The combinatorics of tastes and humours in classical Indian medicine and mathematics

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Tuesday, June 20, 2000

Abstract. This paper explores some combinatoric problems which are treated in the literature of both āyurveda and of jyotiḥśāstra.

Keywords: combinatorics āyurveda jyotiḥśāstra Sanskrit India mathematics medicine

1. The problems according to medicine

The medical literature of ancient and medieval India is extensive. From its simple roots in earliest times, medical thought in India began to be formalized at about the time of the Buddha, and by the early centuries AD several major medical encyclopedias had been compiled. These compilations exerted a pervasive influence on all later indigenous medical writing in India and, through the works of da Orta (1563), van Rheede (1703) and Linnaeus (1748, 1753), on the early development of botanical science in Europe (Grove, 1995, ch. 2l).

There are two principle combinatorial problems addressed in this traditional medical literature of India, that of the six flavours (Sanskrit *rasa*) and that of the three humours or (Skt. *doṣa*).

1.1. PROBLEM 1: THE SIX FLAVOURS (*rasas*)

In the āyurvedic pharmacopoeia, every medical substance (which means in fact every substance: see Ah.9.10)[1] is assessed and classified according to four categories: *rasa*, *vīrya*, *vipāka* and *prabhāva*.[2] These mean something like: flavour, potency, transformed flavours, and special power. There are six flavours, two potencies (sometimes eight), three transformed flavours, and one special power. This classification system is the basis of traditional Indian pharmacology, and it gives rise to many combinations and categories of substances, enabling a physician to work out what medicinal substance best matches the features of the patient's ailment.

The six flavours (*rasa*) are sweet (*madhura*), sour (*amla*), salt (*lavaṇa*), bitter (*tikta*), pungent (*kaṭu*), and astringent (*kaṣāya*). The problem under consideration is to find how many possible combinations there

may be of these six items taken one at a time, two at a time, and so on until all six are taken together.

1.1.1. *Caraka*

The *Carakasaṃhitā*, probably the earliest of the surviving ancient Sanskrit medical encyclopedias, is one of the fundamental texts of classical Indian medicine, and is still studied by traditional practitioners today (Meulenbeld, 2000, 1a.105–15). In its chapter on the substances and flavours, the text states that there are sixty-three combinations of the six canonical flavours.[3]

> There are sixty-three types of them, according to substance, place, time, and special power. We shall now describe them:
>
> Substances having two flavours are fifteen because they combine sweet with sour etc., and sour etc. with the rest one at a time.
>
> Substances having three flavours are said to be twenty. The combination of sour etc., with sweet, sour, salt, and bitter, one at a time in numerical order, is combined with the rest, one at a time.
>
> There are said to be fifteen substances taking the flavours four at a time. In the first place, sweet and sour combine together with salt etc., one at a time. This pair make a combination with the remaining ones, one at a time according to the enumeration of the quadruplets of flavours. Sweet and salt together do the same, with pungent etc., one at a time. This pair make a combination with the remaining ones, one at a time. Sweet and pungent go the same. Sour and salt are combined with pungent etc., one at a time. These two combine with the remaining ones, one at a time. And sour and pungent combine with the remaining ones in the same way. Salt and pungent, pairing with bitter, join with astringent.
>
> They say that there are six which have five tastes because of being excluded one at a time.
>
> And there are six with one flavour, and one with all six flavours.
>
> Thus the sixty-three substances enumerated according to flavours have been explained.

In this passage, the text does not list every possible combination exhaustively, but rather tells us how many possible combinations exist for each particular grouping of flavours (cf. tables, p. 12 below).

1.1.2. *Suśruta*

However, the method of enumerating the substances according to all possible combinations of flavours was followed in another early medical work. The *Suśrutasaṃhitā* is an encyclopedia as long and important as the *Carakasaṃhitā*, perhaps dating from a slightly later period (Meulenbeld, 2000, 1a.350–52). The *Suśrutasaṃhitā* also treats this issue of the combinations of the *rasas* . But, in contrast to the *Carakasaṃhitā*, Suśruta's compendium not only gives a description of how to make the combinations, it actually works out each possible combination and lists them exhaustively.[4]

> In the doublets of the sequential combinations, the sweet flavour makes five combinations, and sour makes just four. The salt flavour makes just three, and the pungent two. Bitter combines with astringent. These are fifteen doublets.
>
> Thus: Sweet and sour 1, sweet and salt 2, sweet and pungent 3, sweet and bitter 4, sweet and astringent 5. These five follow by means of sweet. Sour and salt 1, sour and pungent 2, sour and bitter 3, sour and astringent 4. These four follow by means of sour. Salt and pungent 1, salt and bitter 2, salt and astringent 3. These three follow by means of salt. Pungent and bitter 1, pungent and astringent 2. These two follow by means of pungent. Bitter and astringent 1. This is the only one which follows by means of bitter. Thus the fifteen combinations of doublets have been expounded.

