

## ACCOUNTS OF PATHOGENIC ORGANISMS IN THE EARLY TEXTS OF AYURVEDA

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The codified texts of Ayurveda were composed in the few centuries preceding and succeeding the common era. This period marked the emergence of a rational system of medicine in India from the moorings of religious medicine practiced in the Vedic period. Ayurveda made several advancements in theory and practice of medicine that have not yet been recognised as milestones in the history of medical ideas. This paper is an attempt to review the knowledge of pathogenic organisms and their role in diseases based on textual evidences in the early writings on Ayurveda. A careful study of the early writings on Ayurveda reveals that these ancient physicians were aware of not only pathogenic organisms but also non-pathogenic organisms that naturally inhabited the human body. Pathogenic organisms mentioned in Ayurveda include parasite, worms and perhaps microbes also. These texts provide insights on early notions and ideas about the nature of pathogenic organisms, some of which are microscopic and their role in diseases. There are also interesting observations on communicable diseases, epidemics and infection. Many plants and formulations mentioned in the classical Ayurvedic texts have been found to be effective against pathogenic organisms including microbes.

**Key words:** Ayurveda, Infections, Microbes, Parasites, Pathogens, Sepsis, Vector, Worms

### INTRODUCTION

The contribution of Ayurveda to the history of medical ideas has not been adequately studied and acknowledged. Timelines of the history of development of medicine blissfully ignore significant milestones achieved

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by the tradition of Ayurveda in the advancement of medical science. On the other hand, we must brush aside over enthusiastic and exaggerated claims too.

A careful study of classical Ayurvedic literature reveals that Ayurveda had developed very interesting ideas and notions about various aspects of the human body in health and disease. The classical Ayurvedic texts have documented fascinating observations about pathogenic organisms that have not been adequately studied and evaluated from the point of view of the historical evolution of medical science in the world.

#### CLASSIFICATION OF PATHOGENS IN AYURVEDA

A very interesting discussion is found on pathogenic organisms in one of the chapters of the *Caraka Saṃhitā*, an authoritative text book on general medicine in Ayurveda. The text classifies organisms into normal (*sahaja*) and the pathogenic or invaders (*āgantū*)<sup>1</sup>. The pathogenic parasites are further classified into those that grow on the external surface or internal environment of the body. The external parasites are lice, ants and the like. The internal parasites grow on fecal matter, mucus and blood<sup>2</sup>.

It is interesting to note that Ayurveda recognised the existence of non-pathogenic organisms that naturally inhabit the human body. However, the specific functions of these non-pathogenic organisms have not been elaborately discussed.

