EVOLUTION OF PHYSIOLOGY*

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To trace successfully the evolution of any science is difficult, and this is particularly so in the case of Physiology, in view of the complicated circumstances which attended its growth. Physiology has been inseparably linked to the history and growth of medicine - the mother of all branches of natural science. Botany, Zoology, Chemistry, Physics, Pathology and Bacteriology have all arisen from a study of the art of healing. Mankind is always in search of better and better means for the maintenance of health and cure of disease. This has resulted in new lines of thought and new methods of work from time to time, thus creating new sciences.

In looking at the history of Physiology, one finds that since man began to take interest in problems of life in the ancient days, two distinct explanations of vital phenomenon arose, one as a natural, and the other as a mystical principle. So far as the attempt to explain it on scientific lines is concerned, we have the doctrine of *Pneuma*, which was held by the followers of Hippocrates (who is known is the 'Father of Medicine'), and which was subsequently clearly expressed by Galen. According to this doctrine, the origin of all vital phenomena was a very fine substance known as the pneuma, which existed in the air and was inhaled into the lungs by man from where it was carried by the blood to all parts of the body, where it gave rise to vital phenomena. This explanation was accepted all through the middle ages. It was termed *spiritus animales*. It, however, developed into supernatural theory and became a mystical doctrine. In the progress which took place, the Greeks played an important part.

But, 'The Hindus no less than the Greeks' as Sir B.N. Seal has said, 'have shared in the investigation of physical phenomena, as well as of building up a body of positive knowledge, which has been applied to scientific technique; and Hindu scientific ideas and methodology (e.g. the inductive method or methods of algebraic analysis) have deeply influenced the course of natural philosophy in Asia (in the East as well as the West), in China and Japan, as well as in the Saracin Empire'.

I shall briefly consider the Physiology contained in the ancient systems of medicine. All I wish to point out is that the theories and dogmas held by the ancients are not to be despised. On the contrary, their achievements deserve praise. They served their purpose admirably in their day. Each age must make the best use of the knowledge, it possesses. Who can tell what our successors a thousand or even a hundred years hence will think of us for some of the views and dogmas we hold today?

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Physiology in Ayurveda

In the whole Ayurvedic medicine the theory of Tridosas (Dhatus) is the basic principle. The three Dosas are wind (Vayu, Vata, Maruta), bile (Pitta) and phlegm (Kapha or slesman). The health depends on their normal condition or balance, while disease consist of their derangement. Without vata, pitta and kapha as well as blood, the body cannot exist. The word Dhatu indicates, that they are the elements of the body.

Vata is dry, cold, light, delicate; *Pitta* is greasy, hot, sharp, fluid and acrid; while *Kapha* is heavy, cold, mild, oily, sweet and phlegmatic. *Vata* prevails in advanced age. *Pitta* prevails in middle age and *Kapha* in childhood. Although the Dosas pervade the whole body, yet *Vata* has its chief place below the umbilicus, *Pitta* between the heart and navel, and *Kapha* above the heart.

According to some authorities, in addition to the three Dosas, namely vata, pitta, and kapha, blood is also a Dosa, so that there are altogether four Dosas. The blood, by moving along the vessels cleanses the humours and ingredients of the body, bestows colour, affects the sensation of touch and produces other wholesome conditions. This depends particularly on diet. Sour food causes pitta, sweet food kapha and pungent food vata.

Charak and Sustruta, the great physicians of the ancient Ayurvedic medicine, have given vivid descriptions of the structure and functions of the body. As Hoernle says, 'Its extent and accuracy are surprising, when we allow for their early age, probably the 6th century B.C. and their peculiar methods of definition.' There are hymns in Rigveda, where we find mention made of lungs, the intestines, the kidney and other viscera. The Atharva-veda shows a thorough knowledge of the coarser anatomy of the human body. Anatomy was deligently studied in the ancient schools, and vast amount of facts in regard to the human body were collected. We have definite evidence, that dissection was practised in those days. Thus in Susruta Samhita (SS III. 5.49) it is written :

"Any one who wishes to acquire a thorough knowledge of anatomy must prepare a dead body and carefully observe, and examine all its different parts."

Physiology in Ancient Chinese Medicine

The ancient Chinese Medicine contains an elaborate philosophy of disease, which contains certain physiological principles.