The passage continues with the enumeration of the other combinations for flavours taken three, four, five, and six at a time. It seems more than possible that this exhaustive enumeration is in fact an early commentarial gloss which has been absorbed into the main text of the *Suśrutasaṃhitā*, especially in light of the word *vyākhyāta* "expounded" which is used at the end of this passage. Be that as it may, the approach here is a brute-force listing of all possibilities.

1.1.3. *Vāgbhaṭa*

The famous Sindhi physician Vāgbhaṭa (fl. ca. AD 600), who lived only a century or so after the mathematician Āryabhaṭa, presents the *rasa*-combination problem at the end of his chapter on the flavours in his work *Aṣṭāṅgahṛdayasaṃhitā* (Ah.1.10). He says:

> There are fifty-seven appropriate combinations of the flavours, although sixty-three permutations can be distinguished in all. There are fifteen possible pairs of flavours, reducing them one at a time. With triples, there are ten with sweet flavour, six with sour, three with salt, and one with bitter. Taking them in fours, there are ten with the sweet flavour, four with sour, one with salt.

> Taking them in fives, there is just one with the sour flavour, five with the sweet flavour. There are six fivesomes, six individual flavours, fifteen types of pairs and foursomes, twenty types of triples, and a single substance with all six flavours. That comes to sixty-three.
>
> These distinctions of the flavours can be multiplied according to comparative and superlative gradations of flavours and sub-flavours until their total is greater than any number. They should be prescribed according to the requirements of the humours and medicines.[5]

It is noteworthy that although Vāgbhaṭa tells us that in actual usage only fifty-seven of these combinations are in use, neither he nor any other ancient author or commentator tells us which six combinations are not used.

1.2. PROBLEM 2: THE THREE HUMOURS (*doṣas*)

Classical Indian medicine describes many forms of illness in terms of the appearance of certain humoral substances in the wrong locations, or else as an excess of these substances.[6] The humours in question are wind (*vāta*), choler (*pitta*), and phlegm (*kapha* or *śleṣman*). These substances are located in the body and flow through it, and are closely implicated in all or almost all pathological processes.

1.2.1. *Caraka*

In a passage which suggests the application of quantitative methods to medical problems, the *Carakasaṃhitā* presents a problem concerning the three *doṣas* or corrupting humours, wind, choler, and phlegm.[7] The question is as follows: Given that the three humours may independently increase or decrease in various degrees, or remain steady, how many combinations are there of humoral imbalance? The bare answer is given that there are sixty-two such ailments. But a little later in the same chapter, the the *Carakasaṃhitā* lays out explicitly what these sixty-two combinations are.

In a decidedly opaque verse passage, the *Carakasaṃhitā* describes all the possible combinations, in a way which can be summarized as follows (the figures in parentheses refer to lines in Table I):

*Three humours increased (*sannipāta*):*

- there are six varieties caused by a superfluity of two or of one dominant humours (1–6);
- there are six caused by low, medium, or high superfluity of the humours (7–12);

– there is one caused by equal aggravation of all three humours (13);

*Two humours increased (*saṃyoga*):*

– when two humours are increased, there are six varieties caused by the increase of one, and three by equal increase (14–22);

One humour increased:

– there are three caused by the increase of a single humour (23–25).

