Preksha Dhyana : Human Body

PART-I

ANATOMY AND PHYSIOLOGY

J.S. ZAVERI

"SCIENCE OF LIVING" SERIES—II

PREKSHA DHYANA : HUMAN BODY

PART I

ANATOMY & PHYSIOLOGY

By

JETHALAL S. ZAVERI

B.Sc., D.I.I.Sc., F.I.S.I.

Preksha-Pravakta (Exponent of Preksha)

TULSI ADHYATMA NIDAM

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Publisher's Note

In publishing this booklet, it is hoped to bring to the reader, in simple language, some of the truths, already known to the ancient philosophies, and now known to modern science.

Age of Tensions

In this age of technology, industrialisation and over-urbanization, we are constantly subjected to tremendous stresses and tensions. These, in turn, produce psychosomatic diseases like hypertension, insomnia, and various types of heart diseases. In desperation, people take to drinking and dangerous drugs which give temporary relief, but create more serious problems. The remedy does not lie in drugs or fantasy, but in the process of catharsis and development of the inherent powers.

Philosophy teaches us to realize that our existence is functioning in duality, i.e. there is a spiritual self within a physical body. Science is also proving that life's processes for man lie almost wholly within himself and are amenable to control. The control has to be exercised by the power of the spiritual self, and that inherent potency can be developed by knowing how to live properly, which includes eating, drinking and breathing properly as well as thinking properly.

What is Prekṣā Dhyāna ?

Prekṣā dhyāna is a technique of meditation for attitudinal change, behavioural modification and integrated development of personality. It is based on the wisdom of ancient philosophy and has been formulated in terms of modern scientific concepts. We hope that the synthesis of the ancient wisdom and the modern scientific knowledge would help us in achieving the blissful aim of establishing amity, peace and happiness in the world by eradicating the bestial urges such as cruelty, retaliation and hate.

The different methods of *prekṣā* (i.e. perception) include *śvāsa-prekṣā* (perception of breathing), *śarīra-prekṣā* (perception of body), *chaitanyakendra-prekṣā* (perception of psychic centres), etc. All these are methods of ultimate transformation in inner consciousness. Here, there is no need to sermonize for adopting virtues and giving up evils. When one starts practising perception, one experiences himself that he is changing, that anger and fear are pacifying, that greed and deceit are deteriorating, that one is getting transformed into a 'righteous' person.

Our series on "Science of Living" includes tracts on various facets of *prekṣā dhyāna*.

For a practitioner of Preksha-dhyana, it is necessary to know the functions and characteriatic activities of the human body and the roles played by them in health as well as diseases. This book provides an adequate understanding of the subject in an easy-to-read non-technical text. For convinience, it is divided into two parts. In the first part, an attempt has been made to provide a foundation of basic knowledge of human anatomy and physiology in an accurate and comprehensive way. The term **anatomy** refers to the study of different parts of the body, their form and relationship to each other, while **physiology** deals with the function of the living body. Because the study of the function is meaningless without the knowledge of the structure involved, anatomy and physiology are inter-related and essential for the study of life sciences as well as health-care. The second part of the book deals with various facets of health-care.

Everybody has a right to remain healthy and everybody can develop the ability to protect himself from the sickening effects of the environment and prevent illness. The process of keeping fit and healthy is more a matter of common sense and self-discipline rather than hard work. But basic to the care of health is a working knowledge of the living body. One must first acquire adequate knowledge of the working of various body systems. Then and only then one will be equipped to take better care of one's vital organs such as heart, lungs and liver.

The knowledge and care of the body would positively increase the ability to resist environmental hazards and develop the strength to fight off their attacks more vigorously.

This book is specially useful for the non-medical common man and woman who keenly desires to remain healthy and fit not only in youth but also in old age. The text is complemented with suitable illustrations and tables. It is hoped that it would give the reader in general and Preksha-sadhak in particular an opportunity to learn the way to live a better life.

Benefits of Prekṣā Dhyāna

Prekśā may appear to mean different things to different people because it contributes to increase physical, nervous as well as spiritual energies.

On physical level, it helps each bodily cell to revitalize itself, and facilitates digestion; it makes respiration more efficient and improves circulation and quality of blood.

On mental level, it proves to be an applied method to train the mind to concentrate; it offers a way to treat serious psychosomatic illnesses without drugs; it is an efficient tool for ending addiction and other bad habits; it reveals to one the mysteries of the mind by the realization and the real experience of the inner consciousness which includes the subconscious and the unconscious.

On the emotional level, the strengthening of conscious reasoning controls reaction to environmental conditions, situations, and behaviour of others; harmonization of the functioning of nervous and endocrine system results in control and eradication of psychological distortions.

On spiritual level, regulation of blood-chemistry through proper synthesization of neuro-endocrinal secretions, and dispassionate internal vibrations lead one to attain the power to control the mind and to become free from the effects of external forces compelling one to lose equanimity.

No Theological Dogma

Prekṣā dhyāna can be learnt and practised by anybody without distinction of caste, colour, country and creed.

There is no communal or theological bias, nor does it insist on any particular theological belief.

Though the process is not very difficult to learn and practise, it is essential to learn the technique through experienced and trained teachers. Normally a ten-day retreat (training camp) is a suitable means to acquire proper training.

Review of Results

During the last eleven years, more than 70 training camps have been organised and more than 8000 persons have learnt this technique. Amongst them are scientists, doctors, engineers, professors, teachers, government servants and other intelligentsia, besides the general public. Police Department, Education Department and others have taken part in the special courses organised by Tulsi Adhyatma Nidam. More such courses are being planned for different disciplines, professions and work areas. Over and above those who have been trained in these camps, thousands others have practised *prekṣā dhyāna* and have been benefited thereby. While many of them have restored their physical health, hundreds others have been cured of mental tensions, hypertension and other psychosomatic diseases.

For all this, we are grateful to Yugapradhāna Āchārya Shrī Tulsī and his successor-designate Yuvāchārya Shrī Mahāprajña for their constant guidance and efforts in this direction. These two great spiritual saints have truly blessed the entire human race with the boon of *prekṣā dhyāna*, and we are confident that all and sundry will be benefited by learning and practising this universal and easy-to-learn technique of *prekṣā dhyāna*.

Three permanent training centres have been established viz., 1. *Tulsi Adhyatma Nidam* at Jain Vishva Bharti, Ladnun (Rajasthan), 2. *Adhyatma Sadhana Kendra* at Mehrauli, New Delhi, and 3. *Tulsi Sadhna Shikhar* at Rajsamand (Rajasthan).

JETHALAL S. ZAVERI
Advisor
Tulsi Adhyatma Nidam
Jain Vishva Bharti
Ladnun

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Introduction

Human body is one of the most exciting of nature's miracles. It is a very complex multicellular organism in which the survival and health depends upon proper organisation and co-ordination of a number of physiological and biochemical functions. Integrated result of these activities enable man to live happily and to maintain health. Health-care by proper co-ordination of various body-functions—breathing, eating and thinking is an important facet of the system of Preksha-dhyana.

Everybody desires and has a right to remain healthy and avoid sickness. But to remain free from disorders and diseases, we must have adequate knowledge of the various systems of the body and their mutual relationship. Strange as it may seem, though everyone lives with one's own body, each moment of one's life, one knows little about the structure of its vital organs and less about how they function. Our medical knowledge and experience has developed wonderfully well and advanced to an extent which enables us to treat and cure such dreadful diseases as typhoid and pneumonia. Our surgical techniques can now repair and even replace a faulty heart. But how many of the unfortunate millions who overcrowd the world's clinics and hospitals know which one of their body systems failed to function properly ? Sure, we have developed pharmaceutical wonder drugs to treat psychosomatic diseases such as hypertension. But did any one of the thousands of hypertension victims know that it could have positively been prevented ? It appears that the good old adage "Prevention is better than cure" has been very nearly removed from the book of proverbs.

Each facet of our environment affects our body and its health, sometimes obviously and directly, and sometimes far more subtly. An endless variety of health hazards, such as exhaust fumes from cars and trucks, smoke, soot and industrial dirt from the factories, vapours from oil and other noxious chemicals relentlessly threaten our health almost everyday. Stress-producing situations, such as daily commute in an overcrowded city, are built up in our daily life. Congested and badly ventilated living conditions make matters still worse, and sometime or other we are sure to become victims of the deadly effects of a pollutant or a pathogen.

Scientific and technological development has brought supersonic speeds for travelling. It has, consequently, created conditions which make unprecedented demands on our physiological organs as well as mental equipment. These conditions, however, are most unlikely to change for the better during our lifetime. We can neither fight nor run away from the problems of the modern life.

Throughout life, we are constantly at war with enemies which lurk both within and without. It is our immune system which keeps the enemy at bay and maintains homeostasis i.e. optimum conditions of healh. Homeostatic mechanisms involve not only the circulatory, excretory and other body systems but also the limbic system which deals with our emotions. Disorders such as peptic ulcers, insomnia, asthma result from emotional rather than physical causes. "Psychosomatic illnesses" is the medical term for the diseases of the body resulting from mental or emotional disorder. Our thoughts and actions are influenced to some degree by emotions. Love and hate, envy, revenge —all these play an important role in our behavioural patterns. It is, therefore, necessary to maintain emotional as well as physical health. Hence for a practitioner of Preksha meditation, it is essential to know the intimate relationship between the Brain and the endocrines. The functional interlocking of the nervous and endocrine systems is so remarkable that they are regarded as constituting a single integrated system called neuro-endocrine system. The practitioner of Preksha system must also become aware that meditation can influence the control mechanisms of the body which are ultimately responsible for the homeostasis. These effects are produced by—

(a) A better equilibrium between the sympathetic and the parasympathetic components of the autonomic system, and

(b) Conditioning of the nervous region which controls the visceral functions.

Noble Laureate, Swiss Physiologist Dr. Walter demonstrated that there is an inner protective mechanism against overstress, which promotes restorative processes. In other words, everybody has the capacity to experience relaxation and drain out one's tensions. Regular practice of easy-to-learn technique of relaxation could become a potent drugless remedy for the most dangerous but common diseases such as hypertension.

In the following chapters each bodily system is dealt with systematically. Thus the reader will acquire good knowledge of the working of various body systems. The knowledge of our respiratory system would enable us to learn to breathe properly. Once we know how our stomach and liver operate, we shall be able to eat properly and improve our digestion. The knowledge of the functioning of our muscles would enable us to regularly relax and stop wasting nervous energy. And the knowledge of our neuro-endocrine system which has profound influence upon the mental states, emotions and behavioural patterns of an individual would enable us to remove such psychological distortions as fear, cruelty, hate, etc.

CONTENTS

: I :
Body as a Whole

The study of the human body is fundamental to health sciences. Anatomy and physiology are inextricably interelated and both are essential to students of life-sciences.

The body is characterised by bilateral symmetry. Many body parts and organs occur in pairs. Single organs are usually centrally located along the long axis which divides the body into two halves. The internal framework (skeleton) is a masterpiece of architectural and mechanical design which is composed of more than 200 bones. A prominent structural characteristic is the flexible spine or vertebral column. The internal temprature is maintained at 98.6° F or 37° C.

Regions of the body

The body is divided into :

Axial portion	head and neck trunk—thorax (chest), abdomen and pelvis
Appendicular portion	upper extremity—upper arm, forearm and hand lower extremity—thigh, leg and foot

Organization of the Body

The keynote of the human body is organization. Body is made up of trillions of specialized cells which are supported and nourished by other cells. Cells are grouped into organs and systems and the integrated sum of these systems is the body as a whole.

The cell is the smallest basic structural unit of the body carrying on all the vital functions. Tissues are composed of groups of cells of similar structure with matrix between them. The cells of a particular tissue are specialized for the performance of specific functions. Tissues performing a common function or functions are grouped into organs. A system is a group of organs that work together as a team to perform a series of functions. The important systems of the body are as follows :

1. **The Skeletal System** provides the basic framework that supports the body. It consists of bones, cartilage and the connective tissue which bind them together. It protects the vital but vulnerable organs of the body.

2. **The Muscular System** consists of skeletal and smooth muscles. It works with the bones to provide support and produce movements of body parts.

3. **The Integumentary System**—the skin—is both a mechanical and a chemical barrier between the body and the environment. It protects the body from microbes, from injury to inner tissues, from damage by ultraviolet radiation of the sun. It also protects the body from dehydration. It retains heat in cold season and dissipates excess heat in hot season and helps temperature regulation.

4. **The Digestive System** is concerned with the intake, breakdown and absorption of food materials and the elimination of solid wastes.

5. **The Circulatory System** distributes nutrients and oxygen to the cells and carries away their waste products.

6. **The Respiratory System** provides the means for bringing oxygen into the body and eliminating carbondioxide.

7. **The Excretory System** works to eliminate the waste products of cell activity.

8. **The Nervous System** receives and evaluates information about the outside world and controls and co-ordinates the body's activities.

9. **The Endocrine System** produces chemical substances (hormones) that affect other cells and organs and help to control and co-ordinate their activities.

10. **The Reproductive System** functions for the continuation of the species.

In the chapters that follow, the structure and functions of the major organs and systems of the body will be discussed in greater detail.

Cavities of the Body

For descriptive purposes the body is divided into cavities and the main organs are contained in these cavities. There are four main cavities :

(1) The Cranial Cavity contains the brain and its boundaries are formed by the bones of the skull.

(2) The Thoracic Cavity is situated in the upper part of the trunk and its boundaries are formed by the sternum, 12 pairs of ribs, the thoracic vertebrae and the diaphragm. It contains : the lungs, the heart, the trachea, the bronchi, the aesophagus and the aorta.

(3) The Abdominal Cavity is the largest cavity in the body. It is situated in the middle of the trunk and its boundaries are : the diaphragm, the abdominal walls, the lumbar vertebrae and the pelvic cavity (with which it is continuous). It contains the organs and glands involved in the digestion and absorption of food, the kidneys and the adrenal glands.

(4) The Pelvic Cavity extends from the lower end of the abdominal cavity and its boundaries are formed by the pubic bones, the sacrum and coccyx and the muscles of the pelvic floor. It contains parts of intestines, the bladder, the rectum, parts of ureters, the urethra; the uterus, ovaries (in the female); some of the organs of reproductive system (in the male).

: 2 :
Cells and Tissues

A. CELLS

Unit of Life

The human body and its parts are made up of (i) trillions of microscopic structures called cells, (ii) inter-cellular material (matrix) that the cells produce, and (iii) body fluids. Of these three ingredients, only the cells have the characteristics which distinguish life from non-life viz., growth, metabolism, response to stimuli and reproduction. Cells are thus the smallest living units of the body.

Since cells are the units from which the body is built, we shall commence our study of the body systems with them. The cell is often called the basic element of life. In fact, it is life itself. Can you imagine to compress the functions of a big city viz, transport system, power stations, communication set-up, factories and waste disposal system, all in a tiny sphere of about one-hundredth of a milimeter in diameter ? This is exactly what a cell is. It is hard to believe that a structure too small to see with the naked eye should be as complex as a city.

Size and Shape

Cells are microscopic units with great diversity of size and shape. There are 60 billion (60,000,000,000,000) cells in a human body. Though they are of different sizes, nearly all human cells need a high magnification microscope to be seen and a super microscope to peep inside its body. The smallest cells (certain brain cells) are about 1/200 mm and the largest ones (ova) are about 1/4 mm in diameter. They come in a variety of shapes. Some cells are nearly spherical, others are like tiny cubes and still others are cylindrical in shape. Nerve cells are long, thread-like structures. Red blood cells are only 7.5 microns[1] in diameter. A muscle cell may be more than 2 to 3 cms long but only 50 microns in diameter. Yet with all these differences nearly all the cells share certain features in common. This is the rationale for the "typical cell" we shall now discuss. Most cells carry out specialized functions. Cells of similar forms and functions group together to form tissues.

Structure of the Cell

The development of the electron microscope and other new techniques for probing into their depths has revealed finer details of cell structure for the first time. The cell is found to have one of the most complex structures in the universe. Within its confinement, thousands of chemical reactions take place. Each cell of the body leads a life, that in some respect mirrors, in miniature, the life of the body as a whole.

A typical cell is bounded by a delicate **cell membrane** that encloses the living substance **protoplasm.** Roughly at the centre of the cell is the **nucleus** enclosed in its own membrane. This is the control centre without which it cannot exist. The protoplasm of the nucleus is referred to as **nucleoplasm,** while that outside the nucleus is called **cytoplasm.**

Numerous tiny structures or organelles are dispersed in the cytoplasm. Some, such as **mitochondria**, have their own membrane covering. The number, appearance and arrangement of the various organelles vary with the type of cell and are co-related with the function of the cell as a whole. When a cell divides in two, yielding two smaller copies of itself, all its characteristic organelles are reproduced.

The organelles are specialised "departments" organelles where specific jobs are done. The cytoplasm is highly structured and compartmentalized and contains numerous organelles. The actual assortment of organelles may vary from one type of cell to another; however the functions of each organelle are the same in all cells.

1. A micron is equal to oue-millionth of a meter.

The Nucleus

The nucleus, as its name indicates, is a very important structure. Without it, cell cannot divide and eventually it dies. The nucleus is surrounded by an envelope which is a site of active interaction with the cytoplasm. Each nucleus contains a complete set of hereditary information, encoded in the DNA blue-prints, for all of the structures and functions of the whole body. These are found in a characteristic set of 46 thread-like structures called the **chromosomes**, grouped into 23 matching pairs.

The cell membrane has a 3-layered protein-lipid-protein structure. Its thickness is not uniform. It is far from a passive 'bag' holding in the cell's contents. In fact, it is a scene of frenetic activity. It is semi-permeable and permits certain substances to pass into or out of the cell, while barring the way to others. This external membrane of a cell is as remarkable as its internal structure. It is a bare .0000001 millimetre thick. Acting as a watchman, it decides what shall be admitted or excluded. It seems to have a communication system to talk to other cells. Hormones, secreted by the endocrines or ductless glands and neurohormones are the chemical messengers carrying work orders for regulating the production of various cells.

For its operation, the cell requires a lot of energy which is generated in hundreds of super-minute power stations called **mitochondria**. The process is the familiar combustion process in which sugar is the fuel which combines with oxygen producing energy and leaving behind carbondioxide (and water). During this chemical reaction, they synthesize adenosine triphosphate (ATP) which is the universal source of power for every living being and which can be stored until required. Whenever energy is needed—to think, to speak or to lift a load—(ATP) breaks down into simpler substances releasing energy in the process. All cells have mitochondria except the red blood cells; since they do no manufacturing, they have no need for power.

Reproduction and Division of Cells

Living organisms perpetuate their kind from one generation to another through reproduction. It is a careful duplication and transmission of characteristics from parent to offspring. Reproduction at the cellular level occurs by a process of cell division in which the original cell splits into two cells. We have dealt with the process of reproduction, in detail, in a later chapter. Here we shall give a brief account of a process of normal cell division called **mitosis.**

In almost every tissue, cells wear out and must be replaced. Even after overall growth of the body has ceased, growth still occurs at the cell and tissue levels, providing for the replacement of worn out or damaged structures. New cell formation occurs through cell division. Human life itself begins with the division of a single cell, the **ovum** (female egg) fertilized (by a male **sperm**) in the mother's womb. This single cell divides into two cells which in turn divide into four.

Cell-division (Mitosis)

Mitosis is a continuous process with characteristic sequences of events as one cell becomes two. It begins with the replication of the DNA (**deoxyribonucleic acid**) of the nucleus. The division continues till there are millions of cells of the human body. Even this wonderful phonomen of multiplication is nothing when compared to the transmission of enormous amount of information stored within the fertilized egg. This tiny fragment of life contains the **genes**—the messengers of heredity. They store complete blueprints for building complex chemical plants like liver and coded information on colour, texture and size of the body.

Genes are strung into long thin chains called **chromosomes.** There are 46 (23 pairs) chromosomes in each human cell. The genetic material is a mass, consisting of long thin tangled strands. In the next phase the tangled strands become shortened and thickened into discrete, rod-like structures. Each of these actually consists of two separate strands jointed together by a small body. In the next phase these chromosomes begin to move and align themselves. When the alignment is complete, each double stranded chromosome divides producing two single-stranded daughter chromosomes. One of each pair of formerly jointed chromosomes are dragged outward in the opposite directions. In the next phase the chromosomes lose their discrete shapes, reforming the tangled mass. A pinching in the cell membrane along the equator of the old cell appears and deepen progressively until the old cell separates into two replicas, each surrounded by its own complete cell membrane. Various organelles have been distributed also. Thus when division is completed, two fully equipped, functioning cells have been produced, ready to grow and to divide again.

The deoxyribonucleic acid (DNA) is the dictator of all cells controlling their behaviour by ordering their constituents what to make, what to seek and what to avoid. It can be compared to an architect who designs, draws up plans and prepares blueprints for a building. Actual construction is carried out by contractors **ribonucleic aicd**—RNA.

The divison that commenced in the womb continues throughout life. Millions of cells die and millions are born by the process of division, each producing two new ones which are exact duplicates of the mother cell. The exception to this constant replacement are brain cells called **neurons**. Worn out and damaged neurons keep dying without replacement. We shall learn more about neurons in the next chapter.

Chemistry of Life

Each living cell contains thousands of different kinds of chemicals. These chemicals are not an inert mixture but are constantly interacting with one another. The blue-prints of heredity are encoded in chemical from. The structures of the body are built up from chemical constituents, and differences in chemical composition distinguish one type from another.