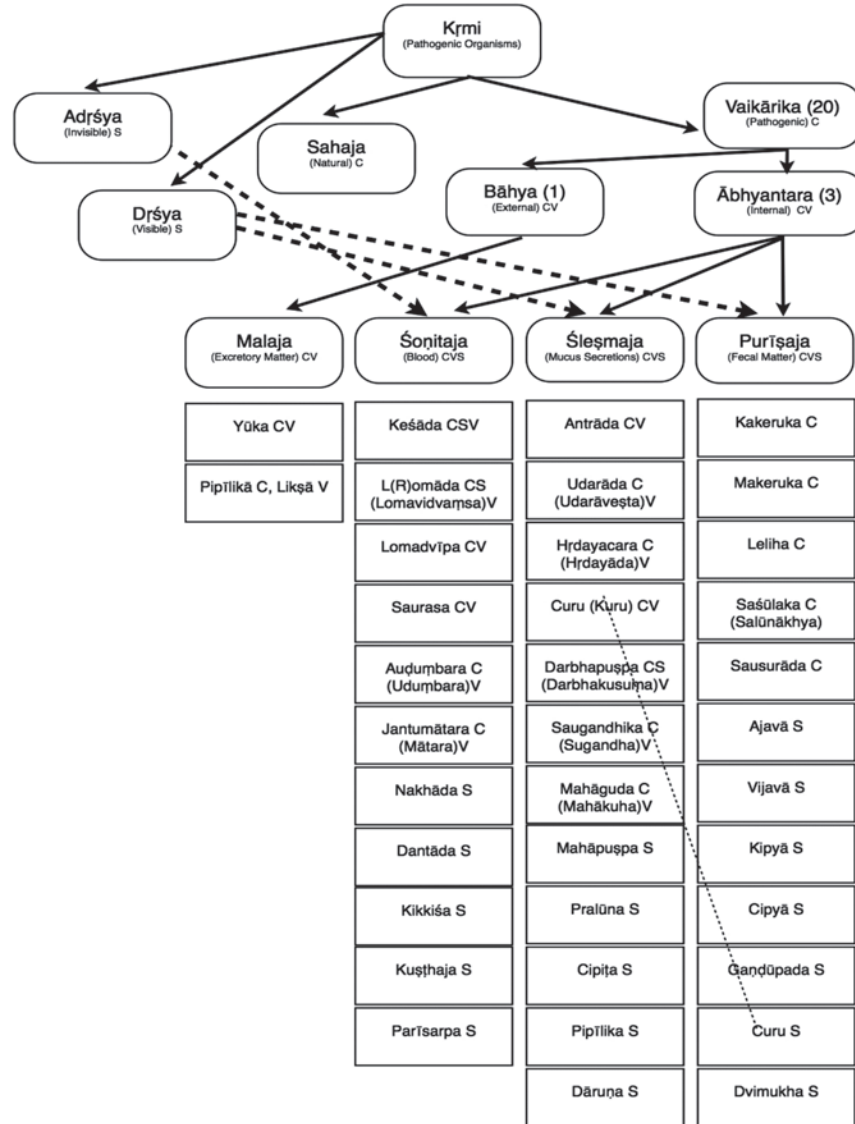
Fig. 1 gives an overview of the classification and nomenclature of pathogens in the early classical Ayurvedic texts.

#### NOMENCLATURE OF PATHOGENS IN AYURVEDA

The nomenclature of the pathogens documented in Ayurvedic texts provides interesting material for discussion and research. It is an intriguing thought to imagine that the ancient observers would have physically seen and described these tiny creatures.

##### **External Parasites**

The external pathogens are young and mature lice as well as ants. It is quite easy to identify and characterize these organisms.



**Fig. 1.** The classification and nomenclature of pathogenic organisms (*kṛmis*) described in the works of Caraka (C), Suśruta (S) and Vāgbhaṭa (V)

### Internal Pathogens growing in the Blood

The nomenclature of these microbes has also been enlisted and these describe either the shape or the pathogenic action of the organisms.

The names of three of the pathogens of the blood are related to the hair. There are the eaters of the hair of the head (*keśāda*) and the small hairs of the body (*lomāda*). The meaning of the name *lomadvīpa* is not clear - *loma* means body hair and *dvīpa* means island. Saurasa is derived from the word *surasā* meaning rich in water or sap. It is a synonym of a few medicinal plants as well as the name of a serpent demon. Saurasa means originating from *surasā* and in this context may refer to the serpent demon to indicate the virulent nature of the organism.

*Audumbara* means similar in appearance to the fruit of *udumbara* and it may indicate the shape or color of the fruit. *Jantumātara* means mother of pathogenic organisms. This name may indicate the ability of the organism to multiply profusely inside the body. *Nakhāda* means that which eats away the nails and *dantāda* is that which eats away the teeth. The exact meaning of the word *kikkiśa* is not clear. *Kuṣṭhaja* means the organisms that are born out of skin diseases and *parīsarpa* means that which spreads all over very fast<sup>3</sup>.