Remaining possibilities:

– the same twenty-five combinations apply when the humours are diminished rather than increased.
– there are twelve combinations caused by taking increased and diminished humours together.[8]

This can be confusing, and a table is helpful to the reader wishing to understand what the *Carakasaṃhitā* is doing. Table I gives a tabular representation of the *Carakasaṃhitā*'s prose description of the first twenty-five combinations of humours in various degrees of superfluity. The combinations according to degrees of diminution would be the same (bringing the total to fifty combinations). Table II shows the combinations of increased, normal, and diminished humours.[9]

There appear to be several problems with the *Carakasaṃhitā*'s presentation, or at least areas of sub-optimal clarity. Some of the difficulties can be solved if we make the assumption that the threefold distinction of increased humour as low, medium, and high is applicable to all the categories in the table where this terminology is not actually used in the text, i.e., lines 1–6 and 14–19. Thus, if by "extra increase (*ulbaṇa*)", the text means a medium increase, then lines 1–6 are talking about combinations which exclude low humoral increase. Other translators have made this assumption. But this does not solve all problems, since there would remain numerous other possible combinations if low increase were tabulated. Thus, one might have a table similar to rows 1–3, but giving combinations of normal and medium humoral increases (instead of medium and high).

To take another problematic example, the text says that there is one combination for humours which exhibit the same level of aggravation (line 13 of Table I). But clearly there should be three: the humours could all be aggravated by low, medium, or high superfluity.

Table I. Caraka's humoral combinations for superfluity of humours (Ca.sū. 17.41–44).

Three humours aggravated

	vāta	*pitta*	*kapha*
1	●	●	○
2	○	●	●
3	●	○	●
4	●	○	○
5	○	●	○
6	○	○	●
7	↑	↑↑	↑↑↑
8	↑	↑↑↑	↑↑
9	↑↑↑	↑	↑↑
10	↑↑	↑	↑↑↑
11	↑↑	↑↑↑	↑
12	↑↑↑	↑↑	↑
13	⋆	⋆	⋆

Two humours aggravated

	vāta	*pitta*	*kapha*
14	●	○	
15		○	●
16	○		●
17	○	●	
18		●	○
19	●		○
20	⋆	⋆	
21		⋆	⋆
22	⋆		⋆

One humour aggravated

23	⋆		
24		⋆	
25			⋆

● = extra increase of a humour (*ulbaṇa*),
○ = normal increase of a humour,
⋆ = unspecified increase of a humour,
↑ = low (*hīna*),
↑↑ = medium (*madhya*),
↑↑↑ = high (*adhika*).

Again, it seems that the text's second type of combination, i.e., for aggravated and diminished humours taken together (Table II) is incommensurate with its previous types of combination. In this second type, degrees of superfluity or diminution are not being considered at all. Only unified values are tabulated: aggravated, normal, diminished. Using the earlier distinctions, then, each of the aggravated or diminished categories could be multiplied by three.

In short, the values described in the *Carakasaṃhitā* for humoral combinations appear unsatisfying due to an incomplete merging of two principles of enumeration, on the one hand the simple notion of superfluity or diminution, and on the other the notion of three degrees of superfluity or diminution.

Table II. Caraka's humoral combinations for increased and diminished humours taken together (Ca.sū. 17.44).

	vāta	*pitta*	*kapha*
51	↑	↔	↓
52	↓	↑	↔
53	↓	↔	↑
54	↑	↓	↔
55	↔	↑	↓
56	↔	↓	↑
57	↑	↑	↓
58	↓	↑	↑
59	↑	↓	↑
60	↑	↓	↓
61	↓	↑	↓
62	↓	↓	↑

↑ = increase (*vṛddhi*),
↓ = diminution (*kṣaya*),
↔ = equality (*sama*).

1.3. SUŚRUTA

In the *Suśrutasaṃhitā* passage noted earlier which enumerates all the combinations of flavours (*rasas*), an enumeration of the humours (*doṣas*) is also mentioned.[10] A similar enumeration is given in another passage where the text is describing how inflamed humours spread through the body in various combinations.[11] A point of interest in these texts is that reference is made not to sixty-two combinations of humours (*doṣas*), but to *fifteen*. This is a far simpler version of events than that of the *Carakasaṃhitā*. The combinations are characteristically spelled out individually in full by Suśruta, and are summarized in Table III.

Even more noteworthy is the fact that Suśruta's scheme is only correct for *four* humours, not for three. There are, of course, only seven ways of combining three items. But there are fifteen ways of combining four. And if we turn to the chapter in the *Suśrutasaṃhitā* on wounds, where this topic is taken up in detail, we find that indeed, Suśruta intends us to consider four humours: wind, choler, phlegm, and blood (*śonita*)![12] This is an interesting issue for medical historians.

