Erb, op. cit., note 5, p. 7; Dr Grappengiesser, Versuch den Galvanismus zur Heilung einiger Krankheiten anzuwenden, Berlin, 1801

® W. Erb, op. cit., note 5, p. 7; for a similar more recent interpretation see E. Stainbrook, op. cit., note 2, p. 158
host of new magneto-electric and volta-electric apparatus was constructed. In the wake of these exciting developments induced currents obtained from magneto-electric and electro-magnetic machines enjoyed wide distribution and increasing popularity among physicians. The fourth decade of the nineteenth century witnessed "a new great upswing of electrotherapy under the constant rattling and humming of induction apparatus".  

Traditional histories refer to that period as the second post-galvanic era of electrotherapy, the epoch of the induced current or faradisation. Names associated with that new movement in electrotherapy were Dr Golding Bird (1814-1854) and Marshall Hall in England, Robert Froriep (magneto-electric) in Germany and Duchenne (volta-electric) in France.

Iwan Rhys Morus analyzed Golding Bird's efforts to transform electrotherapy into viable medicine. Morus concludes that electrotherapeutics did not become accepted as a viable treatment on the basis of any detailed theoretical understanding of the relationship between electricity and the nervous system. Electrotherapeutics became accepted as a system of practices and technologies which blurred the distinction between therapy and experiment by linking

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9 W.Erb, op.cit., note 5, p.8

itself to electrophysiology.¹¹

During the 1840's and 1850's a host of electrical equipment were designed for medical uses. Contemporary advocates of electrical medicine emphasized the technological improvements which made it easier to apply the treatment without detailed technical knowledge. The latter aspect certainly also helped to deprive quacks of their claims to expertise in the application of electricity.¹²

Duchenne's (1806-1875) best known contribution to electrotherapy was the development of the method of localized faradisation.¹³ Erb considered him to be the founder of modern electrotherapeutics.

Duchenne started from the fact that the faradic current may be employed through appropriate methods of application, localised in parts, lying at a certain depth under the skin. Upon this basis he founded his system of "faradisation localisée"¹⁴, by means of which he carried out his investigations of the muscular system in health and disease. As a consequence of his views and methods, the principle was established that electric currents must be localised in the individual diseased parts in order to obtain curative results.¹⁵

Probably as a consequence of an accident in his surgery Duchenne opposed the use of galvanic currents.

¹¹ Ibid., p.52
¹² Ibid., p.49
¹³ A good chapter on Duchenne can be read in Ch.Susskind & M.Rowbottom, op.cit., note 3, pp.71-88
¹⁴ Duchenne published several papers between 1847-50 wherein he first described his method as "galvanisation localisée."
In September 1852 a German physician Robert Remak happened to be present at one of Duchenne's demonstrations in Paris. The strong muscular contractions produced with the help of a "galvanic induction apparatus" in healthy humans left a great impression upon Remak.\(^{16}\)

I cannot deny that these strong muscular contractions surprised me, since I knew that they had not been produced here hitherto by physicians.\(^{17}\)

Immediately after his return from Paris Remak "convinced of the immediate utility of such mighty muscular contractions in paralysis" recommended Duchenne's method to the "Berlin Society for Scientific Medicine." From now on Remak devoted much time to experiments with the electrical stimulation of muscle fibres. Prompted by the publication of Duchenne's *De l'electrisation localisée* in 1855 Remak began to investigate systematically various muscles of the human body with the faradic current:

In the work of that physician (Duchenne) it was stated that muscles are made to contract most readily by the current of induction, if certain points on their surface are touched by the electrodes.\(^{18}\)

Remak wanted "to know the nature of these mystical

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\(^{17}\) Robert Remak, *Galvanotherapie der Nerven- und Muskelkrankheiten*, Berlin, Hirschwald, 1859, p.175

\(^{18}\) Ibid., pp.241-245 (reprint of R.Remak, 'On the therapeutical action of the constant galvanic current', *Medical Times and Gazette*, No.410, p.479)
"points" and after having directed his attention to that subject he "soon found that they corresponded with the points of entrance of the muscular nerves, and that the degree of the contraction of a muscle was exactly proportionate to the number of motor nerve-fibres embraced by the current at its point of application." \(^{19}\)

A bitter and unpleasant row between Duchenne and Remak erupted. Remak did not hold back the accusation that his French colleague tried to keep his methods secret by not disclosing that his (Duchenne's) direct muscle stimulation was in fact an electrical stimulation of the nerve as it spread into the muscle. \(^{20}\)

Hugo von Ziemssen (1829-1902) followed up Remak's idea and carefully investigated the 'motor points' both on the living and dead body.

He confirmed the statement that they represented points where the motor nerves were situated sufficiently near the skin to be reached by the faradic current. The results of his researches were published 1857 in his valuable work *Electricity in Medicine*. \(^{21}\)

Robert Remak (1815-1865) continued to investigate painstakingly the effects of electricity upon the human body. Having started, like Duchenne, with faradisation, he turned his attention towards the galvanic current.

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\(^{19}\) Ibid., p.242  
\(^{20}\) Ch. Susskind & M. Rowbottom, op.cit., note 3, p.104  
\(^{21}\) W. Erb, op.cit., note 15, p.10
Remak argued that in order to be able to understand the physiological effects of faradisation he would have to know the effects of galvanic currents upon the nerves and muscles first. Subsequently Remak reviewed the research accounts of Galvani, Ritter, Nobili, Marianni and Eckhard. All of them had noted the paralysing influence of galvanic currents upon nerves and muscles. Remak became convinced that galvanic currents would have to offer a great deal more to therapy than hitherto suspected. He carried out experiments on a vast number of patients. Romberg had been kind enough to refer some of his patients to Remak for electrotherapeutic treatment. But Remak felt that their number was not sufficient to conclude his research satisfactorily. Therefore he put advertisements into a number of Berlin newspapers asking for interested patients to get in touch. Remak met with an overwhelming response. Within six weeks he had four-hundred willing patients flocking to his private residence, desperate for a cure after colleagues had given up hope and not submitted them to any further treatment:

Thus I was enabled to examine four-hundred patients of the rarest kind in the course of six weeks; I could apply the constant current in about two-hundred cases. One third (contractures, central paralyses) was cured, another third is still receiving treatment - the greatest part of which continue to improve, and in the remaining third of patients the treatment had to be discontinued for a

22 R.Remak, op.cit., note 17, p.8
number of reasons, often owing to lack of time.\textsuperscript{23}

This episode throws some light onto Remak's controversial and colourful character. His fellow practitioners did not like such a successful rival in the neighbourhood, nor did the "Berlin matadors of science"\textsuperscript{24} approve of such unorthodox methods, i.e. advertising for patients in the popular press. Indeed the magnetic attraction Remak must have exerted upon crippled rheumatics made him look suspiciously like a charlatan and thus not suited to enhance electrotherapy's reputation at Berlin University. Remak probably felt forced to resort to such unorthodox methods after having been debarred as a Jew from a university career. Certainly he would have preferred a university laboratory rather than his private living quarters for his research.

But Remak was a Jew!...At that time antisemitism was well established in the state departments. Therefore the poor man had to fight alone and isolated during his entire life.\textsuperscript{25}

The problem of Remak's religion might well have been compounded by his occasional "non-scientific" overconfidence in advertising his claims.

Remak was an ingenious researcher...he was also driven by an enthusiasm, which was not entirely

\textsuperscript{23} Ibid., pp.245-246

\textsuperscript{24} M. Benedikt, \textit{Aus meinem Leben}, Wien, Carl Konegen Verlag, 1906, p.63 (chapter 4)

\textsuperscript{25} M. Benedikt, 'Die Elektrizität in der Medizin', \textit{Wiener Klinik}, 1884, Jahrgang 10, pp.25-41, p.32
free of illusions and too daring hypotheses."

Till his premature death in 1865 Remak endeavoured to spread the gospel of galvanic currents and thus "the first step was made towards the restoration of the galvanic current as a means of treatment." Gradually many sceptics had to concede that "Remak's theories, although somewhat crude, nevertheless contain germs of truth which it would be foolish to ignore".

Wilhelm Erb did not hesitate to acknowledge Remak's contribution to electrotherapy and held him responsible for the rehabilitation of galvanism in clinical medicine.

With the publications of du Bois-Reymond, Eckhard and Pflüger a new era in electrophysiology was entered upon. Erb considered Remak's publication *Galvanotherapie der Muskel- und Nervenkrankheiten* in 1859 as the opening of the third and modern epoch of electrotherapy. Erb felt part of that era. Remak's *Galvanotherapie* concluded that the effects of the continuous current were threefold. Remak distinguished between the catalytic (i.e. electrolytic

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27 W.Erb, op.cit., note 5, p.11
29 W.Erb, op.cit., note 5, p.11; Bruno Kisch celebrates Robert Remak as the founder of modern clinical galvanotherapy.
30 W.Erb, op.cit., note 15, p.11
and antiphlogistic), the antiparalytic and the antispasmodic effects of galvanic currents. The catalytic effect was seen chiefly in inflammatory conditions.

He called them catalytic because an analysis of his observations satisfied him that where the current removed a morbid condition of the tissues caused by defective circulation, or by effusions, this could not only be restricted to electrolysis (alteration of tissue analogous to the decomposition of water) in the narrow sense, but was also due to dilatation of the blood vessels and lymphatics whereby circulation and absorption were facilitated.\(^1\)

Remak observed that patients suffering from chronic rheumatic contractures responded favourably to the catalytic effect of galvanic currents.\(^2\)

The antispasmodic effect was attributed partly to an increase in the power of volition over muscles affected by spasm or cramps and partly to a direct reduction of the exalted excitability of the nerves or muscles.

The antiparalytic effects of the continuous current were chiefly observed in hemiplegia and paraplegia, provided the disease causing those affections had not too seriously injured the nutrition and structure of the brain and cord.\(^3\)

Electrotherapists were eager to persuade their

\(^1\) J. Althaus, op.cit., note 1 (1873 edition), p.471; Althaus does not give a correct translation of Remak's original account. Remak emphasized that the catalytic effect was due not only to electrolysis but also to dilatation of bloodvessels whereby enhancing circulation.

\(^2\) R. Remak, op.cit., note 17, p.246

\(^3\) J. Althaus, op.cit., note 1 (1873), p.472
peers that electrotherapy had undergone a change for
the better. Past practices were portrayed as a
performance related spectacle rather than any serious
attempt at healing:

During the last half of the previous century
electricity was not only subject of serious
scientific research...but also a fashionable object
of dilettantic amusement. Everywhere one entertained
oneself with the discharges from Kleist's
bottle...and sometimes even tried to solve
metaphysical problems with the aid of an all
pervading electricity.  

Remak tried to persuade his audience that his
experiments followed a clear rationale whereas many of
his predecessors dabbled with electricity without
properly recording their findings, nor their methods
and technical aids in use. He argued that his
experiments were regulated and followed a rational
deduction of the therapeutic results in accordance with
present physiological and physical teaching whereas in
the past "only the viewpoint of convenience was adhered
to, namely how to produce electricity as easily as
possible." Now it was regarded as paramount "to
differentiate between the many physiological and
therapeutical effects which the electrical current must
exhibit with respect the manner by way of which they
had been produced."

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34 Rudolf Brenner, Untersuchungen und Beobachtungen auf dem Gebiet der Elektrotherapie, Vol.1, Leipzig, Giesecke & Derient, 1868, p.8

35 R.Remak, op.cit., note 17, p.173

36 Ibid., p.174
During the 1850's and the ensuing three decades German electrotherapy became accepted as part of viable medicine. In the eyes of contemporary observers, significant progress in electro-physics and electrophysiology had been achieved:

Through the epoch-making physiological discoveries by du Bois-Reymond it is now proven, that a galvanic current circulates in the living nerve and muscle and stands in close causal relation to life and the expression of activity by those structures. By the same token the influence of a galvanic current is of no lesser importance, once being applied artificially from outside to nerve or muscle.  

Emil du Bois-Reymond's work on animal electricity resulted in the discovery of "Electrotonus" and the "negative variation". Pflüger's researches led to the formulation of the "General Law of Nervous Excitation."

These were thought to have immediate beneficial consequences for electrotherapy:

There is no reason not to believe that the phenomena of electrotonus...do not exist in the living human being, spreading from the immediately electrically pervaded nervous segment along the entire length of the nerve to central ganglionic cells. We understand these effects to be alterations of the molecular state of the nerve, we are at present unable to judge their importance for the living human. However, a host of therapeutic experiences...convince me that...electrotonus plays a significant role in the effects of the constant current in nervous and muscular diseases.

It was generally felt that the field of electrotherapy...
experienced useful input from the physiology of the electrotonus.

The discoveries of the electrotonus...mark a turning point in the history of physiology, which signifies a fundamental change and enlightenment of our views regarding the life and activity of the nerves and muscles. Thus all aspirations to utilise the electric current in the art of healing have received a clear rationale and above all an unrefutable justification. 

The therapeutical importance of electrotonus consisted in the fact that one had been able to demonstrate alterations of the nerve's behaviour during and shortly after the application of constant currents:

Pflüger's researches on electrotonus appear to us to supply the key to the large majority of the therapeutical applications of the constant current. Cyon has proved that Pflüger's researches...hold good for the nerves of man likewise; and the systematic production of catelectrotonus and anelectrotonus, for the purpose of increasing or diminishing the excitability of diseased portions of the nervous system, has thus been shown to be a therapeutical possibility. The polarising or electrotonic effects of the current may therefore be utilised in certain forms of paralysis and anaesthesia, where catelectrotonus should be produced, and in spasm and hyperaesthesia, where anelectrotonus finds its appropriate sphere of action. We have thus found a scientific explanation for Remak's antiparalytic and antispasmodic effects.

Wilhelm Erb argued in 1872 that the application

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39 R.Brenner, op.cit., note 37, p.258

40 Elie de Cyon, born 1843 in Felsch (Russia), disciple of C.Ludwig, professor of physiology at the Faculty of Sciences and Academy of Medicine in St.Petersburg from 1867 till 1875. His main research focused on the innervation of the heart, the functions of the labyrinth and thyroid gland. He befriended Claude Bernard and worked with him in his laboratory. Cyon retired in Berne, where he died 1912.

41 J.Althaus, op.cit., note 1 (1873), p.473
of any curative agent becomes the more rational and
safe, the better the knowledge about its physiological
(side) effects on the human body. With regard to
electricity:

We are particularly fortunate, since it had already
extensively been examined by two extremely advanced
natural sciences: physics and physiology."

By the early 1860's the host of electrotherapists
was still divided into two camps. Duchenne and his
followers" cultivated mainly the therapeutic
application of the faradic current. Robert Remak
advocated the galvanic current. The initial scepticism
towards Remak's work slowly faded. During the last few
years of his life he witnessed some of his results
being confirmed by other observers.""

Everybody, who experimented only superficially with
the constant galvanic current on the living human,
will have to confirm the correctness of (some of)
Remak's observations, namely in as far as they refer
to the increase of excitability."

Moritz Benedikt (1835-1920), of Vienna, starting
from Remak's position, occupied himself extensively
with the application of the galvanic current. His first

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42 W.Erb, 'Ueber die Anwendung der Elektrizität in
der Inneren Medizin', Ges.Abhlg., Leipzig, Vogel, 1910,
p.193

43 Duchenne: Meyer, Erdmann, Baierlacher, Althaus,
Ziemssen. Remak: Flies, Völcker, Benedikt, Hiffelsheim,
Enrico Torri, Harry Lobb

44 W.Erb, op.cit., note 15, p.12

45 A.Eulenburg, 'Elektrische Wirkungen bei percutaner
Anwendung des constanten Stromes auf Nerven und Muskeln',
Dt.Archiv f.klinische Medizin, December 1866, Vol.3,
pp.117-142, p.118
papers appeared in 1861-62. Later he collected his materials into a larger work *Nervenpathologie und Elektrotherapie* which appeared in 1868.46

Robert Remak had elaborated a method of application which held the direction of the galvanic current responsible for its therapeutical success. The direction of the current was thought to be important in altering nervous excitability since the early days of Ritter and Volta. For example it had frequently been observed that a nerve became unresponsive (exhausted) after the passage of a direct current for about thirty minutes. This exhaustion could be returned to nervous excitability after the passage of an inverse current.47 The systematic use of the so called Voltaic Alternatives (Stromwendungen) in electrotherapy was based on these observations.48 The majority of electrotherapists based their treatment on the directional method.

Meanwhile a process of reconciliation between the followers of Duchenne and Remak had set in. They no longer opposed each other, but rather began to

46 M.Benedikt, *Nervenpathologie und Elektrotherapie*, Leipzig, Fues's Verlag (Reisland), 2nd edition, 1874

47 Ch.Susskind & M.Rowbottom, op.cit., note 3, p.91

48 M.Benedikt, op.cit., note 25, p.42; R.Brenner, op.cit., note 37, p.266
complement each other." The former practice of using either the one or the other form of electricity exclusively was gradually abandoned by defining a legitimate sphere of action for each kind of electrical current:

The induction and the battery current are natural allies, whose power and influence is the larger, the clearer each sphere of action can be defined and limited, in which each of them can exercise its influence.50

Suddenly a publication by a German physician disturbed the academic peace among electrotherapists again. In 1862 Dr Rudolf Brenner (1821-1884) published a paper in the St.Petersburger medicinische Zeitschrift 'Versuch zur Begründung einer rationellen Methode in der Elektrotherapie genannt: Die polare Methode' which initiated a heated argument on the principles of a rational therapeutic application of the galvanic current. In this article Brenner defined the polar method of electrical investigation and treatment and opposed it to the directional method of Remak, Benedikt and others.51 Six years later Rudolf Brenner elaborated his theory further in a two volume textbook Untersuchungen und Beobachtungen auf dem Gebiet der Elektrotherapie. Brenner's polar method was repeatedly


50 R.Brenner, op.cit., note 37, p.290

51 W.Erb, op.cit., note 5, p.12
criticised by Benedikt.

Prior to his publication Brenner had worked as a military surgeon during the Crimean War. There he had enjoyed ample opportunity to treat traumatic paralyses with the aid of the galvanic current. Prompted by his own observations he began to doubt whether many of the obtained effects and cures were really brought about by the correct choice of a certain direction of the electrical current, as taught by contemporary physiological dogma.

