

# Concepts of Human Physiology in Ayurveda

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**Abstract:** *'Human Physiology', or the study of functional aspects of human body, is designated by the term 'Śarīra Vicaya' in Ayurvedic literature. The word 'Vicaya' means the special or detailed knowledge. Detailed knowledge of normal human body i.e., 'Śarīra', is considered helpful in understanding the factors influencing the health. Though most of the basic concepts of human physiology explained in Ayurveda are strikingly similar to the concepts of modern physiology, some concepts like 'Ātmā', 'Manas' and 'Prakṛti' are unique to Ayurveda. Understanding of Physiology in Ayurveda should start with the understanding of innumerable minute individual living units called 'Śarīra Paramāṇus' or 'Aṇu Srotāṃsi'. These units are now known as cells. A group of such functionally and structurally similar units is called a 'Dhātu'. These 'Dhātus' are almost equivalent to the tissues. Seven such 'Dhātus' have been enumerated. Similarly, the individual systems in the body have been designated by the term 'Sthūla Srotāṃsi' and thirteen such 'Srotāṃsi' have been described by Caraka. 'Annavaḥa Srotas', for example, stands equivalent to the digestive system and 'Rasavaḥa Srotas' to the cardio vascular system. Apart from these, the functioning of individual systems has also been described in a considerably detailed manner. Cardiovascular system as a closed circuit, role of liver in the functioning of hemopoietic system, functional significance of brain in the neural mechanisms, basics of digestion and metabolism and basics of immunity - are some such topics worth mentioning. Theory of 'Tridoṣa' is another important theory of physiology. This represents the various reciprocally functioning homeostatic mechanisms at various levels of organization. The state of equilibrium among these 'Doṣas' is responsible for maintenance of health. Three 'Doṣas' – i.e., 'Vāta', 'Pitta' and 'Kapha' in general, represent neural, endocrine and immune mechanisms respectively and form the basis of neuro- immuno- endocrinology.*

## Human Physiology in Ayurveda

'Śarīra Vicaya' is the Ayurvedic term that represents both Anatomy and Physiology. 'Vicaya' means the special or detailed knowledge. As per Caraka, the detailed knowledge of normal human body is helpful to understand the factors influencing health and therefore such knowledge is widely appreciated by experts. (Ca.Śā. 6/3).

## Theory of 'Tridoṣa': A Physiological Perspective

This theory forms the basis of Ayurvedic physiology, pathology and pharmacology. Though, the term 'Doṣa' means 'the disturbing factor', it has got definite physiological importance in normal state. Basically three 'Doṣas'- 'Vāta', 'Pitta' and 'Kapha'- are responsible for maintenance of homeostasis in the body, and health is nothing but a state of equilibrium of these 'Tridoṣas'. Disease is manifested as a result of disturbance in the state of equilibrium among these 'Doṣas'.

The concept of 'Tridoṣa' is basically a theory and any single substance or structure in the body can not represent a 'Doṣa'. Terms like 'Pittavarga' and 'Kaphavarga' have been used in some textbooks and such usage indicates that these ('Vāta'- 'Pitta'- 'Kapha') were perceived to be three groups of physiologically similar substances.

‘Vāta’ is responsible for all movements and it is the initiating and controlling factor. ‘Pitta’ performs the activities like digestion, metabolism, production of heat and that is why it is called ‘Agni’ meaning ‘Fire’. ‘Kapha’ performs the functions like protection, strength, stability and resistance.

As Ayurveda is based on functional understanding of body, the different entities representing ‘Tridoṣas’ at each level of organization can be assumed by analyzing these functions. In generalized terms, the nervous, endocrine and immune mechanisms can be equated to ‘Vāta’, ‘Pitta’ and ‘Kapha’ respectively.

**Homeostasis:** Imbalance in the state of bodily-tissues is known as ‘Disease’ and equilibrium is called ‘Health’. (Ca.Sū. 9/3, Ca. Śā. 6/18). Aim of this entire stream of science (Ayurveda) is to re-establish the state of equilibrium among different tissues (Ca. Sū. 1/53). ‘Dhātusāmya’ is the term given for homeostasis in Ayurveda. In Suśruta’s view, the life on this universe is maintained because of three opposing factors known as Sun, Moon and the Air. The Sun exerts a drying effect on earth whereas the moon is coolant and strengthening in nature. Air brings about all types of movements. In exactly similar manner, the body is sustained by three opposing factors called ‘Vāta’, ‘Pitta’ and ‘Kapha’ (Su. Sū. 21/8).

**Concept of a Cell:** Caraka has explained that the body parts can be divided and re-divided into innumerable individual components called ‘Paramāṇus’. These are innumerable because of their huge number, highly minute structure and limited perceptive ability of sense organs (Ca. Śā. 7/17). This statement indicates that there existed a concept of minute and numerous individual living units in the body. Today we call such microscopic units by the name ‘Cell’. ‘Aṇu Srotas’ is another such very similar term, probably indicative of a cell. Some scholars even held the view that the living body is nothing but the resultant of aggregation of such innumerable ‘Srotāṃsi’. (Ca.Vi. 5/4). ‘Srotāṃsi’ is the plural form of ‘Srotas’. The term ‘Srotas’ means an individual ‘Cell’ - ‘Aṇu Srotas’ and also an individual ‘Organ System’ - ‘Sthūla Srotas’. A tissue is a group of structurally and functionally similar cells. ‘Srotāṃsi’ are structurally similar to their corresponding tissues. Also, each ‘Srotas’ is functionally (Metabolically) related to its corresponding tissue.