Table III. Suśruta's combinations of four humours.

	vāta	*pitta*	*kapha*	*śonita*
1	⋆			
2		⋆		
3			⋆	
4				⋆
5	⋆	⋆		
6	⋆		⋆	
7		⋆	⋆	
8	⋆			⋆
9		⋆		⋆
10			⋆	⋆
11	⋆	⋆		⋆
12	⋆		⋆	⋆
13		⋆	⋆	⋆
14	⋆	⋆	⋆	
15	⋆	⋆	⋆	⋆

⋆ = presence of a humour.

The the role of blood in āyurveda an important topic, and its acceptance as a humour on a par with wind, bile, and phlegm points to a period in Indian medical history before the rigid dogmatism of the three-humour doctrine became firmly established to the exclusion of any other view.[13] Furthermore, the idea of blood as a fourth humour immediately raises the idea of putting āyurveda into some sort of relationship with Greek traditions of medicine, which accepted blood as a humour at an early period.[14]

To sum up the situation in the Sanskrit medical literature, the authors demonstrate a knowledge of certain combinatorial problems, and they know their solutions. They seem to be arriving at the solutions through an iterative process of evaluating all terms individually.

1.4. VĀGBHAṬA

In his *Aṣṭāṅgahṛdayasaṃhitā*, Vāgbhaṭa gives a summary of this problem in which he broadly follows the *Carakasaṃhitā* scheme of sixty-two combinations, rather than the simpler scheme of the *Suśrutasaṃhitā*.[15]

2. The problems according to the mathematicians

Amongst early Indian mathematicians, Āryabhaṭa did not treat of combinations and permutations. However, several other authors did so, and have made important contributions to the history of this branch of mathematics.[16]

Varāhamihira (fl. ca. 550) mentions combinatoric problems in his *Bṛhatsaṃhitā*[17] and again in his *Bṛhajjātaka*.[18] In the former work, which is primarily a collection of omens, Varāhamihira discusses the problem of making perfumes.[19] He is much exercised by the issue of how many different perfumes can be constructed from a given number of aromatic ingredients, clearly a matter of commercial importance. Varāhamihira gives an algorithm for calculating the number of possible subsets of n ingredients taken k at a time.[20] It is a somewhat lengthy procedure which involves creating k series of numbers, each one derived by cross-addition from the one before. The results may be read off sequentially from these number series.[21]

In the *Bṛhajjātaka*, Varāhamihira makes reference to a combinatoric algorithm in the context of calculating the numbers of planetary configurations (*yogas*), but he does not specify details. The presumption may be made that he is referring to the algorithm he described in the *Bṛhatsaṃhitā*.[22]

Thus we see that an algorithm for calculating combinations was known to Varāhamihira. However, he did not apply his methods to our medical problems.

Brahmagupta, who was born in Rajasthan in 598, and completed his *Brahmasphuṭasiddhānta* in 628 (Pingree, 1981, 21, 57), deals with the combinatorics of syllables in metrics in chapter 20 of this work (Kusuba, 1993, 85–6). But he does not take up the medical problems.

Let us turn, then, to the those mathematicians who first engaged with the medical problems we have been discussing.

2.1. PROBLEM 1: THE SIX FLAVOURS (*rasas*)

2.1.1. *Śrīdhara*

Śrīdhara was an important mathematician who flourished probably in the 8th century, and whose works are only imperfectly transmitted to the present (Pingree, 1981, 58).[23] In his *Pāṭīgaṇita*, Śrīdhara says,

> To prepare an ointment with two flavours, one should add the earlier [flavour] to the later [flavours] successively. For an ointment with three or more flavours, one should add the earlier flavour to the combinations of the other flavours which do not have the previous flavour.[24]

This is the earliest mention so far discovered in the mathematical literature of the medical problem of combining flavours. Note that Śrīdhara is describing the possible combinations paradigmatically. He is concise, but he does not present a general algorithm.

2.1.2. *Mahāvīra*

A combinatoric *algorithm* for this problem was first presented by the Jain mathematician Mahāvīra (fl. 9th century).[25] In his chapter on mixed problems, he says:

> Beginning with one and increasing by one, let the numbers going up to the given number of things be written down in regular order and in the inverse order (respectively) in an upper and a lower (horizontal) row. (If) the product (of one, two, three, or more of the numbers in the upper row) taken from right to left (be) divided by the (corresponding) product (of one, two, three, or more of the numbers in the lower row) also taken from right to left, (the quantity required in each such case of combination) is (obtained as) the result.
>
> Tell (me) now, O mathematician, the combination varieties as also the combination quantities of the tastes, viz., the astringent, the bitter, the sour, the pungent, and the saline, together with the sweet taste (as the sixth).[26]

Mahāvīra's algorithm works as follows. If you want to know how many possible combinations there may be of six items (for example the flavours), write them in ascending order, increasing one at a time, and divide each number by the same sequence in decreasing order:

$$\begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 5 & 4 & 3 & 2 & 1 \end{array}$$

Then, the number of possible combinations of a single flavour can be read off by taking the first fraction from the right,

$$\frac{6}{1} = 6$$

I.e., there are only six ways of taking the flavours one at a time.