Having made his initial observations under the hazardous conditions of war only poorly equipped with crude Voltaic Piles he continued his research later with better apparatus from Siemens. His initial suspicion seemed to be confirmed.

After a series of observations on "himself, on healthy individuals, ill patients, colleagues and informed laymen" Brenner concluded:

The physiologists' law of contraction, according to which the opening and closing contraction are dependent on the direction of current, cannot be obtained. The same applies to the relationship between the modification of excitability and direction of the electrical current. This is the case, because the direction of the current itself cannot be produced that easily with certainty.\(^{52}\)

Brenner often argued that it was simply impossible to transfer laboratory results to the daily practice of a physician by using physiological rules like a "stencil through which one wanted to pencil down

\(^{52}\) R.Brenner, op.cit., note 37, pp.272-274
the fundamentals of therapeutic activity." After all the results of physiologists had been obtained in the laboratories on carefully dissected frog nerves which had been laid bare and freed from any surrounding tissue.

As soon as the physiologist intends to send a galvanic current through the nerve, he removes the surrounding tissue, lays the nerve bare, rests it on an insulated surface and has it subsequently at his safe and certain disposal, according to the position of the electrodes, to determine the ascending or descending direction of the current.\textsuperscript{53}

Such experiments could hardly be adopted by a practising physician for curative purposes. The patient could not have himself skinned like the martyrs of physiology, the frogs.

The physician has to concern himself with nerves which are more or less imbedded in surrounding soft tissue, always covered by skin and moist cellular tissue.\textsuperscript{54}

Recent research into the specific resistance of animal tissues to electricity by Lenz, Pschellnikoff, Weber and Pouillet had demonstrated that muscular and cellular tissue was four times a better conductor for electricity than the nerve itself.

Brenner argued that it was inconceivable to dispose over the direction of a current in badly conducting nervous tissue surrounded by tissue of

\textsuperscript{53} Ibid., p.268

\textsuperscript{54} Ibid.
considerable higher conductivity.  

Not the direction of the current but...the poles have to be regarded as the generators of the different physiological effects of the electrical current.  

Brenner thought that electricity acted upon the organism merely at the place of application, i.e. the poles. He argued that the highest density of current occurred at the poles and electricity tended to disperse itself into innumerable extracurrents (Stromesfâden) in the human body. They were thought not to possess enough density to excite the tissue. Hence the direction of the employed current was considered irrelevant.

He concluded that the effects supposed to be caused by the passage of an ascending or descending current were entirely due to the increased or decreased state of excitability in the immediate vicinity of the cathode or anode, respectively.  

The reaction on closing the circuit (make) was thought to be caused by the cathode, the reaction on opening the circuit (break) merely by the anode. Thus Brenner developed his polar method of treatment and investigation. This meant that the indifferent pole was applied to an indifferent spot on the human body (e.g the sternum, patella,

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56 R.Brenner, op.cit., note 37, p.276  
57 Ch.Susskind & M.Rowbottom, op.cit., note 3, p.109
spine) and the active (different) pole had to be applied to the nerve or muscle, intended for treatment. The quality of the active pole could be altered by resorting to the aid of a commutator (Stromwender). Thereby that pole could act alternately as cathode or anode.\textsuperscript{58}

In his 1862 paper Brenner also investigated Pflüger's law of contraction and found a formula, based on his polar method, which appeared to differ from Pflüger's.\textsuperscript{59} Yet Brenner was at pains to point out that a closer examination of his findings on man revealed a substantial agreement between his and Pflüger's results. The latter had been obtained in animal experiments.

Brenner insisted that his claim that "the law of contraction could be demonstrated with utmost certainty by the correct choice of poles independent of the direction of the current in man" did not imply that from now on electrotherapists could ignore the physiology of electrotonus. On the contrary he always struggled to relate his observations on man to the teachings of physiology.\textsuperscript{60}

Many of Brenner's contemporaries misunderstood his intentions and did not realize that Brenner did not


\textsuperscript{59} R.Brenner, op.cit., note 37, pp.286-287

\textsuperscript{60} R.Brenner, op.cit., note 34, p.74 (footnote)
oppose Pflüger's law and the teachings about electrotonus. Brenner was constantly at pains to reconcile his electrotherapeutic experiences with contemporary physiological dogma. He expected that the application of galvanic currents:

will shed new light upon many diseases, particularly paralyses of the motor apparatus.

For Brenner the electrical current was an analytical tool enabling physicians to determine the true pathological extent of a given morbid state previously unknown. Brenner hoped that a proper Electropathology could be founded and elaborated with the help of electricity as a diagnostic and prognostic aid.

Though the motor nerves were the preferred

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61 R.Brenner, op.cit., note 37, pp.279-289 and R.Brenner, op.cit., note 34, pp.72-74
Dr.Wilhelm Filehne also attempted to relate the physiological law of contraction to Brenner's polar method. He designed an experimental arrangement on the frog nerve which was thought to imitate the condition of the human body. He produced a similar electrical shunt - as formed by human muscles- alongside the frog nerve by placing the latter on a piece of muscle. As soon as he touched with one electrode the nerve and with the other the muscle he managed to produce a formula reconciling Brenner's and Pflüger's law. He demonstrated that the effects of the cathode corresponded to the effects thought to be induced by the ascending current and the effects of the anode corresponded to the ones induced by the descending currents of the physiologists. Thus Filehne had solved the problem of conflicting findings by demonstrating "that as soon as the excised motor nerve is not stimulated in an insulated condition, but placed upon a muscle, one finds the same formula (of contraction) for the motor frog nerve and the living intact organism."

62 R.Brenner, op.cit., note 37, p.292

63 Ibid., p.293
objects of electrophysiological enquiries, the effects exerted by the galvanic current upon the sensory nerves and the skin were investigated, too.

Helmholtz describes very accurately the sensations of light and colour in his variously modified experiments, and he seeks to explain them on the basis of the laws of electrotonus with reference to the direction of the current in the retina and the fibres of the optic nerve situated therein.  

After 1863 the acoustic nerve became one of the most favoured objects of electrophysiology and electropathology. On March 5th 1863 Brenner reported his first findings on the electrophysiology and electropathology of the acoustic nerve at the St. Petersburg Medical Society. In the eyes of Erb this marked the beginning of a new era in the electrophysiology of the auditory apparatus. It was hitherto still uncertain whether the acoustic nerve reacted to galvanism; and if so, how it reacted. Brenner dedicated himself to the solution of this question with utmost patience and resilience. Even those scientists who did not always fully approve of Brenner's conclusions appreciated his research by virtue of its execution and method. Among them was Eduard Hitzig:

Brenner proceeded methodically with the necessary

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64 W.Erb, op.cit., note 15, p.99
66 R.Brenner, op.cit., note 34, (Vol.1), p.45
patient, he resorted to rational experimentations. Thus his work stands out from the...frivolous productions which unfortunately continue to put electrotherapy into disrepute among serious scientists.67 (my italics)

The result of Brenner's painstaking labours was positive regarding the physiological and pathological reaction of the acoustic nerve against the galvanic current.68 He established the details of the acoustic reaction to galvanism and found that it obeyed a strict law. He claimed that the acoustic nerve reacted against currents of tolerable intensity with its specific energy - a sensation of sound - during make provided the cathode had been attached close to the ear. The N.acousticus was found also to react with an auditory sensation at the break of a constant current provided the anode had been attached in the immediate vicinity of the ear. Any other arrangements would not result in any sensation.

The so called *Normalformel* (Normal Formula) could be expressed in a table:

<table>
<thead>
<tr>
<th>Cathode (German: Kathode)</th>
<th>Anode</th>
</tr>
</thead>
<tbody>
<tr>
<td>make</td>
<td>break</td>
</tr>
<tr>
<td>Sound</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>Sound</td>
</tr>
<tr>
<td></td>
<td>none</td>
</tr>
</tbody>
</table>

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68 H.v.Ziemmssen, op.cit., note 55, p.119
or more commonly it was expressed in the following manner:

KCS.....loud sound (kathodic closure sound, capital S=loud)
KDS>....sound diminishes and disappears (kathodic duration)
KO......no sound (kathodic opening)
AC......no sound (anodic closure)
AD......no sound (anodic duration)
AOS.....short weak sound (anodic opening sound, small s=weak)

The strength of current required to demonstrate the above formula was found to differ with different individuals, but it always remained about the same for the same person. Brenner also observed that the KC reaction could be far more easily obtained than the AO reaction. Brenner understood his observations on the galvanic reactions of the acoustic nerve as a further vindication of his polar method.

Thus we find that in one of the nerves of special sense the law laid down for the polar actions of physiology - viz. that the cathode excites only on closure, the anode only on opening.\(^6^9\)

The quality of the produced sensations was also investigated:

\(^6^9\) W.Erb, op.cit., note 15, p.105
healthy than those with morbid acoustic nerves. Normal individuals usually describe the sound as more or less loud whistling or hissing, but also as ringing, humming or buzzing, like the noise of boiling water, of wind blowing, of bees flying, etc.\footnote{Ibid., p.104}

In the course of his researches Brenner found a large number of qualitative and quantitative anomalies in the galvanic reaction of the auditory apparatus. These had been confirmed by subsequent observers, i.e. Hagen, Moos, Erb, Hedinger, Erdmann and Eulenburg.\footnote{Ibid., p.231} The number of "galvanic excitants" was all in all six: KC, KD, KO, AC, AD, AO.

Anomalies of the galvanic reaction manifested themselves either as a simple galvanic hyperaesthesia without alteration of the normal formula or galvanic hyperaesthesia with modifications or even conversion of the formula.\footnote{Ibid., pp.231-241 and p.650} The simple galvanic hyperaesthesia of the auditory was characterised by a more or less ready excitability of the acoustic nerve without any modification of the normal formula. The aim of electrical treatment was in such cases to apply the electrodes to the prescribed anatomical location until the normal formula could be obtained. Thus as soon as the normal formula could be re-established the healthy function of the auditory nervous apparatus was assumed to be restored.
In Erb's opinion Brenner had succeeded in settling the vexed question of the galvanic reactions of the acoustic nerve once and for all, so that his successor only had to confirm his results and uphold them against unfounded and superficial objections.

The decade between 1865 and 1876 - a decade once earmarked by Erb for its enthusiasm for electrophysiological discoveries - witnessed a series of electrotherapeutic publications. After 1865 the number of disciples rose "labouring to strengthen and add to the structural edifice of electrotherapeutics".  

The German school of electrotherapy turned its attention increasingly towards the galvanic current, whereas the French continued to favour the faradic current.

In the wake of du Bois-Reymond's research on animal electricity physicists focused their attention on the analysis of the physiology of electrotonus. Pflüger's and du Bois-Reymond's research vindicated the hypothesis that a nerve subjected to electrical stimulation experienced an alteration of its molecular state. During that time the greatest authority was enjoyed by the 'electrotonic theory' in addition to the older "primitive" theory that

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73 W.Erb, op.cit., note 5, p.13

electricity cures by the excitation of tissues.\textsuperscript{75}

There is...a very important class of effects produced by the action of the electric current upon motor nerves. These are the modifying or electronic effects. They are those which are expressed by a change – increase or diminution – in the condition of excitability – chemical, physical or mechanical – of the motor nerves and muscles, which is effected by the passage of the current through these structures and lasts of variable time afterwards. These effects have been made the subject of the closest physiological research, and they have been combined under the name of 'electrotonic phenomena'.\textsuperscript{76}

Electrotherapists investigated Pflüger's Law and the modifications of nervous excitability (electrotonus) probing their relevance for the application on the human body.

For practical purposes we have to know how the law of contraction in motor nerves applies to living man.\textsuperscript{77}

Remak's observations and claims were frequently put to the test to be either confirmed or dismissed. The "correct method" of therapeutical application of galvanic electricity was being investigated, concerning the direction of the current and correct choice of poles.

To reach a conclusion researchers felt that first and foremost many observations and case histories had to be gathered and then evaluated.

A number of questions...can only be solved through the collection of as many observational material and

\textsuperscript{75} W.Erb, op.cit., note 15, p.249
\textsuperscript{76} Ibid., pp.86-88
\textsuperscript{77} W.Erb, op.cit., note 26, p.195
case histories (Kasuistiken) as possible. 78

The majority of electrotherapeutic publications, particularly during the initial phase, were concerned predominantly with electrophysics.

Physical Science has found a series of laws, which determine the behaviour of faradic and galvanic currents in the different kinds of circuits; laws, which determine the strength and density of the current in relation to the length, diameter and resistance of the circuit; laws, which rule the distribution of the current in dense conducting mass and in ramified conductors. 79

Serious, scientifically minded electrotherapists insisted that the benefits of electrical treatment derived not only from electricity alone, but also from the skill and knowledge of the physician who applied it. A.G.Goelet stated in an address to the American Electro-Therapeutic Association:

Electrotherapeutics cannot be appreciated, or successfully applied, without a thorough practical knowledge of the fundamental principles governing the action of electricity. 80

Lisa Rosner argues that for this reason, textbooks on electrotherapeutics frequently began with a discussion of "electro-physics" and "electro-physiology", the impact of electricity on human physiology. 81

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78 W.Erb, op.cit., note 74, p.239
79 W.Erb, op.cit., note 26, p.193
80 A.H Goelet, 'Influences governing the progress of electrotherapeutics', JAMA, 1893, Vol.21, pp.785-788
Erb's *Handbuch der Elektrotherapie* was no exception:

The great requisite is a sound knowledge of physics, and above all a practical acquaintance with the laws of Ohm.\(^2\)

Following Brenner's publications between 1862 and 1869 many renowned electrotherapists focused their attention on the "rational basis" of the two prevalent electrotherapeutic methods, i.e. Brenner's polar and Remak's directional method. In the wake of Brenner's publications the nervous auditory apparatus was comprehensively investigated. In Brenner's experiments it was found that the sensation of hearing was elicited by the "make" of the galvanic current only when the cathode was placed in or near the ear and that an effective auditory stimulation on the "break" of the current could be produced only by applying the anode at similar sites. What Brenner was actually demonstrating were the facts of galvanic electrophysiology that the "make" stimuli arise at the cathode and the "break" stimuli at the anode. Brenner, however, apparently fixing his attention on the "making" of the current, concluded that the cathode produced "exciting" effects and that the anode was "calming". In nineteenth century electrotherapy these conclusions were referred to as "Brenner's polar method."\(^3\)

During that era the continual quest for

\(^2\) W.Erb, op.cit., note 15, p.288 and pp.56-60

\(^3\) E.Stainbrook, op.cit., note 2, p.162
electrophysiological laws in the animal organism continued. It was a tacit assumption that health could be restored to the organism as soon as an organ could be trained or exercised to respond consistently to an electrical stimulus according to a formula, which had previously been established in a healthy individual.

The question is whether the law of contractions can be demonstrated upon the motor nerve of the living, healthy and whole human body in such a way, and with such completeness, that it may serve as a starting point for such applications as...the diagnosis of nerve lesions."  

During that era a certain friction can be discerned between electro-physiologists and clinical electrotherapists. On the one hand electrotherapists constantly strove to legitimate their endeavour with the latest physiological doctrine and "the well known physiological effects of the electrical current." Yet on the other hand they pointed out "how very incomplete physiological science still is and how many important problems remain unsolved."  

They also stressed that the art of treating patients was a delicate business, less well defined and less quantifiable than animal experiments in the laboratory.

The practical physician has not to do with the discovery of physiological facts and their reduction to laws;...Experiments for proving the law of contractions in the living man cannot be

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84 W.Erb, op.cit., note 15, p.74
85 Ibid., p.87
86 Ibid., p.69
compared in exactitude with the experiments of the laboratory. We cannot expose the nerve isolated to a great length and place it upon the electrodes; we have to deal...with nerves which are surrounded with more or less thick layers of well-conducting tissues, and which are permeated by a large number of threads of current diffusion.®

Or to put it more bluntly:

For us who are concerned with electrotherapeutics it is of secondary importance to know how things are, so long as we know they are so generally.®®

(Erb's italics)

®® Ibid., pp.74-75
®® Ibid., p.189
Chapter 10. Analysis of Wilhelm Erb's electrotherapeutic publications and practice

Wilhelm Erb dated the beginning of his own connection with medical electricity back to 1865:

In autumn 1865 I completed my Habilitation in internal medicine at Heidelberg. Soon afterwards an incident in my surgery induced me just by chance to occupy myself more intensively with Remak's book. The latter motivated me to conduct my own examinations. My first publications in electrotherapy appeared between 1867 and 1869.¹

Between 1862 and 1865 Friedreich had already entrusted his young assistant with the faradisation of patients "suffering from muscular atrophies and other nervous disorders."

I have had myself as a young assistant to faradise a patient suffering from progressive muscular atrophy for two hours every day. It had the advantage at all events of providing me an opportunity of practising the art of local faradisation.²

Memorable events like Duchenne's visit to the "Medizinische Klinik" in Heidelberg and a personal meeting with Hugo von Ziemssen in 1864 had already sparked off some interest in the subject.