To sum up, cells participate in every function of the body from birth to death. It is really a supreme wonder how 60 billions of them live in such harmony, each one performing its own assigned duty.

B. TISSUES

Types of Tissues

Groups of cells with a similar structure and function together with the non-living material (inter-cellular substance) between them, form a tissue. Tissues are of many types. They differ in the structure of cells that form them and also in the inter-cellular substance. They can be grouped together into the following categories :

(i) Epithelial or covering tissue
(ii) Connective tissue
(iii) Bone and cartilage
(iv) Muscle tissue, and
(v) Nerve tissue.

(i) Epithelial Tissues

Tissues which cover and protect all external and internal surfaces of the body are called epithelia. The outer portion of the skin, the lining of the body cavities and of the digestive, urinary and reproductive tracts are epithelia. Epithelial tissue provides protection from microbes, from physical injury, from various irritants and from drying out. In kidneys, it acts as a membrane for filtration and dialysis, permitting selective passage of certain types of molecules while retaining others. There are many varieties of epithelial tissues, from thick tough skin to the delicate lining of the alveoli in the lungs. They consist of sheets of closely packed cells on a basement membrane of connective tissue. The simplest epithelia are formed of a single layer of flattened cells. They cover the tubes of the kidney, the inner side of the ear-drums, blood vessels, etc. The lining of the alimentary tract, on the other hand, is much thicker, because they have to secrete the enzymes and mucus. Multi-layered epithelia cover the outside of the body, outer ear, mouth, throat, etc. A special water-proof variety covers the internal surfaces of the bladder and other parts of the urinary tract.

The skin is the thickest epithelial tissue in the body. It is an organ of protection as well as heat regulation. It has two parts : tough epidermis and soft dermis.

(ii) Connective Tissues

Connective tissue is the most widespread and abundant tissue in the body, and also the most varied. The functions of connective tissues are just as varied as their structure. Indeed the implication of their name may be somewhat misleading. Although they do connect, e.g. muscles to bones, connective tissues also support the body, serve as depots for fat storage and help to nourish the tissues they support, surround or permeate.

Connective tissues such as tendons and ligaments provide a mobile supporting framework for more specialised tissues. Capillary blood vessels and nerves pass through connective tissues.

Tendons are one type of dense connective tissues having great tensile strength. Tendons anchor muscles to bones and must withstand the tremendous forces generated by muscle contraction. They are composed of parallel bundles of fibres.

Ligaments bind bones to other bones. Here the bundles of elastic fibres predominate.

Aponeuroses are flat sheets of white fibrous tissues that anchor muscles to other structures. Elastic tissues are found in the trachea, larger arteries and spinal ligaments. They are tough but springy. Most of the body fat is stored in the connective tissues inside special cells, forming a uniform appearance and soft texture.

Blood and Lymph

We generally visualize tissue as a solid mass. Yet blood and lymph are also tissues. Here the matrix is entirely fluid, without suspended fibres. Since, in a sense, blood and lymph connect all the regions of thc body, they are grouped under connective tissue. Unlike the other tissues of the body, the blood is in constant motion, the movement occuring within fixed channels—the blood vessels.

Lymph is mostly water. It is formed by the continual draining of fluid from the intercellular spaces of the cells into the lymph vesses.

(iii) Bone and Cartilage

Two types of firm tissues—**bone and cartilage**—form the inner skeleton of the human body. In early life all bones are made of cartilage which is more flexible than bony tissue. Later on, it is replaced in all weight-bearing parts of the body. Cartilage is a tough but resilient, pliable form of compact connective tissue.

In the adults, cartilage is found in the nose, outer ear, larynx and airpassage in the adults. It is also found in the front parts of ribs and the moving surfaces of some joints. The transformation of cartilage into bone begins in later foetus—life, when calcium is desposited on a matrix made by the bone-forming cells. Until adolescence, a plate of cartilage cells remains near the ends of bones, enabling them to lengthen.

Bone, commonly thought of as a solid and inert substance, is really a living tissue. The hardness and rigidity of bone results from the deposits of inorganic calcium salts. There is a compact outer layer and a porous inner part in most of the bones. Some bones are hollow with a central cavity containing marrow. **Periosteum** is a fibrous covering containing cells which can form new bones to mend fractures.

Bones are joined together in a variety of diffetent ways. Some permit no movement, while some like the vertebral joints (with intervening discs) allow limited bending and rotation. Joints with a lubricated membrane and cartilagenous discs on moving surfaces permit free movement.

(iv) Muscles

Muscles make up the bulk of soft tissues in the human body. Close to half of the body-mass is muscle. Three types of muscles are :

(i) Skeletal or striated muscle

(ii) Smooth muscle and

(iii) Cardiac muscle.

Muscle cells have perfected contractility to an unparalleled degree. The contraction of muscle cells move body parts and the forces they can exert are phenomenal.

Skeletal muscles of the head, trunk and limbs are known as voluntary muscles. They are generally anchored at both ends in the skeleton and produce movement by contracting and relaxing in response to conscious efforts of the will. They are also called striped muscles, because their long, thin fibres have fine, dark and light cross markings called the H band and the I band. Muscle fibre is built up from fibrils aligned together.

The basis of the bodily movement is the ability of the muscular tissues to contract and relax in response to nervous messages. An innumerable variety of movements can be produced because of the complexity of the muscle arrangement in the body. In fact, almost every muscle has an antagonist which produces the opposite action. This enables one to control every movement in force and range, while the intricate arrangement of the muscles across joints allow the greatest possible diversity of action. The biceps and triceps provide an instance of muscular antagonism. While the biecps is contracted, the triceps is relaxed and vice versa.

The muscles of the intestines and certain other structures like blood vessels and the uterus are called **smooth muscles,** because unlike the limb muscles they have no cross markings. They contract involuntarily or automatically and are relatively slow in action. Normally the smooth muscles do their work silently and we are unaware of their action.

The heart or **cardiac muscle** is a unique type found nowhere else in the body. It is intermediate between striated and smooth muscles. It is unique because its contractions are inititated within the muscle itself.

Energy is required to contract the muscle. It comes from glucose which is derived from glycogen stored in the muscles. Lactic acid which is formed during muscular action accumulates in muscles which are used for any length of time and excess amount of it causes cramp.

'Muscle tone or tonus' is the residual degree of contraction in muscles imparting firmness and resistance to stretching. It is important in keeping the muscles in a state of readiness to respond to stimuli.

(v) Nerve Tissue

The cells of never tissue are specialized in two key areas : irritability or reponsiveness to stimuli and conductivity, the ability to transmit impulses. The cell unit of nerve tissue are called **neurons**. They extend to almost every region of the body. They differ somewhat in structure and ranging in size from a few thousandths of an inch to several feet long. However, each one is composed of a **cell body,** an extension called the **axon** which carries impulses away from the cell body and several processes called **dendrites** which carry impulses to the cell body.

In addition to the neurons, nerve tissue includes interstial cells, the **neuroglia**, which support and nourish the neurons. We shall discuss the intricate method of the transmission and impulses by the nerves in the section **'Nervous System'.**

: 3 :

The Skeleton : Muscles ; Skin

The Skin

The 206 bones of the average adult skeleton work together with the muscles and connective tissues to move, support and protest the vital organs making up the human body. It enables us to run, jump and control overselves with a freedom unknown amongst our mechanical creations. Each individual bone is carefully designed to fulfil its role. Ranging in size from the powerful thigh bone (femur) about 500 mm long and 25 mm across—to the smallest of the wrist bones found at the base of the little finger and shaped like a split-pea. The former must withstand 1200 lbs per square rich during walking; hence it is filled with cross-hatching internally for great resistance to pressure. Protection of the brain is one of the most important functions. The skull is made up of eight pieces of bone.

Spine or vertebral column is a marvel of efficient engineering and functionalism. Its vertebrae are formed to compose a cylindrical column strong enough to provide support for the body, yet flexibly articulated to provide for bending, stooping, twisting and a variety of other body motions.

An intervertebral disc of compressible fibrous cartilage is sandwiched between each two adjacent vertebrae cushioning the joint. With this structure, the vertebral column can withstand forces of compression many times the weight of the body.

The rib cage is an excellent example of the versatilty of joints and the protective function of skeleton. It protects two delicate organs—lungs and heart, while being able to expand and contract to bring in fresh supplies of air. Cartilage joins the ribs to the breastbone, providing a movable elastic connection. At the back, the ribs are fitted on to the vertebrae by tiny gliding, rotating joints permitting the rib cage to adopt different rhythms of breathing. In contrast to these is the large ball and socket joint of the hip which holds the rounded end of the femur in a self-lubricating socket. The head rotates on the two top vertebrae in the neck enabling us to shake, nod and turn our heads.

Bone Structure

Bone is like reinforced conerate. Its hardness is imparted by deposits of calcium carbonate and calcium phosphate in the matrix. Strength is imparted by reinforcing fibres. Living cells of the bone are nourished by blood vessels that permeate the bone. Cavities within bones house bone-marrow in which billions of red blood cells and millions of white one are produced everyday.

By three months after coneption, a complete skeleton composed of cartilage is formed. Bones are formed later by ossification. Childrens' bones are more flexible and less brittle and, therefore, less susceptible to fracture. In old age-excessive reabsorption produce osteoporossis and bones become brittle and easily broken.

The Structure of Joints

Our body is in almost constant motion. Legs move in walking and running; hands and arms move in a bewildering variety of activities, jaws open and close; eyes dart back and forth.

We would be as immobile as statues if our skeleton were one continuous structure instead of being composed of more than 200 bones connected in joints. The space between the bones in a joint is filled with a lubricating fluid. It reduces the friction between the moving parts. The whole joint is prevented from moving too far by the ligaments which connect the two bones at the joint, so preventing dislocation

Joints are commonly classified as : immovable, slightly movable and freely movable. The last group consists of ball and socket, pivot, and hinge joints. Shoulder joint is one of the most mobile while in the skull flat bony plates are held together rigidly.

Muscles

Muscles can be called "machines of the body" transforming chemical energy into directed mechanical force and generally producing movement of the body as a whole, of body-parts and of various fluids through specific ehannels.

In a muscular system makes up 42 percent while in a woman 36 percent of the body weight. It consists of 620 muscles working together to move the 206 bones of the skeleton. A further 30 or so muscles are needed to ensure the passage of food though the intestines, to circulate the blood round the body and operate other internal organs.

There are three types of muscle tissue differing in structure, mode of action and functions :

(i) Skeletal (or striated) muscles which are used for locomotion. They are attached to bones. They contract rapidly and their contractions permit movement of arms, legs and other parts. They have a capacity for tremendous power but they cannot keep up their exertion long; after a short time they must rest.

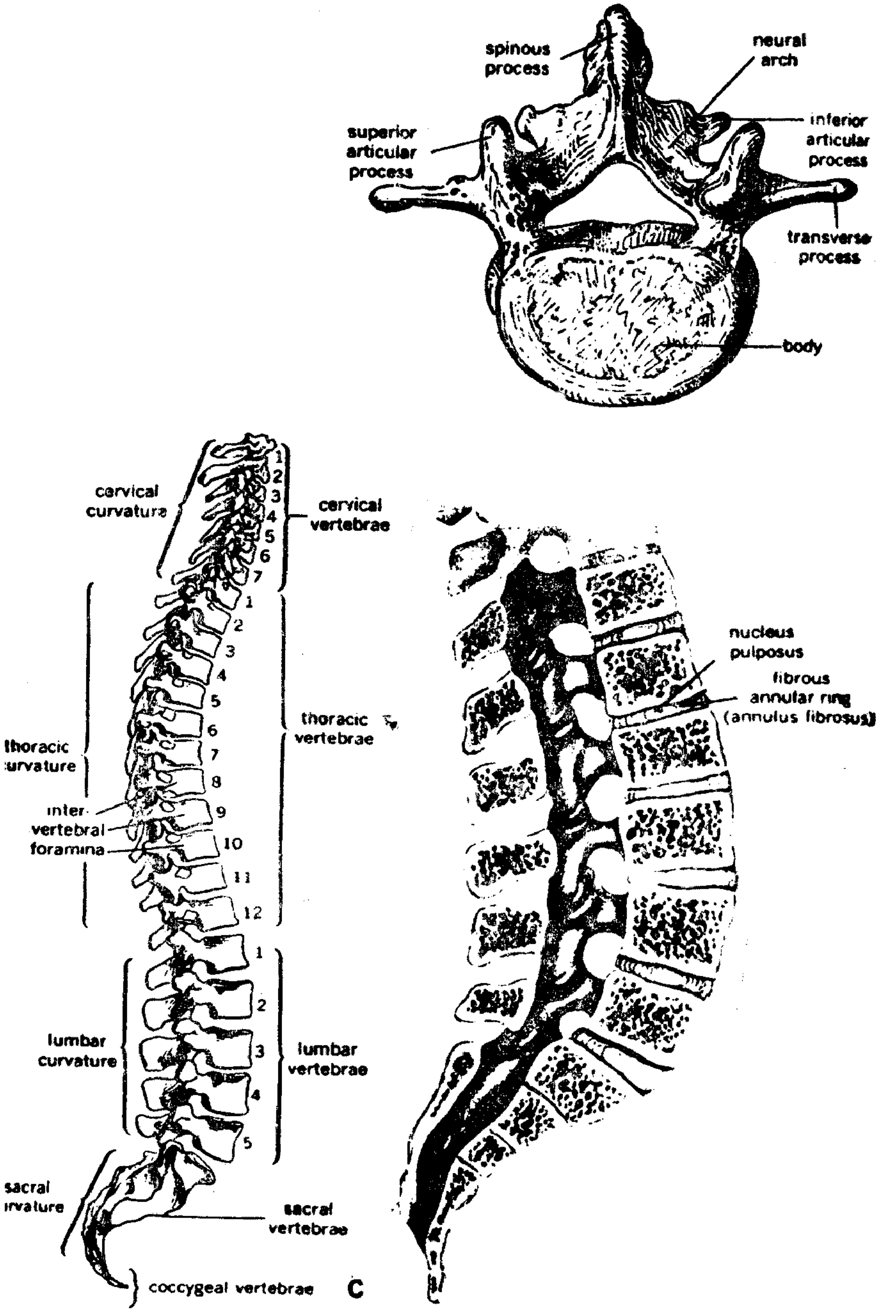
(ii) Smooth muscles which line the various organs and intestine. They are slow and steady and can go on contracting day after day without resting.

(iii) Cardiac Muscle (heart) is the special muscle that forms the wall of the heart. They all operate in the same general way because they are specialized in one common property : contractility. They contract and they relax. The fibers which make up the muscles are able to shorten their length by 30 to 40 percent.

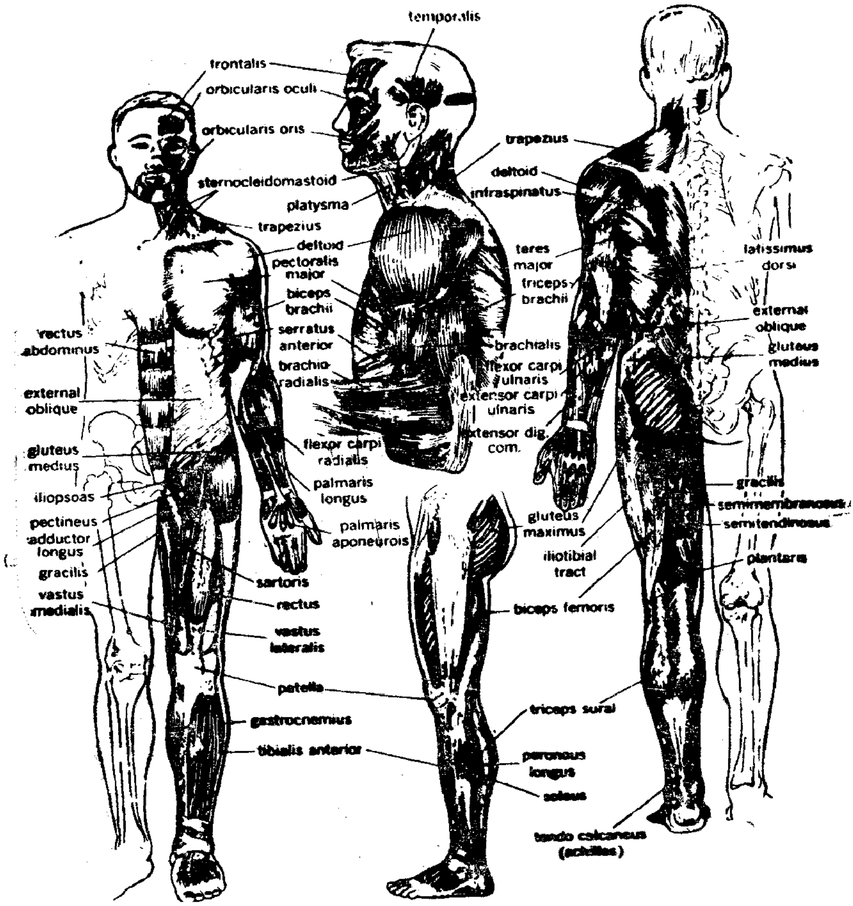
With very few exceptions (such as the blinking of the eye) single muscles never contract by themselves; rather whole sets of muscles contract together or in sequence or in opposition to achieve a variety of movement.

Actions of Muscles

Skeletal muscles are firmly attached at each end to different bones. When a muscle contracts, a pull is exerted on both bones but one is stabilized by contractions of



Vertebral column (A) and a superior view of a typical lumbar vertebra (B). Sagittal section of lower vertebral column showing intervertebral discs (C).



Structure and location of the superficial skeletal muscles: A, anterior view. B, lateral view. C, posterior view.

other muscles and the contraction pulls the other bone towards it. For example, contraction of the biceps muscle draws the lower arm towards the upper which itself is stabilized. Muscles which stabilize the bone (upper arm in this case) are known as fixation muscles. Movements are complex and the performance of any given movement (e. g. flexing of the elbow joint) requires the coordination of several muscles. Muscles which initiate and maintain a movement are called prime movers or agonists while those which oppose a movement or reverse it are called antagonists. Thus, when the biceps muscle contracts to raise the lower aım, it is the prime mover. The triceps musele oppose this action and is the antagonist.

The Control of Muscles

To produce the complex movements necessary for even the simplest handling of task, there must be a correspondingly subtle control mechanism. This is the job of the nervous system: it neautralizes the actions of the muscles that are not required and stimulates the muscles which are required. The brain and spinal cord exercise this control through the motor nerve fibres. Each muscle, however, does not have a 'private line' from the central nervous system (CNS). Impulses from the CNS travel down, branching off to supply a group of muscles which contract together, skeletal muscles contract rapidly in response to messages from CNS and develop tension at the same time to produce an effective mechanical force. The area of contact between the motor end plate and muscle fibre is known as the neuro-muscular junction. As the motor neuron approaches a muscle fibre, it branches to form a complex of nerve terminals—the motor end plate. This end plate between the nerve fibre and the muscle surface, acts as a kind of amplifier increasing the effect of the tiny current coming down the nerve fibre. On the arrival of the nerve impulse a chemical (known as acetylcholine) is released from the motor nerve ending and passes across the gap to stimulate the membrane of the muscle fibre. An electric current passes along the surface of the muscle causing it to contract. It takes one mili-second (1/1000 th of a second) for the current to pass, the contraction being an all-or-nothing response.

Then the fibre relaxes until another impulse arrives.[1]

Smooth Muscles react much more slowly than skeletal muscles. The nerves when present, alter the activity of the muscle rather than initiating it.

Heart Muscle also has a built-in mechanism to maintain rhythmical contraction quite independently, impulses for contraction coming from within the muscle itself.

The Mechanics of Contraction

Skeletal Muscle fibres contract in response to nervous stimuli and the weakest stimulus that can initiate contraction is known as threshold stimulus. When muscle fibres receive a stimulus strong enough to elicit a response, the fibres contract with the maximum force possible or they no not contract at all. But a skeletal muscle as a whole is made up of millions of individual fibres and, therefore, exhibits graded response rather than all-or-nothing one. Thus the same hand that can pick up an egg without cracking it can also wield a sledge hammer.

The Chemistry of Contraction

The muscles convert chemical energy into mechanical work. Muscles need a good blood supply to bring glucose and oxygen and to remove waste products. The actual chemical process involves the oxidization of glucose, thereby releasing energy which is used by the muscles to contract. The process needs a liberal supply of oxygen. In the absence of oxygen, the muscles can convert the glucose to lactic and which still gives the necessary energy.

Skin (Integument)

The skin is rightly described as the largest functional organ of the human body, since it covers an area of 1.5 to 2 square meters in an average adult person. It is the outer covering of the body and has a wide variety of functions in protecting the watery internal environment of the human body from the ravaging effects of the dry external environment. The skin protects the body from microbes, injury to delicate inner tissues, the injurious effects of chemicals and damage by ultraviolet radiation of the sun. It, thus, is

1. If this chemical mechanism is blocked, the result would be paralysis.

both a mechanical and a chemical barrier between the body and the environment.

Structure of the Skin

Skin is a two-layered covering. The outer layer, the **epidermis,** is made from epithelial tissue. The thicker inner layer, the dermis is composed of connective tissue. The skin contains, sweat sebaceous glands and hair. It has been calculated that a single square inch (six square cms) of human skin contains an average of 20 blood vessels, 65 hairs, 100 sebaceous glands and 650 sweat glands, 28 nerves, 13 sense-receptors for cold, 78 for heat, 165 pressure and 1300 for pain.