The number of combinations when the flavours are taken two at a time is given by taking the first two fractions from the right,

$$\frac{5}{2} \times \frac{6}{1} = 15$$

There are fifteen ways in which six flavours may be combined two at a time.

Simlarly, for groups of three flavours there are $\frac{4}{3} \times \frac{5}{2} \times \frac{6}{1} = 20$ combinations; for groups of four there are $\frac{3}{4} \times \frac{4}{3} \times \frac{5}{2} \times \frac{6}{1} = 15$ combinations; grouped in fives there are $\frac{2}{5} \times \frac{3}{4} \times \frac{4}{3} \times \frac{5}{2} \times \frac{6}{1} = 6$ combinations; and finally, there is, of course, only one way of taking all six flavours at once. This adds up to a total of 63 possible ways of taking the full range of flavours in different combinations.

In contemporary notation we can express this as follows. Let the number of combinations of n items taken in groups of k at a time be C. This may be expressed as:

$$C_k^n = \frac{n(n-1)(n-2)\cdots(n-k+1)}{k!}$$

Mahāvīra calls this the *prastārayogabheda sūtra*, or the rule for the variety of the of methods of laying things out, and he provides other example problems based on making necklaces out of various kinds of jewels, on making garlands out of various flowers, and on the possible combinations of heavy and light syllables in a poem.[27]

2.1.3. *Bhāskara II*

The problem of the *rasas* is also mentioned in the famous *Līlāvatī* by Bhāskara (b.1114, d. after 1183).[28]

The *Līlāvatī* describes the general rule of writing ascending and descending fractions to produce the numbers of combinations of items in the same manner as Mahāvīra. However, Bhāskara changes the order of the fractions, so that the top line of figure counts down, the bottom line counts up, and the fractions are picked off from the left rather than the right:

$$\begin{array}{cccccc} 6 & 5 & 4 & 3 & 2 & 1 \\ 1 & 2 & 3 & 4 & 5 & 6 \end{array}$$

He refers briefly to the use of this technique in prosody, in architecture, in music, and in medicine.[29]

2.2. PROBLEM 2: THE THREE HUMOURS (*doṣas*)

Unlike the flavours (*rasa*) problem, the humours (*doṣa*) problem does not seem to have attracted the attention of the mathematicians.

If we posit that the *Carakasaṃhitā* was the first text to frame the combinatoric problem concerning humours, then perhaps it was the difficulties and lack of clarity mentioned above which caused the mathematicians not to take up this particular problem as one of their standard examples, but to restrict themselves to the more straightforward problem of combining the flavours.

3. Discussion

Clearly Caraka, Suśruta, Vāgbhaṭa, and other medical authors were aware of the *results* of the combinatoric problems relating to flavours and humours. Similarly, in the arithmetical literature the particular problem about the medical categories of flavour is explicitly cited from Śrīdhara's time onwards.

But whether the medical authors actually knew the particular algorithm used by Mahāvīra and Bhāskara is a more difficult question. In the medical texts, the authors deal with the combinations paradigmatically rather than computationally. Vāgbhaṭa, for example, first describes fifteen pairs, "reducing them one at a time". This suggests that he is looking at the problem rather visually, and perhaps laying out all the possibilities at length. If we represent the flavours by the numbers 1...6 (say that 1 = sweet, 2= sour, 3 = salt, 4 = bitter, 5 = pungent, and 6 = astringent), then for Vāgbhaṭa's first collection, the pairs, he might have had before him an arrangement something like the following:

sweet	*sour*	*salt*	*bitter*	*pungent*
16	26	36	46	56
15	25	35	45	
14	24	34		
13	23			
12				

Looking at triplets, Vāgbhaṭa's description apparently presents the following arrangement:

sweet	*sour*	*salt*	*bitter*
126	236	346	456
125	235	345	
124	234	356	
123	246		
136	245		
135	256		
134			
146			
145			
156			

And similarly for the other combinations of flavours in groups of four, five, and six, until the total of sixty-three combinations is reached.[30] Caraka works with the same underlying model.