During a visit to Berlin in summer 1865 Erb failed to meet Robert Remak, by then terminally ill. But he was able to attend Wilhelm Griesinger's inaugural clinical lecture at Berlin University and had the pleasure of meeting Carl Westphal, Moritz Meyer and


Eduard Hitzig. We have to assume this meeting was of personal importance to Erb. He still mentioned it forty years later and concluded: "subsequently I became an electrotherapist and neuropathologist."^4

Erb's first two publications in electrotherapy appeared between March and October 1867 in the newly founded medical journal Deutsches Archiv für klinische Medizin. His article 'Galvanotherapeutische Mittheilungen' contained the seeds for his following research and publications.

A number of preliminary physiological questions remain to be answered, before we can make a final judgement on the therapeutic value of the electric current. Above all the anatomical area of application has to be defined - in other words, we have to determine which parts of the human organism can actually be reached by the electrical current. It has to be determined which organs can be reached by currents of adequate strength to have a therapeutic effect without causing (introducing) harm.^5

Erb understood his papers in the first place as a contribution to the joint efforts of electrotherapists to accumulate as many case histories (Kasuistiken) as possible. Once this process was completed a subsequent evaluation of the bulk of patient histories and statistics was expected to help deciding on the real value of electricity in medicine and the correct method

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^3 Moritz Meyer was Robert Remak's brother-in-law.

^4 W.Erb, op.cit., note 1, p.1170


^6 Ibid., p.242
of treatment. The case history was the principal descriptive technique resorted to by clinicians during this era.

Erb also attempted to find out "how far the expectations raised by Remak's writings were borne out by experience." Furthermore Erb emerged as an enthusiastic supporter of Rudolf Brenner. However, he did not support the polar method unreservedly.

With 'Galvanotherapeutische Mittheilungen' Erb managed to secure himself a place in contemporary electrotherapy by proving experimentally that the central nervous system could be subjected effectively to electrical treatment. Until 1866 it was widely taught that

The brain and spinal cord cannot directly be accessed by electricity, for they are covered by bones and soft tissue, which hinder their direct affection with electrical currents.

In the following chapter I will dwell on Erb's first papers in electrotherapy, for in my view they exemplify particularly well the contemporary style and contents of medical publications.

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7 Ibid., p.333: "Da es mir bei diesen Mittheilungen....auf eine Vermehrung des wohl beobachteten Materials und besonders auf die durch statistische Mittheilungen zu begründende Methode der Anwendung des constanten Stromes in verschiedenen Krankheitszuständen ankommt."


9 W.Erb, op.cit., note 2, p.15

I. Galvanotherapeutische Mittheilungen

Duchenne and Robert Remak had demonstrated that the electric current could be applied locally to nerves and muscles provided they were situated in close proximity to the skin. The possibility of applying electricity to organs hidden in the inner depths of the body was doubted by authorities like Hugo von Ziemssen. He argued that the physical laws governing electrical conduction and resistance excluded the possibility of reaching the central nervous system with a current strong enough to bring about therapeutic effects:

The central organs of the nervous system and the nervous roots in the body escape the faradic current unless it is applied in excessive dosages, because they are covered with excellent conductors.\(^\text{11}\)

In the third edition of *Electricity in Medicine* Ziemssen repeated that claim for the galvanic current. On the other hand Remak and Benedikt had frequently mentioned successful galvanic treatment of the brain and spinal cord.

Erb felt that Ziemssen's statement was designed to arouse doubts in Remak's credibility and even worse it would stifle scientific interest in therapeutic experiments with medical electricity. Therefore Erb focused his attention on the employment of electricity to the central nervous system, for he expected some jolly nice results provided it could be demonstrated that galvanic currents reached the brain and spinal cord.

Ziemssen had argued that the organs of the central nervous system were surrounded by a substantial anatomical bulwark of soft tissue and bones which prevented electrical currents from reaching the central nervous apparatus. Erb argued that the possibility of galvanizing the brain would depend mainly on the electrical permeability (conductivity) of the bony skull.

Bones consist not of a solid dense substance...they are perforated by a nexus of numerous fine vascular channels, which communicate on the one hand with the vessels in the bone marrow and on the other with the vessels in the periosteum.\(^\text{12}\)

Inspection with a magnifying glass revealed minute pores and channels on the outer and inner surface of the skull:

They are the numerous passages which lead with only minor deviations through the entire depth of the bone; they are filled with superbly conducting tissue - blood...and the electrical current will prefer to follow them...The current will arrive inside the skull in sufficient intensity provided the electrodes are attached appropriately.\(^\text{13}\)

Erb argued that the greater part of a current followed the shortest route between two electrodes and concluded:

That a current, which had been applied to the skull with two electrodes appropriately attached opposite each other, will send a sufficient amount of electricity into the inner cavity of the skull, and thus to the brain.\(^\text{14}\)

Erb was aware that his apriori deduction could be doubted. Only then he did decide to confirm his apriori

\(^\text{12}\) W.Erb, op.cit., note 5, p.245
\(^\text{13}\) Ibid., p.246
\(^\text{14}\) Ibid., p.247
raisonnement with an experiment. He started with a series of experiments on skulls still filled with brain substance. The skulls had been severed from corpses and sawn into halves. An ischiadic nerve specimen from a frog was used as an electrometer and placed upon the jelly-like brainsubstance. Then a galvanic or induction current was sent transversally through the skull. Both currents had been administered in dosages which had previously been tolerated by patients. The employment of these currents as electrical stimuli succeeded in evoking distinct contraction of the frog muscle. Erb conceded that the experiment did not yet provide clear evidence:

Because...we used a skull separated from the body, whereas in the living (being) the skull is connected to the entire body, which acts as a parallel connection. The latter circumstance must have some bearing onto the "thread" of current being diverted into the skull.

He repeated the same type of experiment on dissected (injured) and intact corpses, even on the corpse of an eight month old infant. He obtained always contractions in the frog-preparation, which served as an electrometer.

Following these experiments there can be no doubt that with the cerebral application of weak, galvanic and faradic currents in a tolerable therapeutic dosage in corpses, extracurrents of such quantity and strength disperse themselves across the brain, that the minute fraction (of current) between point of application and brain is strong enough to evoke contraction in the frog-muscle preparation.

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15 H.v.Ziemssen, op.cit., note 10, p.27
16 W.Erb, op.cit., note 5, p.248
17 Ibid., p.249
Erb then examined his own evidence by submitting himself to a cross examination raising a number of possible objections which could be used to refute his results:

One will object that currents which excitate a frog nerve are by far not sufficient enough to exercise a therapeutic effect on the human brain.  

Erb firmly rejected his own objections:

Despite the differences of the nervous system between frog and man one has to assume that a current which excites the ischiadicus of a frog will also be able to excite the human brain provided it acts with the same density onto the latter.

Erb disliked "the erroneous habit" of inferring only from strong muscular contraction or pain caused by electrical stimulation a therapeutic influence of electricity. This was in his eyes a result of the previous almost exclusive use of induced (faradic) currents. He pointed to the subtle effects evoked by the constant current such as the alteration of nervous excitability or Remak's electrolytic effects. Though he conceded that some of the alleged effects were still the subject of conjecture, others such as the electrotonic effects had been demonstrated in animal experiments.

Erb was in no doubt that the achievement of a healing influence upon the brain depended on some sort of cerebral excitation. He stressed that it was unreasonable to expect massive muscular convulsions of

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18 Ibid., p.250  
19 Ibid., pp.250-251
the entire body or 'exocentric pain'\textsuperscript{20} as manifestations of preceding cerebral excitations for "it is well known that the brain has only few sensory and probably no motor parts."\textsuperscript{21} (my emphasis)

Yet phenomena such as vertigo, anaesthesia, nausea and faintness were certainly caused by direct cerebral excitation, easily evoked by galvanization.

Particularly vertigo is of cerebral causes; may it be evoked by hallucination or imaginations...may it be a consequence of disturbances of the muscle sense or be it provoked by abnormal movements. The seat of vertigo, its place of origin, will always have to be sought in the cerebrum; it is a function of the brain.\textsuperscript{22} (my italics)

Erb emphasized that dizziness had to be a centrally caused cerebral phenomenon:

Dizziness has to be interpreted as a cerebral function, likewise the kind of anaesthesia, which follows application of strong currents to the head - sometimes culminating in total disability to think - cannot be interpreted in any other way.\textsuperscript{23}

He had observed that the experienced vertigo was felt to be the strongest as soon as the electrical stimulus was applied to the 'fossa mastoidea'. If the point of application was the temple or the patient's forehead the resulting vertigo was less pronounced. This was interpreted as proof that the retina, situated in close proximity to the forehead, had not been stimulated and was thus not responsible for the development of

\textsuperscript{20} exocentric = of central causes

\textsuperscript{21} Ibid., p.251; see also Moritz Schiff, \textit{Lehrbuch der Physiologie des Menschen}, Vol.1, Lahr, 1858/59, p.360

\textsuperscript{22} Ibid., p.251

\textsuperscript{23} Ibid., p.252
In Erb's opinion the experience of vertigo or dizziness during the course of electrical stimulation of the head made it clear beyond doubt that the galvanic current really affected the brain. The fact that therapists repeatedly advised against the use of strong currents on the head appeared to confirm his opinion, for on "those occasions cerebral disturbances had been observed, which appeared very threatening to the observer and uncomfortable for the patient."\(^{24}\)

Then he set out to prove that the spinal cord could also be reached by the galvanic current. Now the anatomical conditions were considered less favourable, for the spinal cord was covered with muscle tissue, which was thought to deflect the currents. This disadvantage was, however, thought to be outweighed by the better tolerance of the backbone to strong currents. On the other hand "unlike in the case of the cerebrum one cannot apply the current in any direction across the spinal cord, because it lies only with one side close to the surface of the body."\(^{25}\) Again theoretical reasoning did not suffice to decide that matter. The direct experiment had to deliver a decision.

Erb performed an experiment on an excised spinal cord of a corpse, similar to the previous one on the cerebrum. Though the frog muscle (=galvanometer)

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\(^{24}\) Ibid., p.252

\(^{25}\) Ibid., p.255
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convulsed and thus indicated the possibility of reaching the spinal cord with galvanic currents, Erb realized that "the possibility of galvanising the spinal cord in living man was not proven with absolute certainty, yet". He succeeded in demonstrating on patients that "after interrupting a constant current applied to the back, he obtained contractions from those muscles innervated by nerves, which leave the spinal cord a long way beneath the point where the electrodes were attached." Thus he concluded it was highly likely that galvanic currents of therapeutic value could be applied to the spinal cord and that it was certain that the brain could be reached with galvanic currents of therapeutic value.

Erb left it at that and demanded that pathologists ought to try the galvanic current in suitable cases of cerebral diseases. Erb had to admit that he had not yet recorded any therapeutic successes himself, although he had administered galvanic currents very carefully on the brain on rare occasions. He was convinced that he had opened up a further area of treatment for galvanic electricity. But the present "total lack of knowledge about the finer anatomical and pathological conditions of the central nervous system and the still inadequate experience with

26 Ibid., p.255

27 Ibid., p.253: "nachdem so die Möglichkeit nachgewiesen ist, das Gehirn mit galvanischen Strömen zu erreichen, wird es nun Sache der Pathologen sein, den constanten Strom bei geeigneten Fällen von Gehirnkrankheiten zu versuchen."
galvanic therapy in so many diseases of the central nervous system" made it difficult to predict "which sphere of action" could be opened up for the constant current. In order to remedy that shortcoming therapeutic experiments with constant currents on the central nervous system had to be encouraged and were from now on fully justified and desirable.\(^2^8\)

*With my memorandum I merely wanted to induce others to experiment in the same direction; I intended to grant the constant current - such an invaluable curative agent - a place in the therapy of nervous and muscular diseases.*\(^2^9\) (my italics)

Erb's deliberations concerning the electrical excitability of the central nervous system shed some further light on the history of neurophysiology in Germany. Michael Hagner observed that during the 1860's no vigorous debate on cerebral localization of mental faculties existed in Germany as opposed to neighbouring France.\(^3^0\) Cerebral localization was only timidly and with a great deal of reservation discussed in German medical circles. Hagner argues that it was Eduard Hitzig's experience in electrotherapy, combined with Gustav Fritsch's anatomical expertise, that led to their famous experiments on the electrical excitability of the brain.

\(^2^8\) Ibid., p.257
\(^2^9\) Ibid., p..253
\(^3^0\) M.Hagner, 'Die elektrische Erregbarkeit des Gehirns', in Hagner & Rheinberger (eds.), *Die Experimentalisierung des Lebens*, Berlin, Akademie, 1993, pp.97-115, p.97; M.Hagner,'Aspects Of Brain Localization In Late XIXth Century Germany', in C.Debru (ed.) *Essays In The History Of The Physiological Sciences*, Amsterdam, Atlanta, Rodopi, 1995, pp.73-88, p.75
In 1861 an article by the Frenchman Paul Broca had triggered a debate on the cerebral localisation of language. He had produced evidence that speech and language functions are disturbed in patients who have lesions in and around the third frontal convolution of the left cerebral hemisphere. Broca's work was known and discussed in Germany. Case studies which contradicted Broca's claims were equally well known.

Traditional accounts usually claim that Broca's work was the stimulus for the first experimental studies of movements evoked by focal electrical stimulation of the cerebral convolutions by Fritsch and Hitzig in 1870. Francis Schiller claimed that Fritsch and Hitzig challenged previous assertions that the cerebral cortex was unexcitable.

So far Erb's work on the electrical excitability of the brain has been overlooked by medical historians. I believe that his work partially paved the way to Fritsch's and Hitzig's famous experiments on cerebral localization: I have demonstrated that until 1866 it was widely taught and believed that the brain could not be reached and affected by electricity. This conceptual

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33 F.Schiller, 'Neurology: The Electrical Root', in Rose & Bynum (eds.) Historical Aspects of the Neurosciences. A Festschrift for Macdonald Critchley, New York, Raven Press, pp.1-11, p.8
'obstacle' had to be removed first, otherwise it would have made no sense for electrotherapists, let alone experimental physiologists to employ electrical currents to the skull and its contents, the brain. Erb had questioned that prevailing notion and provided some experimental evidence to the contrary. Thus he had helped to encourage others to use electricity in cerebral diseases which inevitably involved the repeated application of electrodes to the skull.

With reference to the living man it had long been stated that the brain in its osseous case, was not to be reached by the current. My experiments, now universally accepted, have refuted this doctrine.34

The observation of galvanically induced vertigo had alerted Erb to the possibility that electricity did indeed have some sort of influence on the cerebral matter, for vertigo was thought to be a purely cerebral function. Erb maintained throughout the late 1860s the notion that the cerebral cortex had no motor function.35

In 1866 Erb had described the phenomenon of "galvanic vertigo" - i.e. the sensation of giddiness following the application of galvanic currents to the head. This fact was known since Purkinje and Brenner. It was generally recognized among electrotherapists that the sensation of galvanic vertigo was strongly experienced by the patient as soon as the electrodes

34 W.Erb, op.cit., note 2, p.117
35 See footnote 21
had been located in the 'fossa mastoidea'.

On the strength of numerous experiments it may be said that the giddiness is the greater the more nearly the direction of the current is at right angles with the longitudinal axis of the skull. Thus the effect when the electrodes are applied to the temples or mastoid processes is marked, whereas when they rest on the forehead and occiput it is very slight.

We may also recall that Erb had mentioned passingly - in his discussion of the cerebral seat of vertigo - that vertigo may well be provoked by abnormal movements. He did not further elaborate whether he had by any chance observed 'abnormal' eye movements during his sessions of cerebral galvanizations.

On 19th January 1870 Eduard Hitzig reported to the Berlin Medical Society on the physiological and therapeutic implications of various methods of therapeutic electrical excitation. Hitzig confirmed that he had managed to provoke galvanic vertigo in patients as soon as he had applied simultaneously an electrode behind each earlobe in the fossa mastoidea. He had also observed that the very same method of locating the electrodes had produced involuntary movements of the bulbi. Hitzig wanted to know which muscles were responsible for the observed eye movement and used the above described method of applying the electrodes in healthy patients and a control group of

36 Fossa mastoidea = anatomical region behind the earlobe and the processus mastoideus.

37 W. Erb, op. cit., note 2, p. 117

patients with complete peripheral paralysis of the ocular muscles. He noted that in healthy individuals several muscles had to participate in a specific identical muscular contraction. These muscles were known to be innervated by different cranial nerves. Subsequently he speculated that those ocular movements had been generated by the stimulation of central structures. But Hitzig was confronted with several puzzling and contradictory observations. Some patients complained also about vertigo. It was initially far from clear whether the vertigo had perhaps induced the rotational ocular movements or whether it might have been the other way round.

When a strong current is sent through the mastoid processes associated nystagmus-like movements of the eyes occur in a definite direction; thus if the anode be on the right side the two eyes are driven to the left, and are maintained there with an oscillatory movement.39

Hitzig investigated the relationship between vertigo and ocular motion and followed up the idea that the latter might have been evoked by direct excitation of central structures.

M. Hagner already described Hitzig's initial experiments and observations leading to the famous experiments on the electrical stimulation of the cerebral cortex.40 Hitzig's initial electrotherapeutic examinations of patients with galvanically induced vertigo motivated him to design the animal experiments on cerebral localization. Erb described comparable

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39 W.Erb, op.cit., note 2, p.118
40 See footnote 30
observations in 1867 in 'Galvanotherapeutische Mittheilungen'. Both Erb and Hitzig made these observations in the first instance as electrotherapists and not as neurophysiologists. Erb had questioned the notion that galvanic currents were not able to penetrate the skull and reach the brain, but continued to adhere to the physiological dogma that "the brain had probably no motor parts". Hitzig dared to challenge the latter concept, after he had observed ocular movements following electrical stimulation of the head behind the earlobe. Ironically Hitzig's assumption later turned out to be erroneous:

This phenomenon is not due to the direct excitation of any motor centres or fibres.\[^{41}\]

Years later Eduard Hitzig conceded that:

The eye movements in question are not produced by a direct stimulation of the cerebrum, but indirectly through the electrotonification of the vestibular nerves.\[^{42}\]

Erb confirmed many of Brenner's findings and supported the polar method. Like so many of his contemporaries Erb had been busily investigating Pflüger's law of contractions\[^{43}\] wondering whether it also held for the conditions in man. As long as he had only considered the direction of the administered current relevant he had obtained results, which failed

\[^{41}\text{W.Erb, op.cit., note 2, p.118; M.Hagner, op.cit., note 30, p.105.}\]

\[^{42}\text{E.Hitzig, 'Physiologische und klinische Untersuchungen über das Gehirn, in Gesammelte Abhandlungen, (1), Berlin, 1904, p.34}\]

\[^{43}\text{W.Erb, op.cit., note 5, p.258}\]
to match Pflüger's formula.