The Epidermis

The outer layer of the skin is the portion of the body one presents to the view of the world. The innermost part of this layer is continually dividing and pushing towards the surface, during which time the nuclei degenerate and the cells die. The skin cells that are visible, therefore, are dead. This outer layer varies in thickness in different parts of the body. It is thickest on the palms and soles. There are neither blood vessels nor nerve endings in this layer.

Some of the cells are specialized for the production of the dark pigment melamin, which is the major determinant of the skin colour. More melamin is produced among certain races than in others and this is the basis of colour difference among races.

Dermis

Dermis, the inner layer, is a thick layer of dense connective tissue. The structure of the dermis contributes great strength, toughness, distensibility and elasticity to the skin.

The dermis contains blood vessels, lymphotics, nerves and some structures derived from the epidermis (known as accessory organs). These are the sweat glands, hair, sebaceous glands and nails.

The upper layer of the dermis contains small projections. Since the epidermis is built on top of these projections, the order layer is also structured in a series of hollows and ridges which change the outer appearance of the skin.

The patterns (called fingerprints) are so characteristic for each individual that they can be used as means of identification.

Accessory Organs of the Skin

Varied functions of the skin are abetted by accessory organs such as hair and nails. More important but less visible are sebaceous and sweat glands.

Hair

No human is totally hairless. A prominent growth is the hair of the scalp. It protects the head and brain proteins from the harmful effects of the Sun's rays and excessive heat. Facial and chest hairs (on males) are signs of sexual maturation. A hair can regrow even if cut, shaved or plucked out. The colour of the hair depends on the amount of melamin present. White hair is the result of the replacement of melamin by tiny air bubbles. Each hair consists of a root and a shaft.

Nails

The nails form a protective covering on the dorsal surfaces of the fingers and toes. Their appearance may give an indication of general body health. Each nail consists of a root and a body. It takes about six months for the nail to grow out from its base to the finger tip.

Sebaceous glands

These are microscopic structures secreting an oily substance—**sebum**, which forms a protective film over hair and skin.

Sweat glands

These are distributed over most of the body surface but are more abundant in the armpits, the palms, the soles and the forehead.

SWEAT is a clear watery fluid containing 0.5 percent of solids consisting of sodium chloride, other mineral salts and urea. Sweating is one of the mechanism by which the body regulates its temperature. The secretion of sweat is controlled by hypothalamus via the sympathetic nervous system.

Even at normal body temperature water is lost continuously through the skin as insensible perspiration which evaporates as quickly as it is formed. At environment temperature, above 90° F, the sensible perspiration appears as visible drops of moisture on the skin.

Temperature Regulation

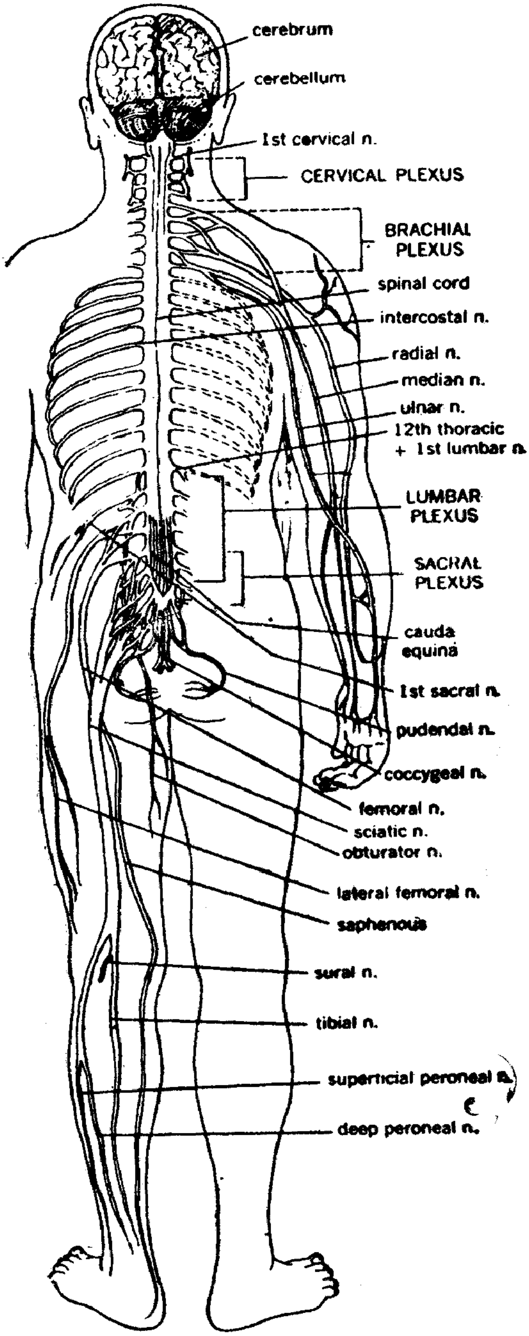
Control of body temerature is very finely balanced in all warm-blooded mammals and it is maintained at an average of 97° C (98.6° F). The body temperature is continuously monitored by the hypothalamus. Thermal receptors in the skin relay information about changes in the temperature of environment to the brain. Various mechanisms keep the body temperature relatively constant even though the skin itself may be quite cool. Skin plays a key role in body-temperature regulation. Heat is lost from the skin surface by radiation, convection and evaporation of sweat. The continuous secretion of perspiration carries off substantial amounts of heat.

: 4 :
The Nervous System

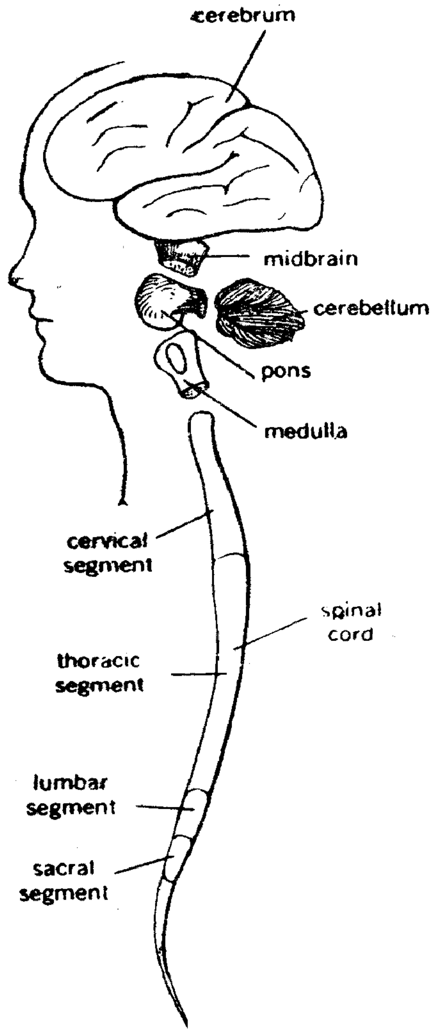
General

The nervous system is the most highly developed communication system in the human body. It co-ordinates and controls the work of other systems (of the body) and through them controls the functions of the body as a whole. It makes possible a range of adaptive responses to changes in the environment. Such responses are central to the behaviour of all living organisms and are known as homeostatic responses. If the body were unable to adapt to extremes of heat or cold, the healthy functioning of the vital organs would be threatened. Recognition of stimuli, storage of information (memory), communication between the various parts of the body, and the extension of effective responses are functions of this system. That is why it is considered to be one of the two most important systems of the body. Its failure will result in total cessation of its activities, paralysis of all the organs and ultimate stoppage of minute vital processes. One would be unable to use one's muscles, unable to move one's hands, blink one's eyes, to sit or stand, even to breathe. The nervous system is intimately associated with the endocrine system, and both together co-ordinate the body's activities and integrate the organism.

The nervous system is made up of two parts : an outer or **somatic** system and an inner or **visceral** system. The former consists of the sense-organs, the muscles, bones and joints. The latter controls the internal organs such as the heart, glands, blood-vessels and intestines. The activities of both are co-ordinated by the Central Nervous System (CNS).



The human nervous system


cerebrum
midbrain
cerebellum
pons
medulla
cervical segment
spinal cord
thoracic segment
lumbar segment
sacral segment

'Spinal Cord

Structural Organization

The structural arrangement of the nervous system is the basis for its division into two parts :

1. Central Nervous System (C.N.S.) consisting of the brain and the spinal cord.

2. Peripheral Nervous System (P.N.S.) consisting of 31 pairs of spinal nerves, 12 pairs of cranial nerves.

The functional relationships are the basis for differentiation of another division, the **autonomic nervous system**.

The Central Nervous System

The brain and spinal cord merge smoothly into one another without any obvious demarcation; the portion above the foramen magnum (the opening in the base of the skull) is considered as the brain while the portion below it is the spinal cord. The brain directs all conscious movements, and a number of unconscious, in voluntary actions as well.

The spinal cord, a shining rope of nerve cells, runs along the channel formed by the vertebral column.

The Peripheral Nervous System consists of the numerous nerves, that branch out from the brain and spinal cord forming the network throughout the body. The P.N.S. includes (i) the cranial and spinal nerves which carry messages to and from the C.N.S. and (ii) the autonomic nerves, which carry messages only from the C.N.S. There are hundreds of peripheral nerves which branch and rebranch, after leaving the brain or spinal cord, to form an intricate network.

The Autonomic Nervous System—Some of the most vital activities of the body, viz., breathing, beating of the heart, the digestion of food, and the formation of urine are normally carried automatically without our giving them much conscious thought. The activities of the internal organs are the province of a special division of the nervous system called the autonomic nervous system. The action of this system is not generally under voluntary control. The autonomic fibres are linked with and controlled by the hypothalamus, a part of the brain.

There are two main divisions of this system—(i) The parasympathetic and (ii) sympathatic. The action of the two divisions is antagonistic. In general, the parasympathetic system exerts its influence during the time of rest ; the sympathetic system prepares the body for emergency conditions and aids in the mobilization of body resources and energy production.

Functional Organization

More than 10 billion neurons comprise the human nervous system. Through the intricate network run impulses that are the foundations of creative thoughts as well as desires. Innumerable bits of data continually flood the body's sensory-organs and pass from the receptors along the peripheral system to the central nervous system. The latter system screens and evaluates the incoming impulses ; stores important data for future retrieval ; formulates decisions and initiates actions via impulses sent along the peripheral nerves to the muscular system.

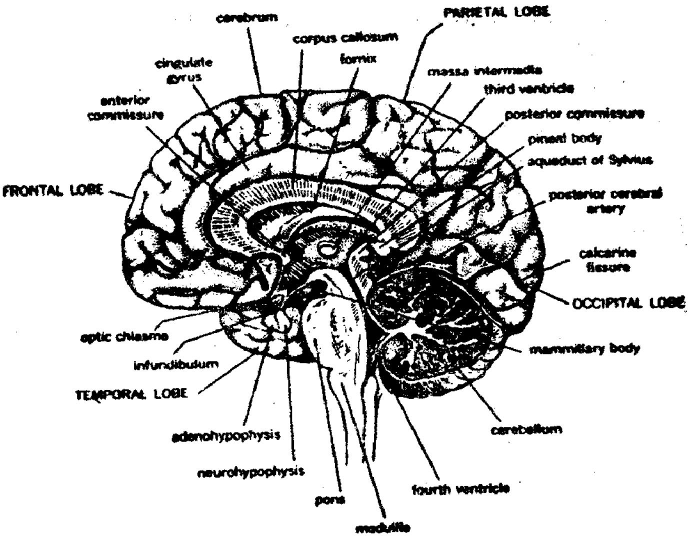
Thus the nervous system has two basic functions—(i) the detection and processing of information from within and outside the body and (ii) production and regulation of movement by muscle-section. Some parts of the brain are also responsible for the control of emotions and the storage of information and are also concerned with personality and intellect.

We shall now examine the components of each division of the nervous system in greater detail.

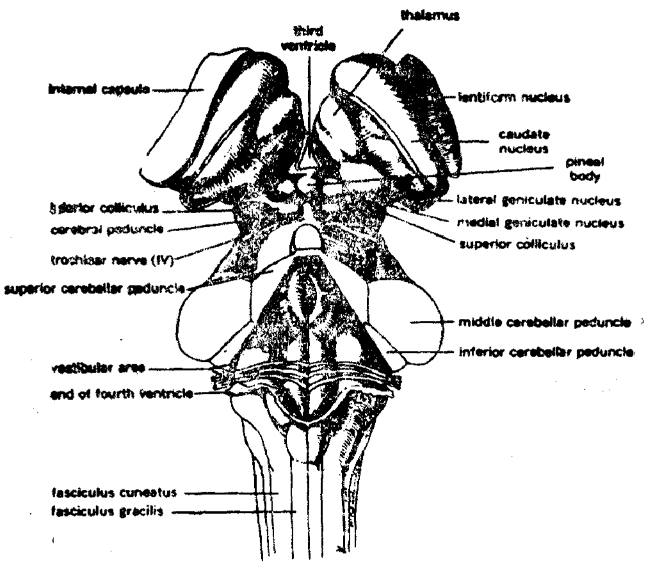
1. The Central Nervous System

A. BRAIN

The brain is the most complex and the most important part of the nervous system. In it are the sites of consciousness, thought, memory, creativity, speech, vision, hearing, smell, control of endocrine glandular secretions and autonomic (involuntary) functions, and the will to carry out purposeful actions. It is only because of the brain (his or hers and our own) that we know anything of the personality of an individual. Inspite of incredibly immense progress made by the electronics technology, a living human brain is a far more compact, yet complex and efficient apparatus



Sagittal section of the brain.



Dorsal view of the hindbrain and midbrain showing the floor of the fourth ventricle.

than the best artificial intelligence modern technology could devise.

It is the seat of personality of love and hate, pleassure and pain—the centre of awareness of the world around us—the source of intellect and creativity. The brain is that portion of the central nervous system which is safely enclosed within the hard bony helmet i.e. the cavity of the skull.

The adult human brain weight about 1.4 kgs. It is composed of some 30,000 million neurons and five to ten times that number of glial cells.

The brain receives about 17% of the cardiac output and about 20% of the total oxygen consumed by the body even though it is only about 2% of the body weight. It has three major divisions :

(i) The forebrain consisting of the two cerebral hemispheres (the cerebrum) and interbrain (diencephalon).

(ii) The midbrain (mesencephalon)

(iii) The hindbrain comprising of

(a) the pons,

(b) the medulla oblongata,

(c) the cerebellum.

The midbrain, pons and medulla oblongata together constitute the brainstem.

Cerebrum

The cerebrum is the most prominent portion of forebrain.

The forebrain and mid brain together make up the cerebrum. It constitutes the bulk of the brain about seven-eighth of its total weight and entirely fills the upper part of the skull. It is composed of an outer grey layer beneath which is a mass of white tissues. Its wrinkled surface allows a very large number of brain-cells to be packed into a limited space.

A deep cleft along the midline of the body seems to separate the cerebrum into two identical hemispheres. Actually, however, the two halves are not completely separated: deep inside, a thick bank of nerve fibres as well as three smaller bands interlink the two halves and provide for an interchange of information between them. Each hemisphere controls the ′ voluntary movements of the other side of the body. Each hemisphere is further divided into four main regions called lobes :

(i) Frontal lobe; (ii) Parietal lobe; (iii) Occipetal lobe; and (iv) Temporal lobe.

The cerebrum contains millions of neurons that are the basis of mind. In fact, man's ascendancy over his environment and other species is due to the size of his cerebrum, which is bigger in man than in any other animal. There are three varieties of activity associated wlth cerebrum :

(i) Sensory perception : The perception of pain, temparture, touch and the special senses of sight, hearing taste and smell.

(ii) The initiation and control of the contraction of voluntary muscles.

(iii) The mental activities involved in memory, intelligence, sense of responsibility, thinking, reasoning, moral sense and learning are attributed to the higher centres.

Cerebral Cortex

Our memories, hopes, plans, attitudes and personality—are all stored within a thin outer layer of the brain composed of grey matter in the cerebrum called the **cerebral cortex**. It is crumpled and wrinkled. If stretched out flat, it would cover nearly 4000 sq. cms. Its average thickness is 1.6 to 4 mm. It contains 10 to 14 billion neurons.

Research has yielded elaborate functional maps of the cerebral cortex. Out of the several lobes in which the cerebrum is divided, the frontal lobe is concerned with personality, behaviour and movement. The lowest left frontal part is the centre for speech. The next are the two parietal lobes which are involved in the analysis of sensations and recognition of the body in relation to its surroundings. Occipetal lobes, situated on the top of the cerebellum at the back of the head comprise the visual area of the brain. A separate projection on either side of the brain is the temporal lobe which interprets auditory information. Hidden inside the temporal lobe is the area concerned with taste and smell.

The pre-frontal region which lies in front of the motor area is very well-developed in man. It has no primary sensory or motor functions, but is connected with other cortical regions and with some of the deeper structures of the brain. It is involved in the control of emotions and the storage of information, and it is the part of the brain concerned, above all, with personality and intellect.

A general picture of the abilities of the two hemispheres has been developed by various experimental studies. The left brain reads, writes and speaks fluently and does difficult arithmetic. The right half seems rather stupid in comparison for verbal capabilities, but has a keener sense of shape, form etc. as well as a flair for musical rhythm and melody. Specialization of two halves is not an inherent difference in capacity, for if one side is damaged, the other one can be retrained to take over all functions. Dominance of one half over the other is responsible for "handedness".

Memory is of two types—'temporary' and 'long-term' memory. Each memory is stored in redundant fashion on many different parts of the brain and is multiplyingly repeated. The storage and retrieval of memories seem to involve both electrical and chemical phenomena including the formation of engram[1] (memory trace). Each of the neurons in a particular engram may be interconnected with numerous other memory traces, and from these interconnections the brain builds up its intricate "filing system".

Thalamus and Hypothalamus. At the base of the cerebral hemispheres, buried deep within the brain, are important structures, including the thalamus and the hypothalamus.

Thalamus is situated near the midline. It is a pair of egg-shaped masses of grey matter. It is predominantly a **sensory relay station** with incoming fibres from the spinal

1. Memory trace engram is fixation of a particular pattern of firing neurons.

cord and brainstem and outgoing fibres to the cerebral cortex.

All sensations from the periphery of the body (head, limbs and trunk) are conveyed to the thalamus. It is here that very crude, uncritical sensations reach consciousness. Critical interpretation of these occur in sensory area of the cerebral cortex. If it is damaged, one loses the ability to localize sensations precisely.

Hypothalamus is a mass of grey matter situated below the thalamus, at the base of the brain. Its importance seems quite out of proportion to its size. Although it constitutes only about 1/300 of the total mass of the brain, it is a vital link in the physical and emotional life of the body. It has neural connections to the posterior lobe and vascular connections to the anterior lobe of the pituitary gland. Hypothalamus contains numerous specialized control-centres including—

(i) **Cardio-vascular regulation** through participation in autonomic responses, regulation of heart-rate, cardiac output, blood-pressure etc. The activities of both components (sympathetic & parasympathetic) are coordinated and controlled.

(ii) **Body temperature regulation**—regulation of production and loss of heat by stimulating shivering and sweating.

(iii) **Regulation of food intake** (both hunger and satiating centres) and gastro-intestinal activity.

(iv) **Regulation of water balance**—it contains receptors which are sensitive to changes of salt concentration in the blood and controls intake or output of water via ADH (anti-diuretic hormone) and thirst centre.

(v) **Control of circadian rhythms** which include wakefulness and sleeping, body temperature cycle etc. and which occur with a periodicity of about 24 hours. Hypothalamus exerts overall control over these rhythms.

(vi) **Stimulation of sexual activity** in concert with the limbic system.

(vii) **Emotional feeling and expression.** Feelings and physical accompaniments are integrated by the hypothalamus, limbic system and prefrontal cortex. Centres of anger, fear, pleasure and pain are located in hypothalamus and elsewhere.

This part of the brain is obviously implicated in the most vital bodily functions, since an injury to it may cause emotional outbrust, over-eating, obesity and reduction of sexual activity.

Cerebellum and Brainstem. The hindbrain comprises of cerebellum and brainstem. The cerebellum, literally meaning 'little brain' sits behind the brainstem below the cerebrum and is concerned with the fine control and regulation of movement and maintaining balance. It looks very much like a small version of the cerebrum. It is divided into two hemispheres and is a mixture of grey and white matter.

The cerebral cortex plays a key-role in the control of muscular contractions that move body parts. But the part of the brain that makes sure that each muscle contracts not too much or too little but just enough to carry out cerebrum's intentions is the cerebellum. Damage to the cerebellum results in the loss of equilibrium and the person's movements will become jerky and uncoordinated.

The *mid-brain*, *pons* and *medulla* together are called the *brain-stem* from their resemblance to the stem of a fruit.

The brainstem connects the cerebrum with the spinal cord. Its uppermost part—the midbrain, is tucked up in the cerebrum. It houses a number of movement coordinating centres and is also responsible for sleep and wakefulness. Beneath this is the pons or bridge connecting it with the cerebellum.

Pons is a bridge-like structure, consisting mainly of white matter and serving as a relay station, linking medulla with the higher cortical centres. Finally the **medulla oblongata** joins the pons to the spinal cord. It is about one inch long portion of the brain-stem. It merges continuously with the spinal cord below and the pons above. Situated here are the centres for the control of key body-functions viz , the cardiac, vaso-constrictor and respiratrory centres.