This form of laying out the possible combinations of the flavours is essentially identical to that described by the mathematician Śrīdhara, and shows no evidence of a knowledge of Mahāvīra's algorithm.

4. Conclusion

The evidence above seems to show that the medical authors had understood the concept of combinatorics, but that they had not developed or were not aware of algorithms for producing results. These algorithmic methods seem only to have been used amongst the mathematicians from Varāhamihira, Mahāvīra, and Bhāskara onwards. Varāhamihira had an early form of algorithm which appears rather clumsy to use in practice. Mahāvīra introduced (or at least was an early adopter of) a delightfully straightforward technique and was also the earliest author so far identified to use the medical problem of the flavours as an example of this algorithmic technique.

This shared set of problems in the medical and mathematical traditions in India illustrates how pre-modern scientific traditions in India sometimes interacted and cross-pollinated. It would be very nice if a late medical author could be found who mentions Mahāvīra's algorithm in the context of the *rasas*. Another of the ancient sciences which the medical authors occasionally used was Pāṇinian grammar, which is quite as complex, in its way, as Indian mathematics. This science too was known and used by the ancient authors and especially medieval commentators, albeit in a simple and somewhat generic manner.[31] The mathematicians, for their part, draw problems and examples from a wide range of life situations, not only from medicine, but also from the digging of wells to the arrangement of the syllables in poetry and the notes in music.

Notes

[1] Abbreviations used in this paper: Ah. = *Aṣṭāṅgahṛdayasaṃhitā* (Kuṃṭe et al., 1995), Ca. = *Carakasaṃhitā* (Ācārya, 1981), Su. = *Suśrutasaṃhitā* (Ācārya, 1992). All translations are my own unless otherwise stated.

[2] Meulenbeld (1987) provides a useful study of these and related categories. He also points out that the category of *prabhāva* is not mentioned in Suśruta's *Compendium*, although a similar idea is discussed in other terms.

[3] Ca.Sū.26.14–22 (Ācārya, 1981, 139–40):
bhedaś caiṣāṃ triṣaṣṭividhavikalpo dravyadeśakāla-
prabhāvād bhavati, tam upadekṣyāmaḥ// 14//
svādur amlādibhir yogaṃ śeṣair amlādayaḥ pṛthak/
yānti pañcadaśaitāni dravyāṇi dvirasāni tu// 15//
pṛthag amlādiyuktasya yogaḥ śeṣaiḥ pṛthag bhavet/
madhurasya tathāmlasya lavaṇasya kaṭos tathā// 16//
trirasāni yathāsaṃkhyaṃ dravyāṇy uktāni viṃśati/
vakṣyante tu catuṣkeṇa dravyāṇi daśa pañca ca// 17//
svādvamlau sahitau yogaṃ lavaṇādyaiḥ pṛthag gatau/
yogaṃ śeṣaiḥ pṛthag yātaś catuṣkarasasaṃkhyayā// 18//
sahitau svādulavaṇau tadvat kaṭvādibhiḥ pṛthak/
yuktau śeṣaiḥ pṛthag yogaṃ yātaḥ svādūṣaṇau tathā// 19//
kaṭvādyair amlalavaṇau saṃyuktau sahitau pṛthak/
yātaḥ śeṣaiḥ pṛthag yogaṃ śeṣair amlakaṭū tathā// 20//
yujyete tu kaṣāyeṇa satiktau lavaṇoṣaṇau/
ṣaṭ tu pañcarasāny āhur ekaikasyāparvarjanāt// 21//
ṣaṭ caivaikarasāni syur ekaṃ ṣaḍrasam eva tu/
iti triṣaṣṭir dravyāṇāṃ nirdiṣṭā rasasaṃkhyayā// 22//

In the initial sentence, Ca.Sū.26.14, the text does not in fact say precisely what these are combinations *of*. The text uses a genitive pronoun, which must refer to the previous verse, which all about substance (*dravya*), not flavour. The impression that the text is talking about *dravya* is strengthened by the fact that it also talks about the combinations being according to substance, place, time, and special power (*dravya, deśa, kāla, prabhāva*). In other words, it looks at first as though this verse is not talking about sixty-three combinations of flavours, but sixty-three combinations of substances according to these other factors.