**Basic Tissues:** Plasma and lymph (‘Rasa’), blood cells (‘Rakta’), muscular and general connective tissues (‘Māṃṣa’), body-lipids including adipose tissue (‘Meda’), tissues resisting easy degradation - like bones (‘Asthi’), bone marrow and nervous tissue (‘Majjā’) and tissues responsible for reproductive functions (‘Śukra’) are the basic tissues from which the body is formed. (A.H. Sū.1/13).

Tissues producing breast-milk (Stanya), female reproductive tissues (Ārtava), ‘Kaṇḍarā’ (tendons), Sirā (blood vessels), ‘Vasā’ (muscle fat), six layers of skin and ‘Snāyus’ (sinews) are the ‘Upadhātus’ (subsidiary tissues). Tissues producing breast-milk and female reproductive tissues are Upadhātus of ‘Rasa’. ‘Kaṇḍarā’ and ‘Sirā’ are Upadhātus of ‘Rakta’. ‘Vasā’ and skin are Upadhātus of ‘Māṃṣa’. ‘Snāyu’ is the Upadhātu of ‘Medas’. (Ca. Ci. 15/17).

Classification of tissues described in Ayurveda is based on some rational observations. For example, ‘Rasa Dhātu’ includes both plasma and lymph (Intravascular fluid). ‘Rakta Dhātu’ mainly stands for RBCs. ‘Māṃṣa Dhātu’ stands for muscular tissue in general but also includes general connective tissue and parenchymal and stromal tissues of different viscera. As ‘coating’ or ‘covering’ is the function of ‘Māṃṣa Dhātu’, even epithelial tissue is included under the same. ‘Medo Dhātu’ includes adipose tissue and circulating lipids

of blood because it is of two types: 'Baddha' (bound) and 'Abaddha' (free). 'Asthi Dhātu' includes all those structures of the body, which resist easy degradation. So, teeth and nails also are included under this 'Dhātu'. 'Majjā Dhātu' stands for everything that fills bony cavities. So, apart from bone marrow, it also stands for Brain substance because this fills up a cavity formed by the union of several cranial bones. 'Śukra Dhātu' mainly stands for all hormones of hypothalamo-pituitary-gonadal axis.

Supplying the nourishment (Prīṇana), delivery of life-principle (Jīvana), providing covering or coating (Lepa), providing lubrication (Sneha), giving mechanical support (Dhāraṇa), filling-in the (bony) cavities (Pūraṇa) and reproduction (Garbhōtpāda) - are the most important functions of these seven 'Dhātus' respectively. (A.H. Sū. 11/4).

### **Physiology of Nervous System**

All movements are due to 'Vāta' and that is why it is called the 'Prāṇa' of all living beings. (Ca. Sū. 18/118). So, 'Prāṇavaha Srotas' stands for the system concerned with the activities of 'Vāta'. 'Prāṇavaha Srotas' stands for the system that transports a specific type of 'Vāta' called 'Prāṇa Vāta'. This is a special Srotas meant for a special type of 'Vāta' (Cakrapāṇi on Ca.Vi. 5/8).

**Brain and Brainstem:** 'Śiras' (Head) is the region where all 'Prāṇas' (most vital entities) are situated and all sensory and motor activities are controlled from. That is why 'Head' is called the 'Most important organ' among all parts of the body (Ca. Sū. 17/12). It is described that all sensory and motor organs along with their 'Prāṇavaha Srotāṃsi', are connected to the brain in a fashion that is similar to the connections between the sunrays and the Sun. (Ca. Si. 9/4). Bhela has explained that the mind is situated in between the head and palate. The efficiency of mind is beyond any other sensory or motor organ (Bh.Ci. 8/2-3).

**Reflexes:** Caraka has opined that one should not suppress the natural urges related to micturition, defecation, ejaculation, flatus, vomiting, sneezing, eructation, yawning, hunger, thirst, tears, sleep and also dyspnoea developed after exertion (Ca. Sū. 7/3-4). It should be noted that one or the other reflex is involved in all these activities. So, the term 'Vega' stands almost equivalent to reflex.

**Concept of 'Vāta':** All functions of nervous system in human body are represented through 'Vāta' in Ayurveda. In general, the functions ascribed to 'Vāta' are: Control and co-ordination of different parts of the body, initiation of all movements, regulation of psychological processes, initiation of all activities of sense organs, transmission of different sensations, production of speech, secreto- motor functions in the gut, expulsion of wastes from the body and control of respiration (Ca.Sū.12/8). 'Vāta' is divided into five sub types – 'Prāṇa', 'Udāna', 'Vyāna', 'Samāna' and 'Apāna'.

**'Prāṇa Vāta':** This is situated in head and is responsible for the control over intellectual functions, cardiovascular functions, sense organs, psychological activities, respiration, and reflex activities like sneezing, belching and deglutition (A.H.Sū. 12/5). Based on this sub-type of 'Vāta', 'Prāṇavaha Srotas' has derived its name.

**'Udāna Vāta':** Its active site is chest region. It is basically responsible for production of speech. The effort and strength required for speech are also the functions of 'Udāna'. It also helps in recall of vocabulary required for well-articulated speech (A.H.Sū. 12/5).