(*a*) *Cardiac Centre.* A number of nervous and endocrine influences work to regulate the rate of the heart-beat. Cardiac centre in the medulla is an important link in this regulatory system. It works through the vagus nerve which joins with the cardiac branches. Impulses from this centre act to slow down the heart-rate. They act antagonistically to the impulses from the cardiac sympathetic nerves which speed up the heart-rate.

(*b*) *Vasoconstrictor Centre.* This regulates the arterial pressure by constricting the smooth muscles of the arterioles. This centre is itself controlled by higher centres, particularly, hypothalamus.

(*c*) *Respiratory Centre.* This controls the rate and depth of respiration. It is sensitive to the concentration of carbon dioxide in the blood. Physical exercise provokes an immediate increase in the rate and depth of respiration. Emotions such as fear also tend to increase the rate as part of body's automatic preparatian for fight or flight.

(*d*) In addition to these centres, the medulla contains control-centres for reflex action such as hiccupping, coughing, vomiting, sneezing and swallowing.

Reticular Activating System

An intricate cone-shaped network of nerve-cells which runs through the medulla, pons, mid-brain and up into parts of the thalamus and hypothalamus, is the brain's filter called R.A.S. It acts as a sort of central clearing house for the flood of information that bombards the brain. It lets only strong or novel signals pass upto the higher brain for conscious perception.

Though hundreds of thousands of sensory messages are received by the brain every second, only those which are important are perceived, while the rest are ignored. Thus, there is a remarkable distinction between sensation and perception.* The process by which the mind converts raw

* A familiar illustration of the distinction between sensation and perception is 'pain'. The same sensation signal from a tooth-ache, for example, effects each person differently. His suffering is perception. This distinction is utilized as an instrument for developing freedom from the vitiating emotions of like and dislike in the technique of Sharira-Preksha.

sensations into perception is complicated. While the sensation varies according to the power of stimuli, perception varies by an infinity of factors, some within the body and the others without. The state of emotion, in particular, may have a profound, and at times, decisive effect.

The R.A.S. action permits one to concentrate on a particular thought or activity, disregarding the background noises and other potential distractions. There is also a limit to the capacity of concentration of the brain in the perception of more than one thing at a time. If, for example, one attempts to hear music and read at the same time, he cancon centrate on one or the other, but not both.

In addition, a continual dialogue between the cerebral cortex and the R.A.S. keeps the higher brain awake and alert.

Protection of the Brain

The brain is the most carefully protected structure in the body. Not ony is it encased in a rigid helmet of bone—the **skull**—but within the skull it is wrapped in a series of three separate membranes—the **meninges**. The three membranes are (from the outside inward) the **dura mater** (hȧrd mother), the **arachnoid membrane** and the **pia mater** (tender mother). Extensions of these three membranes similarly encase and protect the spinal cord. Cavities inside the brain—the ventricles, are filled with cerebro-spinal fluid which provides a cushioning effect.

B. SPINAL CORD

The spinal cord extends from the *foraman magnum* (opening in the base of the skull) down to the level of the second lumbar vertebral. The cord itself is suspended rather loosely in the vertebral canal. It is approximately 45 cms long and is about the thickness of a little finger. It is well-protected by the bony tube of the vertebral column, as well as the three meninges whose multiple joints provide flexibility. From the outside the spinal cord looks white, but like the brain it contains both grey and white matter. Unlike the brain, however, the grey matter is concentrated inside.

Thirty-one pairs of spinal nerves emerge from the spinal cord at regular intervals. They connect the whole body below the neck, *i.e.* the trunk and the limbs, to the brain through the spinal cord. The head and the neck are directly connected to the brain by twelve pairs of cranial nerves. Each pair is composed of (*i*) sensory pathways which carry the message of sensation to the brain, and (*ii*) motor pathways which carry the orders of movement from the brain to the muscles in the trunk and the limbs[1].

The other function of the spinal cord is to provide 'reflex centres' for immediate response to certain incoming stimuli. Actions performed automaticlly in response to a stimulus without conscious decision or thought are called reflex actions. Many such actions are handled by the spinal cord without involvement of the brain.

2. Peripheral Nervous System

The peripheral nerves penetrate every part of the body to provide the links between the brain and the outside world. They branch out from the brain and spinal cord, and run as slender threads through the head, trunk and limbs. Depending on whether they emerge from the brain or spinal cord, they are classified as "cranial nerves" and "spinal nerves". A functional distinction is between sensory nerves which carry messages to C.N.S., and motor nerves which carry impulses away from the C.N.S. There also are some mixed nerves.

The cranial nerves are a heterogeneous group with little in common other than their origin in the brain. The cranial nerves are arranged symmetrically and are usually described as 12 pairs.[2] Actually, however, the olfactory nerves are not really a "pair", but comprising about 15 or 20 on each side. Some of them are, however, exclusively sensory, others exclusively motor and still others mixed. The cranial nerves supply mainly the head and the neck. The extensively

1. Sensory nerves are also called 'afferent', while the motor nerves are called 'efferent'.
2. The twelve cranial nerves are : I. olfactory, II. optic, III. oculomotor, IV. trochlear, V. trigeminal, VI. abducens, VII. facial, VIII. acoustic, IX. glossopharyngeal, X. vagus, XI. spinal accessory and XII. hypoglossal nerves.

branching vagus nerve supplies various structures of the trunk.

31 Pairs of spinal nerves, each containing thousands of nerve-fibres, branch out from the spinal cord. They ennervate the entire trunk and limbs (extremities). Each spinal nerve is a mixed nerve containing both sensory and motor fibres.

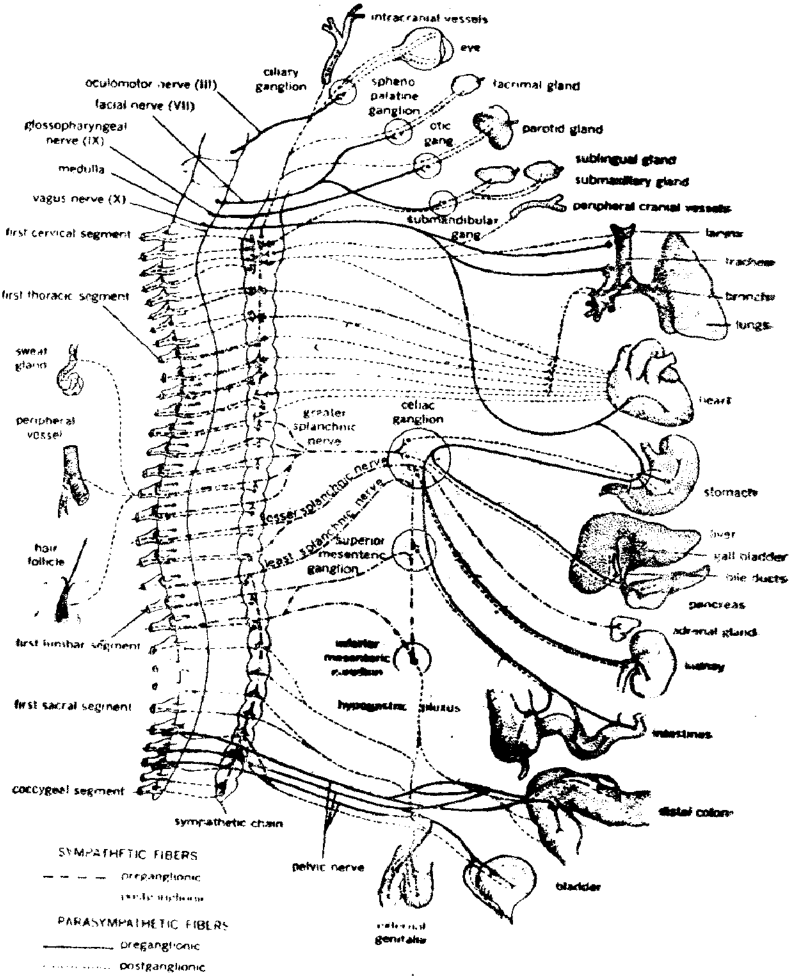
Deep cuts and crushing blows can damage nerves resulting in a loss of sensation or paralysis. Pressing on a nerve for more than 20 minutes makes the body-part served by it to go to sleep, i.e. it produces temporary anasthesia.

Autonomic Nervous System

Autonomic nervous system is also known as 'visceral motor system'. The motor-nerves involved in the control and coordination of inner working of our body form a division of the peripheral nervous system called the 'autonomic nervous system'. A high degree of orchestration of vital organs—the heart, the lungs, the glands is accomplished through intricate sequences of feed-back circuits with interacting nervous and endocrine controls. Appropriate actions are taken automatically and independently of the conscious brain through autonomic nervous system. Autonomic nerves are motor nerves carrying impulses to smooth muscles of the visceral organs, heart and glands. The circuits are completed by association with sensory nerves of the P.N.S. and control-centres of C.N.S.

The autonomic nervous system has two separate divisions: (i) **parasympathetic**, and (ii) **sympathetic**, each providing for a particular type of function.

The para-sympathetic division is concerned with keeping the body systems running smoothly day in and day out and conserving and restoring body-resources, e.g. it causes relaxation of the smooth muscle of the walls of blood vessels thus dilating them and protecting the heart from over-exerting itself. It promotes a harmonious course of the digestive processes. In short, it is the 'repose and repair' mechanism of the body. Structurally and functionally, it is more advanced of the two divisions.



Autonomic nervous system

When an emergency arises, the sympathetic division switches the body into high gear. Its function is as follows :

It stimulates the secretion of adrenaline and other 'fight or flight' hormones. It stimulates the liver to convert glycogen into glusose to provide the need for quick energy. It shunts away blood from the digestive organs to provide greater supply to the heart and skeletal muscles. It postpones the function of digestion and urination to a later time.

The actions of both divisions of the A.N.S. are mostly antagonistic, e.g. the sympathetic nerves act to speed up and strengthen the heart-beat and increase the blood pressure while the parasympathetic nerves slow down the heart-rate and lower the blood pressure.

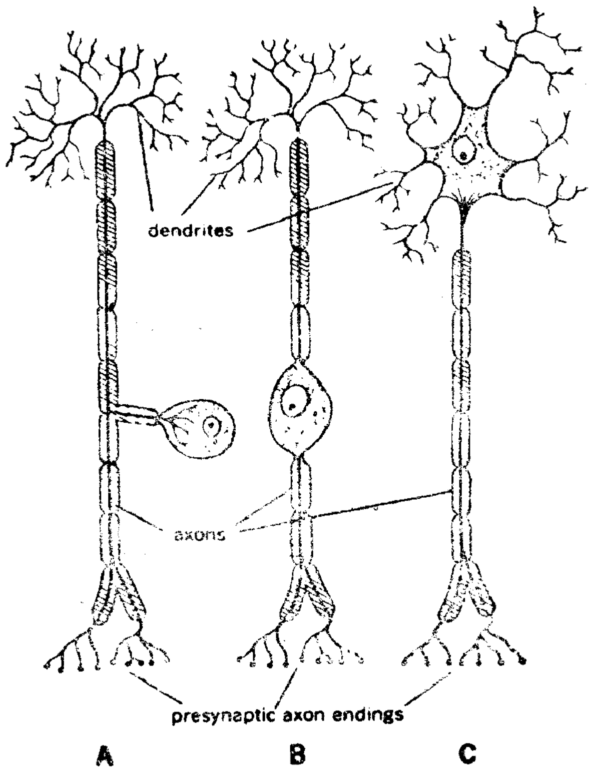
In some cases, however, their action is complementary e.g. both divisions are involved in the completion of a sex act in the male. It seems strange that impulses from one division may cause a particular organ to contract, while those from the other to the same organ produce relaxation. Some explanation is found in different neuro-transmitter chemical messengers released by the nerve-endings of the two divisions. Autonomic nerves are intimately involved in numerous important reflexes such as the regulation of blood pressure, evacuation of the bowels and bladder and the sexual reflexes. Thus it is not surprising that damage to the nerves of this system can have far-reaching and pervasive effects on body functions.

NERVE-TISSUE

Nerve-tissue is made up of the neurons, which are the active conducting elements and the neuroglia (glia means glue) or glial cells which support and provide nourishment to the nerve cells. The neuron is the structural and functional unit of the nervous system. It is an electrically charged cell which cannot be replaced like other cells. Neurons vary widely in size. The smallest cells in the cortex are only 1/200 mm. in diameter while the large motor cells in the spinal cord measure 1/8 mm. in diameter.

Structure of Neuron

Neurons are highly specialized in two key areas of function : excitability and conductivity. A typical neuron consists of a cell body and two types of protoplasmic extensions : axons and dendrites. Some of the neurons are as much as three feet long. Each neuron has only a single axon, but most of them possess numerous dendrites. If the cell body is damaged, the extensions are unable to conduct impulses and the neuron dies. Moreover, the neuron is incapable of dividing itself and when a neuron dies, it is not replaced. All neurons in a body were already present at birth. No new ones are added, but a considerable number might be lost.



Typical neurons: A. monopolar sensory neuron; B. bipolar sensory neuron; C motor neuron

Each neuron conducts impulses in only one direction. The flow is toward the cell body along the dendrites and away from the cell body along the axons. Thus two separate sets of neurons are necessary for the two-way traffic of messages in the peripheral nervous system. Thus a functional classification of neurons yields two[1] main groups viz., (i) sensory or afferent neurons transmit impulses from

1. There is a third group of neurons referred to as inter-neurons. They are restricted to the C.N.S. and relay impulses to various functional centres in the brain or spinal cord.

the periphery to the C.N.S. and (ii) motor or efferent neurons transmit messages from the C.N.S. to a muscle, a gland or some other tissue and produce an action. In some cases the impulse is transmitted along a chain of motor neurons, each relaying the message from its axon to the dendrites of the next neuron in line. Dendrites are extensions of the cell body. They look rather like tree-branches. Branching greatly increases the receptive surface of the neuron. The terminal branches of an axon of a particular neuron are often associated with dendrites of a number of other neurons, and the dendrites of each particular neuron in turn, may be linked with tha axons of a number of other neurons. A nerve impulse thus may be transmitted over an intricate net-work of converging and diverging pathways. Although each neuron functions essentially independently of those around it, it is the collective action that results in our sensations, movements, thoughts and speech, affecting virtually everything that goes on in our body.

Physiology of the Neuron

A neuron 'fires' or transmits an impulse along its entire length when it receives a suitable stimulus. If the stimulus is below a certain level (threshold), the impulse will not be transmitted. After a neuron has fired, it requires a certain time to recover; until it has recovered, it cannot fire again, even if a new stimulus is applied.[1] This refractory period is from 0.0005 to 0.002 second.

Analogy of conduction of electricity along a wire does not hold good in several important respects. A nerve impulse is not a simple electric current. Firstly, it retains its strength, no matter how far it must travel, for it is continually being renewed as it passes along. Secondly, the speed of nerve transmission is much slower, only about 20 metres per second as against the speed of electric current transmission which is 3,00,000 k.m./sec. (=velocity of light).

The Synapse : The successive neurons in a nerve tract

1. All these aspects of neuronal functioning have been mimicked with suitable arrangement of electronic components-condensers, resistors, transistors—and neatly soldered inter-connecting wires on a small plate called chip or integrated circuits.

are not directly connected, The terminal branches of an axon are separated from the dendrites or cell body of the next neuron in the sequence by a small gap (200 to 300 Å) called the synapse. Nerve impulses are transmitted across the synapse by the diffusion of chemical transmitters. The most common neurotransmitter is **acetylcholine**.

The Nerve : Like a muscle, a peripheral nerve is a bundle of bundles. Each individual nerve fibre is enclosed in a connective tissue sheath called the **endoneurium**. A bundle of nerve fibres is wrapped in a sheath called **perineurium**, These bundles, in turn, are grouped into a larger bundle ensheathed in the **epineurium**. Each nerve fibre runs the full length of the nerve and retains its own distinct identity. In the CNS, there is also some grouping of nerve fibres, fibres transmitting impulses associated with a specific type of information (e.g. pain-sensation) lie together in a common pathway called a **tract**. But the fibres of a tract are not ensheathed. If the cell body of a neuron is damaged, the entire cell dies and cannot be regenerated. But if the axon is severed, leaving the cell-body intact, a new axon may be regenerated.

Voluntary Movement and Reflex Action

Willed or voluntary movement begins when the neurons of the cerebral cortex send nerve impulses along nerve fibres to the motor neurons of the spinal cord. From here the impulses are conveyed to neuro-muscular junctions. When the impulse arrives at such a special junction, it induces contraction of the muscle fibre. Reflexes, on the other hand, are involuntary actions, designed to obtain the quickest possible motor response. The withdrawal of a hand from something very hot that has been touched inadvertently is an example of reflex action. It is a protective mechanism of the central nervous system having an incoming sensory and an outgoing motor pathway in common i.e the incoming message is carried directly to the motor-neuron in the spinal cord. The spinal cord and the brain stem are responsible for most of the reflex movements and the use of cerebral cortex is not involved. They are inborn and involuntary actions and they may still be present even after a great deal of brain damage has occurred.

Normally muscular movements are smooth and coordinated because of reflex activity, nervous feedback systems and the mass of information impinging on the spinal motor neurons. If the normal working of the brain and spinal cord is disturbed, movements may become weak, stiff or jerky and actions like walking may become impossible.

The cerebellum is important in regulation of movement and in maintaining balance. It works in close connection with the balance organs called labyrinths. They are situated in the inner ears, deep in the sides of the skull one on each side. They pick up information about the position of the head, analyse it, and send messages to the muscles of the body to help preserve balance.

: 5 :
The Sense Organs

The human body is equipped with a versatile assortment of sensory outposts, making up considerably more than the traditional 'five senses'. Without a continued flow of information the brain would be cut off not only from the outside world, but also from an awareness of the body's internal environment. Our eyes, ears, nose, mouth and the entire body surface are endowed with a vast variety of receptors for collecting useful information from outside. The inner senses such as muscle tone enable us to know where the various body parts are, as well as what the current state of the various body system is.

Touch sensations result from stimulation of tactile nerves, and convey information on the size, shape, texture and localization of objects.

Sense of smell functions in attraction of food and warning of danger. Taste nerves (taste buds) respond to chemical substances dissolved in saliva on the surface of the tongue.

A large portion of the stream of incoming impulses consists of messages from the eyes. Human eyes are capable of not only detecting light, but of distinguishing between different colours, shades of colours and degrees of light and darkness. Analysed and integrated, these messages put together a picture of the outside environment.

The ears are two organs in one. They are the organs of hearing—the perception of sound. They also contain receptors for the sense of equilibrium—the perception of changes in position and movement of the body.

Human senses include ;

Sense of Hearing
Sense of Sight
Sense of Smell
Sense of Taste
Sense of Touch

Sense Receptors

The body's sense reeeptors are the peripheral endings of functional dendrites of sensory neurons. Each receptor is specialized to respond to a particular type of stimuli.

Modality of Sensation and Adaptation

Sensation is the conscious result of the sequence : stimulus→receptor→conducting pathway→sensory area in the brain,

All main types of sensation—sight, sound, etc. are produced by nerve fibres that transmit impulses. Those from the ear are connected by pathways to auditory area ; those from the retina terminate in the vision area ; and touch fibres to specific touch areas in the brain. Thus we actually perceive all sensations in the brain.

Intensity of a sensation is directly proportional to the strength of the stimulus. Our receptors operate efficiently over a wide range of intensities. For example, we can hear a barely audible whisper and can also distinguish the words blaring out of a loudspeaker.

When a stimulus of constant intensity, continues to act on a receptor, it 'adapts' to the stimulus decreasing the frequency of the response. Thus in a swimming pool, at first the water may feel cold but soon it will feel comfortable

1. SIGHT AND THE EYE

The eye is a special organ of the sense of sight. Man depends on sight more than upon any other sense to supply information about his environment. The mobility of his eyes and head and stereoscopic[1] vision give him a panoramic view of the world i.e. information on depth, distance, dimension and movement. Eye's sensitivity to colours and contours enables him to distinguish between different colours and shades of colours. In addition, eyes can be extremely expressive of moods and emotions.

Structure of the Eye

The Eyeball is situated in the orbital cavity. It has a highly complex structure. It is almost spherical in shape and is approximately 2.5 cm. in diameter. The bony walls of the cavity and the fatty cushion help to protect the eye from injury. Further protection is provided by eyelids, eyelashes and eyebrows.

Structurally, the two eyes are the same but some of their activities are coordinated so that they function as a pair.

The antetior one-sixth of the eyeball is covered with a transparent layer called **cornea,** while the posterior five-sixths is covered by a tough fibrous layer called **sclera**. The Cornea, the bulge at the front is a window that lets light rays into the eye and bends or refracts them. A flat circular coloured membrane, the **iris,** lies behind the cornea and gives the eyes their characteristic colours. Between the cornea and the iris is a small compartment containing a clear fluid, the **acqueous humour**, which nourishes the cornea.

The iris governs the size of the **pupil**, a small adjustable hole in its centre that regulates the amount of light entering the eye. The **crystalline lens,** lying behind the pupil, further refracts the light to focus a sharp image on the **retina**, the inner layer of the wall of the eyeball. This thin screen, containing specialized photo-receptor cells, transforms light energy into electrical messages that are transmitted to the brain by the **optic nerve** which runs from the back of the eye. A large compartment, containing a

1. Vision from the two slightly different angles of the eyes.

viscous fluid called the **vitreous humour,** lies between the lens and the retina and makes up most of the volume of the eyeball. The optic and other nerves as well as arteries that supply the eye-muscles pass through two openings at the back. Six external muscles connect the eyeball to the orbital cavity and provide movement and support.