The commentator Cakrapāṇidatta (11th cent.) and later translators add the word "flavour (*rasa*)", as I have done, thus smoothing over a difficult issue. But in spite of this puzzle, in the ensuing verses (Ca.Sū.26.15–22) the text does in fact lay out all the possible combinations of substances having particular *flavours* (not places, times, or powers). No English translation of the *Carakasaṃhitā* I have seen actually translates the text of this passage, preferring instead to paraphrase its presumed meaning (e.g., Sharma and Dash, 1997; Sharma, 1994).

[4] Su.Ut.63.6–16 (Ācārya, 1992, 807–8):
yathākramapravṛttānāṃ dvikeṣu madhuro rasaḥ//
pañcānukramate yogān amlaś catura eva tu// 6//
trīṃś cānugacchati raso lavaṇaḥ kaṭuko dvayam//
tiktaḥ kaṣāyam anveti te dvikā daśa pañca ca// 7//
tad yathā:
madhurāmlaḥ 1, madhuralavaṇaḥ 2, madhurakaṭukaḥ 3, madhuratiktaḥ 4, madhurakaṣāya 5, ete pañcānukrāntā madhureṇa; amlalavaṇaḥ 1, amlakaṭukaḥ 2, amlatiktaḥ 3, amlakaṣāyaḥ 4, ete catvāro 'nukrāntā amlena; lavaṇakaṭukaḥ 1, lavaṇatiktaḥ 2, lavaṇakaṣāyaḥ 3, ete trayo 'nukrāntā lavaṇena; kaṭutiktaḥ 1, kaṭukaṣāyaḥ 2, dvau etāv anukrāntau kaṭukena; tiktakaṣāyaḥ 1 eka evānukrāntas tiktena; evam ete pañcadaśa dvikasaṃyogā vyākhyātāḥ 8 etc.

[5] Ah.1.10.39cd–44 (Kuṃṭe et al., 1995, 179–81):
saṃyogāḥ saptapañcāśatkalpanā tu triṣaṣṭidhā// 39//
rasānāṃ yaugikatvena yathāsthūlaṃ vibhajyate/
ekaikahīnāstān pañcadaśa yānti rasā dvike// 40//

trike svādur daśāmlaḥ ṣaṭ trīn paṭus tikta ekakam/
catuṣkeṣu daśa svāduś caturo 'mla paṭuḥ sakṛt// 41//
pañcakeṣv ekam evāmlo madhuraḥ pañca sevate/
dravyam ekaṃ ṣaḍāsvādam asaṃyuktāś ca ṣaḍrasāḥ// 42//
ṣaṭ pañcakāḥ, ṣaṭ ca pṛthagrasāḥ syuś caturdvikau pañcadaśaprakārau/
bhedās trikā viṃśatir ekam eva dravyaṃ ṣaḍāsvādam iti triṣaṣṭiḥ// 43//
te rasānurasato rasabhedās tāratamyaparikalpanayā ca/
sambhavanti gaṇanāṃ samatītā doṣabheṣajavaśād upayojyāḥ// 44//.
Translation from Wujastyk 1998, 277.

[6] On translating *doṣa* as "humour" see Wujastyk 1998, 30–34, Zimmermann 1989 and Scharfe 1999.

[7] Ca.Sū.17.3–6, which asks several general quantitative questions.

[8] Ca.Sū.17.41–44 (Ācārya, 1981, 100–101):
dvyulbaṇaikolbaṇaiḥ ṣaṭ syur hīnamadhyādhikaiś ca ṣaṭ/
samaiś caiko vikārās te sannipātās trayodaśa// 41//
saṃsarge nava ṣaṭ tebhya ekavṛddhyā samais trayaḥ/
pṛthak trayaś ca tair vṛddhair vyādhayaḥ pañcaviṃśatiḥ// 42//
yathā vṛddhais tathā kṣīṇair doṣaiḥ syuḥ pañcaviṃśatiḥ/
vṛddhikṣayakṛtaś cānyo vikalpa upadekṣyate// 43//
vṛddhir ekasya samatā caikasyaikasya saṃkṣayaḥ/
dvandvavṛddhiḥ kṣayaśm caikasyaikavṛddhir dvayoḥ kṣayaḥ// 44//

[9] Śāstrī et al. (1986, i.339–43) and Tripāṭhī and Pāṇḍeya (1983, i.343–45) also give tabular breakdowns of this material, and Ācārya (1981, 101) analyzes the combinations in a footnote.