#### **Internal Pathogens growing on Mucus Secretions**

Some of the pathogens growing on mucus secretions are also described to be very minute and their names are also descriptive like the intestine chewers (*antrādahò*) and the like. *Udarāda* means eater of the stomach. A variant name *udarāveṣma* means that which envelops the stomach. It is not clear what the name *kuru* means. *Darbhapuṣpa* indicates resemblance to the flower of *darbha* grass. *Saugandhika* or *sugandha* means pleasant aroma but the significance of this word, as the name of a pathogen is not clear. *Mahāguda* means possessing a large anus. *Mahāpuṣpa* means large flower. *Pralūna* means that which appears to be cut off or mutilated. *Cipiṭa* means flattened or blunted. *Pipīlikā* indicates ant like appearance and *dāruṇa* refers to virulence of the pathogen<sup>4</sup>.

#### **Internal Pathogens growing on Fecal Matter**

Pathogens that thrive on fecal matter are known by names like *kakeruka* and *makeruka*, the meaning and implications of which are not very clear. *Leliha* could mean that which is constantly licking. *Sasūlaka* means that which causes pain. *Sausurāda* means that which eats the *sausura* and

the implication of this word is not clear. *Ajavā* and *vjavā* could indicate the slow movement of the pathogen. The meanings and implications of the names *kipya* and *cipya* are not clear. *Gaṇḍūpada* indicates earthworm like appearance and *dvimukha* means having two heads<sup>5</sup>.

### The Innumerability of Pathogens

In his commentary on the *Suśruta Saṃhitā*, Dalhaṇa mentions that the pathogens are innumerable and the twenty types mentioned are categories that can include the rest<sup>6</sup>. Cakrapāṇidatta, the commentator of *Caraka Saṃhitā*, mentions that the nomenclature of the pathogens mentioned are those that are well accepted in his tradition as well as those that are in vogue in other places<sup>7</sup>. This is an indication that different schools of thought in Ayurveda developed different classification systems and nomenclature for pathogens. Indeed, the *Bhela Saṃhitā* gives a different nomenclature for the pathogens<sup>8</sup>. The *Hārīta Saṃhitā* also gives a nomenclature for pathogens that is different from the other texts and lists only thirteen names instead of twenty<sup>9</sup>. It is difficult to determine whether different names have been given to the same pathogens in different texts or whether they indicate different pathogens altogether. As pointed out by Meulenbeld, at least in some cases, the different names used by different authorities may refer to the same pathogen<sup>10</sup>.

### DESCRIPTIONS OF PATHOGENS IN AYURVEDA

The external pathogens are minute, like sesame grains and having many feet<sup>11</sup>.

The descriptions of the parasites that grow in blood are extremely thought provoking. These are minute (*aṇu*), circular (*vr̥tta*) and without any feet (*apādāśca*). Because of their extremely minute size, some are not visible to the eye (*kecit saukṣmyāt adarśanāḥ*)<sup>12</sup>. This description is certainly reminiscent of microbes and could very well be one of the earliest speculations about the existence of microscopic life. In the light of modern knowledge, blood as a medium for the growth of microbes seems to be a purely speculative idea of the ancient Ayurvedic physicians. Blood is considered to be sterile and presence of microbes in blood leads to a life-threatening situation known as bacteremia. However, the symptoms caused by the pathogens of blood as described in Ayurvedic texts do not correlate with

bacteremia. Curiously enough, the description of the pathogens of the blood with its circular shape and coppery red color seems to resemble the red blood cells rather than microbes. Again, it is difficult to determine whether the ancient physicians had any tools to visualize the red blood cells in the first place to mistake them as pathogens.

The pathogens found in mucus secretions are whitish, minute, elongated, thread like, cylindrical like earthworm and broad<sup>13</sup>.

The pathogens found in the fecal matter are whitish, minute, cylindrical, long like silk threads, thick, cylindrical, blackish, bluish or greenish<sup>14</sup>.

#### **Symptoms caused by the Pathogens**

The external pathogens cause itching and eruptions on the skin<sup>15</sup>.