Physiology of Sight

Light is necessary for seeing. Light is reflected into the eyes by the various objects within the field of vision. The eye uses refraction[1] to focus the light rays it receives from the object to the retina. The four refracting media of the eye are, the cornea, the aqueous humour, the crystalline lens and the viterous humour. The process of focussing begins when the light passes through the cornea and is refracted. This is referred to as the coarse focus. The acqueous humour which is a clear dilute solution of salts (mainly sodium chloride) is renewed every few hours. It has hardly any effect on the light rays as it is of a similar density to the cornea. Its main function is to nourish the internal structures of the eye that do not possess a blood supply of their own.

The pupil determines the amount of light let in as a result of the contraction and expansion of the muscles of the iris. The crystalline lens lies immediately posterior to the iris. It is a semisolid body with biconvex surface consisting of 2000 thin layers of transparent tissue enclosed in a thin elastic capsule. To keep the object focussed on the retina the lens thins for distant vision and thickens for the near vision. In old age, it becomes denser and less elastic. As a result, old people need glasses for reading etc. In cataract it loses its transparency and blocks the passage of light rays resulting in a loss of vision Cataract is treated by removing the opaque lens and fitting an artificial intra ocular lens or compensating with external glasses.

The vitreous body is a jelly-like material enclosed in a thin membrane and fills the posterior four-fifths of the eyeball. Its function is to nourish and support the retina (which will collapse inward otherwise) and maintain the

1. Light rays which normally travel in straight lines through air, are refracted or change direction when they enter a denser medium such as water or glass.

spherical shape of the eyeball. It does not interfere with light passing through it.

Accommodation

In a camera, the distance between the lens and the film is adjusted until the correct focus is obtained. In the human eye, the distance is fixed. Instead, the curvature (shape) of the lens itself is changed. This adjustment for near and distant vision is called **accommodation.**

For focussing on a distant object, the lens becomes flatter while to view a nearby object it bulges, becoming more convex.

The Pathway of Vision

An optic nerve from each eye passes into the cranial cavity, converge briefly, seperate again after a partial crisscrossing and continue towards the visual area of the cerebral cortex in the occipital lobes of the cerebrum. The images from the left half of the visual field are transmitted entirely to the right hemisphere while those from the right half to the left one. Since there is continual interchange of information between the two hemispheres, a whole image is perceived rather than two halves.

Rods and Cones

The retina, the screen on which light rays are projected is a network of two types of light sensitive receptors, **rods and cones**, There are about 125 million rods and 5.5 million cones. The cones operate in bright daylight while the rods are used for seeing in dim light.

Colour Vision

Humans possess the ability to see a full range of colours of the rainbow. White sunlight is a mixture of sever colours called the visible spectrum. The red rays have the longest wave-length while the violet rays are the shortest The human eye can distinguish not only these basic colours but also more than seventeen thousand intermediate hues.

Colour-blindness occurs when one or more types o cones is absent. In the red-green colour blindness eithe the red or the green cones are missing. It is a hereditar condition and appears far more frequently in males than i females.

2. HEARING AND THE EAR

Sound

Sound itself is both a physical and psychological phenomenon. Waves of sound caused by a vibrating object are basically minute changes in air pressure. The waves have no significance, no message until they reach the ear. The hearing process is a chain of events in which the waves are conducted through the ear and translated into nerve impulses for interpretation by the brain, The hearer instantly distinguishes the meaning of those signals.

The Three Compartments of the Ear

The ear is divided into three sections :

The external ear
The middle ear, and
The internal ear.

The outer ear consists of the auricle which acts as a sound-gathering funnel and the ear-canal which leads to the eardrum.

The middle ear begins at the tympanic membrane or eardrum. The tympanic cavity is air-filled and the internal air pressure is maintained at the same level as the external atmosphere. It contains the ossicles, three tiny bones named for their distinctive shapes : the **malleus** (meaning hammer), **incus** (anvil) and stapes (stirrup). The three ossicles stretch from the eardrum to the oval window, an opening in a very thin bony wall which seperates the middle and the internal ear. The three bones are linked together but not rigidly, so that the vibrations of the eardrum are magnified in force by the jiggling motion of the ossicles. The amplified vibrations of sound pressure are transmitted to the fluid-filled inner ear via the oval window.

The internal ear contains the organ of hearing and is described in two parts :

The bony labyrinth.
The membranous labyrinth.

The membranous labyrinth has the same shape as the bony labyrinth and fits into it like a tube within a tube.

Both are filled with fluid. Both consists of three parts : a vestibule, a cochlea and three semicircular canals. The receptors for hearing are found within a complex structure which lies within the cochlear duct. More than 20,000 stiff hair-like fibres run across the floor **(Basilar membrane)** of the duct. Their lengths increase progressively from about 0.04 m.m. to 0.5 m.m. They can vibrate like the reeds of a harmonica ; shorter ones at high frequency and longer ones at low frequency. The transmitted sound waves set different portions or the basilar fibres vibrating, stimulating different cells of the receptors which relay their impulses along the auditory nerve to the brain.

The Physiology of Hearing

Sound waves enter the external auditory canal and strike the eardrum setting it vibrating. The vibrations are transmitted to the three tiny ossicles—the hammer, the anvil and the stirrup—in sequence. The foot plate of the stirrup presses against the covering membrane of the oval window, setting up pressure waves in the fluid which winds through the spiral coils of the snail. The pressure produces a wave that travels along the floor i.e., the basilar membrane. This looks something like a long **xylophone** which gets wider as it stretches out along the coil of snail. At the end, it is 12 times as wide as at the base near the oval window. Each sound sets up sympathetic (resonant) vibrations in a particular place. These, in turn, stimulate the hair cells generating a receptor potential, which activates neurons of the cochlear nerve. The impulses transmitted to the brain carry data on the place of the **basilar membrane** to enable the cerebral cortex to determine the frequency of the sound.

Nervous Pathway for Hearing

Like the messages of the other sense organs, the sounds detected by the ears are not meaningful, until they are analysed and interpreted in the brain. The main nervous pathway for hearing go upward to the cerebral cortex in the upper part of the temporal lobe. Each ear sends impulses to both sides of the brain and even a total destruction of the hearing centre in one hemisphere would not interfere with hearing.

Sense of Equilibrium

Ears are two organs in one. Besides being the organs of hearing, they also contain receptors for the sense of equilibrium. Two small membranous sacs in the labyrinth of the inner ear are the organs of static equilibrium, and the three semicircular canals are those of dynamic balance. A movement of the head in any direction will set the fluid in at least one of the canals in motion stimulating the hair cells and initiating impulses that are relayed to the brain. To maintain the body's equilibrium corrective reflexes are initiated in the cerebellum.

3. SENSES OF TASTE AND SMELL— TONGUE AND NOSE

Taste and smell are both chemical senses, that is they are triggered by the chemical content of substances in the environment. Both senses are very much interconnected.

The Taste Buds

The tongue is a most versatile organ. Its dexterity permits it to function in speech, chewing swallowing and sucking besides tasting. Taste buds, the specialized gustatory receptors are situated on the upper surface of the tongue, soft palate and epiglottis. A taste bud consists of a small bundle of cells which have hair-like dendrites protruding through tiny pores into the mouth cavity. Taste impulses from different parts of the tongue etc. are transmitted to the cerebral cortex by the nerve fibres at the other end of the taste cells.

Physiology of Taste

In order to be tasted the chemicals of the food must be dissolved in the fluid medium of the saliva. There are five primary tastes : sweet, sour, salt, bitter and pungent (that of chilli). The large variety of other tastes are either a combination of two or more of these or are associated with the sense of smell. By far the greatest influence on the sense of taste is the sense of smell. What is generally referred to as the taste, is strictly the flavour which is combination of its taste and smell. Food tends to lose much of its taste when the nasal passages are blocked as with a head-cold.

Taste receptors are particularly sensitive to bitter taste. This is an important protective mechanism because many deadly toxins are bitter and are automatically rejected.

A loss of taste is called **hypogeusia;** in **dysgeusia,** things taste wrong or even offensive. Research indicates that trace metal zinc is involved in the proper functioning of the taste buds.

The Nose and Olfactory Receptors

The human nose can deteet lower concentration of a volatile substance than are detectable by a gas chromatograph. The sensation of smell requires an actual contact of odour-producing substance with the receptors.

The hair-like dendrites of about 100 million smell receptors occupy an area about the size of a postage stamp in the uppermost portion of the lining of the nasal cavity. The olfactory tract leads into the olfactory area in the cortex of the temporal lobe where the impulses are interpreted.

Physiology of Smell

In order to stimulate these receptors, a substance must be volatile so that it can be inhaled into the nostril. It must at least be slightly water soluble so that it can dissolve in the mucus coating of the membrane.

The multitude of distinct odours that can be recognised, represent various combination of seven primary classes of odour viz. camphoraceous, musky, floral, pepperminty, etherlike, pungent and putrid.

The human sense of smell is almost rudimentary in comparison to that of other animals. Again, it serves more important roles for them than for humans. They secrete odorous pheromones as media of communication, 'no tresspassing' sign and sex attractants. However, smell serves a number of functions in human life. The aroma of appetizing food starts a flow of saliva and tones up the digestive organs. It can warn of danger such as toxins lurking in spoiled food. A particular perfume or smell can unlock a whole scene of distant past from the filing cabinet of the brain. Olfactory receptors adapt very rapidly and if the same odour persists, one ceases to notice it.

4. SENSE OF TOUCH ETC.

The sense of touch is the most basic means by which a person makes contact with the world around him.

The ability to feel shapes and textures provides the brain with more precise information than the senses of sight and hearing. By holding an object (with closed eyes) the fingers can tell its size, general contours as well as whether it is rough or smooth, hard or soft, wet or dry. Unlike the other four senses, touch responds to more than one type of energy stimulus, temperature and pressure. Moreover, the sense-organs for touch are distributed all over the body. Thus the sense of touch is more than a single sense.

Sense of touch, pressure, heat, cold and pain are provided by a variety of specialized sense-receptors, which are not uniformly distributed over the surface of the body. While pain receptors are the most numerous, heat-receptors are the most sparse. While touch receptors are in the skin or in the tissues immediately beneath the skin, pressure results from the deformation of deeper tissues. While some types of tactile receptors adapt slowly, others adapt within a fraction of a second. But for the rapid adaptation of many touch receptors, we would be unable to wear clothes.

Touch signals pass through the relay station of the thalamus and reach the appropriate area of the cerebral cortex in the parietal lobe.

Besides providing information about the temperature, texture and weight of an object, the sense of touch performs other important functions in our life. Shaking hands, hand holding, caressing and kissing are some examples of tremendous emotional impact.

Pain

Sensation of pain can be extremely useful. It is the body's warning signal for urgent corrective action to prevent danger to the tissues. Pain receptors are stimulated by intense pressure, heat or cold, if tissue damage is produced. There is little or no adaptation of these receptors. Pain impulses are transmitted to the thalamus and relayed to the cerebral cortex for recognition of the kind of pain and localization. Psychic reactions to pain, such as anguish, anxiety, are modified by one's personality, emotional state, ethnic and cultural background.

Temperature

The thermal receptors adapt quickly so that a hot bath or a cold swimming pool soon becomes bearable. They are non-uniformly distributed over the body. The lips and mucous membranes of the mouth and rectum are highly temperature-sensitive but other mucous membranes of the body are insensitive to temperature.

5. VISCERAL RECEPTORS

Sense receptors described above bring in information about the external environment. But the brain needs a continued flow of information about what is happening inside the body as well and the internal organs are also supplied with receptors which are called visceral receptors. They are concerned with respiration, heart-beat, size of the blood vessels and such other vital functions. Usually the conditions are attended to automatically. Mild problems such as hunger or a feeling of fullness in the bowels or bladder, are readily remedied. Visceral pain, on the other hand, may call for a medical assistance.

6. THE KINESTHETIC SENSE

The term **Kinesthesia** is used to denote the conscious recognition of the orientation of the different parts of the body. This **'position sense'** is provided by specialized proprioceptors[1] located in the joints, capsules, ligaments, muscles and tendons. Impulses are transmitted to the cerebellum and result in **reflex adjustment** of the muscles. All kinesthetic transmissions are performed at a high speed.

1. The prefix 'proprio' means self.

: 6 :
Circulatory System

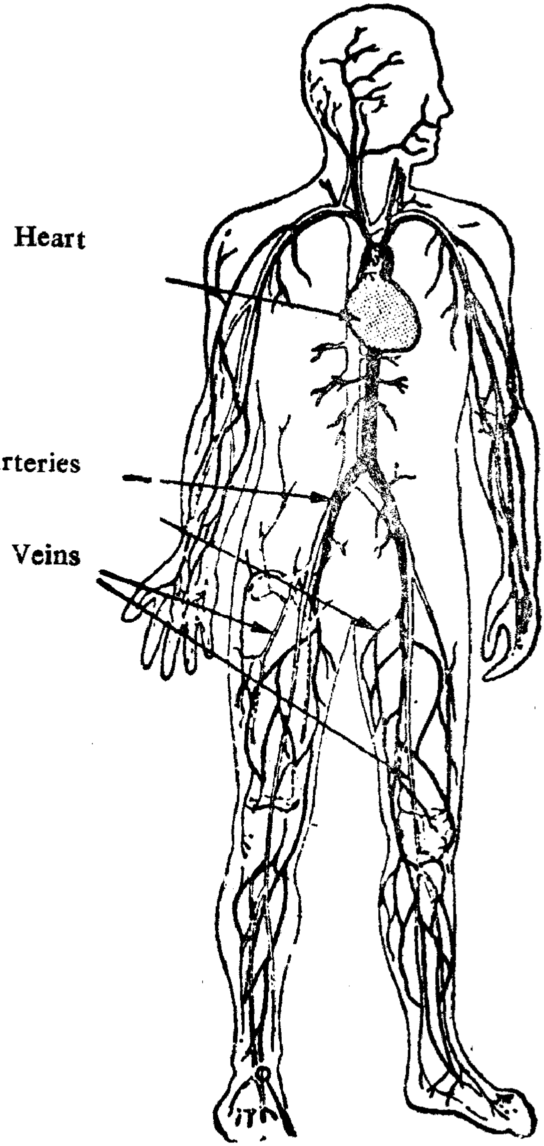
Basic Functions of the System

Blood is 'the essence of life', for this vital fluid carries to every individual cell in the body the nutrients necessary for producing energy and the raw materials necessary for tissue growth, maintenance and repair. It is vital too in clearing away all the waste products of the cells' various activities. It also acts as the body's policeman, liquidating any potentially dangerous invaders. Chemical messengers and other vital substances, too, need a transporting medium to distribute them through the body to keep the cells alive and active. The blood-circulatory system with its intricately branching and inter-connecting tubes provide these services. Thus, the basic functions of this system are in the area of transport—carrying anything and everything that needs to be shifted from one part of the body to another. Oxygen from the air that is breathed into the lungs and nutrients absorbed from the intestines are carried and distributed to all the body cells. Hormones—chemical messengers—that regulate and co-ordinate the activities of the body, are carried by the blood, from the glands that secrete them, to the target cells on which they act. It also provides a continual supply of water for the needs of the body. The waste-products such as carbon dioxide (CO_2), urea, etc. removed by it are carried to the lungs, kidneys and liver, where they are processed and excreted. Finally it is an important link in the body's system of temperature-regulation.

Organs of the System

The propulsive force that keeps the blood moving is the steady beating of a powerful pump—the **heart**. The contractions of the heart drive blood into **arteries** which branch and rebranch into smaller tubes, **arterioles**

CIRCULATARY SYSTEM
(Cardiovascular System)



ultimately leading into tiny **capillaries**, that penetrate the tissues. Here, the delivery of the nutrients and chemicals, and exchange of gases take place. In time, the blood reloaded with wastes begins the return-trip draining it into successively larger **veins** and ultimately reaches the heart. The very name of the circulatory system implies that whatever blood goes out from the heart comes back to it, completing the circuit. The general sequence of circulation is :—

heart—→artery—→capillary—→vein—→heart.

The exception is : Blood from the digestive tract and accessory organs follows a special pathway with an extra loop*→from capillary→veins→capillary.

The Heart

If a super-salesman called on you to sell a miracle pump which was designed to last three-quarters of a century and pump more than a thousand million times, circulating 400 million litres (75 to 80 million gallons) of essential liquid to keep your factory functioning, you may not believe him. But the human **heart** is just that miracle pump. Every day it pumps and circulates blood through about 100,000 k.m. of blood-vessels, which form a completely closed system called **circulatory system**.

The human heart is a strong red-brown muscle 15 centimetres long and 10 centimetres across, weighing about one-third of a kilogram. It sits on the front and centre of diaphragm which divides the chest from the abdomen. Two thirds of it lies to the left of the medium plane. It is suspended by ligaments and is surrounded by two lungs which fill the rest of the chest. A cage-like bony framework made up by the curved ribs etc. protects these three vital organs in the chest.

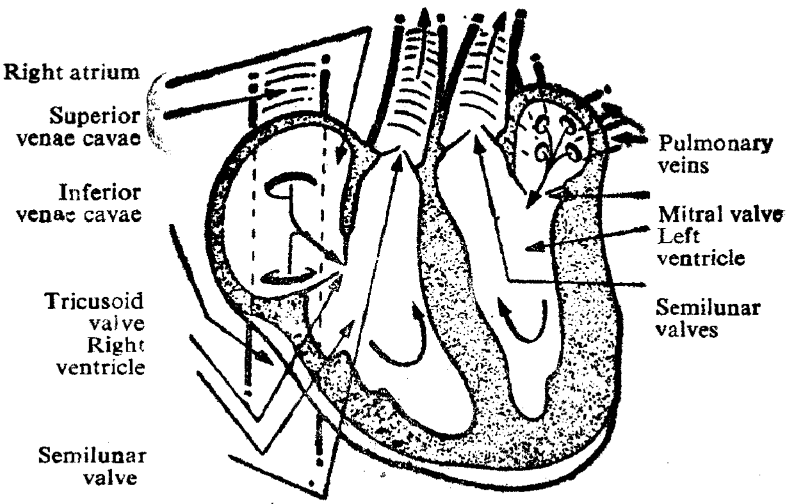
The heart is a hollow muscular organ. Interior of the heart is divided into a right and left side by a partition known as **septum**. Blood cannot pass directly from the left to the right side of the heart or vice versa. However an congenital defect—'a hole in the heart' is quite common

*Also see "Digestive System".

and the blood is shunted through the defect, from one side to the other (usually from left to right). Each side is again divided into an upper and a lower chamber with openings guided by one way valves. The heart, thus, has four clambers :

Right and left **atria**
Right and left **ventricles**.

Blood flow through the heart



It is actually a dual action-pump—one to send the blood into the lungs and the other to push it out into the body.

We generally speak of **a** circulatory system, but actually we have **two** separate systems viz. (*i*) Systemic Circulation—through the body, and (*ii*) Pulmonary Circulation—a circuit from the heart to the lungs and back again.

While the first supplies blood to all parts of the body, the second one is a short loop from the heart to the lungs. Both circuits begin and end in the heart, and there is no mixing between them.

The Functionting of the Heart

One sometimes woders how the heart manages to pump day and night for seventy years or more without resting. The answer, of course, is that the heart does rest, between every beat. The resting period is called diastole and, its duration is twice as long as that of systole, which is the period of muscular contraction.

Blood-vessels—Arteries, Veins and Capillaries

There are more Than 100,000 kms. of blood vessels in a human body. Multitudinous branches of blood-vessels of various sizes form a complex inter connceted net-work that reaches practically every cell in the body. The main types of blood-vessels are **arteries, veins** and **capillaries**.

The blood-vessel which carry the blood from the heart to the body are commonly known as arteries, while those which carry the blood in the opposite direction, *i.e.* toward the heart are called veins. Since, the pressure in the arteries is higher than in the veins, the walls of the former are thicker and stronger than those of the latter. Walls of the arteries consist of three layers of tissue. The outer layer consists of fibrous tissue, the middle layer of smooth muscle and elastic tissue and the inner lining of epithelium tissue. Although composed of the same layers of tissue, the walls of the veins are much thinner than those of the arteries.

Arteries vary in cross-section (size) from 25 mm. thick **aorta** down to less than 1.5 mm. in diameter. The blood-flow is helped along by rhythmic contractions in the muscular artery-walls.* Arteries are generally embedded deep into the muscles as a protection from all but severe injuries.

Oxygenated blood leaves the heart chamber via the **aorta** which emerges from the left ventricle and soon branches into two, one going upwards to the heart and the other downwards to the trunk and limbs. Aorta divides into arteries which again divide into smaller vessels called arterioles. The division progresses and ends into tiny thin-walled capillaries. These gassamer cobwebs link the smallest arterioles to the snallest venules. The wall of a capi-

* When you take a pulse at the wrist, you are feeling the contractions o ateries and not those of heart.

lary is composed of a single thin layer of endothelial cells which permits the passage of water and other small molecular substances. Their diameter is approximately that of a red blood cell.

Capillaries are so small (.006 mm. dia.) that the red blood cells have to pass through them in single file. They permeate the tissues and service the body-cells directly. Oxygen, food materials and hormones transported in the blood are transferred to the cells, while cell-products, produced for export, diffuse into the blood. This exchange is so rapid that each given unit of blood spends only one to three seconds in a particular capillary. Total length of capillaries is more than 99% of the entire length of the circulatory system.