**'Vyāna Vāta':** The active site of 'Vyāna Vāta' is Heart. It makes the circulation of blood possible by controlling the heart. Vyana makes 'Rasa' (the intravascular fluid including

plasma and lymph) to get forcefully ejected out of the heart and makes it circulate throughout the body (Ca. Ci. 15/36). So, sympathetic and parasympathetic control of heart is indicated by 'Vyāna Vāta'. Some authors have ascribed the functions of somatic nervous system also to 'Vyāna Vāta' as movements like flexion, extension, opening and closure of eyelids have been said to be under its control (Ca. Ci. 28/9).

**'Samāna Vāta':** Active site of 'Samāna' is adjacent to gastro intestinal tract. It performs the functions like reception of food, its digestion through the activation of 'Agni', its division into useful and waste parts and its onward propulsion (A.H. Sū. 12/8). All these functions are either those of parasympathetic nerves supplying the gut or those of enteric nervous system.

**'Apāna Vāta':** This is active in pelvic region. 'Apāna' governs physiological processes like micturition, defecation, ejaculation, menstruation and parturition (A.H.Sū.12/9). Autonomic nervous system has got a definite role in most of these activities.

### **Physiology of Gastro Intestinal Tract**

'Annavaḥa Srotas' has got its roots situated in stomach, especially on its left side. 'Purīṣavaḥa Srotas' has got its roots in large intestine, especially at rectum (Ca.Vi. 5/8). 'Annavaḥa Srotas' and 'Purīṣavaḥa Srotas' together form the complete gastrointestinal tract. 'Annavaḥa Srotas' includes upper and middle part of the gut whereas 'Purīṣavaḥa Srotas' is lower GIT.

**Deglutition, Mucous secretion and Secretion of Enzymes:** The food is brought towards the gut through 'Prāṇa Vāta'. There, various fluids making its bonds loosen, act on it. Also, the food is softened here. Then the 'Samāna Vāta' stimulates 'Jāṭharāgni'. This 'Agni' finally digests the food (Ca.Ci.15/6, 7). After the food reaches stomach, several digestive juices act on it. Gastric juice, pancreatic juice, and enterocytes in the intestines - all contain important digestive enzymes and act on food. Secretion of these enzymes is mostly under the control of parasympathetic nerves and intrinsic enteric nervous system. This is how 'Samāna Vāta' stimulates 'Agni'.

**Digestion in Upper GIT:** First stage of digestion is called 'Madhura Avasthāpāka'. This takes place in the stomach. During this stage, there occurs the release of froth-like 'Kapha' (Ca. Ci.15/9). Salivary juice and mucous secreted in the stomach serve many protective functions but do not directly participate in the actual process of digestion. These are therefore indicative of froth-like 'Kapha', which is 'Malarūpī' in nature.

**Digestion in Small Intestine:** 'Pitta' that is present in between stomach and large intestine is called 'Pācaka Pitta'. Though made up of five basic elements, it is dominant in fire principle. So, it is devoid of liquidity and is called 'Anala' ('Agni'). This digests the food and splits it into essential nutrient part called 'Sāra' and waste part called 'Kiṭṭa' (A.H. Sū. 12/10-12). The 'Pācaka Pitta' is directly responsible for digestion of the food and therefore stands for all amyolytic, proteolytic, lipolytic and nucleic acid splitting enzymes. Gastrointestinal hormones like gastrin, secretin, cholecystokinin etc. also must be regarded as the representatives of 'Pācaka Pitta'. 'Sāra' (Nutrient) portion separated at this stage gets absorbed and thereafter it is called 'Rasa Dhātu'.

**Release of Bile Juice:** In the small intestine, 'Accha Pitta' (Bile) is released (Ca. Ci. 15/10) during the second stage of digestion. This stage is called 'Amla' 'Avasthāpāka' and during this phase, the bile juice and pancreatic juices are secreted into the duodenum. The bile is

liquid and it is called the 'Accha Pitta'. 'Accha' means 'liquid in form'. This is the 'Mala' of 'Rakta'. Bilirubin is a derivative of hemoglobin metabolism and represents this 'Accha Pitta'.

**Factors influencing Digestion:** Digestion of food depends on following important factors: optimum temperature, 'Vāyu', fluid medium, lubricating substances, time and appropriate administration. 'Vāyu' helps in movement of food in the gut. Fluids make the food particles easily breakable. Lubricating substances make the food softer. Time factor makes sure that the food is completely and properly digested. Along with all these factors, if the administration also is proper, the resultant digested material will be capable of maintaining 'Dhātusāmya'(Ca. Śā. 6/14,15).

**Absorption and distribution of Digested Material:** After the completion of the digestive process, the digested material reaches all parts of the body through the vessels called 'Dhamānīs' (Ca.Vi. 2/18).

**Large Intestine:** After the nutrients are absorbed from the small intestine, the remaining undigested portion of food reaches the large intestine. Here, it experiences the drying effect of 'Agni' and there is formation of solid fecal matter along with the release of 'Vāta' of 'Kaṭu' (pungent) nature. This stage is the third stage of digestion and is called 'Kaṭu Avasthāpāka' (Ca. Ci. 15/9-11). In the large intestine, except for absorption of water and some electrolytes, no digestive activity takes place. But this absorption of water makes the remaining undigested material hard and this material is called feces. Due to the activity of bacterial flora, some pungent gases like methane and ammonia are also produced here. These represent 'Kaṭu' nature of 'Vāta' released during this stage.