The pathogens of the blood cause destruction of hairs of the head, body, eyelashes and the nails as well. They also cause horripilation, itching, pain and spreading of wounds. When they proliferate, they eat away the skin, vessels, ligaments, muscles and cartilage<sup>16</sup>.

The pathogens in the mucus secretions cause salivation, drooling, loss of appetite, indigestion, fever, fainting, yawning, sneezing, distension of abdomen, body ache, vomiting, weight loss and roughness<sup>17</sup>.

The pathogens found in fecal matter cause loose stools, weight loss, roughness and horripilation. They also cause biting pain and itching around the anus and they come out of the anus again and again<sup>18</sup>.

#### **Diseases caused by Pathogenic Organisms**

The role of pathogenic organisms in causation of diseases has been well recognized by Ayurveda. However not many diseases have been listed in this category. Skin diseases known as *kuṣṭha* are specifically considered to be associated with *kṛmiś* or pathogenic organisms. Infestation with pathogenic organisms is a specific stage in the progress of skin diseases. One of the types of diseases that affect the head and the heart are said to be caused by pathogenic organisms i.e., *kṛmija śiroroga* and *kṛmija hṛdroga*<sup>19</sup>. The role of pathogens have not been described in classical Ayurvedic texts

in the case of many diseases that we know today to be caused by pathogens. Examples are amebiasis, tuberculosis and malaria. These diseases are well described clinically without implicating pathogens in the disease process.

### **Did ancient Ayurvedic Physicians know about Microbes?**

The pathogens have not been properly classified in the Ayurvedic texts, it seems. The term *kṛmi* includes parasites, bugs, worms and probably micro-organisms also. Meulenbeld prefers to consider the *kṛmis* as worms, though he admits difficulties in interpreting the term *kṛmi*. He points out that ancient Indians did not clearly distinguish between the phyla of invertebrates or their developmental stages. Following Chakravarthy, he attempts to identify many of the intestinal worms expressing difference of opinion on many occasions. However, Meulenbeld does not consider the possibility of the existence of microorganisms having been known to the ancient Ayurvedic physicians<sup>20</sup>. He suggests that round worm, tape worm and thread worm may have been known to Ayurveda but maintains that none of the descriptions could be applicable to microbes, which are invisible and could not have been seen by the ancient Ayurvedic physicians.

While the pathogens growing in mucus secretions and the fecal matter can be considered as intestinal worms, the pathogens in the blood deserve to be studied more closely. These are said to reside inside the blood vessels and as already mentioned, may also be invisible due to their minute size. It is interesting to note that they are described to have a circular shape and are without feet. Moreover they have a coppery hue. It is difficult to identify these pathogens with reference to organisms that we know today because the descriptions are not sufficiently detailed and because blood is considered to be sterile.

Moreover, it is debatable whether invisibility means not visible to the naked eye or a small size that is not easily noticed. There is no evidence available to suggest that the ancient Ayurvedic physicians had access to magnifying glass, not to speak of microscopes. In these circumstances, it is difficult to judge whether invisible *kṛmis* in the blood are microbes. In his commentary on the *Aṣṭāṅga Hṛdaya*, Aruṇadatta clarifies that the pathogens of the blood are indeed totally invisible to the human eye and are therefore microscopic. He adds that their existence can be only inferred<sup>21</sup>. This is a

very clear statement of the existence of microscopic life and a strong evidence to suppose that ancient Ayurvedic physicians were aware of microscopic life albeit they could not study it in sufficient detail.

On the other hand, the pathogens of the blood don't appear to be worms either. We can say that they are an indication of the fact that the ancient Ayurvedic physicians came very close to discovering microscopic life but could not carry these studies further for want of appropriate instruments and tools.