Following Brenner's publication (1862) he paid more attention to the relative position of the poles to the nervous section intended for excitation. Only then he succeeded in obtaining Pflüger's formula "with great precision in humans":

According to Brenner's method one can demonstrate nicely the different polar effects in man...One chooses an easily accessible nerve, e.g. the N.medianus in the elbow...and applies one pole to the left and the other pole to the corresponding anatomical site on the right. Then one makes and breaks the circuit. On make contraction occurs at the nerve "armed" with the cathode followed by a contraction on break....at the site, "armed" with the anode (This observation held only as long as the strength of current remained weak to moderately strong)."

Erb lent initially only qualified support to Brenner's polar method.

I believe he [Brenner] goes too far in claiming that the polar effect can be...exploited in therapy regardless of the direction of the current."*^ Erb referred to Pflüger who had already demonstrated that as soon as aelectrotonus occurred in one given nervous segment inevitably catelectrotonus had to develop in the neighbouring nervous section."*®

It depends...on the relative position of these electrotonic nervous areas, whether and which stimulating effect can evolve and into which direction - centripetal or centrifugal - the polar effects can be propagated. In my view therefore it cannot be irrelevant in electrotherapy, whether the produced effect of one or the other pole propagates itself towards the periphery or the centre. Without any doubt there are cases in which the direction of the propagation is not unimportant - cases in which

*® E. Pflüger, Die Physiologie des Electrotonus, Berlin, Hirschwald, 1859, p.431
the ascending catelectrotonus or anelectrotonus acts
differently from the descending ones. Therefore one
is justified in paying attention to differences (in
direction of the current) in defining
therapeutic methods.""

Erb also endorsed Brenner's demand for the
creation of an "electropathology" of the motor
apparatus. Erb himself had not yet been able to confirm
all of Brenner's findings. But at the time of
publication of his 'Galvanotherapeutische
Mittheilungen' he was following up Brenner's idea. He
was engaged in examining various paralyses and muscular
diseases in their reaction against faradic and galvanic
currents. In that context Erb briefly mentioned a case
of facial paralyses which became repeatedly the subject
of later publications."

Erb also dealt with a question which motivated
contemporary electrotherapists to conduct a host of
experiments: the question whether electrotonus could be
reproduced in man in accordance with Pflüger's
experiments on the frog. Erb drew attention to some of
his own experiments, though he stressed:

These experiments can hardly decide that matter, for
I do not dispose of the necessary apparatus, nor am I
sufficiently trained to perform experiments which
would find favour in the critical eyes of
experimental neurophysiologists.""

Nevertheless he mentioned them, since he managed to
reproduce consistently the same result. In contrast to
contemporary physiological teaching he had found

" W.Erb, op.cit., note 5, p.263
"" Ibid., p.269
"""" Ibid., p.271
negative increase of excitability in catelectrotonic areas and positive increase of excitability in anelectrotonic areas. Again, this finding became subject of many subsequent publications.

The final paragraphs of his first part of the 'Galvanotherapeutische Mittheilungen' are dedicated to Remak's observations on the constant current. Erb was particularly interested in Remak's catalytic effects and their possible effects on the vascular system. He welcomed the possibility of reaching hidden organs via the galvanization of their vasomotor nerves, thus broadening the potential of therapeutic intervention with electricity. Erb insisted that only extensive experimentation, supported by clear therapeutic experience, would help eventually to solve these questions.

Erb's results were considered to be of fundamental importance "for the entire question of galvanotherapy in cerebral and spinal diseases". Burckhardt and Ziemssen confirmed Erb's findings and subsequent editions of Ziemssen's textbook on electricity in medicine were amended accordingly.

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50 H.v.Ziemssen, op.cit., note 10, p.27
II. Electrotonus in man

The question

Whether under the circumstances peculiar to man, the phenomena of electrotonus, known...from the frog, could be demonstrated. 51

occupied contemporary electrotherapists considerably.

Fick had proclaimed in 1866 that the phenomena of electrotonus could not be produced in living man with the constant current. 52 But it was considered to be fairly easy to demonstrate electrotonic effects (alterations of excitability) in the excised frog nerve:

A stimulus of uniform strength (electrical, mechanical, chemical) is applied to the nerve, in the neighbourhood of the points of application of the electrodes, before and during polarisation (i.e. the passage of the galvanic current) and the effect estimated from the amplitude of the muscular contraction produced under the varying conditions of experimentation. 53

The alteration of nervous excitability of a nerve segment either side of its polarized portion was always tested with an electrical stimulus of the induction current. One serious source of error in those experimental arrangements was considered to lie in the accidental formation of parallel shunts. Therefore Hitzig recommended that "the stimulating (testing) electrode had to be fixed firmly to the skin, so that


53 A.de Watteville, A Practical Introduction to Medical Electricity, London, Lewis, 1884, (2nd ed.), p.111
it could not be moved at all nor that its pressure exerted upon the skin could be altered, thereby creating the accidental formation of electrical shunts".\(^{54}\)

Albert Eulenburg, of Berlin, was the first to investigate that question. His paper on electrotonus in man was completed in December 1866.\(^{55}\) He wanted to ascertain the existence of descending extrapolar and catelectrotonus in man. He limited his investigations to motor nerves which located comparatively close to the skin, i.e. N.accessorius, N.medianus, N.ulnaris, N.radialis and N.peronaeus. He performed his experiments on six medical students, which assisted him with "devoted patience".\(^{56}\)

Eulenburg obtained results "in harmony with the doctrines of physiology".\(^{57}\) He found "with the highest possible consistency a negative increase of excitability in anelectrotonic areas and a positive increase in the catelectrotonic areas". Thus his results were entirely in accordance with Pflüger's results, which had been obtained on a polarised frog nerve.\(^{58}\)

\(^{54}\) E.Hitzig, op.cit., note 51, p.166


\(^{56}\) Ibid., p.122

\(^{57}\) W.Erb, op.cit., note 2, p.88

\(^{58}\) E.Hitzig's summary of Eulenburg's experiments, in op.cit., note 51, p.166
Eulenburg had used the 'method of minimal contraction' which allowed him to express his results quantitatively. He employed shocks discharged by the induction apparatus as the testing stimulus. The strength of that stimulus was expressed in terms of the distance (mm) between the primary and secondary induction coils at which minimum contraction appeared first. Eulenburg first determined the weakest possible stimulus (measured in distance between the induction spirals) which had to be applied to the non-polarized nerve to induce a muscular contraction.

The experiment was repeated by administering the stimulus again between muscle and the polarized nervous portion. The polarization was brought about with a constant current of either descending or ascending direction. Then he obtained the first minimal muscular contraction in the anelectrotonic portion with an electrical stimulus which had been facilitated by a smaller distance between the induction spirals as previously needed. That meant that the electrical discharge was stronger, hence the stimulus greater than in the previous experiment. This in turn meant that the excitability of the anelectrotonic area had decreased (negative increase). Vice versa the discharge needed to provoke a muscular contraction in the catelectrotonic area had been facilitated by a greater distance between

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59 Eulenburg and Erb used du Bois-Reymond's sledge inductorium, the strength of current could be regulated by altering the gap between the primary and secondary coils. The smaller the gap the stronger the discharged induction current.
the spirals. This indicated that the stimulus was weaker than before, thus the excitability of the catelectrotonic area against induction current must have increased. Eulenburg concluded cautiously that some principles could be "abstracted" from his findings for the therapeutic use of currents.

Extrapolar descending anelectrotonus is...to be induced...as soon as one wants to reduce to the abnormal state of pathologically increased nervous excitability; Vice versa extrapolar descending catelectrotonus was to be induced as soon as one wanted to restore nervous excitability...to life.  

But Eulenburg warned against drawing conclusions too hastily:

I do not consider my experiments to be conclusive...I do rather understand them as the start of a series of critical experiments on the physiological and pathological effects of the constant current in man.  

As it happened Erb had mentioned briefly an observation in 'Galvanotherapeutische Mittheilungen' which contradicted Eulenburg and Pflüger. Prompted by those inconsistencies Erb investigated that matter further. He published his findings in July 1867 in the Deutsches Archiv für Klinische Medizin. Erb had performed the first thirty-seven experiments on his own left ulnar nerve, followed by nine control experiments on a "healthy strong labourer". He was assisted by his medical colleagues Dr Fritsch and Dr Rosenfeld. Dr Bernstein had been present during some of those

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60 A.Eulenburg, op.cit., note 55, pp.140-141
61 Ibid., p.141
62 W.Erb, op.cit., note 5, p.271
63 Ibid.,(Vol.3) pp.512-528
experiments, confirming the authenticity of the obtained results. Erb resorted principally to Eulenburg's experimental techniques and arrangement. He did not, however, consider the accessorial and median nerves as suitable. These nerves were judged to be too short to have three electrodes comfortably placed on them. The two polarising electrodes were placed above the nerve in the upper arm, 10 to 12 centimetres apart. For the purpose of excitation Erb employed secondary faradic currents, conveyed to the nerve by means of a fine electrode.

In order to be able to ascertain the modifying impact of the constant polarizing current he resorted to Eulenburg's 'method of minimal contraction'. The distance between the two coils at which minimum contractions occurred were noted alternately during the passage of the current and on opening the circuit. Erb also attempted to record the visible and palpable alterations of the muscular contractions and presented his results in tables.

"Very much to his surprise and dissatisfaction" Erb ascertained with great regularity an increase of excitability in the anelectrotonic zone and a diminution in the catelectrotonic zone. Erb repeated his experiments carefully trying to avoid all sources of errors he could possibly think of. Nevertheless, he always established findings which conflicted with

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64 Ibid., p.518
65 W.Erb, op.cit., note 2, p.88
Pflüger's law of contraction. Erb was obviously disappointed and puzzled:

I would have preferred...results in accordance with physiological facts...that would have saved a lot of tedious and time consuming work and it would have strengthened the rational basis for certain electrotherapeutic measures." (my italics)

But "there was no denying the facts", one could "only attempt to explain the anomalies, trying to bring them into compliance with long known and well established facts". Erb declined to offer any reasons for the differing results. Only further extensive experiments by other researchers would eventually help to decide whether Eulenburg's or his findings would be the "norm" and what the reasons were for the differences in the physiological behaviour.

Either the connection of the living nerve with the body and particularly with the central nervous system or whether perhaps the alterations of the electrical currents, permanently produced in the living nerve...caused the abnormal reaction? (my italics)

He did not dare to decide that question and felt it had to be left to a more competent expert. Erb warned that his experiments should not be used to draw any further conclusions from them for electrophysiology nor electrotherapy. In that respect he agreed with Eulenburg who had also considered it to be "unscientific" to draw generalizing conclusions from his results."

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66 W. Erb, op.cit., note 5, p.521
67 Ibid., p.521
68 Ibid., p.525
69 A. Eulenburg, op.cit., note 55, p.139
My experiments were by far not sufficient enough; they prove certain changes in excitability against only one excitant; these experiments cannot prove anything for other different kinds of excitants, e.g. pathological stimuli or physiological stimuli which act during life onto the nerve. Perhaps the reason for my abnormal results lies in the specific quality of the one excitant I used. After all in therapy it is not about the increase or decrease of (nervous) excitability against electrical currents, but against totally different stimuli, whose qualities are partly still unknown to us. Therefore I believe...only therapeutic experiments will be able to deliver the final decision - even if these therapeutic experiments have for the time being still to lean against the laws found by physiology.\textsuperscript{70}

At the end of summer term 1867 Erb also presented these results during a meeting at the "naturhistorisch-medizinischer Verein" at Heidelberg. Helmholtz attended that meeting, too. Professor Helmholtz, respected for his competence and expertise in physiology, suggested that the observed abnormality was probably related to a nerve's location in the intact human body. Helmholtz argued that every nerve was more or less imbedded in a bulk of well conducting muscle tissue. As a direct consequence of this the current diffused rapidly with increasing distance from the polarizing electrodes. Therefore, for example only in a short distance from the positive pole (anode) the density (of current) would decrease so quickly, that one could assume for the current to have established its exit close to the anode: in other words a negative pole (point of exit) had established itself very close to the positive pole (point of entrance). Subsequently an unsuspecting observer finds himself actually examining

\textsuperscript{70} W.Erb, op.cit., note 5, p.525
catelectrotonus where he assumed anelectrotonus."^71

This meant that Erb must have placed the stimulating electrode (induction current) not close enough to the electrodes of the polarizing constant current. Thus he had examined the phenomena of catelectrotonus near the anode, believing that he had ascertained anelectrotonus and vice versa. Instructed by Helmholtz and equipped with an especially designed stimulatory electrode Erb repeated the experiments described above."^72

In the light of Helmholtz's interpretation Erb obtained the "desirable correspondence with physiological facts" and noted with relief that "the results obtained with the new experimental arrangement appeared to endorse firmly the correctness of Helmholtz's opinion."^73 Erb concluded that the differing results between him and Eulenburg could be accounted for by simple anatomical and physical differences. He found it reasonable to assume that the different results between him and Eulenburg could be put down to "only minor differences in experimental arrangement, e.g. different sizes of the polarizing electrodes." Nevertheless this incident was a further reminder that "physiological findings cannot be


^72 Erb-Helmholtz Electrode: a special construction which allowed the stimulating electrode (induction current) to be passed through a fine glass tube and thus to be placed very close and insulated in the immediate proximity of one of the polarizing electrodes.

^73 W.Erb, op.cit., note 5, p.527
utilized unreservedly in electrotherapy". After all, the living organism displayed different conditions from the dissected frog in the physiological laboratory.\textsuperscript{74}

Erb added a postscript to the July paper in October 1867 reporting the new findings. He formulated the electrotherapeutic rule that "one has to let that very pole act upon the entire extent of the nerve or muscle which is to be impressed with that particular polar effect."\textsuperscript{75}

Erb basically recommended the polar method of treatment, though he does not express it very clearly. Already in his preceding 'Galvanotherapeutic Memorandum' Erb mentioned that he only ascertained Pflüger's law consistently when he paid greater attention to the position of application of the pole in relation to the nervous segment intended for excitation.\textsuperscript{76}

Further attempts to demonstrate on the animated nerve of man the laws of electrotonus, established by Pflüger on the dissected frog nerve, continued to be made by Samt, Runge and Brückner.\textsuperscript{77} Their results were

\textsuperscript{74} Ibid.
\textsuperscript{75} Ibid., p.528
\textsuperscript{76} Ibid., pp.261-265
often inconclusive and contradictory.  

In his Handbook of Electrotherapy (1882) Erb dismissed Samt's, Brückner's and Runge's experiments without any further explanation as faulty, insisting on a more "scientific" approach in investigating the subject of electrotonus in man.  

III. Erb's work in electro-otology (1869-1871)

Die galvanische Reaktion des nervösen Gehörapparates im gesunden und kranken Zustand. August 1869

Brenner's publication had made the acoustic nerve a bone of contention among electrotherapists. Provided Brenner's findings and observation on the acoustic nerve were found to be correct they vindicated his polar method. Brenner had claimed that the direction of any therapeutic current in nerve or muscle did not have any bearing onto the genesis of either cathodic or anodic effects, but rather the poles themselves were responsible for the generation of the effects produced at the site of their application. Subsequently a battle broke out between the advocates of the directional and the supporters of Brenner's polar method. The question was which one of the two methods relied on a more rational basis which would

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78 A.Waller & A.de Watteville, 'On the influence of the galvanic current on the motor nerves of man', BMJ, May 27, 1882, p.767

79 W.Erb, op.cit., note 2, p.90

80 R.Lewandowsky, 'Die Anwendung der Elektrizität in der praktischen Heilkunde', Wiener Klinik, 1877, Jahrg.3, p.360
justify its use in diagnosis and therapy? This and other issues were passionately discussed during the assembly of German natural scientists in Dresden in 1868.