[10] Su.Ut.63.3 (Ācārya, 1992, 806):
doṣāṇaṃ pañcadaśadhā prasaro 'bhihtas tu yaḥ//
triṣaṣṭyā rasabhedānāṃ tatprayojanam ucyate// 3//.

[11] Su.Sū.21.28 (Ācārya, 1992, 104–5).

[12] Ibid.

[13] See Meulenbeld 1991.

[14] See, e.g., Phillips 1973, 48–52 et passim.

[15] Ah.su.12.74–79 (Kuṃṭe et al., 1995, 208–10):
vakṣyante 'taḥ paraṃ doṣā vṛddhikṣayavibhedataḥ/
pṛthak trīn viddhi saṃsargas tridhā, tatra tu tān nava// 74//
trīn eva samayā vṛddhyā, ṣaḍekasyātiśāyane/
trayodaśa samas teṣu ṣaḍ dvyekātiśayena tu// 75//
ekaṃ tulyādhikaiḥ ṣaṭ ca tāratamyavikalpanāt/
pañcaviṃśatim ity evaṃ vṛddhaiḥ kṣīṇaiś ca tāvataḥ// 76//
ekaikavṛddhisamatākṣayaiḥ ṣaṭ te punaś ca ṣaṭ/
ekakṣayadvandvavṛddhyā saviparyayayā 'pi te// 77//
bhedā dviṣaṣṭir nirdiṣṭāḥ triṣaṣṭiḥ svāsthyakāraṇam/
saṃsargād rasarudhirādibhis tathaiṣāṃ doṣāṃs tu kṣayasamatāvivṛddhibhedaiḥ/
ānantyaṃ taratamayogataś ca yātān jānīyād avahitamānaso yathāsvam// 78//.

[16] Kusuba (1993) provides an important study of this topic.

[17] Chapter 76, especially verses 13–22 (Tripāṭhī, 1968, ii.834–51).

[18] Chapter 13, verse 4 (Chatterjee, 1912, 227). On Varāhamihira and his works see Pingree 1994, A5.563b ff.; on his combinatorics cf. Katz 1998, 228–9.

[19] Chapter 76, especially verses 13–22 (Tripāṭhī, 1968, ii.834–51).

[20] Chapter 76, verse 22.

[21] For details of the working, see, e.g., Iyer 1885, 147–8.

[22] Chapter 13, verse 4 (Chatterjee, 1912, 227). For Bhaṭṭotpala's commentary on this verse, see Jośī 1996, 259–63. Bhaṭṭotpala (fl. 966/969) gives Mahāvīra's algorithm in his commentary both on this verse and on chapter 12, verse 19 (Jośī, 1996, 251).

[23] A unique, though partial, manuscript of a previously unknown work by Śrīdhara, Wellcome MS Indic α 1217, was discovered by Prof. David Pingree in the Wellcome Library (Pingree, 1981, 59). Hayashi (1995) has argued that this work, though perhaps derived from a work by Śrīdhara, is not the original.

[24] *Pāṭīgaṇita* rule 73 (Kusuba, 1993, 86–7):
dvirasavyañjanasiddhyai pareṣu pūrvaṃ vinikṣipet kramaśaḥ
pūrvarasarahitayuktiṣu tryādirasārthaṃ vinikṣipet pūrvam.

[25] Pingree 1981, 60 and Pingree 1994, A4.388. For a recent account of Mahāvīra's text, see Katz 1998, 228–30. See also Kusuba 1993, 87–9.

[26] Rangācārya 1912, 94, 150.

[27] Miśraka chapter, verses 220–221, 335cd–336cd.

[28] On Bhāskara, see Pingree 1981, 26, 61–3 and Pingree 1994, A5.299 ff.. On combinatorics in this work, see Kusuba 1993, 89–95.

[29] 6th paricchedaḥ 110–112 (Colebrook, 1993, 71, 41): *vaidyake rasabhedīye tan noktaṃ vistṛter bhayāt*.

[30] After writing this passage I discovered that the same notational idea had occurred to Hilgenberg and Kirfel (1941, 62), q.v. for combinations of four and five flavours.

[31] See Wujastyk 1998, 144 (Ācārya, 1992, 121), where Suśruta shows knowledge of the grammatical *dhātupāṭha* (1.582).

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