The capillaries coalesce into venules, which are the branches of the larger veins, which eventually drain into the right auricle through two **venae cavae.** Contraction of skeletal muscles puts pressure on the veins pushing the blood towards the heart. Many veins of the limbs and abdomen have one-way valves in their interior, so arranged that they allow the blood to flow only towards the heart and prevent it to flow in the opposite direction. Usually the total diameter of veins returning blood from an organ is at least twice the total diameter of the arteries. This is because of the sluggish flow of blood in the veins which requires the greater capacity to maintain the balance between the incoming and the outgoing blood volume. All the veins of the systemic circulatory system (except for the cardiac veins) empty into either the superior or inferior vena cava which drains into the right auricle.

Cardiac Cycle

A full cardiac cycle takes less than a second. Yet during that brief time a complicated sequence of events takes place. The working part of the heart is its muscular walls. They contract and relax rhythmically. This rhythm is self-initiated requiring no nervous or chemical stimulation. During relaxation, blood from the tissues with a high carbon-dioxide content carried by veins, enters the upper right chamber (right auricle). At the same time, oxygenated blood from the lungs carried by the pulmonary vein fills up the upper left chamber (left aruicle). Then the walls contract. The pressure inside the chamber increases. The blood is forced out from both the auricles. The impure blood from the right auricle rushes first into the right ventricle through the one-way valve and then out of the latter into the pulmonary artery from where it reaches the lungs. Simultaneously, the oxygenated blood from the left auricle rushes first into the left ventricle and then out of the latter into the aorta, from where it is distributed throughout the body through arteries and ultimately into tiny capillaries.

Red blood-cells carrying oxygen squeeze through the tiny capillaries in a single file and deliver the load of oxygen to the cells and get reloaded with carbon-dioxide. The flow now reverses its direction and travels towards the heart through the veins and ultimately drains into the upper right chamber by way of two venae cavae. By the time the blood is ready to move towards the heart, the pressure has dropped down to almost zero and the heart is not capable of exerting suction pressure. The flow towards the heart must, therefore, be aided by something outside the system. Such assistance is given by the contraction of muscles which squeeze the veins and push the blood upward while one-way valves prevent the back-flow.[1]

The phase of contraction is called systole, while that of relaxation ts called diastole. When the heart rate is normal *i.e.* at the rate of 70-72 beats per minute, diastole lasts for .49 seconds and systole for .36 seconds. During heavy physical exertion the heart-rate increases to 170 beats per minute. At this rate, diastole is only .12 seconds while systole lasts for .23 seconds.

It should always be remembered that with every heartbeat, first both auricles and then both ventricles contract sending blood out ; then both sides relax and receive blood from both routes.

Nourishment of the Heart

For proper functioning, the heart, like any other organ, must be adequately nourished. In fact, it needs ten times

1. In its return-journey through veins, blood from the limbs and abdomen must flow against gravity. Three important mechanisms aid in the veinous return : (i) vascomotor action, (ii) muscular pump, and (iii) respiratory pump.

the nourishment required by the other organs and tissues. The nourishment is not, however, obtained from the blood passing through its chambers, but from its own blood supply. It is fed by two (right and left) coronary arteries which arise from the aorta just after its emergence from the left ventricle. Both branch out again and again sorrounding the heart-muscle and nourish it adequately. Heart-attacks or coronaries are caused by narrowing or partial blockade of these arteries.

Cardiac Output

Under resting conditions each systole pumps about 70 ml. of blood into the aorta. This is called stroke volume. The cardiac output is defined as—stroke volume × heart-rate.

With an average heart-rate of 70-72 beats per minute, the cardiac output comes to about five litres.[1] Thus in the space of just one minute, a volume equivalent to all the blood in the body passes through the heart. But during heavy exercise, the amount pumped can increase to over 25 litres per minute.

The cardiac output does not remain constant but is adjusted to meet the varying needs of the body. The heart is capable of increasing its output by fivefold or even more. It has been estimated that during a man's life-time a total of 500,000,000 litres blood is pumped. Under normal conditions the liver receives 28% of the total cardiac output; the kidneys 24%, the skeletal muscles 15%, the brain 14% and the heart 5%.

Heart-rate steadily slows down as one gets older ; it is 140 before birth, 90 as a child and 70-72 as an adult.[2]

The Blood-Stream

Blood is a red-coloured fluid with a salty taste and a characteristic odour. Its specific gravity is only slightly more than water, about 1.055, but its viscosity is about five times as high and hence it is not as free-flowing as water.

1. Every adult has total blood volume of 4.5 to 5 litres.

2. Actually the normal range extends from 60 to 100 .Incidentally heart-rate of a mouse is 700, that of a rabbit 150, while an elephant's is only 25 beats per minute.

The volume of blood varies with the size and the age of a person. An average sized adult man has about 5 litres and an adult woman 4.5 litres of blood circulating in the system.

Besides the oxygen, a variety of other substances must be delivered to the cells and tissues to keep them alive and vigorous. Glucose, fat, amino-acids and water are some of the more common, while copper and cobalt, iodine and phosphorus are a few of the uncommon requirements of the cells.[1] Salts, minerals, vitamins and hormones are also carried by the blood-stream for delivery to appropriate places. At the same time, carbon-dioxide and other waste products are also carried by the blood to the kidneys and other sites for excretion.

Thus blood is ever-changing, yet its overall composition remains surprisingly constant.

Composition of the Blood

Blood is composed of about 55% fluid and about 45% solid matter. A single drop of blood contains more than 250 million blood cells, suspended in a clear fluid. The apparently homogeneous fluid is actually teeming with countless numbers of substances of thousands of different kinds each with its own specific job to do. The main components of the blood are :

Blood plasma—a clear straw-coloured fluid in which are dissolved salts, proteins, fats, sugar, hormones, vitamins, as well as waste products such as urea and lactic acid. Indeed, this clear, rather sticky, fluid is far more complex mixture—perhaps one of the most complex mixtures in the universe. 90 to 92 percent of the volume of plasma is water and 8 to 10 percent other constituents. Water, not only serves as the fluid medium of transport, but also acts as a solvent that brings together an intricate variety of chemical substances and helps them to react.

The solid elements also called formed elements, suspended in the fluid plasma, make up 45 percent of the total volume of blood. They include three main types : red blood cells (RBC) or erythrocytes, white blood cells (WBC) or leukocytes and platelets or thrombocytes.

1. See "Nutrition" in the second part of this booklet.

Normal blood contains approximately :

Red	cells 5×10^{12}	per litre	
White	cells 8×10^{9}	"	"
Platelets	250×10^{9}	"	"

Red Blood Cells (Erythrocytes)—these are small flattened bi-concave discs. 3000 of them would be needed to measure an inch. It contains a red pigment, haemoglobin and the huge masses of red cells, hundreds of millions in each drop that together give blood its rich red colour. The shape and structure of these cells represent an extreme of adaptation for its function. They are the gas carriers of the body.

They should be correctly called corpuscles rather than cells, because they have no nucleus but they are often called red cells.

There are five million red cells per cubic milimeter. Every second three million cells die and equal number of them are born. In the embryo, red cells are formed in the liver, spleen and bone-narrow. At some time before birth, the liver and spleen shut down their red cells production, and the function is taken over entirely by the bone-marrow. A red cell has an average life-span of 120 days during which it makes 300,000 trips, travels more than 1000 km., carrying three quadrillion molecules of oxygen.[1]

Haemoglobin has a strong affinity for oxygen and when they come into contact the oxygen is taken up, forming oxyhaemoglobin. This process normally takes place in the lungs. Oxygenated arterial blood has a bright red colour while that in the veins, having lost its oxygen, has a bluish-purple hue.

Haemoglobin of the red cells is an iron containing pigment called haem, combined with a protein, globin. Total amount of iron in the haemoglobin of all the red cells is about 3 grams. But it is priceless, as one cannot live without it. A continual intake of iron in diet is essential for the promotion of new RBC. Men lose only about 1 mg of iron each day but a woman loses about 20 mg during each normal menstrual period. A minimum of 5 to 15 mg of iron must be consumed in the daily food. Need for

1. Quadrillion is 1000000000000000 $= 10^{15}$

iron increases greatly during pregnancy. Each haemoglobin has four iron atoms which combine loosely with four molecules of oxygen in the lungs. There are about 280 million molecules packed into each of the 5 million red blood cells in each cubic millimetre of blood. Contents of haemoglobin in the blood is an index of health.[1]

White Blood Cells (Leukocytes). These are essentially colourless, as they do not contain haemoglobin. They are larger than red cells. They are not uniform in size, shape and appearance. Unlike red cells which are carried passively along in the blood-flow, white cells move actively. The main functions of most of the white cells are performed outside the actual blood, in the neighbourhood of tissues. These soldiers of the body are second-line defenders, (skin and mucous membranes are the first line), against foreign invaders ready to fight to death, if need be. Red cells outnumber the white cells by about 700 to 1. The life-span of a white cell is extremely variable. It may be only a few hours, or with luck may be measured in months. On the whole, the life of the white cell is harder than that of the red cell. It is likely to meet an untimely death in the service of the body. A continuous production of new white cells is, therefore, essential. The red bone-marrow is also the site of the formation of the leukocytes. Some others are produced in the various lymph nodes, the spleen, the thymus gland and the tonsils.

Platelets (Thrombocytes)

They are also called clotting cells (thrombo means clot). They are more numerous than white cells, but less so than red cells. They live in the blood for five to eight days after which they are destroyed in the spleen and other organs. They are a key link in the mechanisms for the prevention of blood loss and they go into action when a blood-vessel is cut or pierced and blood is being lost. A substance called platelet factor initiates a chain of chemical reactions leading to the formation of a clot which effectively plugs the cut or hole. Blood-clotting is a complicated chain of chemical reactions involving 13 separate factors.

1. The normal level of haemoglobin in the blood is 13.0 to 18.0 grams/100 ml for men and 12.0 to 16.0 grams/100 ml for women.

Blood-Pressure

Blood-pressure is the propelling force in the arteries. It is a measure of the pressure exerted on the walls of the arteries[1] by the flow of blood.

It depends upon—(a) the output of the heart, and (b) the resistance encountered by the flow in the smaller arteries and arterioles. The pressure in arteries and arterioles reaches a peak called the systolic pressure with each contraction of the heart and then gradually decreases to a minimum, the diastolic pressure, before the next contraction. It is commonly measured in the artery just above the elbow and is always expressed as two figures e.g. 120/80 in healthy young adults. When outside these limits, it is either high or low.

Blood-pressure is an extremely fluctuating physiological function and it is rather difficult to define 'normal' blood-pressure. Firstly, it rises and falls at different times of the day. Secondly, it is higher when one is actively exercising than when one is resting or sleeping. Again, when one is emotionally upset, it rises, and falls down when one becomes calm and quiet. And so the pressure is arbitrarily defined as 'normal' where more than 90 percent of the blood-pressure of population happens to be.

If the pressure is too low, the tissues may not receive adequate supply of nutrients. A few years ago, low pressure was considered undesirable. Nowadays, however, if there are no adverse symptoms, such as dizziness, fatigue or fainting, the low pressure is regarded a protection from the development of atherosclerosis or hardening of the arteris.

Constant high blood-pressure, on the other hand, is definitely injurious. Hardening of the arteries (atherosclerosis is caused by the deposition of the blood clots, fats and calcium on the inside walls of the arteries, making the normally soft elastic arteries to become hard, inelastic and partly or completely blocked.

The risk of developing atherosclerosis is directly related to the level of blood-pressure. If the arteries to the heart,

1. The blood-pressure in the veins is steady and close to zero.

called coronaries, are blocked, death of heart cells is inevitable and a heart-attack may follow. If the arteries to the brain become obstructed, strokes may occur. Thus continuous high blood-pressure or hypertension is the indirect cause of death viz. heart-attack and stroke.

Emotional stresses, like excitement, agitation or annoyance also cause hypertension. Whenever one encounters a stressful situation, an innate mechanism is automatically put into action, causing an excessive flow of adrenalin and resulting in a marked rise in a blood-pressure, acceleration of heart-rate and other physiological changes. If the mechanism is repeatedly activated, e.g. due to stresssful situations built into our daily life, it will ultimately result in hypertension. Fortunately, there is also another innate protective mechanism which produces diametrically opposite conditions. Regular practice of relaxation and meditation can activate the protective mechanism which normalizes the blood-pressure.

Unlike the heart-rate, the blood-pressure tends to rise as one grows older. For a new-born baby it is 40 ; it rises quickly to 80 by the end of the first month, and then continues to rise more slowly. By the tenth year, it is about 100. At puberty, the adult level of 100-120 is reached. After 25 years, it creeps up by about .5 per year. It is 140 at 60 and 160 at 80.

THE LYMPHATIC SYSTEM

The lymphatic system communicates with the blood circulatory system and is closely associated with it. It has several functions which complement the function of the blood circulatory system.

Though technically the blood circulatory system is a closed system, there is a continuous leakage of fluid and proteins out of the capillaries into the tissues. To prevent the blood from thickening, the fluid must be returned to the system. This service is provided for by the 'lymphatic system'. Almost all tissues have lymphatic channels, which drain excess fluid into this system. It can be regarded as a part of the circulatory system. Besides returning body-fluid to the blood, it transports substances such as fats, hormones and enzymes from their manufacturing sites to the blood-stream.

Lymph—the fluid which has passed into the lymphatic vessels—is a watery plasma-like fluid. Wherever there are blood-vessels, there are also lymph-vessels. Lymphatic system resembles blood-system. Lymph capillaries unite to form large vessels which unite, in turn, to form larger vessels. Finally, they converge into two main ducts which empty into the various portions of the blood-system.

Lymph-capillaries are very thin-walled tubes which are even more permeable than blood-capillaries, but it is a one way permeability. Once, fluid, protein and other particles have entered, they stay inside and cannot leak into the tissue.

Lymphatic system is also the head-quarters for the important line of defence against diseases. It provides the body with lymphocytes and other anti-body-producing cells for defending it against disease-germs and other foreign invaders.

SPLEEN

Strange as it may seem, **spleen** is classified as a lymphoid organ. It is a dark purple coloured organ, 14 cms. long, 8 cms. broad and 3 to 4 cms. thick. It is situated directly below the diaphragm above the left kidney, and behind the stomach. It is a versatile organ performing a number of different functions. Some of the important functions are :—

(1) The spleen acts as a filter capturing and removing bacteria, debris, parasites and other infectious agents from the blood-stream.

(2) It is the grave-yard of the red blood cells. Old and worn-out cells rupture as they try to squeeze through the narrow channels of the spleen and are destroyed. The haemoglobin from the destroyed cells is broken down ; iron and globin are salvaged and returned to the blood-stream for recycling.

(3) Spleen joins with other lymphoid organs (particularly the thymus) in the immune response of the body. They produce antibodies (immunoglobulins) which are released into the blood-stream conferring humoral immunity against specific bacterial infections.

(4) Before birth, spleen manufactured red blood-cells. It is ready to regain its ability to produce red cells in an emergency such as anemia.

(5) It acts as a blood-lake and a reservoir for red cells sending stored blood into circulation when needed. The blood stored in the spleen has a higher concentration of blood-cells and can increase the hematocrit[1] of the system by as much as 3 to 4%.

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1. Percentage of the red cells in the total blood volume is called hematocrit. Its average value is about 45% in man and 42% in woman.

: 7 :
Respiratory System

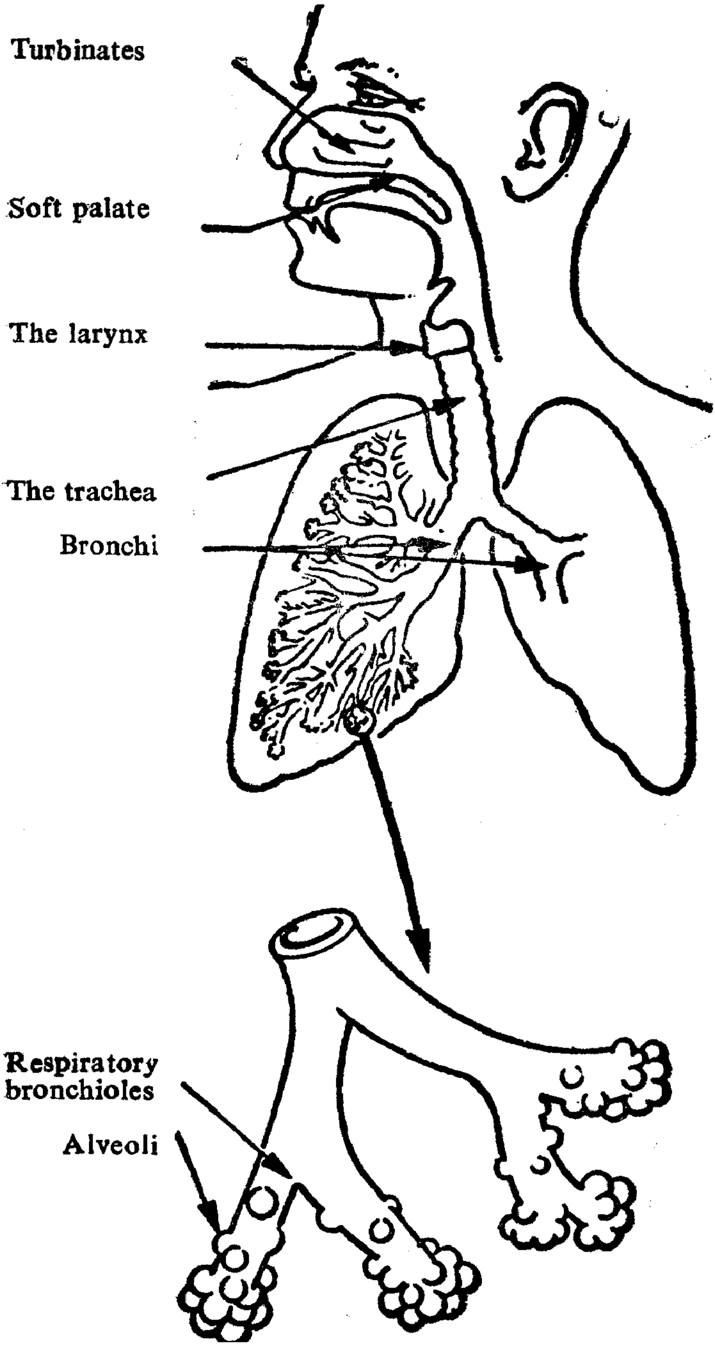
Respiration

The body needs a continual supply of oxygen. One may survive for a long time without food, for less than a week without water, but one would not last more than a few minutes without oxygen. In addition, for a continual supply of oxygen, the body also needs some means of disposing of the waste carbon dioxide produced by the function of the body cells. The body also needs an efficient distribution system to deliver the oxygen to all 600 billion body cells and carry off their cabon dioxide. The word respiration is used to describe all the processes associated with the release of energy in the body. Breathing makes a continual replenishment of the oxygen in the lungs, drawing in fresh air from the atmosphere and expels the unwanted carbon-dio-oxide outside. Blood circulation delivers the oxygen and brings waste gases to the lungs. We have already discussed the circulatory system in the previous section. Here we shall discuss the anatomy and the functions of the respiratory system.

Organs of the System

The respiratory system includes passageways and tubes through which the air passes : the *nose*, *pharynx*, *larynx*, *trachea*, *two bronchi*, *bronchioles*, arranged in a sequence that branches and rebranches and look like an inverted tree. The tubes end in tiny air sacs called *alveoli* in which the exchange of gases takes place. The bronchioles and alveoli constitute the lungs. The system includes a bellows arrangement—the rib cage—operated by muscles (of which the diaphragm is especially important) and controlled by nerves.

RESPIRATORY ORGANS



The Nose

The nose is the gateway to the respiratory tract. It filters, warms and moistens the incoming air. Nostrils and the area just inside are lined with a picket-fence of short stiff hairs. This is the first line of defence, screening large particles out of the entering air. The interior of the nasal cavity is lined with mucous membrane. Dust and other fine particles and bacteria are caught in the sticky mucus. The mucous membrane also helps to moisten the incoming air. It also contains dense vascular plexus (with copious blood supply) which acts as a radiator to warm the air. The jutting shelves—turbinates—increase the radiating surface making the warming action more effective.

It is also possible to breathe through the mouth but the mouth is not supplied with the apparatus for cleaning, warming and moistening the air. Mouth-breathing, therefore, must be avoided.

The Pharynx and the Larynx

The pharynx is an important junction for the passageways leading into the body. Both air and food have to pass through it. The passage connecting the pharynx with the trachea is called larynx or 'voice-box'. Its main function is the production of speech. But it is also important in breathing and protecting the trachea from foreign objects. The epiglottis is a hinged 'trap door' at the entrance of the larynx. During swallowing it closes like a lid to prevent the entry of food into the trachea.