During the last Naturforscherversammlung in Dresden I had to experience that a certain camp resisted with only poor reasoning from a one sided biased viewpoint against the clearest and most simple results of Brenner's examinations which pass every scientific test.\(^{61}\)

Erb's own examinations and observations had convinced him that Brenner's data were "mostly" correct:

From my experiments I came to the conviction that provided not only the observer exercises some patience and skill but also the patient, the galvanic excitation of a sensation of sound is in the majority of cases possible. However, on part of the subject some patience, self-discipline and skill is needed to give the correct testimony; only after repeated experiments it will be easier to interpret the sensations correctly. Therefore one is not allowed to declare something as untenable only because it did not succeed on the first experiment.\(^{62}\) (my italics)

Erb insisted that it was possible to ascertain the 'normal formula' with great regularity. In August 1869 Erb published a paper 'On the galvanic reaction of the nervous auditory apparatus in health and disease' which contained a collection of thirteen case histories confirming Brenner's normal formula. He conceded that the formula only held for currents of moderate strength. The effects of stronger currents were considered to be irrelevant for medical purposes, since they could not be applied to the head without causing


\[^{62}\text{Ibid., p.141}\]
discomfort. Equally irrelevant for medical practice was the question:

How the galvanic current acts upon the exsected...and thus maltreated nervous auditory apparatus, since we will never be able to excite it in an isolated condition on the living human individual. Our task is simply to investigate how the nervous auditory apparatus reacts under given circumstances to the galvanic current - irrespective of certain physiologists who turn their noses up against such undertakings and feel offended by the sight of such efforts." (my italics)

In his paper Erb communicated the results of physiological excitation experiments on patients without known ear diseases who had attended the out-patient department seeking help for other ailments:

My results are in total harmony with Brenner's findings on numerous healthy individuals.®®

"Pathological observations" on patients with known otological problems who had accidentally come to his notice were also described:

These cases are neither numerous nor exhaustive; it is merely a case of stating the fact that alterations of the normal formula in diseased ears occur and can be recorded with precision and exactitude.®®

His article did not aspire to any new claims. He only wanted to report his own findings and observations which he had obtained in a series of control experiments intended to scrutinize Brenner's findings:

Nobody is more convinced than me that my reports are not fully matured and developed yet and they are still piecemeal...I believe, however, that I can stand by the facts I report. I know that they do not contain anything new at all, they merely confirm Brenner's results. However, it seems that his work

®® Ibid., p.141
®® Ibid.
®® Ibid.
is not widely accepted. Therefore I hasten to add my own bit for the cause of such a highly important and interesting matter which deserves recognition. I hope that my intention will be taken into account whilst judging my work and I hope that others will follow my example...analyzing the matter earnestly. I am optimistic that with the help of my article Brenner's 'electro-otriatic' will be protected from premature and thoughtless verdicts by superficial observers.®

Erb did not describe any "therapeutic experiments":

I have not yet conducted any further therapeutic experiments on (diseased) ears; this was not my intention at this stage. However, I do hope to occupy myself in the course of future examinations more intensely with that aspect, for the expected results should be of eminent theoretical importance for electrotherapy on the whole.®

Erb repeatedly expressed his distress about the criticism directed against Brenner. In his view the apparent failure to reproduce consistently Brenner's Normalformel could only be put down to inexperience on the part of the experimenter or by the use of a faulty method: "Those who refute the existence or correctness of Brenner's findings are simply mistaken!"

Erb had to admit that the reproduction of the normal formula in healthy individuals was not an easy task at all and in attempting to do so one had to master a lot of technical problems.® The acoustic nerve was not an easy anatomical target for a galvanic current which could be administered only in a weak to moderate dosage to the head. The nerve was situated so deeply that strong currents were necessary to excite it and the latter gave rise to such disagreeable

®® Ibid., p.155
®® Ibid., p.147
®® Ibid., p.131
concomitant phenomena such as the excitation of the eye, facial nerve, nerves of taste and salivation or even induced nausea and vertigo:

Only few nerves of the body are surrounded by so many almost unsurmountable obstacles; almost everywhere dense and compact bones resisting conduction; the dry tympanic membrane, the air-filled middle ear, which is only bridged by small bones - they all are mighty obstacles for the galvanic current, particularly for a current of such a weak nature which can only be applied to the head. Therefore one can expect a priori that in many cases it will either be impossible or only with difficulty to excitate the nervous auditory apparatus with galvanism; further we may suspect that in view of the complicated conditions it may come to sometimes abnormal results; nevertheless from a larger number of cases one can extract the regular pattern of the reaction.\(^8^9\) (my italics)

Some audiologists and electrical physicians did not manage to obtain the normal formula at all. Sycyanko totally denied the possibility of acoustic nervous excitation with galvanic electricity.\(^9^0\)

Bettelheim and Benedikt did not fully agree with Brenner's results either. Their Viennese colleague Schwanda had also reported entirely negative results. Brenner had noted that in many patients suffering from ear disease the acoustic organ appeared to be very susceptible to galvanic stimulation whereby the existence and regular appearance of the acoustic reaction could easily be demonstrated:

It is in fact, especially among those suffering from aural affections, and in whom the nervous mechanism of hearing often reacts with an almost marvellous readiness and ease to the galvanic current, that we can conduct investigations without any annoyance to

\(^8^9\) Ibid., p.132

the patient and obtain the most striking results.\textsuperscript{91}

Erb insisted that the occasional negative result did not justify a total negation of the possibility of acoustic excitations. Therefore he attempted to illustrate the possible causes for failure and offered some \textit{tricks of the trade} which would help the experimenter to ascertain positive results.

His own experiments had been conducted with fairly simple apparatus. One of the largest obstacles for success was the pain induced in the healthy patient. Erb knew what he was talking about since he himself had endured considerable pain whilst performing physiological excitation experiments (\textit{physiologischer Reizversuch}) on himself. Sometimes he had almost fainted.\textsuperscript{92} This did not surprise him since marked sensitivity of the meatus and ear drum was particularly common in individuals of the upper and educated classes!

The sensation of pain was particularly distressing when the ear electrode was inserted into the auditory meatus according to the 'internal method of investigation'. Thereby the meatus was filled with salt water and a fine wire or sponge electrode introduced, whilst the 'indifferent' electrode was held in the hand or on the sternum. Erb found this method not only painful but also faulty, since the water gave rise to disturbing extraneous sounds.

\textsuperscript{91} W.Erb, op.cit., note 2, p.231

\textsuperscript{92} W.Erb, op.cit., note 81, p.134
Hence Erb preferred to use the external method, already known to Brenner, which was felt to be less unpleasant for the patient and yielded satisfactory results. The position of the indifferent electrode was thought to be important not for the kind of excitation but for the very possibility of excitation to take place:

We are dealing with a very deeply located nerve and therefore it follows from the simplest rules of physics, that the second electrode should not be placed near the ear electrode. It is an entirely faulty arrangement to place the second electrode on the Processus mastoideus of the same side. A moist sponge electrode, larger and best of the 'medium size' is placed and firmly held immediately in front of the auditory canal, pressing slightly upon the tragus, but without occluding the canal or filling it with water. The indifferent electrode is most advantageously placed on the nape of the neck. The strength of the current is to be gradually increased, and repeated cathodic closures, and now and then AC, are made...the person experimented upon is being instructed to pay as close attention to his aural sensations as possible, disregarding the concomitant phenomena.  

Despite his resourceful manipulations Erb had to admit that the galvanic reaction of the acousticus remained a "highly delicate and difficult operation."

It was of utmost importance for the experimenter to remain calm and patient, trying to avoid any rush or unnecessary discomfort for the patient. Skill and experience was essential:

I experienced that in my own case; for even though I am not inexperienced in galvanic investigations I did gain even more competence and dexterity in ascertaining the galvanic reaction following months and months of intense occupation with that matter...therefore beginners and inexperienced physicians should perform their first experiments in patients with an ear disease, who offer much more

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93 Ibid., p.134 and see also W.Erb, op.cit., note 2, p.104
favourable conditions, and then proceed to examine healthy individuals."

Of equal importance was the experimenter's skill in interviewing the patient who had to be encouraged to describe his own sensations "adequately and correctly." Therefore Erb preferred to experiment on educated patients belonging to the upper classes. Nevertheless, he often also reported findings on peasants, artisans, paupers and day labourers. Having mastered the difficulties of examining the ear and ascertaining Brenner's normal formula Erb concluded with utmost confidence that:

With perseverance, patience and self-sacrifice on the part of the subject, and practice and dexterity in the experimenter, it is usually possible to determine the law in the majority of healthy individuals. I cannot but express my conviction that those who reached negative conclusions either lacked the necessary patience and skill or proceeded with entirely inappropriate methods. With repeated training and use of the recommended manipulations they will succeed - provided they have the necessary willpower at all - to banish the recurrent failure from their experiments." (my italics)

Erb insisted that the sensation of aural sounds was caused by a direct galvanic excitation of the nervous auditory apparatus and not, as for example Althaus and Benedikt claimed, by a reflex mechanism. This illustrates once more quite nicely Erb's concept of how medical electricity acted upon diseased structures.

Erb published a second paper in electro-otology in July 1871. Therein he hardly dealt with any

"W.Erb, op.cit., note 81, p.136

R.Brenner, Untersuchungen und Beobachtungen, Leipzig, Giesecke & Derient, 1868, pp.85-87

W.Erb, op.cit., note 81, p.145
therapeutic questions. The greater part of this article, however, was concerned with Benedikt's mounting criticism against Brenner and Erb. 

III.b. Zur galvanischen Behandlung von Augen-und Ohrenleiden. (July 1871)

Brenner's experiments and findings on the nervous acoustic reaction had provoked some opposition among electrical physicians and otologists. Schwartze, Bettelheim, Schwanda and particularly Moritz Benedikt denounced Brenner's research. On the other hand Hagen, Eulenburg, Hedinger and Erb submitted a host of affirmative observations in various medical journals supporting Brenner's results. Hugo von Ziemssen thus proclaimed in 1887 that sufficient evidence and confirmation had been accumulated in support of Brenner's theory "that made every principal doubt in the existence of the specific acoustic reaction inadmissible." 

Erb's second publication in electro-otriatric is mainly a defence of Brenner against a series of polemical articles published by Benedikt in the Wiener medicinische Presse in 1870. Erb fully endorsed Brenner's opinion that the induced aural sensations resulted from a direct electrical excitation and electrical permeation of the nervous auditory

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98 H.v.Ziemssen, op.cit., note 10, p.121

99 M.Benedikt, Wiener.med.Presse, 1870, No.37-52
apparatus. He found it particularly difficult to comprehend how some electrical physicians could hypothesise that the provocation of aural sensations could be accounted for by a reflex-mechanism mediated by the trigeminal nerve.

I will briefly describe Erb's therapeutical observations and recommendations which illustrate his approach to electrotherapy in general. Again his publication does not claim to communicate anything new to the scientific reader, but rather wants to defend Brenner's claims and protect them against careless and "badly motivated" attacks.

Moritz Benedikt had opened up the entire question of electrotherapy of oculo-motor paralyses in 1864 and thus brought it to the forefront. Erb felt that some of Benedikt's results were rather astonishing, but nevertheless they needed to be put to the test. Since so far nobody else had come forward with any control examinations, Erb decided to present some of his case histories:

These are some observations on oculo-motor paralyses and on nervous affections of the auditory apparatus, which I decided to publish together, for they often appear in tandem in the same individual. I do believe that I should not hold back such observations, since particularly the specialists concerned do not seem to deal sufficiently yet with these questions.

Professor Knapp and Professor Becker "had been kind

100 W.Erb, op.cit., note 81, p.143
101 This thesis was defended by Althaus, Benedikt and Schultze.
102 W.Erb, op.cit., note 97, p.157
103 Ibid., p.157
enough" to refer some of their patients for electrical
treatment to Erb.
The majority of patients had been suffering from
"peripheral, probably rheumatic paralyses." They
usually responded well to electrotherapy as opposed to
patients suffering from centrally caused oculo-motor
paralyses. In those cases the negative response to
therapeutic attempts had often forced Erb to
discontinue galvanic treatment.

Erb's method always relied on the principle of
local treatment, i.e. the galvanic current had to be
applied to the seat of the lesion as directly as
possible. This required knowledge of the seat of the
disease in question. Erb had to admit that the present
lack of information concerning the seat of rheumatic
oculomotor paralyses made it difficult to develop a
therapeutic plan. The seat of the lesion was thought to
be either intracranial or intraorbital. Erb
therefore designed an approach which would allow for
both possibilities:

The current shall be directed transversely through
the anterior or posterior temporal region or through
the mastoid processes, with the anode attached on
the affected side.

He also followed Remak's and Benedikt's advice.

104 W.Erb, op.cit., note 2, pp.445-446: "the exact
seat of the lesion may be deduced in many cases...it may
be in the orbit (the three ocular nerves, the optic
nerve, the first branch of the trigeminus), or in the
middle cranial fossa (three ocular nerves and the whole
of the trigeminus), or in the posterior cranial fossa
(trochlear nerve, abduccens, facial, auditory etc.) or it
may be situated in the bulbar nuclear region, medulla,
owns, peduncle."

105 W.Erb, op.cit., note 97, p.157
They had recommended in such cases additional galvanization of the cervical sympathicus. The older Remak had frequently observed a beneficial effect of the anode once it was applied to the afflicted organ. Erb decided to attach the anode to the suffering part, but it also appeared to be beneficial to reverse the direction of the applied current:

Hardly anybody who is aware of our present lack of knowledge regarding rheumatic nervous and muscular diseases and the catalytic effect of the galvanic current will demand an explanation.\textsuperscript{106}

Erb used a Stöhrer Battery consisting of six to eight elements. The strength of the produced current was strong enough "to induce a slight hint of giddiness - but any stronger effect upon the brain was avoided."

Erb admitted that he did not quite understand why Remak had recommended concomitant galvanization of the cervical sympathetic nerve, since he could not register with certainty any beneficial side effect which would justify that specific approach. On the other hand for the patient's sake he did not want to omit a procedure recommended by an authority like Robert Remak.

Eventually Erb decided that the most effective method of application had to be the direct excitation of the paralysed muscles with the cathode.\textsuperscript{107}

I proceed thereby in such a manner that the anode is applied to the nape of the neck, whilst passing the cathode back and forth over the closed lids, near to the insertion of the muscles to be influenced for some minutes. I define the adequate strength of current...by the facial contractions induced with the cathode on excitation of the...facial

\textsuperscript{106} Ibid.

\textsuperscript{107} W.Erb, op.cit., note 2, p.449
nerve. Usually I choose such a strength of current which causes vivid contractions on excitation of the frontal branches of the facialis; then also a burning sensation develops on the lids, which becomes only in very sensitive individuals so strong that the strength of current needs to be reduced.\footnote{108}

The rationale behind his procedure was to make sure that the suspected lesion was located favourably in "a path of the densest part of the current." He had chosen the above described position of electrodes because he "believed that thereby it was most certain for the paralysed nerve and muscle to be hit directly by threads of current." Though he conceded that this resulted only in an imperfect and weak direct galvanization of the paralysed muscles "for the direct galvanic or faradic excitation of the ocular muscles was known to be impossible or only difficult to achieve".\footnote{109}

Erb denied the possibility that the reported cures brought about by this mode of treatment might have depended upon the initial irritation of the facial skin which triggered a reflex response mediated by the trigeminal nerve. Moritz Bendikt had argued initially that the acoustic nerve was stimulated via a reflex mediated by the trigeminus. Later he elaborated his theory and invoked a reflex via the sympathicus or a reflex mediated alteration of minute blood vessels in the immediate vicinity of the acoustic nerve. The main

\footnote{108} W.Erb, op.cit., note 97, p.158

\footnote{109} Ibid., p.158: "bekanntlich ist eine direkte Reizung der Augenmuskeln mittels des faradischen oder galvanischen Stromes mit Sicherheit gar nicht oder nur sehr schwer möglich."
gist of Erb's argument against the reflex theory was that it could not be proven whether the respective experimental arrangement used by the supporters of the reflex theory would not also allow for the current to reach the acoustic nerve directly: "So why resort to a complicated detour of a reflex when the direct excitation appeared to be more logical:"

Since nothing is known in physiology of an intimate reflex relation between the skin of the face and the external ocular muscles, therefore one should not expect them either under pathological conditions...it was usually about the obstructive interference with a centrifugal conduction path which was to be removed with electrical treatment.\textsuperscript{10}

Ten years later he admitted that he could not entirely exclude the possibility that a reflex mediated by the trigeminus might have been responsible for the allegedly positive results:

The possibility of such reflex influences is certainly not to be denied, but the facts to prove their existence are wanting. As far as I know, nothing is known of an intimate reflex relation between the facial skin and the ocular muscles. I have myself sought in vain to prove it by strong faradic irritation of the skin around the eyes, and in all my many attempts to induce dilatation of the pupil by means of irritation of the skin I have never been able to discover any movement of the external ocular muscles. I cannot, therefore, believe thoroughly in those reflexes, and must resign, however, unwillingly, this convenient way of combating ocular paralysis.\textsuperscript{11}

Finally Erb concluded his discussion of oculo-motor paralyses with an analysis of his own cases which he had submitted to electrotherapy. He had observed mainly paralysis of the abducens. All the cases of

\textsuperscript{10} Ibid.

\textsuperscript{11} W.Erb, op.cit., note 2, p.432 and p.450
rheumatic paralyses of the abducens appeared to be cured, but in centrally caused paralyses a cure had not been observed. Erb also recorded the successful treatment of two cases of oculomotor paralyses and two cases of paralyses of the musculus trochlearis. Rheumatic paralysis was normally cured very quickly and easily, particularly when the treatment commenced following soon after the onset of the disease. But he had to admit that there were still plenty of cases in which galvanic treatment remained ineffective.

Despite Erb's zealous campaign on behalf of Brenner, the question of the galvanic reaction of the nervous auditory apparatus remained unresolved.

Professor Hensen of Kiel remained sceptical:

The ear is not suited for the application of galvanic excitation, only few threads of current will reach the terminal apparatus or acoustic nerve. It is difficult to know what exactly is being excited by such experiments. Constant currents induce, namely as soon as the cathode is attached to the meatus, an aural sensation on make; however... disturbing concomitant effects cannot be avoided. Frequent attempts have been made to define certain rules according to which the healthy and possibly the diseased ear reacts, but they do not seem to have been sufficiently conclusive.112

Case history:

Rheumatic paralysis of the abducens, Franz J Kast, aged 34, engine driver, (referred by Prof. Becker), suffers from diplopia for ten days, apparently from a chill, right sided abducens paralysis present; the eye cannot be moved outwards beyond the middle line. Galvanic treatment: 8 cells, stabile, transversely through the temples, galvanization of the sympathetic, the cathode labile along the region of the rectus externus, the anode being on the left side of the neck. Immediately afterwards the eye could be moved farther outwards. After the fourth sitting the double images closer together, the eye able to be carried almost into the external angle. After 10 daily sittings: cure.
IV. Zur Pathologie und pathologischen Anatomie peripherischer Paralysen

The term 'reaction of degeneration' was first introduced by Wilhelm Erb:

Under this term...is included a regular series of quantitative and qualitative modifications of electrical excitability, which are exhibited under definite pathological conditions in nerves and muscles, being intimately related...with certain processes of tissue change (degenerative atrophy) occurring in the nerves and muscles together. This degeneration is characterised essentially by the diminution and loss of faradic excitability in both nerves and muscles, whilst the galvanic excitability of the latter remains unimpaired, is sometimes notably increased, and always undergoes definite qualitative modifications.\(^{113}\)

A great sensation was created in 1859 by Baierlacher's publication of a case of facial paralysis in which the facial muscles gave no reaction to the faradic current, but on the other hand responded inordinately to galvanism.\(^{114}\) This fact was not unknown before 1859. Similar observations had already been made by Halle, Onimus, Legros, Duchenne and Robert Remak in the 1840's.