### **Physiology of Respiratory System**

**Functions in General:** 'Prāṇa Vāta' situated at 'Nābhi', comes out through the throat to consume a nectar-like substance called 'Viṣṇupadāmṛta' from the atmosphere. After consuming this nectar of atmosphere, it re-enters the body speedily and nourishes the 'Jīva' (Śā. Pū. 5/51). Though the site of 'Prāṇa Vāta' is described to be 'head' in all earlier textbooks, Śārnāgadhara has described it to be 'Nābhi' in this reference. 'Nābhi', in Saṃskṛta language, just means 'a center'. So, this is indicative of a particular center in the head. 'Raktaṃ jīva itī sthitiḥ' is the opinion of Suśruta and this means that the terms 'Jīva' and 'Rakta' are synonyms. So, when translated with this background, the above verse gives the following meaning: "Because of the activity of 'Prāṇa Vāta' that is situated in brain, a nectar-like substance is consumed through the act of respiration. This substance in turn, nourishes the 'Jīva' (Blood)." This nectar-like substance must be oxygen. Nervous control of respiration and transportation of oxygen through blood also can be inferred from this reference.

**Lung – Phupphusa:** On the left inferior aspect of the heart, 'Plīhā' (spleen) is situated and on its left side there is 'Phupphusa' (Left lung). On right side, the corresponding organs situated are 'Yakṛt' (Liver) and 'Kloma' (Right lung) respectively (Su. Śā. 4/31). Suśruta has used two different terms to mean left and right lungs- 'Phupphusa' for left lung and 'Kloma' for right lung. This conclusion is drawn because of the fact that the term 'Phupphusa' has not been used in its plural form.

## **Physiology of Cardiovascular System**

Cardiovascular system ('Rasavaha Srotas') originates at heart and ten great vessels attached to it (Ca. Vi. 5/7). Ten vessels may be indicating two venae cavae (superior and inferior), one aorta, four pulmonary veins, one pulmonary trunk and two coronary arteries- as all these are directly connected to heart.

**Contents of Cardiovascular Compartment:** The term 'Rasa' stands for all circulating fluids in the body including the fluid portion of blood (Cakrapāṇi on Ca.Ci. 15/36). 'Rasa' is also the minutest and essential fraction of properly digested food. Heart is the site for this 'Rasa' (Su. Sū. 14/3). This 'Rasa' circulates in the body along with 'Rakta' (Ātañkadarpaṇa on Mā. Ni. 33/4). Ten great blood vessels connected to heart carry the 'Rasātmaka Ojas', on which the whole life process is dependent (A.H. Śā. 3/18). From the above references it is clear that three major substances circulate in the cardiovascular compartment- the first one is 'Rasa'- the liquid nutrient portion of blood (Plasma); the second substance is 'Rakta', the oxygen- carrying red material (RBCs); and the third one is 'Ojas'- the white substance that is responsible for immunity (WBCs).

**Autonomic Control of Heart:** 'Vyāna Vāta' is responsible for the forceful ejection of 'Rasa Dhātu' from the heart that later circulates all over the body to perform its function of providing nutrition (Ca. Ci. 15/36 and Su. Ni. 1/17).

**Cardio Vascular System is a Closed Circuit:** 'Rasa' is ejected out of the heart. It is then carried to all parts of the body. The blood vessels called 'Sirās' bring it back to the heart (Bh. Sū. 21).

**Structure and Functioning of Heart:** Appearance of heart is similar to that of an inverted bud of lotus. When the individual is 'awake', this lotus blossoms forth and when he is 'asleep', it closes up (Su. Śā. 4/32). The narrow apex of the heart is directed downwards and broader base is directed upwards when the individual is standing. This observation is reflected in this explanation saying that the heart looks like an inverted bud of lotus. To indicate 'life' and 'death', the terms 'awake' and 'asleep' are often used in Sanskrit literature. So, meaning of this statement is that functioning of heart continues till the death of an individual.

**Mean Flow Velocity of Blood:** The manner, in which 'Rasa' moves all over the body, is exactly similar to the manner in which sound, fire and water move (Su.Sū. 4/16). As per the view of different commentators, velocity with which sound moves is greater than that of fire and the velocity of fire is greater than that of water. Therefore, it can be said that this is the explanation of the mean flow velocity of blood which is maximum in the aorta and minimum in the capillaries. This is because the smallest cross-sectional area, which receives the entire output of the blood from heart, is aorta and accordingly, the mean flow velocity is highest in that vessel.

## **Theories for Microcirculation**

**'Kedāri – Kulyā Nyāya':** This theory describes different tissues as different fields, which receive water through different channels, which in turn, are connected to a big reservoir of water. Nutrient fluid in this case is 'Rasa', which nourishes all tissues through specific channels. This theory explains the importance of pressure-gradient, which determines the flow of fluid into the tissue-spaces as this is similar to the movement of water in the direction of gravitational force in the above example (Cakrapāṇi on Ca.Ci. 15/16-17).

**‘Khale- Kapota Nyāya’:** This theory explains the auto-regulation of blood flow by tissue-factors. Blood flow to each tissue is regulated depending on the metabolic needs of the particular tissue. The example given to explain this theory is that of different pigeons, picking up the grains from the same field and then returning to their original places. Here, the choice regarding the amount of grains purely depends on the need of the individual pigeon (Cakrapāṇi on Ca.Ci. 15/16-17).