The most glorious period in Chinese history is the middle of the Chan Dynasty, 722 B.C. when history, literature, art, philosophy, religion and administration had reached a high degree of development. This dynasty is called the age of Philosophy, when most of the philosophers such as Kuan Tzu, Chaung Tzu, Lich Tzy and above all Lao Tzu, Confucius and Mencius flourished. They wrote on all kinds of subjects and influenced every branch of knowledge. The study of medicine, under such circumstances, developed into an elaborate system of theoretical knowledge. It was dominated by the scholastic subtlties of visionary philosophers, and was characterised by reverence for authority. As regards the theory and causation of disease, two doctrines were evolved, which formed the basis of Chinese medicine. They are as follows :—

1. *The doctrine of two principles called Yin and Yang*

Everything is supposed to originate from them. Yin and Yang represent the male and female forces. They stand for Heaven and Earth, the sun and the moon, day and night, heat and cold, life and death, strong and weak. In medicine everything is classified under these two divisions.

2. *The doctrine of five elements*

These are metals, wood, water, fire and earth. The human body is supposed to be made up of a mixture of these primordial substances. Health consists in the existence of these substances in proper proportions. Their imbalance results in disease.

Physiology in Greek Medicine

It was Empedocles of Agrimentum in Cicily (504 to 433 B.C.), who was a philosopher, physician and poet, who introduced in physiology the doctrtne of elements, earth, air, fire and water as the four-fold basis of all things. According to this, the human body is supposed to be made up of these four primordial substances, health resulting from their balance, disease from their imbalance. This doctrine of humours was taken up by Hippcerates and subsequently by Galen.

Hippocrates made an attempt to deal with medicine in a raticral way, and said that the most important thing in the practice of medicine is observation. His eminence is three fold: (a) he dissociated medicine from theurgy and philosophy; (b) he crystallised the loose knowledge of the Coan and Cnidian schools into systematic science, and (c) gave the physicians the highest moral and ethical inspiration. In the 3rd century B. C. while working at Alexandria, Erasistra'us placed the subject of physiology on a sound footing. He is called the *Father of Physiology*. He had a good knowledge of the anatomy of the heart and described the trachea, auricles, cardiac valves and chordae tendinae. He is said to have differentiated the anterior spinal roots as motor in function, and the posterior as sensory. He attributed the feeling of hunger to emptiness of the stomach and recognised the action of skeletal muscles in the mechanism of movement. He thought that the diaphragm was the only muscle concerned in respiration. He associated the higher intelligence of man with the greater elaboration of the cerebral convolutions.

The basis of his physiology, according to Singer, was the observation, that every organ has a three-fold system of vessels, arteries, veins and hollow nerves. In these tubes were found blood and two sorts of Pneuma (spirits). The idea at the back of the pneuma was in part an explanation of the need of respiration for life, but it became a mythic notion and was a hindrance to the progress of physiology for centuries.

Galen's physiology: Galen was born in 130 A.D. and died in 200 A.D. In the physiology of the neuro-muscular system, Galen showed by experiments on primates and lower mammals, that longitudinal sections of the cord causes no muscular paralysis, whereas transverse section causes complete loss of sensation and power of muscular movement below the level of lesion. Semi-section of the cord only causes paralysis on the side of the lesion. He demonstrated the origin and functions of the phrenic nerve. He showed the parts played by the intercostals and accessory muscles in addition, to diaphragm in respiration. He discovered the functions of the recurrent laryngeal nerve, and at will could stop the cries of animals by tightening a ligature round this nerve. He believed in the intrinsic nature of the heart beat, and made important observations on the functions of oesophagus, stomach, intestines and bladder. He knew of insensible perspiration. Galen postulated three pneumata, while Erasistratus had only two. The food stuffs were taken as chyle from the alimentary canal and to the liver and there changed into blood. The lowest pneuma, the *natural spirit*, was localised in the liver, veins and right heart, and with the ebb and flow of the venous blood was distributed to all parts of the body. In the lungs this blood was purified by the discharge of fuliginous vapours. The dynamic manifestation of this natural spirit, the natural force, was concerned with the sensual desires, nutrition, and blood formation.

The second pneuma, the *vital spirit*, was localised in the left heart and in the arteries. It was produced by the interaction of air (brought in from the lungs by the Pulmonary vien) with blood, which passed from the right side of the heart to the left through minute pores in the interventricular septum. The dynamic manifestation of this vital spirit, the pulsatile force, was concerned with courage, anger, personality and bodily heat. It served thus to ensure the activity of the heart, the production of heat in the left ventricle and its distributton by the arteries. Its auxiliary functions were connected with respiration and with the pulse. *The third Pneuma* or *Psychic spirit* was produced in the brain, when the blood in the arteries reached there. This spirit was connected with intellectual activities, sensation and movement. The intellectual activities were imagination, the power of thought and memory. Sensation included vision, smell, taste, hearing and touch. The psychic spirit was the only chief agent of a soul (Parche), which was located in the brain substance.