Baierlacher's article in a Bavarian medical journal, however, had directed more widespread attention towards these facts and was followed by independent observations by Moritz Meyer, Brenner, Grünewaldt, Neumann, Ziemssen, Eulenburg to name but a few. They all had observed that these phenomena were to be found not only in rheumatic facial paralysis, but in

\(^{113}\) W.Erb, op.cit., note 2, p.176

\(^{114}\) Ibid., p.177
all forms of motor paralysis, especially those of traumatic origin, and in every nerve. It was often thought that there was no distinction to be made between the altered nervous and muscular response to the faradic and galvanic current.\textsuperscript{115}

Erb regularly sifted through the national and international medical literature and knew about reports on rheumatic facial paralyses. He had already made similar observations on patients with rheumatic facial paralysis, but was dissatisfied with the lack of progress regarding a "scientific pathology" of these paralyses. So far researchers had merely recorded the described phenomena without attempting to elucidate their origin and subsequent progress.\textsuperscript{116} What was missing hitherto was the exact description of the succession of morbid appearances from the onset of the paralysis. Above all nobody had so far inquired what were the therapeutic and prognostic implications of the observed phenomena?

Hence Erb set out to record in minute detail observations made with the aid of electrical examination on three cases of rheumatic facial and one case of traumatic ulnar paralyses from the onset of the disease. Clinical records were taken accurately over weeks in regular intervals.

\textsuperscript{115} Ibid., p.178

So far no literature exists which records the course of the alterations of excitability from the very first day of the paralysis in an orderly manner.\textsuperscript{117} (my italics)

All patients displayed a similar reactive pattern against electrical stimulation. His main conclusion was that nervous and muscular excitability and their alterations had to be differentiated clearly from each other and were not to be conflated. Simple it might be, but this fact had hitherto not been respected.

Initially faradic and galvanic excitability of the nerves vanished gradually. Direct muscular excitability also diminished against both types of current. The decrease of nervous excitability was sometimes preceded by a moderate increase in excitability for the first two days. Then a progressive uniform lowering of galvanic and faradic excitability set in. This made itself known by the retarded appearance of the minimal contraction and by the decrease of the maximal contraction.\textsuperscript{118} Nervous excitability gradually diminished so that by the end of the first week, or during the second, it had completely disappeared.

Excitability is seen to diminish more and more, so that of the end of the first, or during the second week it has so completely disappeared that the strongest galvanic or faradic currents, at least when applied superficially, are unable to effect the slightest contraction. The defect begins in that part of the nerve which is nearest to the lesion, and spreads rapidly to the periphery. In this respect

\textsuperscript{117} Ibid., p.557

\textsuperscript{118} W.Erb, op.cit., note 2, p.178
the nerve behaves in the same way to both
currents. Faradic and galvanic excitability recede in
the same ratio at once, and without any qualitative
change.\textsuperscript{119}

Erb observed that the condition of absolute
inexcitability varied in its duration. He suspected
that it depended on the causes of the paralytic lesion
(rheumatic, traumatic, section) from the duration and
intensity of its effect upon the nerve and from the
greater or smaller possibility of a restoration of the
nerve. The stage of complete inexcitability tended to
be short in milder cases that underwent rapid cure,
lasted a long time in severe affections and could be
permanently established in incurable cases.

The first signs of returning nervous excitability
appeared in some of his patients suffering from
rheumatic facial paralyses after roughly eight weeks,
sometimes it lasted over several months or years. In
animal experiments Erb observed that the phase of total
nervous inexcitability lasted in rabbits five to six
weeks following a crush injury of the ischiadic
nerve.\textsuperscript{120}

When the first signs of returning excitability
appeared they were gradually restored just as they had
disappeared very gradually. Rarely the nervous
excitability returned completely to its previous norm,
i.e. that which was displayed prior to the affliction.

\textsuperscript{119} Ibid., p.179

\textsuperscript{120} W.Erb, op.cit., note 116, p.565
One of his female patients (Mrs Gradolf) still displayed diminished nervous galvanic and faradic excitability 13 months after the onset of her rheumatic facial paralysis.

When the first signs of returning excitability appear, at the same time for both currents, but not until the repair of the lesion and reproduction of the nerve have made some progress. It is first to be seen in that part of the nerve next to the brain, and manifests itself by slow degrees towards the periphery, and it is a long time before it is re-established. These statements hold equally for both kinds of currents and without any qualitative distinction. In mild cases complete restoration is soon effected, but where the injury is more serious there remains an impairment of excitability for a longer or shorter time; and it is not uncommon in these circumstances to find the voluntary power completely re-established, while the electrical excitability of the nerves is undoubtedly defective.\textsuperscript{121}

With respect to the latter case Erb had sometimes observed that in some patients whilst inexcitability of the nerve still existed voluntary movements had been performed, i.e. voluntary power was restored while electrical excitability was still suspended.

Duchenne had already noticed this with faradic current in many instances.

It only means that the nerve at a particular stage is a good conductor of brain impulses but a bad one of electricity. This condition is usually of short duration, but it sometimes lasts for days and weeks, according to the gravity of the lesion, the rapidity of the cure and the distance of the point excited from the site of the lesion. Further consideration of this remarkable fact, which has often been discredited, leads to the conclusion that the conductivity of the impulse of the will to the muscle and electric irritability of the nerve are

\textsuperscript{121} W.Erb, op.cit., note 2, p.180
two distinct qualities and may exist apart.\textsuperscript{122}

During the very first days of the paralyses there was no marked alteration of direct faradic and galvanic muscular excitability. Towards the end of the first week since onset of the respective traumatic or rheumatic paralyses Erb noted a decrease of muscular excitability against both types of currents.

Against the faradic current...the muscle reacts almost exactly as does the motor nerve. Here, too, a constant decrease of excitability takes place, proceeding in the course of the second week, to its total disappearance. The strongest currents, at least when applied to the skin produce then no effect.\textsuperscript{123}

It was quite different with galvanic currents. In the first weeks, as before, a gradual loss of direct (muscular) galvanic excitability took place. However, during the second and third week of his observations the direct (muscular) excitability increased against the galvanic current but not against faradism.

But during the second week...this diminution is replaced by an increase of galvanic excitability, which with the lapse of a few weeks may reach a very high degree of exaltation, and exhibit also certain qualitative changes having reference both to the formula and mode of contraction. This increased excitability is quickly manifested. Very weak currents will suffice to excite the muscles. With 8,6,4 and at last even with 2 cells it is often possible to induce opening and closing contractions of considerable energy, while the current is so weak as hardly to affect the galvanometer and to produce no action in the corresponding muscle of the healthy side. Together with this increase of excitability there is a change in the mode of contraction, which becomes constantly more pronounced. Instead of the normal contraction, short and quick as lightning, it

\textsuperscript{122}\textit{Ibid.}

\textsuperscript{123}\textit{Ibid., p.181}
becomes slow and prolonged and even with comparatively weak currents passes into a stage of tetanus, which lasts as long as the stimulus continues. This sluggish contraction with little energy is especially characteristic of the reaction of degeneration, and is always present, so that it may be regarded as pathognomonic of this condition. The change in the nature of the contraction as well as the increase of galvanic excitability may be well shown where corresponding muscles approach each other at the surface, as to be reached by the same electrode, as, for instance, at the chin, in facial paralysis of one side. If an electrode be applied here, with each closure of the ascending current contraction occurs only on the paralysed side, the sound one remaining unaffected. If then this is excited, at each closure a short lightening like contraction occurs, followed after some delay by the sluggish protracted movement of the affected muscles. Not less remarkable than this change in the mode of contraction is the qualitative change in the law of contractions displayed at the same time. This depends especially upon the increasing force of the ACC. This soon becomes as powerful as the KCC, and in most cases it is considerably more so (ACC > KCC). Hence besides the sluggish contraction we have another important mark of the reaction of degeneration.\(^{124}\)

The very remarkable differences between the faradic and galvanic excitability of the muscles gave further incentives to investigate the reaction of degeneration. Neumann attributed the different behaviour of the paralysed muscles against induced and constant currents to the physical differences of currents produced by induction apparatus and galvanic batteries.\(^{125}\)

In 1868 Erb put less emphasis on the assumed dissimilar physical properties of the two types of currents (i.e. faradic and galvanic) but rather on the

\(^{124}\) Ibid., p.182

\(^{125}\) Neumann, *Deutsche Klinik*, 1864, Nr.7; W.Erb, op.cit., note 116, p.568; W.Erb, op.cit., note 2, p.186
duration of their impact:

one could only conclude that paralysed muscles almost completely lose their excitability against currents of short duration but maintain their excitability against currents of longer duration.\textsuperscript{126}

Twenty years later in his\textit{Handbuch der Elektrotherapie} he put it somewhat differently:

why it is that degenerated muscles lose the power of responding to currents of short duration, while they react in a more marked manner to those that last longer, has still to be discovered, and it is a question for physiologists to answer. Decidedly there are chemical and molecular changes in these muscles which must be investigated before any light is thrown on the matter.\textsuperscript{127}

The exalted and modified muscular excitability against galvanism persisted for some time and gradually diminished again, likewise did the mechanical hyperexcitability of the muscle, which had been observed during that stage.

But there is another phenomenon which appears during the gradual subsidence of the reaction of degeneration, and which certainly is intimately connected with these changes. I mean the increased mechanical excitability of the muscles...It can be seen in all cases...and the muscles are found to respond with an evident but sluggish contraction to any, even a very slight, mechanical stimulus. The best means of eliciting it is a gentle quick blow of a percussion hammer, or the finger, or mere pressure, or sudden extension by weight.\textsuperscript{128} (my italics)

\textsuperscript{126}\textit{W. Erb, op.cit., note 116, p.569}

\textsuperscript{127}\textit{W. Erb, op.cit., note 2, p.186}

\textsuperscript{128}\textit{Ibid., p.186 and W. Erb, op.cit., note 116, p.543}

Erb claimed priority over Hitzig's discovery of the increased mechanical excitability as a feature of the reaction of degeneration. E. Hitzig, 'Ueber die mechanische Erregbarkeit gelähmter Muskeln',\textit{Virchows Archiv}, November 1867, Vol.41, p.301
I want to draw attention once more to the observations which Erb made on either patients and or experimental animals during the course of the second and third week of his electrical examinations of peripheral paralyses.

Let us recapitulate: During the second and third week of his experiments the phase of indirect (nervous) inexcitability against galvanism and faradism coincided with an increase of direct (muscular) excitability to the galvanic current of the affected muscle. Erb wondered whether that particular finding might help to solve the riddle of Haller's muscular irritability. It occurred to him that the muscular excitability displayed during that period in the absence of any nervous excitability serving the muscle in question could well be a specific muscular excitability inherent to muscular substance only. Erb considered the pros and cons of that suggestion and concluded that a number of reasons spoke against that conclusion:

Firstly the abnormal excitability of the muscle had not been present immediately after the cessation of the nervous influence, rather it took over a fortnight to emerge; therefore it could not have been primarily inherent to the muscle.

Secondly the abnormal (hyper) muscular excitability continued to express itself after the nervous influence had been restored. This fact spoke against the idea that it was a specific muscular
excitability independent of nervous influence.

Thirdly and probably most importantly he had no firm evidence that the direct galvanic stimulation of muscular tissue had not also stimulated minute intact nerve fibre terminations in the muscle. He could not totally exclude the possibility that the assumed muscular stimulation had in fact been a stimulation of fine micro nerves in the muscle.

And last but not least the muscles which exhibited this form of temporary (hyper) excitability were affected by marked histological change which in itself could simply be the reason for the alteration of its behaviour. Even if one could safely exclude any nervous influence, one could still assume that muscular tissue acquired a particular muscular excitability due to a specific pathological anatomical alteration of its substance. Therefore it was inadmissible to draw any irrefutable conclusions regarding a potential specific irritability of the intact muscle.

As much as I am convinced of the existence of that specific irritability, the above reasons...are not suited as proof for its existence. They only speak indirectly for its actuality in as much as the pathological anatomical alterations do not cause a specific irritability [to come into existence] but merely increase or alter an already existing one.  

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\(^{129}\) W.Erb, op.cit., note 116, p.575
Whereas the first part of Erb's paper was aimed at an illustration of the exact succession of alterations of nervous and muscular excitability during the course of the disease, the second part was aimed at an interpretation and analysis of those changes.

Erb was intrigued by the corresponding pattern of reaction against galvanic and faradic excitation in rheumatic and traumatic paralyses. He had also observed the case of a young 22-year-old patient, Peter Schmieg, who suffered from terminal "pneumophthisis" complicated by caries of the left petrous bone and mastoid bone with an almost complete left-sided facial paralysis. Soon afterwards the patient died. A histological examination of the diseased facial nerve, which had partly been visible through the hole created by the putrid abscess behind the ear, revealed "marked anatomical changes." Erb wondered whether those histological changes were somehow related to the alterations of excitability which he had previously recorded in patients suffering from rheumatic facial and traumatic paralysis. Peter Schmieg had also displayed some signs of altered nervous and muscular excitability but had been too ill to undergo a full electrical examination.

Therefore Erb decided to reproduce traumatic paralyses experimentally in animals observing their progress and examining the injured structures histologically. To that end he either squashed or
severed ischiadic nerve preparations of frogs and rabbits.¹³⁰

I invested a lot of labour in the question of the anatomical causation of the connection between the nervous lesion and the subsequent alteration in nerves and muscles; I aimed to investigate how the process proceeded locally, whether it stood in direct connection with the local inflammation, caused by the crush injury.¹³¹ (my italics)

He succeeded in recording results - mainly in the rabbits - which corresponded exactly with the patterns observed in his patients. The anaesthetized animals had been inflicted with a circumscribed bruise or crush injury to both their ischiadic nerves. Then Erb observed the resulting paralysis and followed its progress by examining the affected nerve and its innervated (calf) muscles electrically. Shortly after onset of the paralysis he recorded a decreased nervous and muscular excitability against both currents.¹³² During the second week the muscles displayed hyper-excitability against mechanical stimuli and the galvanic current with a qualitative alteration of the law of contraction. All these alterations slowly resolved afterwards.¹³³

The majority of experiments were performed by

¹³⁰ Ibid., p.46
¹³¹ Ibid., p.55
¹³² W.Erb, 'Beiträge zur Pathologie und pathologischen Anatomie peripherischer Paralysen,' in Zentralblatt f.d.med. Wissenschaft, 1868, Nr.8
¹³³ J.Ibeling, 'Wilhelm Erb und seine Bedeutung für die Neurologie', M.D., Ludwigs-Maximilian-Universität München, 1940, pp.5-37, p.14
traumatising only one nerve initially. After a short period of time (circa ten days) a further second trauma was inflicted upon the corresponding contralateral nerve. As soon as the nerve, which had initially been injured, showed signs of recovery, i.e. spontaneous movements in the affected dependent limb, the animal was killed and the nerves and muscles of both sides subjected to histological examination. In rabbits he observed the first voluntary movements around the twenty second to twenty-fifth day following the injury. This crucial period (day 22-day 25) was interpreted as a stage in which considerable nervous regeneration must have occurred "for a propagation of the Willenserregung to the muscles had been possible; therefore voluntary movements occurred." The anatomical specimen from the contralateral side served as control sample, since it stemmed from the injured side which had not yet shown any signs of recovery (restoration of movement = regeneration of nerve).

Immediately after the death of the experimental animal the "sufficiently regenerated" nerve was stimulated electrically, mechanically, chemically and thermically above and below the lesion. The same was done with the contralateral control specimen. Electrical stimulation above the lesion of the regenerated nerve resulted in contraction; the same stimulus, i.e. stimulus of the same strength of

134 W.Erb, op.cit., note 132.
current, applied below the lesion resulted in no or markedly feeble contractions. There only stimuli of greater strength (stronger currents) resulted eventually in a weak contraction. Most electrical stimuli which were applied to the control specimen did not result in any contraction if the specimen was examined immediately after the injury had been inflicted upon the nerve, i.e. no time had been available for a possible regeneration of the nervous tissue. Other control specimens had only been removed from animals after a longer time span. In other words these nerves remained longer in the animal but were excised before the animal exhibited any first signs of voluntary movements in the muscles served by those traumatised nerve. These nervous tissues had had some time to undergo moderate regeneration. As soon as these nerves were electrically stimulated above the lesion they required generally a weaker stimulus than those nerves which had served muscles already displaying voluntary movement. Once an electrical stimulus was applied below the lesion it required again a markedly stronger current to effect a contraction. Any mechanical stimulation above and below the lesion on nerves which had been allowed either no time, some time or a lot of time to allegedly regenerate, always resulted in marked contractions. The results of chemical and thermal stimulation were often inconclusive.
The immediate consequence of a traumatic nervous lesion was the tissue degeneration (Entartung) of the peripheral nerve. Following a crush injury the nerve fibres underwent the similar changes which had already been described in the past as a consequence of complete slashing of nerves.  