The Trachea, the Bronchi and the Bronchioles

The trachea or windpipe is a cylindrical tube about 11 cms. long and about 2 to 2.5 cms in diameter. It lies in front of the aesophagus. Its tubular walls are reinforced by C-shaped rings of cartilage. It divides into two branches—**bronchi**, one leading into each lung. It is also lined with mucus-secreting cells. Inhaled particles are trapped in the mucus. The **cilia** (fine hairs) in the lining of the trachea and bronchi whisk up the dust laden mucus upwards towards the pharynx where they can be expectorated. The trachea with its two branches—the **bronchi** and their numerous branches the **bronchial tubes** and **bronchioles**, looks very much like an inverted tree. Each tiny bronchiole terminates in a cluster of minute air sacs, the **alveoli** which look like a miniature bunch of grapes. An extensive network of capillaries surrounds each alveolus. Gases diffuse back and forth between the alveoli and capillaries network, and the actual exchange of oxygen and carbon dioxide occurs here.

The Chest

The lungs, the heart and major blood vessels are protected by the bony rib cage called chest or thoracic cavity. It is closed at the top by the muscles of the neck; enclosed on the sides, back and front, by the ribs, the vertebrae, and the sternum; is bounded below by the diaphgram, a large sheet of muscle that assumes a dome shape at rest. It is constructed so as to expand and contract readily as the lungs inflate and deflate. The major portion of the chest is taken up by the two lungs. In the centre between the two lungs is situated the heart and major blood vessels.

The Lungs and the Pleura

A pair of human **lungs** contains about 300 million[1] alveoli covering a total surface area more than 90 sq. mtrs., enough to carpet a tennis court. This enormous surface area provides for an efficient exchange of gases. The two lungs are cone-shaped with the base resting on the diaphragm and the apex into the root of the neck. They are freely movable except at the roots. The right lung is larger and broader than the left, but is slightly shorter. The right lung is divided into 3 lobes and the left one is divided into 2. They are light, porous and spongy. Their internal structure is a mass of branching tubes and air sacs. The alveolus is a roughly globular structure about 100 micrones in diameter. In has an extremely thin wall and is surrounded by a network of equally thin-walled capillaries. The total surface area of the capillary network is about the same as that of the alveoli. Each lung is enclosed and protected by a double-walled membrane, the **pleura**, which also lines the inner surface of the chest wall. A small amount of fluid between two layers

1. The estimate of the number of alveoli in an adult human body varies between 250 millions and 600 millions and area 70 to 90 sq. m.

acts as a lubricant preventing the lung and chest surface from sticking together.

BREATHING

To a common man respiration is the physical act of breathing in which air is alternately drawn into the lungs and expelled from them. Mostly this is an unconscious act that goes on throughout the day and even when one is asleep In a lifetime, one will take in about 13 million cu. ft. of air. The technical term for breathing is ventilation and it includes two phases : inspiration or breathing-in and expiration or breathing-out. To a physiologist it is divided into : (i) **external** respiration i.e. passage of oxygen from the lungs into the blood and the passage of carbon dioxide from the blood to the alveoli and (ii) **internal** respiration in which the body cells exchange carbon dioxide for fresh oxygen carried by the blood. The final aspect of respiration is **cellular** respiration i e. chemical reactions of oxidation within the cells and release of energy.

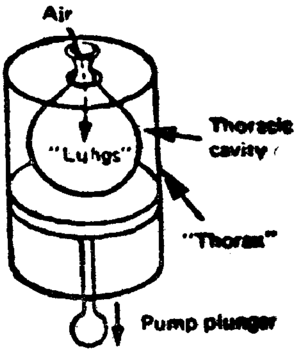
Mechanics of Breathing

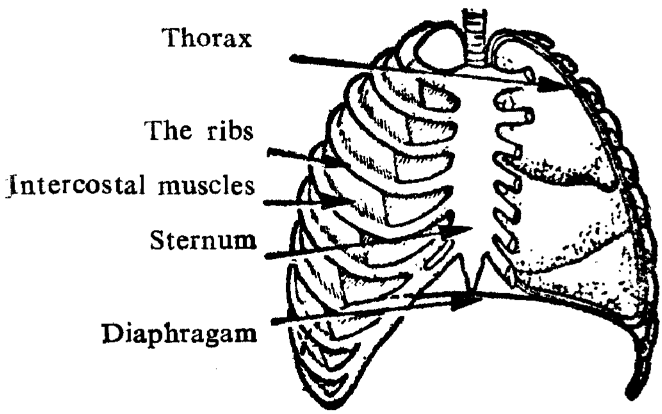
The lungs may be regarded as elastic sacs the interior of which is opened to the outside via the bronchi, trachea and nose. When the pressure inside is greater than the pressure of the atmosphere, air is expelled from the lungs which is called expiration. When the outside pressure is greater than that of inside, the air flows in. This is inspiration. The pressure differentials are created by the action of diaphragm and other muscles.

The muscles concerned with breathing are (i) the intercostal muscles between the ribs, (ii) the diaphragm between the thorax and the abdomen and (iii) clavicular muscles between the collar bones.

The important mechanism for increasing the volume of the chest cavity is the contraction of the diaphragm. This sheet-like muscle separates the chest from the abdomen. It forms the floor of the chest cavity. It has a dome shape when it is relaxed. When it contracts, it flattens out and descends expanding the chest. In quiet respiration, it moves down about 1.5 cm. producing an increase of about 400 cms^3. In forceful breathing the diaphragm may descend as much as 7 cms. producing a far larger increase in capacity.

MECHANICS OF BREATHING





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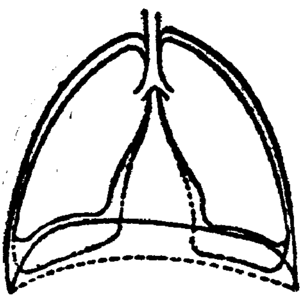
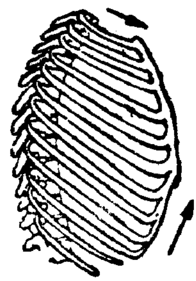




(2)

1. The depth of the thorax increases when the diaphragm contracts and descends.

2. The intercostal muscles raise the ribs and increase the fore-and-aft diameter of the thorax, and cause the width of rib cage to increase.

The circumference of the chest cavity is increased by another mechanism, the contraction of the intercostal muscles which makes the ribs swing upward and outward expanding the chest cavity. The expansion of the chest cavity automatically inflates the lungs. The third mechanism for breathing is operated by the collar bone. Diaphragmatic breathing is slow and deep ; costal breathing is rapid and shallow. At the end of the inspiration the inspiratory muscles relax, the chest votume is decreased and elastic recoil of the lungs expels the air through the passages into the atmosphere

The total lung capacity is the maximum amount of air the lungs can hold after a maximum inspiration. It is an average of about 6 litres. In a forceful expiration, one can expel about 5 litres in one blow. Even the most forceful expiration does not expel all the air from the lungs In normal quiet breathing, the volume of air that flows into and out of the lungs with each breath is about ½ litre. Thus, there is normally some air in the lungs after expiration and room for additional air upto 3 litres—after normal inspiration. The volumes and capacities can be modified by breathing exercises and by practising scientific total breathing.[1]

Gas Exchange in the Lungs—External Respiration

The air we breathe into our lungs contains about 21% oxygen and about 79% nitrogen. Small quantities of water-vapour, carbon dioxide and other gases are also present. The air we breathe out contains 15% oxygen and 5% carbon dioxide and 79% nitrogen. An exchange of the two gases occurs in the lungs. Oxygen passes out through the thin walls of the alveoli and in through those of the capillaries that surround them. At the same time, there is a net movement of carbon dioxide in the opposite direction.

The factors which favour an effective gas exchange in the lungs are : exceedingly thin walls of the alveoli and capillaries and extremely large surfaces for exchange. The capillary net-work accommodates a large volume of blood —just under a litre at a time. The capillaries themselves are so narrow that the blood cells have to pass through them in a single file ; thus each red cell is exposed to the alveolar

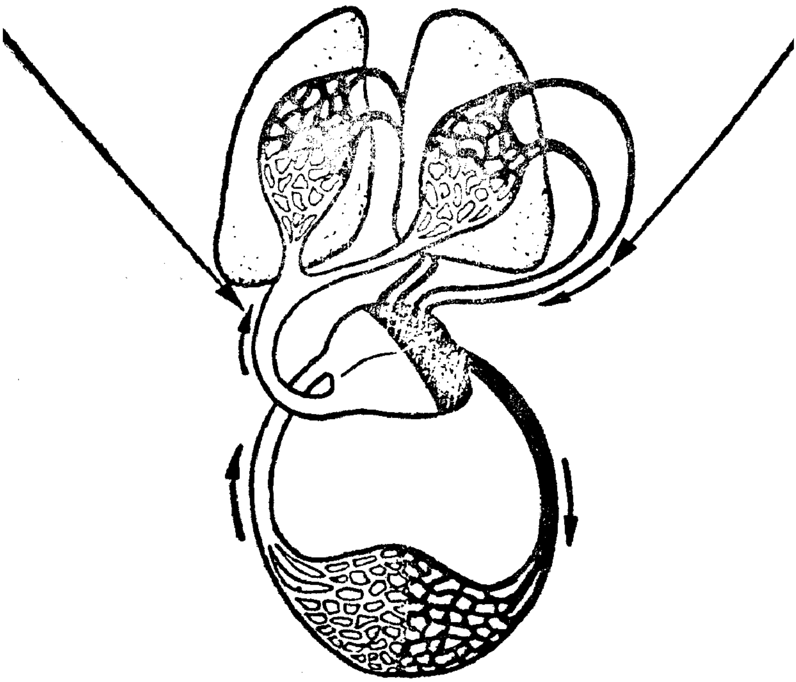
1. This aspect of breathing is fully dealt with in part II.

air. Transporting facility is provided by the haemoglobin in the red blood cells.

GAS EXCHANGE IN THE LUNGS & TISSUES

The right side of the heart pump deoxygenated blood from the body tissues into the pulmonary artery to the lungs.

In the lungs blood is oxygenated. The oxygenated blood flows in the pulmonary vein to the left side of the heart.



Transport of Gases in the Blood

The blood leaving the lungs is a bright scarlet red. Each haemoglobin molecule can combine (reversibly) with four molecules of oxygen. This oxygenated red blood flows to the heart and from there out into the systemic circulation. There is a continued diffusion of oxygen out of the red cells through the capillary membranes into the tissue fluid and from there into the cells.

The transport of carbon dioxide is more complex than that of oxygen. Most of it is carried in the plasma in the form of bicarbonate ions (HCO_3), some is carried in the form of carbamino haemoglobin and a small amount dissolves in the plasma. Nitrogen which constitutes nearly four-fifths of the volume of air is generally ignored by the body.

Internal Respiration

The major function of the circulatory system is to deliver oxygen and carry off carbon dioxide. The gas exchange between the blood and tissues is very similar to that in the lungs except that the gases go in the opposite direction. Carbon dioxide from the tissues goes into the blood and oxygen from the blood goes into the tissue fluid and from there into the cells.

Control of Respiration

Normally breathing is an unconscious act that goes on continually throughout one's daily activities and even when one is asleep at night. Breathing can also be controlled (consciously) voluntarily to some extent. One can breathe rapidly or slowly, deeply or shallowly at will. One can even stop breathing entirely for a time. But most of the time respiration is under automatic control by special centres in the central nervous system. They are located in the medulla and pons. The medullary respiratory centres set the basic rhythms of respiration. The hypothalamus and cerebral cortex also participate in respiratory control.

The average adult at rest and not emotionally excited breathes about 14 to 20 times a minute. Emotional stimulation, pain, temperature, carbon dioxide level and age cause variations from this basic level. Like the heart-beat, the respiration-rate tends to decrease from the birth to adulthood and increases in old age[1].

In addition to the normal actions of respiration, the respiratory passages participate in a number of reflex mechanisms and other modified movements. Both cough-

1. A new born baby breathes rapidly from forty to seventy times a minute. By the end of the first year, the rate is 35 to 40. By five years, about 25 and at ten years, 20 times per minute. By the late teen years, the normal adult level of 14 to 20 is reached.

ing and **sneezing** are protective reflex mechanism used to clear the respiratory passages. A cough serves to clear the trachea and bronchi while sneeze serves to clear the passages of the nose and the mouth. A **sigh** is a deep long-drawn inspiration immediately followed by a shorter but forceful expiration. A **yawn** is a deep inspiration through a wide open mouth. It produces a more complete ventilation of the lungs than usual.

: 8 :
The Digestive System

Energy is essential to maintain such vital functions and processes as breathing, blood circulation and brain function. It is derived from foodstuffs which can be divided into several classes. Most of the food for human consumption is derived from vegetables and animals. Since they have already built up the complex molecules of proteins, carbohydrates and lipids (fats). Food materials cannot be utilised by the tissues until they have been broken down to smaller components and turned into a soluble form in order to reach the cells through the process of digestion. The digested materials can then be absorbed and sent to the tissues for production of energy.

Digestive Processes

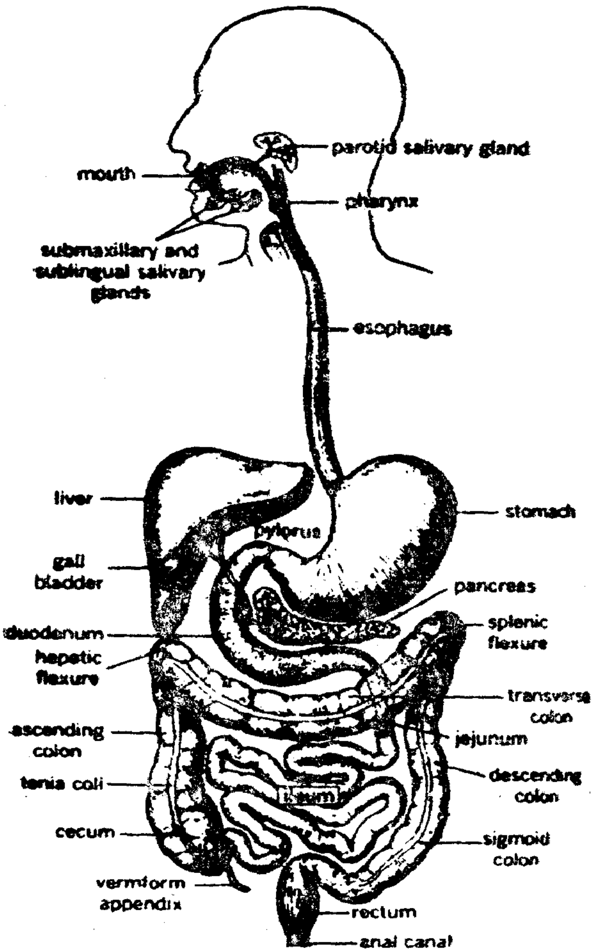
Two types of actions take place in various digestive organs :—

(*i*) Mechanical actions
(*ii*) Chemical actions

Mechanical Actions. Grinding, mixing and churning the food play an important part in digestion. Mere mechanical actions are, however, not enough. They move the food materials along, moisten and liquefy them and pulverize them and thus prepare the way for chemical actions of the digestive enzymes in various organs.

Chemical Actions. They convert the large and complicated molecules of the foodstuff to smaller simpler units so that they can be extracted from the digestive organs by the blood vessels, sent into the blood stream and can pass through cell membranes for assimilation by the tissues. Water, mineral oils and vitamins do not undergo chemical action in order to be absorebed.

THE DIGESTIVE SYSTEM



Organs of the Digestive System

The digestive system is composed of the **alimentary canal** and accessory organs which contribute their secretions to the tract. The digestion of food begins in the **mouth** and ends in the **bowel**. The passage (tract) from the mouth to the **rectum** (the end portion of the bowel) is called **gastro-intestinal tract** which is like a tube, about 9 metres in length, elaborately looped and coiled within the body. Various processing stations are located along the way to prepare and process the food and absorb useful materials The accessory organs of the digestive system include **salivary glands**, the **pancreas**, the **liver** and **gall bladder**.

1. Mouth and Salivary Glands

The first station on the route of the alimentary canal is **mouth**. Food spends possibly the shortest time of the whole process in the mouth. Nevertheless, it is one of the most important parts of the digestive process, since it is here that the food undergoes its first stage of conversion into a substance which can eventually be more readily absorbed by the cells of the body. Solid food token into the mouth is first broken up into small pieces and then chewed and ground to pulp by the **teeth**. Grinding the food up is essential to increase the surface area of the food. **Saliva** enters the mouth through ducts from three pairs of **salivary glands** which are accessory organs of the digestive system. Saliva contains the enzymes, one of which is **ptyalin** which starts off the chemical breakdown of starchy foods into sugar. The **tongue** pushes the food between the teeth, shapes masticated food into a convenient **bolus** and shoves it downwards to the **aesophagus**.

2. Aesophagus

The ground food-mass, lubricated and softened by saliva, passes backwards on the epiglottis into the **aesophagus** which is a muscular tube about 2.5 cms.in dia and 25 cms. long, leading down through the chest and diaphragm to the **stomach**. It is a flexible tube and if the mass of food is larger than its diameter, it can expand to accommodate it. Swallowing the moist ball of food is a chain of complicated movements, involving operation of reflex mechanisms to ensure that the food will go where it is meant to. First the soft palate rises blocking off the nose and prevent food from entering the nasal cavity. Both the aesophagus and trachea open into the mouth. The valve called **epiglottis** guards the trachea during the swallowing process, preventing the food from entering the trachea. However, sometimes, inadvertently, this automatic guarding mechanism may fail and the portion of the food may enter the trachea, which is usually thrown out by a typical fit of coughiag. If, however, a piece of food gets lodged into the trachea, it creates hazard to life and must, therefore, be removed quickly. Once the food enters the aesophagus, it is propelled down to the stomach by alternate waves of contraction and relaxation of the muscular tube.

3. The Stomach

The food has now reached the second processing station of the tract. The muscular collapsible bag called **stomach** is tucked up in the abdomen at the lower rib-line under the diphragm and **liver**, and resembles a deflated balloon when empty. Its size and shape vary depending on how full it is. Its average size is about 22 cms. in length. When full, it slants across the body, big at the top and small at the bottom. Its capacity is two to three pints. It retains food for several hours, during which time partial digestion of protein takes place. Like the mouth, the stomach performs its function by both mechanical and chemical actions. The muscular contractions of the stomach act, like a churn and mix food thoroughly with the digestive juices. They toss, turn and mix the stomach contents, gradualy macerating the food materials mixing them with the acid gastric juice and converting them to a semi-fluid mixture. The lining of the stomach contains 35 million **gastric glands** which secrete four to five pints (2 to 3 litres) of gastric juice per day. Gastric juice contains **mucin, hydrochloric acid** and **enzymes pepsin** (the main component) and **rennin.**[1] Hydrochloric acid is very important in digestion as it activates enzymes (biological

1. Infants and children whose main diet is milk have a special need for the abilities of rennin. It is not a very important component in the dault.

catalysts), helps in the digestion of protein and destruction of bacteria. It continues to be produced even when the stomach is empty. Rennin acts on the milk and separates its solid portion. Thereafter, in the presence of the acid, pepsin breaks down the proteins to polypeptides which would be finally digested in the intestine. Some form of sugar is absorbed by the blood-vessels from the stomach itself. **Mucin** lines the stomach and protects it from the acid and prevents it from digesting itself. Gradually the thick gruel-like mixture of food and digestive juices called **chyme** is pushed by vigorous peristaltic waves of the stomach towards the **pyloric valve** which opens into **duodenum**, the first part of the small intestine. The function of the pyloric valve is to restrict the admittance of the highly acidic mass into the duodenum—no more than can be instantly neutralized by alkali arriving from **pancreas** and **liver**. **Peristalsis** is the name given to the slow automatic movement of the stomach and also along the whole length of the gastro-intestinal tract, propelling the content onwards. After the stomach has been empty for a long time, intense rhythmic hunger-contractions may sweep over its body.

4. Small Intestine

The stomach extends from the aesophagus to the **duodenum**, the first portion of the **small intestine**. The lower end of the stomach which becomes considerably narrower is connected to the small intestine through **pyloric valve**. The small intestine which is a coiled twisted mass in the centre of the abdomen is divided into three parts : (i) **duodenum** (adjacent to the stomach), (ii) **jejunum** and (iii) **ileum**, totalling more than 7 metres. It is the third processing station of the digestive track. Like the stomach, it mixes and moves the food. It is here that the main work of digestion and about 90% of the **absorption** of the food constituents into the blood-stream takes place. A variety of enzymes and other digestive substances secreted not only by the small intestine but also by the **liver** and **pancreas**, act here and complete the breakdown of **proteins, carbohydrates** and **fats** into simple constituents. Here too, the major work of absorption takes place and nutrients are absorbed through the intestinal wall into the blood-circulation. Normally, 3 to 10 hours are required for chyme to pass from the pylorus to the end of the ileum.

(a) Duodenum. The first part of the small intestine is about 16 to 17 cms. long. A 'C-shaped' tube, the **duodenum** begins at the **pylorus,** passes behind **the liver** in front of the right **kidney** and across the **aorta**. It encircles the head of the **pancreas.**

The structure of this organ is similar to that of the stomach. The only difference is that its inner lining is very much wrinkled, resulting in greater surface area in a smaller space. This is an important organ in the digestive system. The **pancreatic juice** and the **bile** enter the tract about 7 cms. from the pylorus and commence their digestive action on food. Also, here—but not elsewhere—are glands, called the **Brunner's glands,** beneath the mucous membrane. Small quantities of thick gruel-like mixture of semi-digested food and gastric juices are squirted into the duodenum through the gate-keeper like valve. Since this is highly acidic, too much at a time would damage the lining of the duodenum, which is notorious as a site of ulcer, since it bears the brunt of jets of acidic chyme that periodically squirt into it from the stomach. To neutralize most of the acid, alkaline digestive juices from the **pancreas** and **gall bladder** pour into the duodenum via the **pancreatic duct** with the characteristic split-second timing and meet the chyme. These juices contain three main enzymes which separate the proteins, fats and carbohydrates into basic building blocks.