### **Physiology of Hemopoietic System**

The roots of Hemopoietic system are explained to be Liver and Spleen (Ca.Vi. 5/8). Role of liver and spleen in the functioning of hemopoietic system is very important. RBC synthesis occurs in liver and spleen in between 3<sup>rd</sup> and 5<sup>th</sup> month of intrauterine life. Liver stores some important hemopoietic factors like Vitamin B-12, folic acid and iron. It produces many clotting factors also. Cells of monocyte-macrophage system destroy RBCs in the spleen after they complete their life span.

**Role of Bone Marrow:** In the cavities of larger bones ‘Majjā’ is present whereas in the smaller ones it is ‘Sarakta Meda’(Su. Śā. 4/10). This ‘Sarakta Meda’ is indicative of Red bone marrow.

**Formation of Bilirubin:** Byproduct of metabolism of ‘Rakta’ is ‘Pitta’.(Ca. Ci. 15/18). This ‘Pitta’ is Bilirubin, the product of hemoglobin metabolism. This is formed in the monocyte-macrophage system, mainly in the spleen.

**Hyperbilirubinemia:** When the ‘Pitta’ exceeds its normal levels, there is manifestation of symptoms like yellowish discoloration of feces, urine, eyes and skin (A.H. Sū. 11/7). When the total serum bilirubin level exceeds 2mg/dl, usually there is manifestation of clinical jaundice.

### **Endocrinology and Metabolism**

Normal vision, normal appetite, normal thirst, normal body temperature, normal softness of body parts, normal complexion, normal nourishment and normal intellectual functions- are all the functions of normal ‘Pitta’ (Ca.Sū. 18/50). These parameters are good indicators of many of metabolic activities. For example, impaired Vitamin A metabolism leads to problems in vision. In hyperthyroidism there is excessive hunger and increased body temperature. In diabetes mellitus there is polydypsia and polyphagia. In hypothyroidism, normal softness of the skin and subcutaneous tissue is lost. In Addison’s disease the excessive pigmentation leads to alteration in the complexion. In Cretinism, the mental growth is retarded.

**Intermediary Metabolism:** The five ‘Agnis’ viz., ‘Bhaumāgni’, ‘Āpyāgni’, ‘Āgneyāgni’, ‘Vāyavyāgni’ and ‘Nābhasāgni’ are the causative factors for the metabolism of five groups of respective ingredients of the food. Normally, the specific tissues are nourished from those ingredients of food which are similar to the respective tissues in their composition (Ca. Ci. 15/ 13-14). The function of ‘Bhūtāgnis’ is to metabolize the ingredients of food and to ‘sort them out’ into five groups depending on the predominance of particular ‘Mahābhūta’. These functions of ‘Bhūtāgnis’ can be explained through the functions of liver. Basically, whatever is digested and absorbed has to reach liver first and metabolic interconversion of the substances occurs there. For example, plant-derived amino acids can be used to synthesize human proteins, glucose can be converted into glycogen or in to fat, amino acids can be converted into glucose – and so on. ‘Sorting out’ of different substances occurs in liver and

that is the function of 'Bhūtāgnis' too. After the digestion in gastro intestinal tract is over, the ingredients of food ('Rasas') undergo metabolism once again. This metabolic end- product is called 'Vipāka'(A.H. Sū. 9/20). This indicates that 'Vipāka' is the end product of the action of 'Bhūtāgnis'. In other words to say, 'Bhūtāgnipāka' itself produces 'Vipāka' and therefore, 'Vipāka' in general, stands for intermediary metabolism.

**Metabolism at the Tissue-Level:** Each tissue derives its nutrition through the activity of so called 'Dhātvaṅni'. Metabolism at tissue level is dependent on these 'Dhātvaṅni'. Some part of the tissue becomes supportive whereas some part becomes waste after the metabolism at this level (Ca. Ci. 15/15).

**Different Metabolic Pathways at Cellular level- 'Kṣīra- Dadhi Nyāya':** This theory speaks of transformation of one substance into another in a particular order through the activity of respective 'Dhātvaṅni'. The example given to state this theory is that of transformation of milk into curd, curd into butter and butter into ghee in the particular order (Cakrapāṇi on Ca. Ci. 15/16-17). All metabolic pathways like Glycolytic pathway, Krebs' cycle, TCA cycle,  $\beta$ - oxidation pathway, Urea cycle, Gluconeogenesis etc. could be the examples for this type of transformations with the involvement of their specific enzymes.

**Metabolic State of a Tissue:** 'Jaṭharāgni', though is situated in its own site, has its fractions situated at the tissues. If these fractions become over active, there will be 'Kṣaya' (Catabolism) of 'Dhātu' and if they become depressed, there will be abnormal 'Vṛddhi' of 'Dhātu' (A. H. Sū. 11/34). In fact, several classical humoral hormones determine the metabolic state of a tissue. For example, many amino acids circulating in the blood stream are taken up by muscles and they are utilized to synthesize muscle proteins under the influence of thyroxin, growth hormone, insulin and testosterone. So, these hormones can be grouped under 'Māṃsa Dhātvaṅni'. If thyroid hormone levels increase in the blood, there is muscle wasting and loss of weight due to 'Māṃsa Kṣaya'. Similarly, Calcitonin, parathormone and Vitamin D3 can be included under 'Asthidhātvaṅni'. In hyper parathyroidism, osteoporosis or 'Asthikṣaya' is evident.