### ROLE OF PATHOGENS IN DISEASE CAUSATION

Ayurveda was aware of the role of pathogenic organisms in some diseases. Diseases affecting the skin were especially thought to involve pathogenic organisms at a particular stage of development. But it is not considered to be the primary cause of the disease. Pathogens come into the picture after the disease has progressed to some extent. Suśruta refers to this stage as *jātakṛmi*, which means literally the stage of the disease that gives birth to pathogens<sup>22</sup>. Vāgbhaṭa points out that when *kleda* or secretions are accumulated, skin diseases attract pathogenic organisms which eat away the skin, muscle and lymph. It is interesting to note that Vāgbhaṭa uses the term *āvāhana* to describe the process of infestation of skin diseases with pathogenic organisms<sup>23</sup>. *Āvāhana* means to invoke or invite. The idea is that the body attracts pathogens after the pathological derangement has taken place. The notion of pathogens attacking a healthy body and thereby becoming the direct cause of disease is not found in the classical texts of Ayurveda.

### The role of Pathogens in Transmission of Disease

It is fascinating to find that the *Suśruta Saṃhitā* mentions about communicable diseases and how it spreads from one person to the other by contact. He lists the modes of transmission of disease quite comprehensively, (1) Frequent interaction with the diseased person, (2) Physical contact of the body, (3) Through breath, (4) By eating together, (5) By sitting together, (6) By sleeping together and (7) By wearing the same garlands and ornaments<sup>24</sup>. The *Caraka Saṃhitā* talks about epidemic diseases and how such diseases spread and kill large number of people at the same time. However, it is not clear whether the role of pathogens in transmission of disease was adequately



understood. While the classical texts themselves are silent, one commentator opines that a disease is transmitted on close contact between people because the sin is transferred from one person to the other<sup>25</sup>. The *Caraka Saṃhitā* says that the same disease affects many people because common factors like the land, water and air get polluted and the seasons get deranged<sup>26</sup>. There is no evidence to suggest that Ayurveda recognized the role of pathogens in transmission of infectious diseases as well as epidemics.

#### **Vectors or flies depositing Larvae?**

The *Suśruta Saṃhitā* observes that flies deposit pathogens in wounds causing them to suppurate and aggravate<sup>27</sup>. Could this be a very early reference to the role of flies as vectors in carrying pathogens? It is not clear whether the text refers to worms, microbes or parasites in this context. Suśruta could have very well been talking about the condition known as myiasis, in which flies deposit larvae on wounds, which looks like worms. On the other hand, the role of mosquitoes in the transmission of the malarial parasite has not been understood or described in Ayurveda. For that matter, even the role of parasites in causation of malarial fever has not been recognized though the clinical features of the disease has been well described. Filariasis is another disease that has been well described without an understanding of the role of mosquitoes in its transmission.

#### **Antiseptic Procedures in Surgery and Wound Management**

The *Suśruta Saṃhitā* points out that a wounded person is to be protected from demons. It is interesting to note that Ayurvedic surgeons observed that people who are wounded either due to surgery or physical trauma are susceptible to suppuration of their wounds. It seems that they sensed that the injured people are being attacked by some invisible beings that are referred to as *rākṣasas* or demons. In order to prevent this attack, fumigation with certain herbs and plant resins have been advised. Interestingly, these fumigants have now been shown to have microbicidal activity. Suśruta also mentions that the patient who is recovering from a wound should follow certain physical and mental discipline (*yama* and *niyama*)<sup>28</sup>. This means that the ancient Ayurvedic surgeons seem to have also observed that hygiene helps to prevent wounds from suppurating and becoming difficult to treat.

This is an intriguing example of a case where the ancient surgeons seem to have encountered the phenomenon of infection that leads to sepsis of wounds, but did not fully understand the process and mechanism, but nevertheless developed interventions that were fairly effective in managing the situation.

It is simply stunning to think that ancient Ayurvedic surgeons sensed the invasion of the bodies of wounded people by invisible beings. However, they were not able to identify microbes and speculated that demons were attacking the patients.