This hypothesis of the Pneuma is a remarkable piece of constructive thought to account for the physiology of the whole body, but it did incredible harm to the progress of physiology, because more stress was laid upon it, than upon Galen's experimental work by the subsequent workers and physiology cannot progress in an atmosphere of dogmas, however ingeneous they may be.

Physiology of the system of Arabian Medicine (Unani Hikmat)

It is stated, that the body has natural functions and virtues of faculties. A study of these constitutes the physiology of Arabian medicine. These natural functions are classified into three categories:

(a) *The Animal*, which are peculiar to the animal kingdom.

(b) *The Psychical*, some of which are common to man, and higher animals, and some are peculiar to man alone.

(c) The natural virtues are the nutritive and reproductive; the nutritive include the attractive, retentive, digestive and expulsive.

The animal virtues or functions are connected with the phenomenon of respiration and circulation as well as simpler emotions of fear, anger, disgust and the like, which are common to man and animals.

The psychic virtues or functions include motor and sensory powers common to all animals, and the higher mental faculties common to man, namely thought, memory, imagination etc. There are five external senses, namely taste, touch, smell, hearing and sight. Corresponding with these there are five internal senses.

In Kitabu'l-Maliki or Liber Regius of Ali ibnul-Abhas al Majusi who died in A.D. 928, there is a chapter dealing with animal virtues and vital functions, which deals, with two opposite movements of expansion (inbisat) and contraction (inquibad). These movements occur in the heart and correspond with diastole and systole, and in the lungs, inspiration and expiration.

It is stated that the heart draws air from the lungs to mix with the blood for the elaboration of the vital spirit, just as the lungs inhale it from without, and that the vitiated air (al-fudulu'd dukhamiyya) is expelled by the reversed process.

The un-nutritious residue of the digested portion is rejected, but a portion of this is converted into phlegm, which has no special location. Another portion is converted into three humours - blood, yellow bile and black bile.

In the normal body, the humours exist in a state of mixture, but they can be separated by means of drugs or otherwise. Each humour may be normal and natural, or abnormal and un-natural.

To understand the significance of the Arabian medicine, let us take another look at history. While in Europe, medicine as a science was at a standstill, the light of knowledge had not altogether extinguished in other parts of the world. Many of the works of Hippocrates and Galen and other Greek Physicians were safely evacuated to Constantinople, where they were carefully preserved. From there, the medical knowledge spread to Mesopotamia. Baghdad was the centre of Arab culture, where the enlightened ruler Harun-ul Rashid rule. He founded there a University, a hospital and a Medical School. The books of Hippocrates and Galen were translated into Arabic.

From Arabia, the Muslim influence spread to the West and the East. On the East, it spread to Persia, Afghanistan and India, as the Unani system of medicine. In India, it flourished in certain centres, notably in Lahore, Lucknow, Hyderabad (Dn.), Aligarh and Delhi. Even today, there are many votaries of this system and it is practised in many parts of the country. Thus in India, we have the Ayurvedic and Unani systems of Medicine for many centuries. On the West, it spread to Balkan Peninsula, Italy and Spain.

Physiology in the Mediaeval Period (1096-1438)

The mediaeval age was the period of fuedalism and ecclesiasticism and in learning (including medicine and physiology) there was obedience to authority. Even before the downfall of the Roman Empire in the West, there was collapse of Greek Philosophy. For centuries, the social history of Europe was its rebuilding and the organization of nations from the various tribal groups. At that time, the greatest need of the European society was spiritual uplift, rather than intellectual development. Under these circumstances the Christian church, with its spiritual appeal made a wonderful contribution. The growth of the Christian virtue of compassion towards the sick and suffering led to new departures in medicine, particularly in nursing the sick, and erecting hospitals for their care and treatment. There was, however, absolute suppression of experimental science and independent enquiry and there was surprising ignorance of Hippocrates and his teachings. But Galen and his writings were supreme. Avicenna and his writings, which were translated from Arabic into Latin, were also read by the physicians.