**Physiological Effects of Normal Metabolism:** At the end of 'Bhūtāgnipāka', three groups of metabolites are formed: 'Madhura', 'Amla' and 'Kaṭu'. 'Guru' (Heavy) is another name for 'Madhura' whereas 'Laghu' (Light) includes remaining two i.e., 'Amla' and 'Kaṭu'. These groups are called 'Vipākas'. 'Madhura Vipāka' promotes the synthesis of reproductive factor and promotes the excretion of feces and urine. 'Amla Vipāka' opposes the formation of reproductive factor and promotes the excretion of urine and feces. 'Kaṭu Vipāka', on the other hand, opposes the synthesis of reproductive factor and causes retention of urine and feces. Effects of 'Vipāka' on the formation of 'Doṣas' are as follows: 'Madhura Vipāka' promotes 'Kapha', 'Amla Vipāka' promotes 'Pitta' and 'Kaṭu Vipāka' promotes the formation of 'Vāta'(Ca. Sū. 26/61,62). Effects of this stage of metabolism may be of manifold. Some products may be used for tissue synthesis whereas the others may be used for the purpose of energy. Anabolic effects may be called 'Guru' and catabolic ones, 'Laghu'. Again, 'Doṣas' synthesized here are of 'Dhāturūpi' type ('Malarūpi Doṣas' are formed during 'Avasthāpāka').

**Importance of Normal Metabolism:** 'Agni' itself is present in the body in the form of Pitta. When it is normal, it performs the functions like maintenance of normal digestion, normal

vision, normal body temperature, normal complexion, valor, happiness and nutrition. When it is abnormal, all these functions also will be abnormal (Ca.Sū. 12/11). Other functions of endocrine system are described under the functions of 'Pitta'.

**Concept of 'Pitta':** 'Pitta' includes all those factors responsible for digestion and metabolism. For all practical purposes, 'Agni' & 'Pitta' are to be considered as identical entities (Su. Su. 21/9, Ca.Sū. 12/11).

**'Pācaka Pitta':** 'Pācaka Pitta' is equivalent to 'Jaṭharāgni' (A.H. Sū. 12/11). As its functions suggest, all enzymes responsible for digestion along with all gastrointestinal hormones and all local hormones of G.I.T. are to be included in it.

**'Rañjaka Pitta':** It is responsible for synthesis of 'Rakta'. It is situated in stomach ('Amāśaya') according to Vāgbhaṭa and the sites are liver and spleen according to Suśruta. Gastric intrinsic factor is the best candidate to represent Vāgbhaṭa's view, as it is required for the absorption of Vitamin B<sub>12</sub>, which in turn is needed for DNA synthesis of RBC precursors in bone marrow.

**'Bhrājaka Pitta':** As is known, pigmentation of skin is under the control of some hormones like ACTH & MSH from anterior pituitary. Some enzymes in the skin responsible for the metabolism of certain drugs applied topically also can be considered under 'Bhrājaka Pitta' along with the hormones controlling pigmentation.

**'Sādhaka Pitta':** All functions ascribed to this 'Pitta' are of cerebrum, limbic system, hypothalamus and other CNS structures. For motivation and other psychosocial behaviors Norepinephrine is a very essential neurotransmitter in the brain. Incidentally, it also acts on heart as a cardiac stimulant. During emergency situations it is released from adrenal medulla and it helps for "fight or flight phenomenon".

**'Alocaka Pitta':** This is said to be responsible for normal vision. Photosensitive chemicals in the eye, called Photo-pigments and the whole process involved in photochemistry of vision can be represented by 'Alocaka pitta'. Also, neurotransmitters involved in the visual pathway can be included under this.

## **Immune System**

**General Functions:** When the Śleṣma (Kapha) is in normal state, it is called 'Bala' as well as 'Ojas'; but when it attains an abnormal state, it is then called 'Mala' (Waste) and 'Pāpmā' (Disease) (Ca.Sū. 27/117). From the above statement it is clear that 'Bala', 'Ojas' and 'Kapha' are identical entities, at least when 'Kapha' is in normal state. When 'Kapha' is in its normal state, it provides compactness, stability, virility, immunity and resistance (Ca.Sū. 18/51).

**Importance:** The most essential fraction of all bodily tissues is called 'Ojas'. Eventhough it resides in the heart, it circulates all over the body to maintain the normal healthy status of the body. It is 'Snigdha' (unctuous) and 'Somātmaka' (mild and cool) in nature. Though predominantly white in colour, it has got some yellowish and reddish tinge. If this is lost, life also is lost and if this remains intact, life continues (A. H. Sū. 11/37-38).

'Ojas' has been described to exist in different forms in the body. The fraction of 'Ojas' that circulates all over the body through the cardiovascular system, moves along with 'Rasa Dhātu'. This is called 'Rasātmaka Ojas'. Another form of 'Ojas', is present in all tissues and is called 'Dhātutejorūpi'. This indicates the immune mechanisms present at

tissue-level. A third form of 'Ojas' is 'Śukra mala rūpi'. This enters the fetus to provide protection to the fetus during intrauterine life. Another form of 'Ojas' is described as 'Jivaṣoṇita rūpi' (Hemādri on A.H. Sū 11/37-38).