This theory of demonic attack on the wounded patient and the consequent implementation of procedures like fumigation and cleanliness to protect the patient enabled the Ayurvedic surgeons to prevent sepsis of wounds.

Another interesting practice that has an implication in aseptic surgery is the special treatment of surgical instruments in alkaline solution, water and oil. This procedure is known as *pāyanā*. Each surgical instrument is heated till it becomes red hot and then dipped in alkaline solution, water or oil<sup>29</sup>. The primary purpose of this process seems to have been to temper the surgical instrument. However, this also helped to sterilize the instruments used in surgery and thus helped to prevent sepsis of surgical wounds.

#### **Treatment of Diseases involving Pathogenic Organisms**

The *Caraka Saṃhitā* puts forth a threefold strategy for management of pathogenic organisms. These are (1) *Apakarṣaṇa* - extraction or removal of the pathogenic organisms, (2) *Prakṛtivyaghāta* - creating unfavourable environment for the pathogenic organisms and (3) *Nidānaparivarjana* - avoiding the causative factors<sup>30</sup>.

The method of *apakarṣaṇa* may include methods to kill the pathogenic organisms before removing them. The texts mention herbs and medications that are *kṛmighna*, which means to literally kill the pathogens<sup>31</sup>.

#### **Medicinal Plants from Ayurveda with Microbicidal Properties**

Ayurveda may have sensed the existence of microbial life and to some extent their role in diseases. Treatment procedures for management of

pathogens have been described and herbs and formulations have been listed for use in diseases involving pathogenic organisms. A very interesting topic that emerges from the discussion of pathogenic organisms in Ayurveda is the microbicidal properties of medicinal plants described in the classical Ayurvedic texts.

Although the pathogenic organisms described in Ayurvedic texts include parasites and worms and perhaps not microbes, the medicinal plants that have been ascribed with *kṛmighna* property (the ability to kill *kṛmis* or pathogenic organisms), have been shown to have microbicidal activities as well as has been revealed by modern scientific research on medicinal plants. *Tulasī*, *Haridrā*, *Vidaṅga*, *Vacā* and *Guggulu* are examples.

#### CONCLUSIONS

The classical texts of Ayurveda that were composed and edited in the time period spanning a few centuries before and after the Common Era have documented the Ayurvedic understanding of the role of pathogenic organisms in development and progress of diseases. However, rather than being the primary cause of a disease, they get involved in a particular stage of the disease. One of the most fascinating aspects of these accounts is the classification of organisms into the natural and the pathogenic. Although there is no further description about the natural and harmless organisms that live in the human body, the very reference to such organisms raises the question as to whether the ancient Ayurvedic physicians were aware of microbes. Such a supposition gains strength when we consider the reference to invisible pathogenic organisms residing in the blood vessels that are circular in appearance and without feet. However, in the absence of evidence of the use of any microscopic instruments, it is difficult to judge whether these invisible organisms are microbes, though textual statements confirm that some of these pathogens cannot be seen by the human eye and that Ayurvedic physicians were aware of microscopic life. *Kṛmi* is a broad term and may be aptly translated as pathogenic organisms instead of worms as it includes parasites, worms and perhaps microbes also. Ayurvedic texts make mention of communicable diseases and epidemics. Yet, they did not recognize the role of pathogenic organisms in transmission of disease. The description of flies depositing pathogenic organisms on wounds may be an early reference

to their role as vectors or it could be the depositing of larvae on wounds, a condition known as myiasis. Ancient Ayurvedic surgeons observed that wounds were prone to suppuration and speculated that this happened due to attack of the wounded person by invisible demons. This could be a very early reference to infection of wounds and consequent sepsis. Treatment procedures and formulations have been prescribed for management of diseases involving pathogenic organisms and modern scientific research has shown that many medicinal plants used in Ayurveda have microbicidal properties. The contributions of Ayurveda in understanding of pathogenic and non-pathogenic organisms form the point of view of the history of medical ideas need to be recognised. Medicinal plants and formulations mentioned in the classical texts of Ayurveda can offer valuable leads in discovery of medications against pathogenic organisms including microbes.