The Renaissance

The 16th century may be regarded as the first stage, when a change was noticeable, although some indication of it had occured in the previous century. The close interrogation of nature, which was to lead to the development of modern science had begun. Painters examined the human frame, and the surgeons dissected it. A new culture had developed and thus the new era known as the Renaissance had dawned.

From the point of view of the evolution of medicine, and physiology, the period which is of the greatest interest to us is the middle of the 16th century. The Protestant Reformation was steadily spreading. The Art was flourishing. The new learning was everywhere working like heaven. It was under such circumstances, that in the year 1543, the printing press of J. Operinus in Basel published a book "De *Corporis Humani Fabrica*", the structure of the human body by Andreas Vesalius, which has been described by Sir William Osler as 'the greatest book ever printed from which modern medicine dates.'

In laying the foundation of Human Anatomy, Vesalius laid the foundation of Modern Medicine. The year 1543 when his book was published marks the beginning of a new era. From that time anatomy became a method of thinking. The history of medicine from then onwards was to a large extent the history of application of anatomical methods. Physiology at the time of Vesalius was still speculative and philosophical in character. In the17th century, anatomy developed into *anatomia animale* and an anatomical physiology was born based on experimental studies. In the 18th century, Pathology became anatomical. Accordtng to the new concept disease was attributed to alteration in the anatomy of the organs, which later developed into a concept of their dysfunction. Diagnosis became the diagnosis of the organs; percussion and auscultation were introduced as methods enabling the physician to observe anatomical changes.

Vesalius also made certain direct contributions to Physiology. In a brief chapter at the end of 'De Corporis Humani Fabrica' he gives a concise description of the technique and results of experiments on living animals. After accurate study of the anatomy of the dead body, he says, that one should proceed to examine the functions of organs or to acquire data from which those functions could be deduced in the living animal. He recognised the reciprocal action of the anatagonistic muscles. By tightening ligatures on nerves, he showed the dependence of the movements of skeletal muscles on nerve supply. He also repeated experiments on longitudinal and transverse section of muscles, ligature of recurrent laryngeal nerve etc., which had been performed earlier by Galen. By removing the nerve-sheath he demonstrated that it is through the nerve itself that a muscle is stimulated. By various methods he showed, that the pulsation of the arteries is dependent on the heart, and is not an innate quality of these vessels. He proved, that dogs could survive splenectomy. He studied the respiration of the foetus when removed or left *in situ* after caesarian section and removal of the membranes. For these experiments he used full term bitches or sows. In order to see the lungs in movement he removed a rib and other tissues of a dog without damage to the transparent pleura. He studied the action of the epiglottis and noted the presence of the pericardial fluid. By an experiment, he demonstrated, that if the lungs of an animal are collapsed and the heart has almost stopped pulsating, successive artificial inflation of the lung through a reed tied in the trachea will restore the activity of the heart to normal. This is what is done in artificial respiration even today. Such experiments give most valuable information about normal function of different organs of the body.

William Harvey: A disciple of Andreas Vesalius, William Harvey was the last of the ancients and first of the moderns and the real founder of experimental physiology.

His great achievement was the demonstration of the circulation of the blood by means vivisection and ocular inspection. He gave a clear idea of the work of the auricles and ventricles with their respective valves. He gave a truer conception of the pulmonary circulation and of general circulation, than was ever grasped before. He conjectured that in the tissues blood passed from arteries into veins. The existence of capillaries was not known at that time. This knowledge came subsequently with the discovery of the microscope. From 1616 onwards Harvey went on demonstrating the circulation of blood. He was a naturalist, and had intimate knowledge of the work of his predecessor. He says: "Foremost of all among the ancients, I follow Aristotle, amongst the modern Fabricius of Aquapendente; the former as my leader, the latter as my informent all the way." There was some opposition to his views, but on the whole, they were accepted much more readily than the long subservience would have led one to believe. This was a great tribute to him and to the value of experimental demonstration of physiological facts.

17th Century: With the 17th century, one feels, that one steps from the ancient into the modern world. Harvey introduced one way of arriving at physiological truth, namely the testing of hypotheses deduced from the study of structure by experiments on living animals. His method was used with success by other physiologists, but they were also quick to appreciate the advantages offered by new sciences of mathematics, physics and chemistry. Mathematics and physics owed much to the studies of Galileo Galilei (1561-1642); chemistry in its relation to medicine had its origin in the work of Valentine, Paracelsus (1493-1541) and Vas Helmont (1577-1644). Both Chemistry and Physics were advanced very much by Roberts Royle (1627-1691), who settled in Oxford tn 1654, and carried out there some of the work "which made him perhaps the greatest figure in the scientific world of his time." The wise use of physics and chemistry in the 17th century led to progress in physiology, but over emphasis, of these sciences as means of elucidating physiological problems had a harmful effect, in that it led to partial division of physiologists into an iatro-physical (or iatro-mathematical) and an iatro-chemical school.