**Classification of Immunity:** Immunity is classified in to three types: Innate (Sahaja), Acquired (Kālaja) and Artificial (Yukti kṛta) (Ca.Sū. 11/36).

**Factors Influencing Immunity:** The following factors influence the promotion of immunity: place of birth, time of birth, favorable weather, excellence of genetic qualities, excellence of properties of food being consumed, excellence of physique, good ability to tolerate various factors, excellence of mental status, favorable factors related to nature, youthfulness, exercise and cheerful attitude (Ca. Śā. 6/13).

**Antigen-Exposure and Host Response:** Substances, which have opposite qualities to those of bodily tissues, (when gain entry into the body) encounter the opposition by the bodily tissues (Ca. Sū. 26/91). Etiological factors, 'Doṣas', and 'Dhātus' determine the bodily immunity or susceptibility for the disease. When all the three factors do not support each other or when they are weak due to passage of time, either the disease does not manifest at all or it takes some time in manifestation or the disease is very mild or all its signs and symptoms are not fully manifested. If the situation is opposite to that is mentioned above, the corresponding results also will be otherwise (Ca. Ni. 4/4). This means that susceptibility of a particular tissue to any antigenic attack plays an important role in the manifestation or non manifestation of a disease. At the same time, the potency of the causative agent also is important. Virulent strains of infectious agents produce severe symptoms. Along with these two factors, homeostatic mechanisms also are important. If immune system is normally functioning, injurious agents will be tackled effectively.

**Concept of Active and Passive Immunity:** Treatment of the diseases manifested due to the presence of opposing agents in the body, should be planned either by administering the substances having opposite qualities to them or by prior sensitization of the body by administering the similar substances as those of offending agent (Ca. Sū. 26/104). This forms the basis of active and passive immunity. Prior sensitization of the body with specific antigen makes one develop active immunity. On the other hand, antibodies can be procured out of an animal in which active immunity has been already produced, and can be administered to the individual suffering from the same disease. Other functions of immune system are described under the functions of 'Kapha'.

**Concept of 'Kapha':** Functions of immune system and all such other protective mechanisms in the body have been grouped under 'Kapha' in Ayurveda. 'Ojas' is also closely related with 'Kapha'.

**'Avalambaka Kapha':** Situated in the thorax, 'Avalambaka Kapha' protects the 'Trika' and other vital structures like heart, through what is called 'Am̐bukarma'. Other anatomical sites where other types of 'Kapha' are situated also are dependent on this (A.H. Sū. 12/15-16). 'Trika' region indicates the meeting point of three bones. As this is present in thorax, it must be indicating the junction between the sternum and clavicles, behind which, the thymus gland is situated. 'Am̐bu' means liquid or water. So, 'Am̐bukarma' must be referring to lymphatic drainage.

**‘Kledaka Kapha’:** This is present in stomach and it moistens the ingested food (A.H. Sū. 12/16-17). Mucous secreted in stomach plays important role in offering protection to mucous membrane of the stomach along with providing liquid medium for digestive process. Also, Gut Associated Lymphoid Tissue helps in providing protection by preventing the entry of any microbes through gut. HCl secreted in stomach also provides innate immunity to some extent. All these mechanisms can be explained through ‘Kledaka Kapha’.

**‘Bodhaka Kapha’:** This is said to be present in oral cavity and helps in the perception of taste. Salivary juice secreted in the oral cavity not only helps in the process of taste perception but also performs some protective functions. Root of the tongue is the site of ‘Bodhaka Kapha’. Tonsils are the important lymphoid tissue-containing structures present there.

**‘Tarpaka Kapha’:** This sub-type of ‘Kapha’ is present inside the head and is responsible for the protection and nourishment of sense organs. Microglia and other similar Glial cells of brain tissue are some of the important entities, which may represent ‘Tarpaka Kapha’.

**‘Śleṣaka Kapha’:** This Kapha is present in the bony joints and is responsible for lubrication and easy movements. Movements are most obvious in synovial variety of joints and synovial fluid reduces the friction between two articular bony surfaces. But ‘Slesaka Kapha’ is not only synovial fluid. For several reasons known and unknown, these joints are the sites of prominent inflammation in most of the systemic autoimmune diseases like Systemic Sclerosis, Systemic Lupus Erythematosus and Rheumatoid arthritis. Such involvement must be, therefore, ascribed to the problems of ‘Śleṣaka Kapha’.

### **Physiology of Male Reproductive System**

The roots of ‘Śukravaha Srotas’ are the testicles and penis (Ca. Vi. 5/10). Testicles synthesize the hormone testosterone and also they are the sites of spermatogenesis. Penis is the male copulatory organ through which the seminal fluid is deposited in the female reproductive tract. The factor, which is responsible for the formation of ‘Garbha’ (embryo), is known as ‘Śukra’ (Ca.Śā. 2/4). ‘Śukra’ is distributed all over the body in the same manner in which the fat in the milk and juice in the sugar cane plant are distributed (Ca.Ci. 2/46). Also, this is present in males and females. All hormones of hypothalamo-pituitary-gonadal axis can thus be included under the term ‘Śukra’. In some references, ‘Śukra’ stands for only semen.