After only a few days (2-4) the medulla coagulated and the medullary substance arranged itself in a mass of solid particles and drops of myelin and fat. From the third week onward:

There appears a marked decline - most likely through resorption - in the fatty degenerated medullary substance. After extensive resorption nothing remained of the former fibres other than a small pale band with irregular undulating contours...this band consists of the original primitive sheath and the remaining axis cylinder.  

Erb concluded that the axis cylinder must have persisted. He thought that he was often able to see the axis cylinder resting in the primitive sheath (Primitivscheide) and he had apparently observed with the microscope during the stage of the regeneration of the nervous fibre that a new fibre would join such a small pale strip within the "Primitivscheide" (sheath of Schwann) which had to be regarded the axis cylinder. Above all his experiments had demonstrated that even in markedly degenerated fibres conduction of Willenserregung (excitation exercised through volition)

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135 These had been described by Waller, Schiff, Lent, Hjelt, Neumann and many others; W.Erb, op.cit., note 116, p.57 and op.cit., note 2, p.187

136 W.Erb, op.cit., note 116, p.58
and the electrical excitation had been possible provided the lesion had been traversed by regenerated fibres. In those cases the conduction could have only occurred through the remaining axis cylinder:

For these reasons I became convinced that as a consequence of a crush injury to the nerve the axis cylinder persists in the peripheral nerve. The degeneration is hence restricted to the (nervous) medulla. The degeneration spreads in all cases from the seat of injury...towards the periphery...and reaches the smallest ramifications of the nerve.\textsuperscript{137}

Degeneration and subsequent regeneration progressed from the lesion towards the periphery. Erb felt at that moment unable to say anything precise about the manner in which the axis cylinder became altered at the lesion and which changes it underwent in order to regain its conductivity again.\textsuperscript{138} At the seat of injury the manifestations of an \textit{adhesive inflammation} of the neurolemma developed swiftly: swelling, cellular increase, thickening and scarring atrophy (shrinking) of the connective tissue.

Erb noted an increase of cellular elements in the neurolemma which resulted in its thickening and a consecutive (cirrhotic) hypertrophy of the neurolemma spreading to the finest branches across the cross-section.\textsuperscript{139}

Such a rigid envelope of tissue surrounding the nerve fibre...can only be detrimental to the

\textsuperscript{137} Ibid., p.59

\textsuperscript{138} Ibid.

\textsuperscript{139} Ibid., pp.60-61
regeneration of the nerve and must delay it.\textsuperscript{140} He was, however, convinced that this obstruction would gradually be overcome by metabolism (\textit{Stoffwechsel}) thus ensuring eventually a complete nervous regeneration.

The muscle tissue was also submitted to a thorough histological examination and analysis.\textsuperscript{141} The affected muscles invariably underwent a progressive degenerative atrophy. During the early days of paralysis Erb was unable to detect any significant histological changes in the muscle tissue. During the second and third week a gradual diminution in bulk of the muscular fibres themselves (atrophy) set in, which became increasingly prominent. The transverse striae became less pronounced and an increase of muscular nuclei took place. Erb also believed he had found evidence for an alteration of the contractile substance, possibly of chemical or molecular nature. This alteration of the contractile substance expressed itself in so far as the fibres displayed a greater tendency to undergo \textit{waxy degeneration}.\textsuperscript{142}

The changes in the muscular fibres were accompanied by a cellular infiltration and hypertrophy of the interstitial connective tissue, similar to that

\textsuperscript{140} Ibid., p.61

\textsuperscript{141} Ibid., pp.75-76

\textsuperscript{142} Initially Erb had hoped to explain the changes of muscular excitability with the phenomenon of \textit{waxy degeneration} and the subsequent growth of young muscle fibres. He was unable to prove any connection between those events.
which had been observed in the neurolemma.  

Then Erb attempted to relate the clinical findings, i.e. the changes of direct and indirect excitability, to the pathological anatomical findings, i.e. the histology of the injured nerve and paralysed muscles.

First a brief synopsis: He had found that the rabbits usually showed signs of first voluntary movements in their previously paralysed limbs around the 22nd to 25th day following the nervous trauma. This was interpreted as evidence for a certain amount of recovery of the nervous tissue at the site of lesion, for it indicated that a brain impulse must have been conveyed to the muscle. An electrical stimulus applied above the lesion also resulted in a contraction. The same stimulus applied below the lesion did not result in any contraction. Erb concluded therefore:

Whereas the conductivity of the nerve to any excitation was intact at the same time the receptivity of the same nerve for an electrical excitation was decreased or nil.  

It had also been observed that mechanical stimuli applied either above or below the lesion always resulted in marked response.

The histology at the site of the lesion (at the time of conduction) revealed the existence of small regenerated fibres with intact axis cylinder. The

\footnote{W.Erb, op.cit., note 114, pp.77-78 and W.Erb, op.cit., note 2, pp.192-193.}

\footnote{W.Erb, op.cit., note 116, p.70}
nervous tissue below the lesion revealed numerous regenerated fibres alongside degenerated fibres; the axis cylinders appeared intact, sometimes already enveloped by medullary sheaths, but the main parts of the medulla seemed destroyed:

**upper portion of nerve above lesion:**

- conductivity (voluntary impulse) present
- faradic excitability present
- galvanic excitability present
- mechanical excitability present
- axis cylinder intact or restored
- medullary sheath intact

**lower portion of nerve below lesion:**

- conductivity present
- faradic excitability decreased
- galvanic excitability decreased
- mechanical excitability present
- axis cylinder present
- medullary sheath mainly destroyed

Thus it appeared to be plausible that:

The conduction of the excitatory process in the nerve takes place through the axis cylinder.

The facts also suggested that:

the electrical excitation of the nerve was dependent on the presence of the medullary sheath and that the mechanical excitation was not necessarily dependent
on the preservation of the medullary sheath, but could arise in the axis cylinder only.\textsuperscript{145}

The same hypothesis was repeated twenty years later in the 1882 edition of his \textit{Handbuch der Elektrotherapie}:

I will not affirm, for I am not yet sufficiently satisfied of it, that this power of conduction belongs to the naked axis cylinder, while the other property marks the acquisition of a medullary sheath, and that in consequence the axis cylinder in the regenerated fibres must be considered the conducting part, and the medullary sheath as that which receives the electrical stimulus. This hypothesis seems to me very plausible.\textsuperscript{146}

Eulenburg had offered a different explanation for the same findings. Eulenburg hypothesised that the motor nerve was endowed with three different specific nervous energies (one of galvanic, one of faradic and one of voluntary excitability), which could be lost individually.\textsuperscript{147} Erb considered Eulenburg's hypothesis untenable since it made no distinction between the property of conductivity (of excitation) and of perceptivity to excitation. Erb related the nervous property of conductivity and the nervous perceptivity to an electrical stimulus to two different and distinct anatomical substrates.

However in a "certain sense" Eulenburg's hypothesis could not be dismissed as unjustified,

\begin{itemize}
  \item \textsuperscript{145} Ibid., p.71
  \item \textsuperscript{146} W.Erb, \textit{Handbuch der Elektrotherapie}, Leipzig, Vogel, 1882, p.194
\end{itemize}
since:

The possibility of excitation by different agents was associated with anatomically different sites of the nerve, whereas the conduction was only connected with one anatomical structure (axis cylinder).\textsuperscript{148}

A discussion "under which general pathological category" the aforementioned pathological processes "could be ranked" followed. Erb believed that contemporary pathology was still in a state of fermentation and flux. Thus the question posed could only be answered with difficulty:

Since the definition of general pathological processes and above all the anatomical and histological criteria used to make such definitions, were still unsatisfactory and inadequate, so that they could not easily be applied to every case.\textsuperscript{149}

The histology was reminiscent of chronic hypertrophic inflammatory processes which were often to be found in the connective tissues of numerous organs. Even some clinical facts would "fit the bill", namely the pain which patients often felt in the paralysed muscles.

Erb understood that the question was not yet definitely solved. Notwithstanding, he could not help being reminded of inflammation. He certainly wrestled with that particular problem of definition, being aware that "advocates of the strict definition of inflammation would have difficulties in agreeing with him, because an obvious inflammatory stimulus was missing." But in view of the fact that the concept of

\textsuperscript{148} W.Erb, op.cit., note 116, p.74

\textsuperscript{149} Ibid., p.79
neuroparalytic inflammation had not yet fully been expelled from science, he felt justified in voicing his opinion. His 'pro-inflammation bias' was further vindicated by recent reports from Eulenburg and Landois from Vienna which supported the concept that "a series of inflammatory processes could purely be interpreted as vasomotor neuroses".\textsuperscript{150}

Erb was much more interested in the question of the causal relationship between these histological changes with the initial injury. A choice of viable explanations had to be scrutinized.

It was conceivable that an inflammation precipitated locally "by the operation itself" had spread from the seat of lesion. In Erb's opinion three reasons spoke against the "spreading of the inflammation from the seat of the lesion":

1. It is almost inconceivable that an irritation, which stemmed from a comparatively insignificant operation should propagate itself with such consistency across an entire extremity.

2. even if it were the case, such a distribution per contiguitatem would require a certain amount of time; yet also the more distant muscles at the foot always displayed the characteristic alteration almost contemporaneously with the altered muscle tissue closer to the lesion

3. such a transmission of an inflammatory irritation should spread uniformly to all sides (upwards and downwards): yet immediately above the lesion the nerves appear completely unaltered.\textsuperscript{151}

He believed it was much simpler to assume that

\textsuperscript{150} Ibid., p.80

\textsuperscript{151} Ibid., p.81
vasomotor nerves mediated the correlation between nervous lesion and the subsequent anatomical alterations in the connective tissue. To be precise Erb assumed a paralysis of vasomotor nerves, which would initiate a cascade of events resulting eventually in hypertrophy of the connective tissue:

It has frequently been demonstrated that such vasomotor nervous paths are contained in the large nerve trunks and that dissection of the latter results therefore in marked vasodilatation and subsequent rise of temperature. It is conceivable that as a consequence of a nervous lesion, akin to Cohnheim's observations on inflammation, that a migration of colourless blood corpuscles, which form the cellular aggregates in connective tissue, takes place. Furthermore as a consequence of the increased transudation of nutritive material from the hyperaemic vessels a hypertrophy of the connective tissue develops.\(^\text{152}\)

It posed greater difficulties to explain the mechanism by which the histological alteration of the muscular fibres\(^\text{153}\) and the degeneration of the medulla had been induced. Erb suggested "direct trophic effects of nerves" which must have generated those changes:

The suspension of the connection with the central organ or at least specific parts of it, provokes the...alterations in the muscle fibres akin to the degeneration of the nervous medulla.\(^\text{154}\)

He considered also the additional possibility that as a consequence of the degeneration of the sheath of the medulla substances were produced which acted as

\(^{152}\) Ibid., pp.80-82

\(^{153}\) atrophy, swelling of nuclei, alteration of contractile substance

\(^{154}\) W.Erb, op.cit., note 116, p.81
chemical irritants to the adjacent muscle and connective tissue, thereby enhancing the inflammatory processes. He dismissed it without further explanation quite authoritatively as unfounded.

Having expressed a preference for a "direct nervous influence upon trophic processes (Ernährung), akin to the nervous impact upon secretion and contraction", Erb wondered how the trophic influence might be conveyed to the muscle fibres. Whether the trophic "influence" reached the muscle through the same pathways which transmitted the motor impulse or whether the trophic impulse was communicated by different paths, i.e. vasomotor, or through unique trophic nerves remained an unsolved problem. Further experiments were regarded as helpful and desirable.

Erb envisaged experiments designed to paralyse vasomotor and potential trophic nerves separately so that the consequences could be observed for each case. Control experiments should then be set up in which only the "motor conduction" should be disrupted whilst at the same time vasomotor and trophic routes should be kept intact. Unfortunately such experiments were not likely to be conducted at the present stage, for anatomical knowledge was still lacking regarding the location of vasomotor and motor pathways in the central organ.\textsuperscript{155}

\textsuperscript{155} Since Stilling's and Claude Bernard's research it was known that vasomotor nerves were contained in the anterior roots of the spinal cord nerves.
Only clinical observation would be able to depict suitable cases or already known disease pictures which could be related to those aforementioned ideas. Erb had a specific form of disease in mind: progressive muscular atrophy.

Latest clinical and particularly therapeutic experiences urge us to accept...the opinion that progressive muscular atrophy is caused by an ailment of pathways located in the Sympathicus. It seems that the trophic disturbances of the muscles are quite like the ones found in rabbits as a consequence of traumatic paralysis. The motor conduction of the nerves and their electrical excitability remains preserved as long as there are muscle fibres which are able to contract.

Another disease offered a suitable example with the reverse characteristics, i.e. cerebral paralyses (hemiplegia).

Evidently in the case of cerebral paralyses the motor conduction is disrupted, whereas vasomotor and trophic paths are intact and subsequently no significant trophic disturbances and no disturbances of electrical excitability emerge in the paralysed nerves and muscles.\textsuperscript{156}

Erb had to admit that all this was mere conjecture: "though in the light of the facts such assumptions were simply forced upon one's mind." He was convinced that he had excluded the possibility of the inflammatory process being propagated per contiguitatem from the seat of the lesion. Also the concept of neuroparalytic inflammation had not entirely been rejected from pathological science. Therefore the relationship between the nervous lesion and the

\textsuperscript{156} W. Erb, op. cit., note 116, p. 82
subsequent anatomical nervous alteration (of inflammatory nature) could only be explained by a paralysis of vasomotor and probable trophic nerves.\textsuperscript{157}

I want to add a few words regarding the manner in which Erb exploited electricity in his research: I conclude that his investigation on the 'Reaction of Degeneration' epitomises in many respects his experimental electrical practice: Following personal clinical observations at the bedside or in the dissection room or after having carefully scrutinised current medical literature, Erb designed experiments in order to seek an answer to a specific question he had formed as a result of his clinical experience as was the case with rheumatic facial paralyses. Alternatively he decided to conduct experiments in order to scrutinize a conclusion drawn by a fellow researcher as was the case with Brenner's work on the nervous auditory apparatus.

Erb adhered to Virchow's concept of a natural scientific method in medicine. He partly received his answers from bedside observations where nature had indeed performed her own experiments and partly from the animal experiment in the laboratory.

Erb conducted pathological-anatomical and pathophysiological experiments or a combination of both. In the first type of experiment a pathological lesion was artificially inflicted upon the experimental

\textsuperscript{157} Ibid., p.83
animal and subsequently a tissue sample was examined macroscopically and histologically. In the latter kind of experiment an operation was conducted on the living animal, for example the division of a nerve, and the ensuing organic alterations were documented and analyzed. Erb compared experimental results with pathological cases, in a reciprocal movement between physiology and pathology. In experiments such as the aforementioned on the 'Reaction of Degeneration' Erb adapted electricity to the task of analyzing normal and altered nervous and muscular tissues. Electricity became thus also a means of diagnosis and differential diagnosis. This is, however, hardly a novel employment of medical electricity. Francis Schiller is correct when he claims that "Erb's work and fame consisted mainly in an extension of Duchenne's."\(^{158}\)

For all its technical inventiveness, Duchenne's major innovation...was his adaption of medical electricity to the task of analyzing normal and abnormal bodies.\(^{159}\)

In advertising the natural scientific method Virchow frequently invoked metaphors which stressed its democratic character. Schmiedebach analyzed Virchow's experimental practice and compared it with the way in which Ludwig Traube (1818-1876) conducted and

\(^{158}\) F.Schiller, op.cit., note 33, p.8

communicated his experimental research and results. Schmiedebach characterised Virchow's experimental practice as rather individualistic and autocratic in comparison with what he dubbed Ludwig Traube's more collective (republican) approach. Traube routinely mentioned a host of witnesses, colleagues and mechanics which had contributed in their many ways to set up an experiment. Traube often encouraged active dialogue by precisely explaining the applied method. On the other hand Virchow often merely reported his experimental results without detailed account of chosen methods or any mention of possible alternative interpretations other than his own.\textsuperscript{160}

Erb's experimental strategies and the manner in which he communicated them to the medical community were more akin to Virchow's individualistic style. I am only aware of one instance where Erb has mentioned witnesses.\textsuperscript{161} Admittedly he critically studied and scrutinized his own results, but this was always a self-appraisal. Erb himself thought of possible objections and queries questioning the results of his investigations in order to dismiss or accept them. There is certainly an element of subjectivity in it. On the whole the rhetoric and tone of his written accounts

\textsuperscript{160} H.P.Schmiedebach, 'Pathologie bei Virchow und Traube', in M.Hagner & H.J.Rheinberger (eds.) \textit{Die Experimentalisierung des Lebens}, Berlin, Akademie Verlag, 1993, pp.116-134

\textsuperscript{161} W.Erb, op.cit., note 5, p.518
is authoritarian. Only on one occasion throughout a series of experiments on traumatic nerve lesion did he raise rhetorically the question whether the results and observation produced with animal experiments could be utilised in human physiology and then only to accept it at once:

There can be no doubt whatsoever, that...the results can unreservedly be transferred to the corresponding traumatic paralyses in humans.¹⁶²

Finally I would like to draw attention to an entirely different aspect of Erb's electrical investigations. Scanning through Erb's research papers prior to 1875 it becomes clear that he routinely tested muscles not only for their electrical excitability but always also for their mechanical excitability. The first was done with the aid of electrodes whereas the latter was usually performed with a percussion hammer:

But there is another phenomenon which appears during the gradual subsidence of the reaction of degeneration, and which certainly is intimately connected with these changes. I mean the increased mechanical excitability of the muscles...It can be seen in all cases...and the muscles are found to respond with an evident but sluggish contraction to any, even a very slight, mechanical stimulus. The best means of eliciting it is a gentle quick blow of a percussion hammer, or the finger, or mere pressure, or sudden extension by weight.¹⁶³ (my italics)

This demonstrates that the technique resorted to in eliciting the knee jerk, discovered in 1875 by Westphal and Erb independently of each other, was

¹⁶² W.Erb, op.cit., note 116, p.83

already standard practice amongst physicians interested in nervous and muscular disorders prior to 1875. Thus Finke's claim that the reflex-hammer, i.e. percussion-hammer, became an attribute of neurologists only from 1875 cannot be sustained.  