There were other influences, which affected the growth of physiology. These were the improvement of the microscope and other instruments, the foundation of learned Societies in various countries; the publication of scientific journals, and advances in macroscopic and microscopic anatomy.

It may be pointed out that Harvey had to postulate a connection between arteries and veins although he could not see it. The final proof of Harvey's theory of circulation was provided by Malpighi, who described the capillaries in frog's lungs in 1661. Malpighi's work was confirmed and extended by Leeuvenhock of Delft in 1688, who gave an account of capillaries of different sites and in a large number of animals. It thus established the circulatory system as a closed one, and gave an impetus to the study of interaction of blood and tissue.

The Red Blood Corpuscles were first seen by Jan Swammerdan in 1658. In 1665, Malpighi saw them but did not realise their importance. He thought they were fat globules. Their real nature was discovered by Leeuvenhoek in 1674. The lacteals and lymphatic system were also discovered in the 17th century. In 1622 Gaspero Aselli (1581-1626) saw the lacteals, but he thought that they went to the liver. In 1651, Jean Pacquet (1622-1674) published his discovery of the Thoracic Duct, and the Receptaculum Chyli. He also showed that Asellis' lacteals open into the duct and the duct itself opens into the venous system.

The study of respiration was greatly helped by Robert, Boyle and Robert Hooke. Hooke proved that respiration is not dependent on lung movement, but upon passage of air through the lungs. In 1669, Lower described the experiments showing that air mixes with the blood in the lungs and gives the blood its red colour, while venous blood owes its dark colour to loss of air. Oxygen was discovered by John Mayo.

The pioneer of Metabolic studies was Sanctarius (1561-1636) of Padua. Malpighi made great contribution by his work on the structure of the glands namely, liver, kidney, spleen. He also showed that liver is a gland which secretes bile. In 1671, de Graaf showed, that the Pancreatic juice is one of the fundamental digestive secretions. Van Helmont's work introduced chemical ideas into physiology, and stated that all physiological processes are due to the action of ferments. He was the first to use the word *Gas* and *Gas Sylvestre* (carbon-dioxide), which is described as arising during the fermentation of wine.

The anatomy and physiology of the nervous system showed less progress than other parts of the body. Rene Descartes' book 'De Homine' issued in 1662, which is often called the first monograph on physiology, suggested the reflection of nervous impulses outward from the central nervous system. It may be mentioned, that in modern times the scientific concenptions of Rene Descartes have been acknowledged by Palvov as the starting point of his work on "Conditioned Reflexes".

18th Century: In the 18th century Herman Boerhaave (1668-1738) published his book '*Institutiones Medical*' in 1708. He was very good chemist and one of the ablest Medical teachers. According to him, all functions and actions of the body are to be described to the working of the physical and chemical laws. After Boerhaave came Albercht Von Haller (1708-1777) who wrote his monumental work: 'Elementa Physiologie Corporis Humani' in 1757 to 1765. This contains a scholarly analysis and synthesis of all previous work. With this, the modern systematic study of physiology may be said to begin. Haller made many contributions to Physiology, one of the most important of which is his idea of 'irritability', especially of muscle, both skeletal and cardiac.

In 1726, physiology was recognised as an integral part of the medical curriculum by the appointment of Andrew Sinclair as the Professor of Institute of Medicine at Edinburgh.

John Hunter (1728-1793), who was a leading Surgeon in London was pioneer in Geology, in fossil anatomy and in Biology. His method of investigating animal function is described as comparative anatomical physiology. Rev. Stephen Hales (1677-1761) made important contributions to cardio-vascular physiology. He measured the blood pressure and investigated the variations in calibre of capillaries under different influences. The knowledge of the anatomy and physiology of the lymphatic system was greatly increased in the 18th century by William Hunter (1718-1783), and by John Hunter. The cerebrospinal fluid was discovered in 1774 by Domenico Cotugno (1736-1822).

So far, as digestion and absorption of food are concerned, the work of Boerhaave, Rene de Reaumur and Spallanzani is important.