Fatty portion of ‘Majjā’ forms ‘Śukra’. This ‘Śukra’ comes out of bones through the pores created by ‘Vāyu’ and ‘Ākāśa Mahābhūtas’. As if the water oozing out of new mud pot, ‘Śukra’ also oozes out of these pores and then circulates all over the body through ‘Śukravaha Srotāṃsi’ (Ca.Ci. 15/32-33). ‘Majjā’ stands for even brain substance. ‘Mastakamajjā’ is the term given to indicate brain by Dalhaṇa, the commentator of Suśruta Samhitā, while commenting on Su.Śā.10/42. Hypothalamus secretes GnRH and Hypothalamo-hypophysial portal system carries this to the anterior pituitary. Anterior pituitary, in response to GnRH, secretes FSH and LH into the blood stream. These hormones then circulate all over the body and stimulate ovaries and testicles to secrete their own hormones.

**Ejaculation:** When the person gets excited because of the sexual urge, determination and romantic mental attitude, ‘Śukra’ comes out through the urethra (with which the bladder is connected) as if the melted ghee. This occurs because of the heat produced by the physical exertion during copulation. The simile given to describe this process is the flow of water from a place of lower altitude to a place of higher altitude (Ca.Ci. 15/34-35). Generalized

sympathetic stimulation is an essential feature of sexual activity. Erection requires parasympathetic stimulation whereas ejaculation is dependent on sympathetic one. Also, ejaculation is brought about by 'Apāna Vāta', which represents the sympathetic activity in this case.

**Physical properties of Semen:** The semen is 'Snigdha' (unctuous), dense, slimy, sweet, non-irritating (mild), and white just like a piece of alum crystal (Ca.Ci. 30/145-146).

### **Physiology of Female Reproductive System**

Menstrual blood ('Raja') also is a derivative of 'Rasa' only. Menstruation occurs in females once in every month and lasts for about three days. This process of menstrual cycle begins at the age of twelve years and stops at about fifty years of age (Su.Sū. 14/6). During the act of copulation, production of 'Śukra' occurs in females also; and it should not be thought that it is of no use in the process of production of embryo i.e., it is also of definite use (A.S. Śā.1/72). Features of 'Rakta' and 'Ārtava' are similar. 'Ārtava' is responsible for the production of embryo (Su. Sū. 15/5). 'Rakta' and 'Ārtava' are similar functionally. This is because the function of 'Rakta' is to 'Give life' ('Jivana') and the function of 'Ārtava' also is to give life to a new individual (embryo). So, 'Ārtava' means ovum in this context. This 'Ārtava', after getting nourished over the period of a month, enters (the uterus and then) vagina through the specialized structures called 'Dhamanis' meant for the transportation of the same. 'Vāta' is responsible for this movement of 'Ārtava'(Su.Śā. 3/10). This is the explanation regarding the process of ovum entering the uterus through the Fallopian tube. If not fertilized, it is shed off through menstrual fluid.

**Physiology of Lactation:** Breast-milk is formed out of 'Rasa Dhātu' (Ca. Ci. 15/17). The essential nutrient fraction of 'Rasa Dhātu', enters the breasts from the entire body and it is known as 'Stanya' (Su. Ni. 10/18).

**Development of Breasts:** Ducts in the breast tissue of non-pregnant women are narrow and are constricted. During pregnancy and after delivery they get dilated as a natural phenomenon (Su. Ni. 10/16-17).

**Various Stimuli for Milk Letdown:** Breast-milk is originally formed from the essential fraction of food. It is ejected out of breasts because of touch, sight and even because of mere remembrance of the baby. Uninterrupted love of mother towards her baby is the cause of its flow (Su. Ni. 10/12-13). Emotions, touch or even sight of the baby cause the hypothalamus of mother to release oxytocin stored in the posterior pituitary. This causes the myo-epithelial cells surrounding the glandular apparatus to contract and exert a squeezing effect, thus allowing the milk to flow.

### **Urinary System**

The abode of urine called 'Mūtrāsaya' supports the wastes of the body and is one of the very important vital structures in the body. Minute 'Nāḍīs' (specialized structures meant for transportation) arising from the large intestine, carry the urine continuously and contribute in the urine formation. This process is just similar to the manner in which many small tributaries and rivers contribute their water to the ocean. Openings of these 'Nāḍīs' cannot be traced out because of their minuteness and huge number. Because of this urine, carried by these 'Nāḍīs' from the proximity of stomach, 'Basti' (urinary bladder) gets filled up continuously throughout the day and night through the process of filtration. This process is

similar to the fashion in which a new earthen pot kept immersed in the water up to its neck gets filled up (by the water) after some time through its sides (Su. Ni. 3/20-24). 'Mūtrāśaya' in the above reference has been told to be very vital, and therefore, definitely is indicative of kidneys, from a functional point of view. Suśruta probably knew the role of kidneys in the formation of urine. He probably also had observed that there exists some relationship between water intake and urine formation. The fact that increased water intake results in increased urinary output must have been the reason for this observation. Also, decrease in the urinary output observed in the persons suffering from diarrhea or vomiting might have been another reason. So, he proposed the existence of invisible minute channels connecting GIT and urinary tract. This prediction is not totally wrong because cardiovascular system definitely connects both these systems. Water is absorbed from the gut into the venous circulation and this is carried to the kidneys through the arterial system. Also, the capillaries at Gut and glomerulus are definitely microscopic. The example of mud pot in the above explanation indicates the role of filtration played by the kidneys in the formation of urine. Thousands of 'Nāḍīs' taking part in the process of filtration may stand for nephrons from a functional point of view.

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