#### ABBREVIATIONS

*Aṣṭāṅga Hṛdaya* - AH

*Bhela Saṃhitā* - BH

*Caraka Saṃhitā* - CS

*Cikitsā Sthāna* - Ci

*Nidānasthāna* - Ni

*Hārīta Saṃhitā* - HS

*Tṛtīya Sthāna* - Tr

*Suśruta Saṃhitā* - SS

*Sūtra Sthāna* - Sū

*Uttara Sthāna* - Utta

*Vimāna Sthāna* - Vi

#### NOTES & REFERENCES

1. See CS, Vi, 7.9 - The natural organisms inhabiting the body which are different from the 20 pathogenic organisms have been mentioned. In the commentary by Cakrapāṇi, it is clarified that the organisms that are seen naturally in the body do not cause diseases – *śarīrasahajāstvavaikārikāḥ*. It is pertinent to point out that only the CS makes mention of the natural non-pathogenic organisms.
2. See CS, Vi, 7.9 – The pathogenic organisms have been classified into four types based on the substratum of growth i.e. feces, mucus, blood and waste products. However, only the external pathogens are described under the category of organisms growing on waste products. The text classifies waste products into external and internal, describes the pathogens growing on external surface of the body. There is no direct mention of pathogens growing on internal waste, but obviously this is included in types that grow on feces, mucus and blood. However AH, Ni, 14.42 explicitly classify pathogenic

organisms into the external and internal. Suśruta classifies them into three types that grow on feces, mucus and blood.

3. See *CS, Vi, 7.11, SS, Uttā, 54.15* and *AH, Ni, 14.51* for descriptions of the pathogens that grow in the blood.
4. See *CS, Vi, 7.12, SS, Uttā, 54.12* and *AH, Ni, 14.47-50* for descriptions of the pathogens that grow in mucus secretions.
5. See *CS, Vi, 7.13, SS, Uttā, 54.8* and *AH, Ni, 14.46* for descriptions of the pathogens that grow in the feces.
6. See Dalhaṇa's commentary on *SS, Uttā, 54.7* pointing to the innumerability of the pathogens - *jāti-grahaṇam kṛmīṇāṃ nānāntyakhyaṇāpanārtham, taccānāntyam viṃśatyā mevāvaruddham*
7. See Cakrapāṇidatta's commentary on *CS, Vi, 7.10* about the different names for pathogens in different geographical regions - *kṛmīṇāṃ saṃjñā svaśāstravyavahā rasiddhā deśāntaraprasiddhā ca boddhavyā*
8. See *BS, Sū, 26.31-33* for an enumeration of pathogens. Elaborate descriptions are not available in this text. The names of the pathogens are 1. *mṛjjā*, 2. *jarāyuja*, 3. *levā*, 4. *rūpaka*, 5. *bahurūpaka*, 6. *parīsarpa*, 7. *visarpa*, 8. *gotraja*, 9. *netraja*, 10. *romāda*, 11. *rohita*, 12. *kaṣṭa*, 13. *dāruṇaka*, 14. *śiroja*, 15. *dantaja*, 16. *śleṣmaja*, 17. *śakṛdāśraya*, 18. *lohita*, 19. *kālaka*, 20. *śatamātrka*. Meulenbeld derives these names differently and reads *majjāja* instead of *mṛjjā*, combines *levā* and *rūpaka* into *lambā rūpaka* and splits *rohita* into *antrāda* and *ahita*.
9. See *HS, Tr, 5* for descriptions of pathogens. This text classifies pathogens into external and internal and lists six and seven names in each category making it a total of thirteen. The six external parasites are 1. *kṛṣṇayūka*, 2. *śvetayūka*, 3. *carmayūkikā*, 4. *bindukī*, 5. *matkuṇa*, 6. *mastakayūkā* and 7. *yaṣṃikā*. The seven internal parasites are 1. *pṛthumuṇḍā*, 2. *kaṃcukasannibha*, 3. *dhānyāṅkura*, 4. *sūkṣma*, 5. *aṇu* and 6. *sūcīmukha*
10. See Meulenbeld's (p.624) observations on the aptness of the term *udarāveṣṭa* of Vāgbhaṭa to describe the round worm. He points out that this could be the *gaṇḍūpada* of Suśruta and the *kiṃcukasannibha* of Hārīta.
11. The descriptions of the external pathogens can be seen in *CS, Vi, 7.10* and *AH, Ni, 14. 44*.
12. The works of Caraka (*Vi, 7.11*), Suśruta (*Uttā, 54.19-20*) and Vāgbhaṭa (*Ni, 14.51*) unanimously state that the pathogens growing in the blood are invisible. While Caraka and Vāgbhaṭa mention that some of them are invisible, Suśruta categorically states that all pathogens growing in the blood are invisible.
13. See *CS, Vi, 7.12* for description of shapes of pathogens growing in the mucus.
14. See *CS, Vi, 7.13* for description of shapes of pathogens growing in the feces.