In physiology of Respiration, the outstanding contributions were by Joseph Black (1728-1799) and Antoine Laurent Lavoisier (1734-1794). Laviosier identified the Gas Sylvestre as carbon dioxide. Joseph Priestly (1733-1804) identified Oxygen. But it was Lavoisier who correctly interpreted that in respiration, Oxygen is taken in by the body and CO_2 is given out.

The first observations which led to the discovery of vitamins were made in the 18th century. In 1747, John Huxham recommended a vegetable diet for 1200 sailers of the fleet as treatment of Scurvy. Captain Cook (1728-1779) used special antiscorbutic food stuffs during his voyage round the world, and in 1795, the Admiralty ordered a general use of lemon juice which effectively checked Scurvy.

In the Nervous System Winslow classified the sympathetic system into three divisions. Robert Whytt (1714-1766) examined the reactions of animals after extripation of various parts of the central nervous system, and showed that spinal cord is essential for reflex action.

19th Century : During the 19th century progress in physiology became very rapid. The Cell theory came into prominence. Owing to improvements in the microscope in the first half of the century and the invention of the microtome in the second half, the individual cell in the body was studied carefully, and it was recognised, that it was the essential unit in the body structure and function. Schleiden (1804-1881) and Schwann (1810-1882) first enunciated in clear terms these new ideas. Huxley in 1853 also gave a clear exposition of this. It is to such workers, that we owe our knowledge of the protoplasm, the nucleus, the nucleolus, Karyokinasis, genes etc. This work is not yet complete, and is still going on with increasing interest and rapidity. It has also influenced Embryology and through the 'neurone theory' the progress of neurophysiology.

Some other influences on physiological progress were the discovery of the laws governing diffusion, the enunciation of the first and second laws of Thermodynamics, Darwin's Origin of Species and his ideas of Evolution, Graham's investigation of Osmosis and of Crystalloids and colloids, and the papers of Vant Hoff and Arrthenius on Osmosis and on Electrolytes in solution.

Many new instruments were invented during this century such as Galvanometer, and improvements in the achromatic lenses of the compound microscope. Joseph Lister introduced antisepsis into surgery. Ludwig (1816-1895) introduced mercurial manometer and the Kymograph; while du Bois Raymond invented the induction coil and the technique of faradic stimulation. Helmholtz produced the Ophthalmoscope in 1851, the Phakoscope, and Ophthalmometer in 1852. Lipmann invented the capillary electrometer tn 1872, and Mosso the Ergograph in 1884. Rontgen discovered X'rays in 1893. Laennec's invention of the stethoscope in 1819 added greatly to the instrumental equipment of the physiologist and the physician.

A discovery of the greatest importance to neurophysiology as well as to cardio-vascular physiology was announced in 1845 , when the Weber Brothers demonstrated the inhibitory action of the vagus nerve on the heart beat. The other great physiologists of the period were Carl Ludwig, Virchow and Claude Bernard. Claude Barnard was the greatest of the French Physiologists. He did his pioneer research work on the Vasomotor system. Brown Sequard in America did work on the cervical sympathetic. Ludwig and Von Cyon in 1866 investigated the effect of temperature on the heart beat and published their discovery of the Depresser nerve and the nervi Erigentes.

Much useful work was done on the blood, cerebrospinal fluid and lymph. In the 19th century the tissues were generally recognised as the chief seat of the oxidative processes. In studying respiration, attention was paid to the gases in the blood. In 1845, Mayer (1814-1887) pointed out, that living animals derive their kinetic energy, as well as their heat from the potential energy of the oxidative process. J. S. Haldane and Joseph Barcroft contributed much to the modern study of respiration.

Wohler started modern metabolic chemistry in 1824 by his discovery, that benzoic acid given in the food is excreated as Hippuric acid to the urine. In 1828, he synthesised urea from Ammonium Cyanate, thus starttng to bridge the gap between organic and inorganic compounds. Lavoisier initiated the modern study of metabolism. In 1819, Magendi showed that protein was necessary for the diet. In 1883-84 Max Rubner (1954-1932) began to make accurate measurements of the calorific value of various food stuffs, and of nitrogenous residues etc. Great advances were made in the physiology of digestion. In 1822, Beaumont (1785-1853) in America, began his studies on Alexis St. Martin, a trapper, who developed a gastric fistula as a result of gunshot wound in that year. He studied the composition and function of gastric juice. In 1846, Claude Bernard began his work on pancreatic secretion. In Russia, Pavolv carried out his investigation on pancreatic secretion and continued this work, which laid the foundation of our modern knowledge of the subject. He also did pioneer work on Conditioned Reflexes.