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Concluding Chapter

The heroic view that doctors in the past embraced science primarily because it made them better healers has long been challenged.¹ It is now being argued that physicians took up science as an ideal before it actually facilitated any effective medical therapy. Thus it is argued that rather the rhetorical uses of science enhanced the authority and status of the medical profession.

My thesis suggests a compromise between these two interpretations:

The concurrent perception of the potential of science was an extremely hopeful and optimistic one which seemed to be justified in the face of contemporary positive changes in medical therapy. The activation of electrotherapy during the early phase of the implementation of Virchow's natural scientific medicine was above all motivated by cautious expectations that medical therapeutics could be advanced and aided by basic science.

In the eyes of contemporary physicians this was a perfectly reasonable assumption. Admittedly "there was as yet no recognized symbol of the therapeutic potency of basic science, like diphtheria antitoxin in the mid

Erb and his colleagues, however, had already witnessed substantial changes in drug therapy. At the beginning of the century alkaloids were still unknown, by mid-century chemically manufactured morphine derivates had been introduced into medical therapy utilising their narcotic effects or as in the case of apomorphine as an emeticum. Contemporary texts often celebrated the introduction of chloralhydrate into drug therapy by Liebreich in 1869 as a tangible sign of therapeutic progress. Likewise physicians expected similar progress in the field of non-pharmaceutical medical therapy and turned their attention to the promotion of electricity, gymnastics, air, water and diet.

Part of the thesis followed Erb's assessment by demonstrating that, particularly after the late 1850's and during the 1860's, electricity was perceived as part of viable medicine. In the wake of du Bois-Reymond's and Pflüger's research some new theoretical understanding of the relationship between electricity and the nervous system had emerged. During this era "every electrotherapist tempted by the progress of physiology, consciously or unconsciously conceived some

^ Ibid., p.459

^ A.Eulenburg, 'Ueber den Entwicklungsgang der Pathologie und Therapie im gegenwärtigen Jahrhundert', Wiener Klinik, 1876, Heft 1, Jahrg.2, pp.1-28, p.27 (Chloralhydrate was discovered by Liebig in 1832)
idea about the therapeutic action of electricity."*

The main intra-scientific rationale behind the therapeutic use of electricity hinged upon the assertion that electricity permeated all tissues. This notion relied heavily upon current physiological research into electrotonus which taught that the molecular state of nerves and muscles experienced an alteration under the impact of an electrical stimulus. The electrotonic theory enjoyed initially great authority. The older "primitive theory" that electricity cured by excitation continued to be accepted. The knowledge of the current's exciting and modifying effects upon nerves was, however, perceived to be "inadequate to explain all the cures which it has been made to work."5

These for the most part imply a lasting influence upon the nutrition of the body (molecular, chemical or histological modifications).6

Another theory, based upon the catalytic action of the current, was advanced by Robert Remak. As a result of his observations upon the curative effects of galvanism in states of inflammation, in contusion, extravasation, rheumatism and neuralgia, Remak concluded that these effects were brought about by alterations of the molecular structure and the

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5 Ibid., p.128
6 Ibid.
conditions of osmosis within the tissues themselves, and partly also by changes in the circulation and blood supply of the parts. Related to this notion was the hypothesis that electricity also exerted an influence upon trophic nerve fibres powerful enough to effect vital changes of the catalytic class in the tissues and organs over which they presided. Erb for example subscribed to the notion that trophic nerves "those channels of nutrition" existed, although he had to concede that their anatomical existence was not yet proven.

Clinical observation and physiological experiment alike point to the conclusion that there are separate trophic centres for...tissues...although the resources of anatomy and physiology have not yet sufficed to distinguish them.®

In addition to the initial enthusiasm for electrophysiological discoveries, electricity had a subtle, less tangible kind of attraction during the sober post-revolutionary era in Germany. The paraphernalia of an electrifying room and electricity itself discharged also a certain aesthetic appeal - they were related to the mechanisms of modern traffic and improved unimpeded communications between German speaking lands aspiring to unification. Applied electricity in the telegraph system was so useful in running the railways that contemporaries identified the

7 Ibid., p.129
8 Ibid., p.131
electrically operated telegraph with the nervous system of an animate organism. Conversely electricity was perceived to be a beneficial stimulus in managing the nervous system. The artificial electrical stimulus was supposed to facilitate the unhindered journey of the nervous impulse along the nervous path.

I highlighted Erb's political, social and academic background. Thus the initial part of the thesis examined the institutional setting at Heidelberg University. The latter has already been the subject of numerous historical studies. Borscheid illustrated the intimate relationship between chemical research programmes at the university and the government's perception that experimental chemistry would eventually help to alleviate the side effects of a recent agricultural depression and thus prevent political unrest among its famine stricken population.* Tuchman concluded that similar expectations led to the financing of a new chair of experimental physiology at Heidelberg a few decades later. State officials and university professors alike shared the conviction that science would eventually raise standards within medicine and improve medical therapy. Tuchman and Borscheid agree that experimental sciences received such strong support in Baden during the middle of the nineteenth century because of their perceived utility.

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I attach great importance to Tuchman's observation "that in 19th century Germany historical circumstance brought the new scientific method, meaning a hands-on approach, experimental/natural sciences and political liberalism together." I strongly agree with her, although I believe that her thesis did not expand satisfactorily on the causal relationship between those distinct phenomena. The main objective of the second chapter was to clarify how in Baden economic and educational reform, the latter stressing a distinct hands-on approach in higher education, were linked with liberal political aims of the ruling elite.

I also identified Heidelberg as the hotbed of a specific contemporary political movement which aspired to German unification under sole Prussian leadership - the kleindeutsche school. Baden's elite and above all the ruling Grand Duke were decidedly prussophile. This aspect has not been mentioned by Tuchman at all. My observation thus weakens her claim that Baden chose educational and economic reforms which did not reflect Prussian developments and aims. I conclude that Baden pursued these reforms in tandem with Prussia.

Erb's persona was deeply anchored in the mentality and culture of 19th century German Bildungsbürgertum. Erb has been depicted as "highly

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10 A. Tuchman, 'Science, Medicine and the State, The Institutionalization of Scientific Medicine at the University of Heidelberg', Ph.D., University of Wisconsin, 1985, p.7
characteristic for an entire epoch in medicine" and "as a typical representative of a specific age."\textsuperscript{11}

Three specific characteristics are frequently singled out by historians as emblematic for his era: realism, national consciousness and natural science. Erb's scientific outlook and method has consistently been described as sober, realistic and pragmatic. "His conscience was the conscience of facts, his confession was realism."\textsuperscript{12} Natural science and national consciousness played an important role in Erb's life as they did for the majority of likeminded contemporary physicians and scientists.

Erb was groomed during a period at Heidelberg University when many national liberal university lecturers were adopting \textit{kleindeutsche} aspirations. They were advocating national union under Prussian leadership. Among them were Erb, his teachers and colleagues including his mentor Nicolaus Friedreich, a personal friend of Virchow. Friedreich activated Erb's interest in neuropathology and taught him in the spirit of Virchow.

Part and parcel of Virchow's objective was to emancipate the clinical medicine from a rapidly institutionalising physiology. Virchow is, of course, well known as the founder of cellular pathology and

\begin{footnotes}
\item V.v.Weizsäcker, 'Wilhelm Erb', \textit{Dt.Med.Wschr.}, 1921, Nr.52, Jahrg. 47, pp.1595-1596, p.1595
\item Ibid., p.1595
\end{footnotes}
promoter of pathological anatomy, yet the clinician Virchow had received less attention. Therefore I stressed particularly Virchow's intellectual debt to J.L. Schönlein, who exerted like Johannes Müller a considerable influence upon the younger Virchow. Schönlein had opened up the Klinik as a shared space for empirical and theoretical knowledge: the composing and comparing act of making a diagnosis was the most substantial ingredient of Schönlein's methodology and became the focus of clinical enterprise.

Erb like many of his clinical colleagues stressed individualisation at the bed-side. This is not to be confused with the prescription of highly individualistic therapies, as for example practised by homeopaths. The process of individualisation as then understood by German naturwissenschaftliche physicians was essentially a continuation of Schönlein's classificatory approach, i.e. the phenomenological description of disease at the bed-side aided by post-mortem examinations, auscultation, percussion, chemical and microscopical examinations. Although electricity was promoted as a therapeutic agent by Erb and fellow electrotherapists, it was first and foremost applied as an analytical-diagnostic tool. This aspect of natural scientific electrotherapeutic practice has been discussed in chapter 10.

It is thus not surprising that Erb emerges above all as a nosologist. Individualisation at the bed-side
required meticulous note taking and constant comparison of symptoms, thus leading to the identification or composition of new neurological disease pictures.

I attempted to demonstrate the meaningfulness of medical reform after the failed 1848 revolution, for the divided medical profession was initially only united by a common political goal: national unity. Virchow successfully exploited these sentiments rhetorically by alluding to medicine as a construction site which could be built up only through teamwork. Virchow encouraged cooperation by engaging physicians in the Baconian process of collecting and comparing facts. This found its expression in the increasing cultivation of clinical casuistry among academic physicians. Of course his agenda had a further appeal because it conveyed a sense of fellowship and harmony to medicine which most physicians also wanted to see in national politics.

All of Erb's publications were based on a collection of case histories which he frequently recycled and related to the case histories of other authors. Even the "famous discovery of the patellar tendon reflex" is in his case arrived at by repeatedly

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browsing through old case notes, compiling and comparing the data and observations.

Virchow's aspirations inevitably struck a chord with German physicians, associated with national liberalism, yearning for national unity. Such an ambitious goal could be achieved only by disciplining physicians' demeanour and habit of mind in the first place: Natural scientific medicine like natural sciences was above all about the rigorous employment of the natural scientific method.

Under natural science we understand...also the conscious *insight into the method* which serves to enlarge the knowledge of organic and inorganic nature. (my italics)

Thus the scientific physician had above all to demonstrate that he was able to comprehend and cultivate the exact methods of science: In the case of Erb's medical practice, electricity permitted him to import scientific habits associated with the laboratory to the bed-side. It enabled him to demonstrate his mastery of scientific exactitude:

Once I have convinced myself of the accuracy of scientific facts by my own efforts and toilsome labour it is such a nuisance to have to think about the reasons why others who studied the same object arrived at negative results. After having assured myself of the extreme difficulty of galvanising the ear by way of numerous self-experiments and on many other individuals and after I also gained the conviction that it is possible with some patience and skill to reach consistently the same results also in healthy individuals, I cannot but express in the strongest terms my certainty that those who arrived at negative results either did not have the

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necessary patience or lacked in dexterity or resorted to wholly useless methods. With extensive exercise...everybody will be able to eradicate the repeated mishaps from his experimental results—provided, of course the willpower and required resolution exists in the first place.16

Scientific medicine was in the first place about rigor, hard labour, self-discipline and restraint. Electrotherapy and electrodiagnosis were time consuming and labour intensive. The precision and attention required throughout examination and treatment—as illustrated by the therapy of the acoustic nerve, were reflected in the meticulous note taking, representations of results in exhaustive tables and thorough presentation of clinical findings.

Furthermore electricity not only helped to analyze neuro-muscular disorders, it also served to translate pathological findings into visual images as has been illustrated with the 'Reaction of Degeneration.' It was thought that by electrically exercising diseased muscles and nerves their orderly function could be restored in accordance with the prevailing perception of disease as the "normal gone wrong."

By the same token the employment of electricity had a twofold pedagogical function: not only did the physician have to be able to master electricity but in doing so he had to learn to control himself to cope with the conventions and patterns of laboratory

routine, particularly also with its less attractive features such as the monotony of repeating failed experiments.

I hold it as indispensable for anyone who would practise electrotherapeutics that he be thoroughly acquainted with the action and strength of the currents he uses. Make experiments upon your own body; verify the law of contractions in different nerves; practise faradisation of all parts that are within your reach. Become familiar with the sensations which different current strengths produce...and learn how the senses, the skin, and the brain react to electricity. It is only in this way that the required certainty and precision can be acquired.17

One by-product of the current streamlining of surgical and medical education into one united medical profession was the "practical physician" (praktischer Arzt) who began to define himself by vocation rather than lifestyle and association with the upper social class. This development was prompted by a complex variety of causes but also offered a chance to continue a theme developed in Tuchman's thesis: the gradual encroachment of the hands-on approach into the academic sphere.

Academic achievement was no longer regarded as the result of exceptional talent but should also be available to the ordinary Bürger, provided he worked hard enough.

The introduction of tools and apparatus into medicine not only symbolized technological progress but also evoked associations with a craft or trade which

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17 W.Erb, op.cit., note 4, p.301
required manual dexterity and skill. Erb often alluded
to the 'tricks of the trade' in discussing the pitfalls
of difficult electrotherapeutic experiments and how to
avoid them.

In the preceding chapters I claimed that a
partial aim of educational reform was also to integrate
a generation of craftsmen and artisans who would
otherwise have been left unoccupied in the wake of
simultaneous economic reform, i.e the introduction of
occupational freedom. The latter had been regarded as a
necessary pre-condition for national union.

Parallel with these developments the idealistic
notion of Wissenschaft for its own sake and the
romantic, highly individualistic idea of Genius were
being dismissed and science was asked instead to mix
with ordinary people. Thus the introduction of utensils
into clinical medicine marked its having come down to
earth from the transcendent heights of speculative
medicine. Medicine was not only supposed to be
practised by ordinary people but also aimed at the cure
of commonplace ailments in common people. Erb and
Friedreich both understood therapy as the central task
of their professional role as physicians.

Despite Virchow's efforts to mediate between
theory and practice a certain friction between Klinik
and experimental physiology (rational medicine) can
still be discerned.

The move "back to the clinic" had already been
inaugurated by Johann Lucas Schönlein and continued under Virchow. Virchow was confident that clinical science had the potential to become an exact science but never dismissed the value of physiology. He was at pains to mediate between a healthy empiricism, bedside observation and rationalism. One less well known part of Virchow's objective consisted in the activation and renewal of clinical medicine.

Erb's electrotherapeutic practice illustrates the dialectic attempt to promote a partnership between theory and practice, empiricism and rationalism, the bed-side and the laboratory. Nevertheless, a mild friction between science and medicine remained.

Erb was above all a clinician, stressing systematic observation at the bed-side, the careful description of nosologically distinct diseases and the application of remedies. The arrow of his activity points from the bed-side to the laboratory: following a bed-side observation he conducted experiments in the laboratory. He never proposed to be a competent electrophysiologist - on the contrary he needed Helmholtz's assistance to interpret his findings as demonstrated in his examinations on electrotonus in man. Erb was constantly striving to base his electrotherapeutic practice on a rational theory and did not hide his disappointment when his electrotherapeutic results could not entirely be reconciled with physiological facts. Yet at the same
time he stressed the idiosyncrasies of the animate organism which could not simply be compared with dissected frog nerves stripped of their flesh in the laboratory. Erb always conceded that: "Electrotherapy is still a purely empirical science... yet physiological facts do serve as a good guide in planning therapy and therapeutic experiments."\(^{18}\)

Utmost importance, however, was attributed to the research conduct. The "correct" method by which a result was achieved legitimated its very scientificity.

Erb was by no means an original character, he did not intend to be one. His highly pragmatic attitude and the apparent lack of any stated personal beliefs or ideas suggest a seemingly unbiased researcher. This was the very intention of natural scientific physicians who claimed that they consciously parted from the allegedly ideological excesses of romantic speculative physicians by simply collecting and comparing facts.

Natural scientific electrotherapy demonstrates not only the attempt to direct and control the nervous impulse or to flush away obstacles in its path. Its practice illustrates above all the epistemological attempt to discipline and correct the mind, habit and willpower of the electrotherapist himself. The very operation of electro-medical apparatus forced the physician to tame his own passions by endlessly

repeating the experiments in an attempt to find consistent results and standardize medical electricity.

Contemporaries contrasted themselves with their natural philosophical forefathers. I put this down to their disappointment with their gifted "parents" who had nevertheless failed to fulfil their political aspirations. Yet on the other hand the natural scientific method as exercised in electro-therapeutic practice expressed a research maxim which had already been conceived by Johannes Müller.

H. Rheinberger identified Müller's fishing technique aided with a fine closely meshed net to recover plankton at the island of Helgoland as the quasi metaphorical step in which Müller managed to give a material form to this research maxim:

The endless repetition of collecting specimens thus made surprise possible which prevented him from hasty conclusion.\(^\text{19}\)

Erb abhorred jumping to any conclusions and thus frequently merely reported his findings or compared them with the accumulated data of others simply confirming what they had found. Although this was hardly fascinating or rivetting this was exactly the point of the exercise. Electrotherapy in the age of natural scientific medicine was not meant to be mesmerizing.

Postscript

After 1875 Erb focused his attention on the causal relationship between tabes dorsalis and syphilis, questions of medical education and the promotion of neurology as a medical discipline separated from psychiatry. Although he continued to support medical electricity as a valuable therapeutic agent he had to admit that it remained far from clear how electricity interacted with the human organism. Yet on the other hand Erb always insisted that the beneficial effects observed after application of electricity had to be explained by some still unknown organic mechanism and were not related to a possible psychological impact exerted by the therapist.
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