15. See *CS, Vi*, 7.10 for symptoms caused by the external pathogens.
16. See *CS, Vi*, 7.11 for symptoms caused by parasites of the blood.
17. See *CS, Vi*, 7.12 for symptoms caused by parasites of the mucus.
18. See *CS, Vi*, 7.13 for symptoms caused by parasites of the feces.
19. See *AH, Uta*, 23.12-15 for description of *kṛmija śīroroga* and *Ni*, 5. 43-44 for description of *kṛmija hṛdroga*
20. See Meulenbeld pp. 622-627, for discussion on the chapter dealing with *kṛmis* in his translation of the Mādhava Nidāna
21. See commentary of Aruṇadatta on *AH, Ci*, 14.51, where he explains that the pathogens of blood cannot be seen with naked eye and can only be inferred by signs-*kecidadarśanaḥ pratyakṣapramāṇāsamadhigamyāḥ kāryeṇaivānumīyante*.
22. See *SS, Ni*, 5.6, 8, 25, 26 where the involvement of pathogenic organisms in specific stages of the disease is explained.
23. See *AH, Ni*, 14. 4-5 where the disease is said to attract *kṛmis* as it progresses.
24. See *SS, Ni*, 5.33-34 for a description of the modes of transmission of diseases. It is interesting to note that this topic is taken up in the chapter on skin diseases, which is explicitly stated to involve pathogenic organisms and are communicable. In *AH, Ni*, 14. 41, the same topic is discussed followed by a description of *kṛmis*. It almost looks like the ancient physicians sensed the connection between pathogenic organisms and communicability of diseases. But in fact, they did not discover this important link. Gayadāsa addresses this issue in his commentary on the above verse in *Suśruta Saṃhitā*, by raising the question - "How does disease get transmitted from one person to the other?" and he answers, "By transfer of sin, just by contact with a person, the sin is transmitted from one to another".
25. See Gayadāsa's commentary on *SS, Ni*, 5.33-34
26. See *CS, Vi*, 3.6 for a description of epidemics. The role of pathogenic organisms in the spread of epidemics has not been recognized.
27. See *SS, Ci*, 1.119-122 where it is mentioned that flies can deposit pathogenic organisms on wounds and cause severe swelling.
28. See *SS, Ci*, 1.133 for instructions to protect a wounded person from being attacked by demons called as *niśācaras* here.
29. See *SS, Sū*, 9.12 for a description of the methods of tempering the surgical instruments in water, oil and alkaline solutions before use.
30. See *CS, Vi*, 7.14 for methods of treatment of pathogenic infestations.
31. See *CS, Sū*, 4. 11 for list of drugs that have *kṛmighna* action.

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