Research work on internal secretions was taken up. Moritz Schiff began his work on experimental thyroidectomies. He is rightly called a pioneer of Endocrinology. Brown Sequard also did work in this field by producing Addison's disease experimentally in animals. The internal secretion of Pancreas was shown to be of importance in connection with Diabetes Mellitus before the end of the 19th century. In 1869, Langerhans described the islets (which bear his name). In 1889 Von-Mering and Minkowski showed by experiment the relation of pancreatectomy to diabetes. This resulted in the discovery of insulin later. The discovery of internal secretions in the 19th century was a great achievement, and its implications for physiology and medicine are of the great importance.

In the physiology of the nervous system two concepts were put forward which were of great importance, namely the neurone theory and the synapse concept.

The chief advance in neurophysiology was in the study of reflex action. In 1811, Charles Bell (1779-1842) made the important discovery, that the anterior spinal nerve roots are motor in function and posterior roots non-motor. In 1820, Magendi gave definite proof, that the posterior roots were sensory in function, and enunciated the Bell-Magendi Law.

In 1870 Fritsch (1838-1891) and Hitzig (1838-1907) inaugurated the physiological study of the cerebral cortex by experiments on dogs. The work on the autonomic nervous system was carried out by Langley and Gaskell at Cambridge.

Important work was done on the special senses, especially the eyes. Thomas Young put forward his hypothesis of colour vision in 1801. Helmholtz, from 1853 onwards, elaborated his hypothesis of vision and explained the mechanism of Accommodation. Hearing was also the subject of publication by Helmholtz (1863-1869).

Physiology in India

Great Britain is undoubtedly the fountain-head of physiology as well as modern medicine in India. This movement started in the early days of the 19th century. At this time instruction in Ayurvedic and Unani Systems of medicine was imparted in the Sanskrit College and the Madrassa in Calcutta. It was in 1822, that the first medical school was started in that city. The credit for this is mainly due to Lord William Bentinck, the Governor General, for introducing higher medical education in India. He appointed a committee in 1833 for improving the medical school in Calcutta and the education imparted there. The deliberations of this committee have had a profound effect on the future course of medical education in India. In October 1834, the Committee submitted a report and made several recommendations for the improvement of the Calcutta Medical School. These recommendations were approved. The result was, that the medical school was abolished and the medical classes at the Madrassa and the Sanskrit College were also done away with.

The old order changed, yielding place to new. The foundation of a new medical college of Bengal was sanctioned in 1835. The original staff of the College consisted of Drs. M. J. Bramley and H. H. Goodeve. In Bombay, it is to Sir Robert Grant, who was Governor from 1835 to 1838, that the credit for the introduction of modern medical education is largely due. Soon after he became Governor, his attention was directed to this subject. In 1837, the medical and physical society of Bombay was organised, and in the same year, the Government directed its Managing Committee to look into the subject of medical education. Before this, a medical school had been started in Bombay in 1826. It functioned for 6 years and was abolished in 1832. This was rather disheartening and so the movement for the establishment of a new institution moved rather cautiously but steadily. After consulting various bodies, Sir Robert Grant wrote to Calcutta, the then capital of India, advocating enthusiastically the establishment of a medical college in Bombay. The proposal was approved by Lord Auckland's Government. But before this information reached Bombay, Sir Robert Grant unfortunately died on 9th July, 1838. A condolence meeting was held on 28th July, 1838 at the Town Hall in Bombay, when it was decided, that as a mark of respect to his memory, and in gratitude for his public services, a medical college so ably planned by him be established in Bombay and that it should bear his name. This institution was thus named Grant Medical College. The cost of the building was defrayed equally by public subscriptions and by contribution from Government. The foundation stone of the edifice was laid on 30th March, 1843 by the Lord Bishop of Calcutta. It was completed in Ocotber, 1845. The College was associated with the Jamsetjee Jeejeebhoy Hospital, named after Sir Jamsetjee Jeejeebhoy, who offered a donation of rupees one lakh provided the Government contributed an equal sum for the establishment of the hospital. The foundation stone of the hospital building was laid on 3rd Jan, 1843, and it was opened for the reception of the sick in 1845. The original members of the staff were Dr. Charles Morehead as the Prtncipal, Dr. John Peet and Dr. H. Giraud. I had the honour of being on the staff of this institution for 21 years (1920 to 1941).

In Madras, when Sir Frederick Adam was Governor, a medical school was established in 1835. It was of the same standard as the medical school founded in Calcutta in 1822 rather than the College founded in 1835. The original staff consisted of Surgeon William Mortimer and Assistant Surgeon George Hardinge. In 1847, Madras Medical School was raised to the standard of the Medical Colleges in Calcutta and Bombay, but its name remained unaltered until 1st Oct, 1850.

This briefly is the history of the establishment of the three oldest medical colleges in India, where the teaching of modern medicine and Physiology was first started. Subsequently, other medical colleges of a similar kind were established, namely the King Edward Medical College, Lahore (1860), King George Medical College, Lucknow (1912), Lady Harding Medical College, Delhi (1916), Carmichael Medical College (now known as R. G. Kar Medical College) Calcutta (1916). Medical College, Vizagapatam (1923), Prince of Wales Medical College, Patna (1925), Seth Goverdhandas Sunderdas Medical College, Bombay (1926), Medical College Rangoon (1924). Since Independence, the number of such colleges has increased rapidly, so that now we have over 90 medical colleges in the country.

In Bombay, Physiology was originally known by '*Institutes of Medicine*' a designation by which, it was known till lately in the Scottish Universities. It was taught at first here by Dr. Charles Morehead, the first Principal of the College, who was Professor of the Institutes and Practice of Medicine.

We have had some excellent and renowned teachers of Physiology in India in the past, such as Dr. Charles Morehead, Lt. Col Mayer and Lt. Col. Rose Hutchinson in Bombay, Lt. Col. Mckay in Calcutta, Lt. Col. Donovan in Madras, and Dr. Caleb in Lahore. In later years, with the establishment of whole time Professorships in the subject, Physiology has entered a new phase and now we witness a marked increase in the output of original work from the Physiological laboratories in all parts of India. It is no longer a subject of the medical curriculum only, for now several Universities in the country grant B.Sc. and M.Sc. degrees in Physiology. It is also an encouraging sign that the subject has been taught not only in Medical Colleges, but also in the Science Institutes of certain Universities, such as Calcutta, where the late Prof. Mahalanovis did excellent work. The movement has even spread to the schools, where Physiology is taught as one of the subjects for the matriculation or school final examination.

The Physiological laboratories here, speaking generally, are fairly well equipped, and many teachers are paying equal attention to teaching and research. I may perhaps relate a personal incident. In 1928, the late *Sir Walter Fletcher*, an eminent physiologist of the Cambridge School, who was then Secretary of the Medical Research Council in England, visited the Physiological laboratories of Grant Medical College. After very careful inspection, he turned round to me, and expressed great pleasure at what he described as '*The latest edition of Foster in India*". What is true of the laboratories of Grant Medical College is also true of laboratories in many other parts of India.

Finally, May I remind you, that Sir William Osler in an address delivered in January, 1901 on 'Medicine in the 19th century' before John Hopkins Historical Society in Baltimore (USA) said :

> "The study of Physiology and Pathology within the past half century has done more to emancipate medicine from the routine and thralodm of authority than all the work of all the physicians from the days of Hippocrates to Jenner, and we are as yet on the threshold".

This is a general review of the growth of the knowledge of Physiology during the last 3,000 years. This progress has continued with increased activity during the 20th century.

One fundamental concept, which was stressed by Claude Bernard, emerges from this study, namely that the internal environment upon which the free life of the higher animals depends should remain constant. Such animals are placed in variable external environments, but the effects of these are all neutralised by various mechanisms, so that the internal environiment (the lymph or plasma) in which the tissue cells live, remains for all practical purposes unchanged in its composition and in its physico-chemical properties. Water, oxygen, heat and reserve chemical substances are taken up by the circulating fluid in due amount to maintain the constancy of the internal environment. The nervous system presides over the whole to safeguard further the harmonious existence of the tissue cells and to co-ordinate their activities.

This is a brief and rapid survey of the main stages, through which the science of Physiology has evolved and has reached the present stage of development. It is essentially incomplete, but it can be of some help to us in our work. We learn, that scholars in different parts of the world working for a period of extending over 3,000 years have expounded certain ideas and made certain discoveries, thus constituting the science of Physiology, which has been of immense benefit to mankind. It is one of the lessons of the history of Science, as mentioned by Sir M. Foster, that each age steps on the shoulders of the ages which have gone before. The value of each age is not its own, but in part, in large part, is a debt to its forerunners. And this age of ours, if like its predecessors it can boast of something of which it is proud, would, could it read the future doubtless find much of which it would be ashamed.

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