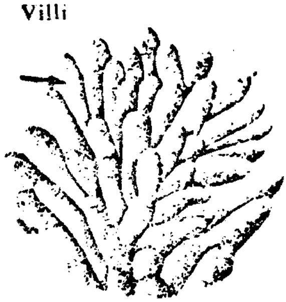
(b) Jejunum and Ileum. There is no clear demarcation between **jejunum** and **ileum**, although their membranes differ somewhat in structure. The jejunum constitutes about two-fifths of the small intestine and the somewhat longer ileum, the rest. The ileum ends in a right angled **T-junction** with the **large intestine**. The greater part of food-digestion and absorption takes place in the jejunum and the ileum. The slightly acidic liquid which enters the jejunum leaves it as an alkaline one. During its passage, virtually all the nutrient materials are extracted.

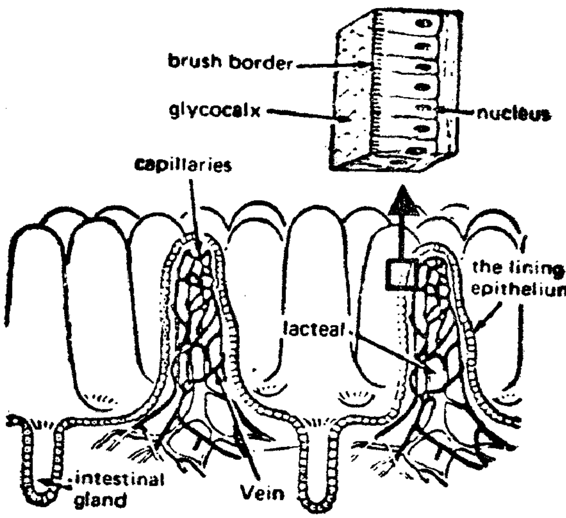
The Absorption Process

The structure of the small intestine is specialized so that the **absorption** of nutrients can proceed most efficiently. The absorption of valuable nutrients results from efficient **enzyme** action and the way with which the intestinal lining absorbs them from the cavity of the intestine. Perhaps the most important components of the intestine are millions of **villi**—tiny finger-like projections on its walls. These are the working structures of the small intestine in its function of absorption of digested nutrients. Each **villus** contains a network of capillaries, and a lymph vessel. (See, figure). Nutrients pass through into the small blood-vessels which run into larger ones and eventually into the **hepatic vein** which leads to the **liver,** where breakdown continues, before final delivery to the other cells of the body. Once absorbed by the body, the broken-down substances provide the raw materials for the building of longer and more complicated molecules which are better suited to the needs of the body.

SMALL INTESTINE

Villi





The end products of digestion which are absorbed include **glucose** (from carbohydrates), **amino-acids** (from proteins) and a **milky fatty emulsion.** They are put into circulation—glucose and amino-acids via the blood-stream and fatty emulsion via the lymphatic system. Over and above these three main nutrients, the following are also extracted and made available for bodily functions :

(i) Salts and Minerals

Calcium, Potassium, Sodium, Iron, Phosphorus, Iodine.

(ii) Vitamins

(a) Soluble in fats
(b) Soluble in water

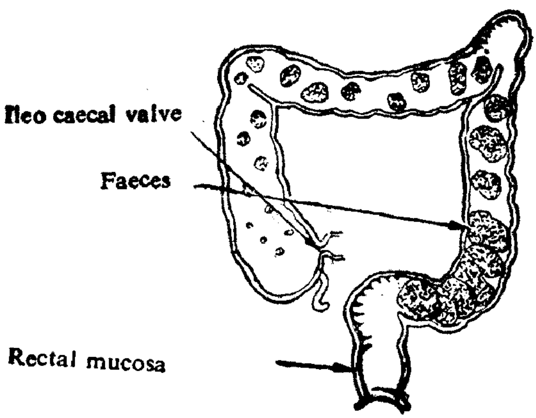
(iii) Water

Out of these, absorption of **vitamins** generally takes place in small intestine, while salts and water are absorbed in large intestine. What remains of the food after assimilation then passes into the large intestine, where the final stage of the digestive process takes place.

5. Large Intestine or Colon

Next to the **small intestine** comes the **large intestine** or bowel. It is much wider— 6 to 8 cms. in diameter—but

LARGE INTESTINE



shorter—only about 2 meteres in length. First it passes upwards, and is called 'ascending colon'. It bends when it reaches the bottom of the liver and remains horizontal upto the spleen. This is known as transverse colon. It, then, bends downwards and is called 'descending colon'. Its last part is in the pelvic cavity and is called the rectum, which is about 25 cms. long, and is rich in muscular tissues. Finally it ends at the external opening, the anus. The obvious differences from the small intestine are : larger diameter, a puckard rather than tube-like outside, and the longitudinal muscle being arranged in bands. The lining secretes mucus, but no digestive enzymes.

This is the fourth and last processing station of the tract. By the time it is reached, almost all the useful nutrients have already been digested and absorbed. What remain are indigestible stuff together with salts, bile-pigments, and large valuable quantities of water (the digestive juices are about 95% water). The function of the large bowel is extraction of salt and water (that can be usefully recycled) and the formation of the faeces from the indigestible food-stuffs like cellulose, bowel secretions and bacteria. The lower parts contain many organisms which manufacture a variety of useful substances including vitamin-K and several vitamins of B group as well as the smelly compounds responsible for the odour of faeces. Not all the inhabitants of our colon are hostile parasites. Millions of symbiotic (mutually helpful) bacteria live there and cause us no harm; they may indeed protect us from harmful micro-organisms.

The appendix is a blind-ended projection from the colon. It has no known useful function, but becomes a nuisance when inflammed or infected by faecal material and has to be removed.

ACCESSORY ORGANS OF DIGESTION

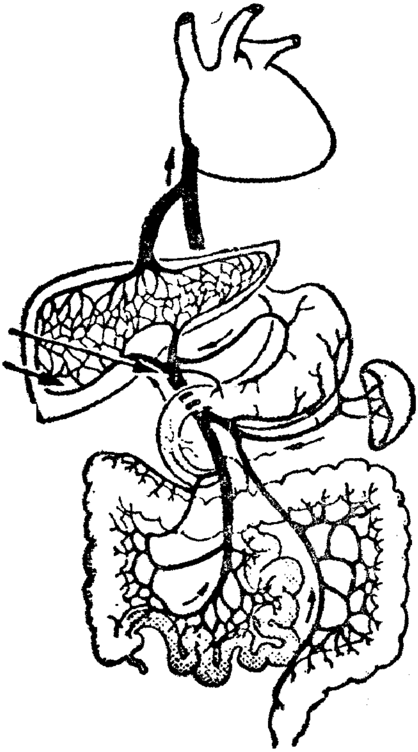
Liver, **gall-bladder** and **pancreas** are the accessory organs of digestion. They work together in the digestion and metabolism of nutrients. Apart from their production of the digestive juices, they control the storage and release of glucose regulating the energy supplies.

6. Liver and Biliary System

The **liver** itself is an amazing chemical factory within the body, generally underrated and abused. Even when badly damaged, its cells have enormous powers of regeneration.

The liver is the most important and an extraordinary organ which contributes to the process of digestion outside the gastro-intestinal tract. It is not only the largest but the most versatile single organ in the body. It lies in the upper

The Portal System



part of the abdomen on the right side beneath (and loosely attached to) the diaphragm. It is reddish brown in colour and weighs about 1.5 to 2 kg. A remarkable feature of the liver is that it receives a double supply of blood : (a) fresh arterial blood from the hepatic artery arising from the aorta, and (b) from the **portal vein** carrying the finished products of digestion from the intestine. Both these large blood-vessels branch repeatedly into a network of thousands of tiny capillaries making the liver a highly vascular organ.

Blood from both the blood-vessels mixes in the liver through its **kupffer cells**. Blood from liver carrying the nutrients reaches the vena cava through the **hepatic vein.** Thus nutrients processed by the liver reach the blood-circulation through vena cava.

Bile-ducts and Gall-bladder

Production of bile is only one of the many functions of the liver cells. Bile contains 86% water, bile-salts, bile-pigments and cholesterol etc. It aids in the emulsification and digestion of fats.

The ducts carrying the bile secreted by the liver to the gall-bladder are called bile-ducts. Bile is a thick, dark-green, alkaline digestive juice Attached to the lower surface of the liver is a small blind pear-shaped pouch called the gall-bladder which receives, stores and concentrates bile. The gall-bladder is far too small to hold the 1000 cc of bile produced daily by the liver, so it has the ability to concentrate the bile up to 20 times. When required, bile from the gall-bladder passes into duodenum together with the pancreatic juices through a common duct. Bile-salts are responsible for breaking globules of fats into tiny droplets.

The bile-salts are not lost alter fulfilling their role in the digestive procsss, but are carried back to the liver to be resecreted into the bile. This illustrates the high efficiency of the system which recycles the very small amount (3 to 4 gms) of bile-salts present in the adult.

Functions of Liver

Liver is the largest chemical factory in the body, and has at least five hundred known functions. It is an exocrine gland.[1]

All the absorbed nutrients from digestion pass through this biochemical factory.

The cells of the liver contain a variety of enzymes for many chemical processes, and they are also the vital stores of essential material. The metabolism of each of the three groups of food-material, viz., carbohydrates, fats and proteins takes place in the liver.

1. Glands producing secretions, which drain out through ducts and have an effect only near the area where they are released, are called exocrine (exo=outside), in contrast to endocrine (endo=inside) or ductless glands manufacturing hormones which pass directly into the blood-stream, circulate all over the body and at places far from where they are secreted. For further details, see later section.

If the body-cells require immediate energy, the liver releases some of the glucose back into the blood-stream for delivery to the cells. The remaining glucose is converted into **glycogen**—a larger molecule—which can be stored in the liver and some muscle cells. When all the glycogen storage areas are filled up, the remaining glucose is converted into fat and stored. The liver has the proper enzymes which are necessary to carry out the conversions of carbohydrates, proteins and fats into one another.

Another function of the liver is to store important vitamins including A, D and B_{12} and iron.

The liver neutralizes the injurious effects of the toxics such as poisonous drugs and liquor. Besides, whenever a toxic substance reaches the liver from the intestines etc., it is processed in the liver, and rendered excretable through bile or urine. However, the poison of excessive drinking or hypnotic drugs could destroy the liver cells.

Yet another function of the liver is to produce urea. When amino-acids absorbed by the blood-vessels in the villi (in the intestine) reaches the liver-cells, it is de-aminized, i.e. nitrogen is separated and transformed into urea which is excreted through urine by the kidneys.

Over and above the above-mentioned functions connected with the digestive system, the liver has to perform some important functions pertaining to the general components of blood. For example, (i) production of new red blood-cells during the foetal life, and (ii) assistance in maturing them later on and withdrawing them from the circulation on their becoming worn-out, (iii) breaking-down of haemoglobin from the worn-out red blood-cells and converting it into an iron containing pigment, bile-pigments—bilirubin and biliverdin (while most of the iron is reutilized, bilirubin etc. is excreted).

Lastly, it also assists in keeping the body-temperature constant.

7. Pancreas and the Islets of Langerhans

Pancreas is the most important producer of digestive juices in the whole digestive system. It is a versatile organ, the second largest gland in the body (the largest is the liver), and functions both as a digestive organ (exocrine gland), and as an endocrine gland. In fact, it is two unrelated organs into one.

The **pancreas** is an oblong, rather flattened, boneless, fatless and fleshy gland about 15 cms. long, grey-pink in colour, and weighs about 85 gms. It consists of a head, a body and a tail; its head rests in the curve of the duodenum and its tail touches the spleen. The pancreas is connected to the duodenum through the pancreatic duct which extends throughout its length.

Scattered throughout the pancreas, between the glands that pour juice into the pancreatic duct, are many pin-head-sized clusters of special cells. These are the **islets of Langerhans.**

Exocrine Function

The exocrine portion of the pancreas produce 1000 to 1200 ml (2 pints) of alkaline fluid daily. This pancreatic juice contains several digestive enzymes.

Highly acidic gruel which leaves the stomach can spell disaster in the digestive tract by eating away the delicate lining of the small intestine (duodenum). To neutralize it, the pancreas (in association with the gall-bladder which sends the bile to duodenum) must produce enough alkaline juice. It waits on call, ready to supply a powerful arsenal of digestive enzymes as soon as they are needed. It does not begin to pour its products into the duodenum until food reaches there. Commencing its action through nervous control, the pancreas is proded into full action by the chemical message of the hormone secretion produced by the duodenum as a measure of self-protection. These hormones stimulate the pancreas to produce juice rich in sodium bicarbonate which neutralizes the acid of the chyme.

Pancreatic juice has five main enzymes. Three of these complete the digestion of proteins begun in the stomach. The others are (i) amylase (which digests carbohydrates), and (ii) lipase, the only fat-digesting enzyme in the body, which works on the tiny fat droplets prepared by the bile.

Endocrine Function

The endocrine portion (the **Islets of Langerhans**) of the **pancreas** contain two main types of secreting cells, **alpha** and **beta** cells which secrete the hormones—**glucagon** and **insulin**. While many people may have a rough idea of what insulin does, only a few would have ever heard of glucagon. Both **glucagon** and **insulin** are concerned with the regulation of the body's carbohydrate metabolism, but their effects are opposite. (Yet the two hormones do not antagonize or block one another ; they work independently). When the blood-sugar-level rises after a meal, for example, the secretion of **insulin** is stimulated, and it causes the blood-sugar-level to fall. When the blood-sugar-level falls below the normal value, **glucagon** is secreted which raises the glucose-level of the blood. Thus, insulin and glucagon together keep the blood-sugar-level within a relatively narrow range.

Insulin acts in several ways to lower the blood-sugar-level. It facilitates the transport of glucose through cell-membranes, since the rate at which a cell utilizes glucose is determined to a large extent by the rate at which it enters the cell. Insulin thus speeds up the rate of glucose metabolism. It also acts on the cellular enzymes that catalyze the conversion of glucose to glycogen, and thus helps to take glucose out of circulation and store it away.

Insulin also stimulates synthesis of fatty acids from glucose and inhibits the conversion of amino and fatty acids to glucose in the liver.

Failure to produce insulin in adequate quantities results in **diabetes mellitus**, i.e. increase of blood-sugar which appear in the urine. In the absence of insulin, cells would try to burn fat and/or protein which would have to be drained from muscle tissues, while unburnt sugar would pass out of the body in sweetish urine taking with it a lot of water and useful salts.

Consumption of sweets in excess amount requires increased insulin production.

Thus, the so-called **accessory organs** perform a phenonenal multiplicity of biochemical functions unequalled by any other organs.

Metabolism

Metabolism is the name given to the biochemical processes consisting of the breakdown of the basic food-materials with the release of energy and their re-arrangement into complex substances which build up the living tissues. It involves the digestion of food in the stomach and intestines, the absorption and storage of digested materials, their incorporation into the tissues of the body and finally their release and breakdown to water and carbon dioxide with the liberation of energy[1].

1. This is discussed in greater details in the IInd Part of this book.

: 9 :
Endocrine System

Glands

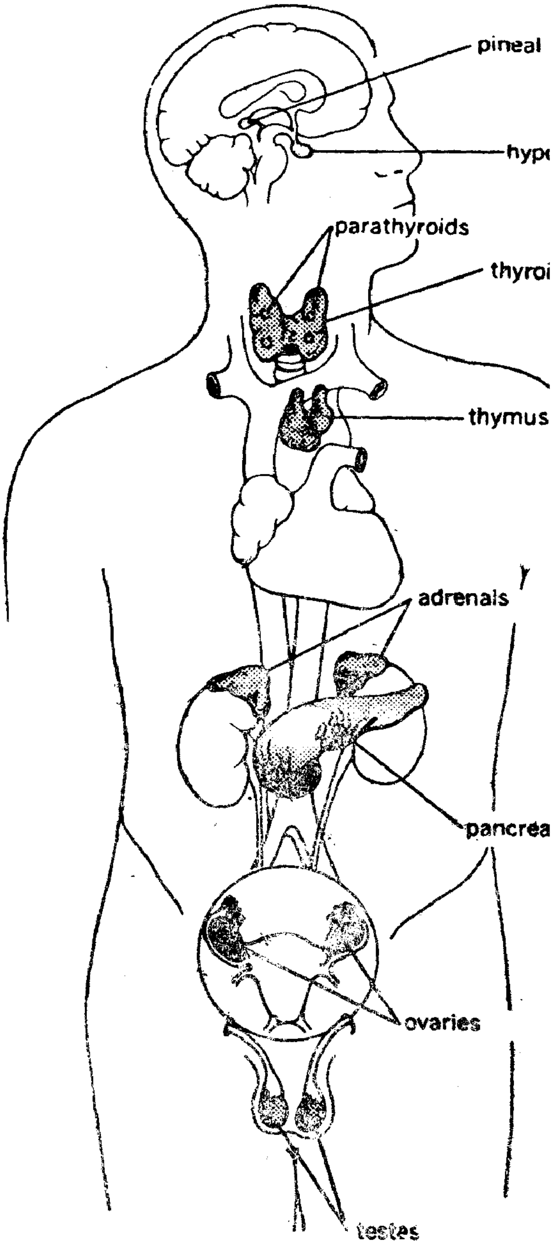
A **gland** is composed of a cluster or accumulation of cells. Every gland might be likened to a chemical factory in which all cells are working and the production of the factory is their secretions. Some glands, such as those of the skin and the gastro-intestinal tract, produce secretions which drain out to the surface or into a body cavity via a **duct** and affect only near where they are released. These are called **exocrine glands** (exo=outside). They are—**liver, pancreas, kidneys, salivary glands** etc.

In contrast, the **endocrine glands** (endo=inside) a specialized organs, ductless and their production passes directly into the blood-stream, circulates all over the body and acts at places far from where it originated.

We have already dealt with the important exocrine glands in the previous chapters. In this chapter we shall, therefore, deal with the **ductless endocrine glands**, their secretions called **hormones** and their profound effects on the physical functions, mental states and behavioural patterns of an individual. Unlike continuous anatomical structures of most of the systems of the body, the glands of the endocrine system are scattered through the body like islands. Nevertheless, they are unified into a finely coordinated system, function in a marvellously harmonious fashion and coordinate the activities of the body.

Endocrinology is one of the latest and the fastest developing areas of bio-medical research. The endocrine system, at its simplest, works like a thermostat. Just as, the thermostat may instruct the central heating to switch on or off, the endocrine system regulates various functions of the vital organs of the body to match the external conditions,

ENDOCRINE SYSTEM



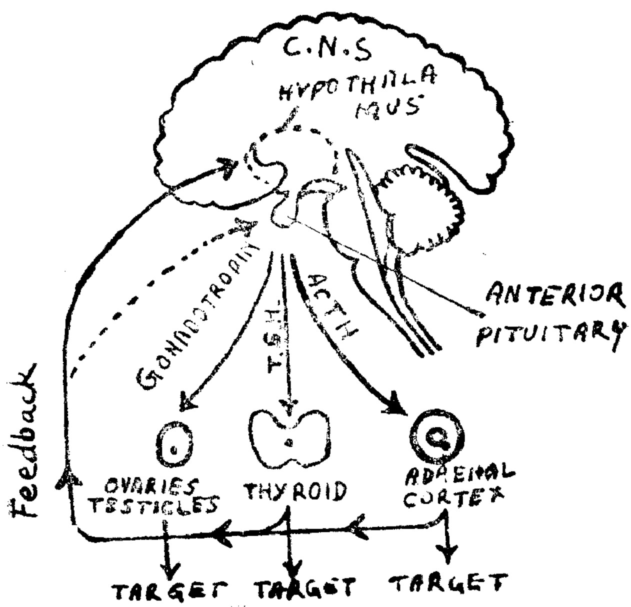
m..re important of the endocrine glands and their locations in the body.

This analogy is, however, oversimple. The endocrine system is, in fact, an elegant system which controls numerous positive-negative systems to keep the conditions inside the body stable.

The main endocrines are : the **pineal, pituitary, thyroid, parathyroid, thymus, adrenals, islets of Langerhans** and **gonads** (sex-glands). All these glands are comparatively small, are devoid of ducts and have access to very rich vascular supply. The products of these glands are organic chemical compounds called hormones. They are effective in very small quantities. They regulate such important body-processes, as growth and development, sexual activity, pregnancy and birth, metabolism and maintain homeostasis in the organism. Secretions of one gland profoundly influence and control the activities of others.

Regulation of body-processes depends on regulation of hormone production. For the most part, hormone-secretion of endocrine system is under the control of **pituitary** and **hypothalamus.** Variety of trophic hormones secreted by the pituitary reach thyroid, adrenals and gonads via the blood stream and stimulate each of them to secrete specific

Feedback System



(peripheral) hormones in definite quantiiies. An efficient feedback system of plus-minus or minus-plus chemical interaction regulates the function of these three glands as well as the trophic function of the pituitary. The feedback system works like this : with the increased level of a peripheral hormone, the secretion of the stimulant—the trophic hormone—is inhibited and vice versa.

A brief discussion of individual members of the system now follows.

(i) The Pineal Gland

Until recently, the status of the pineal gland as an endocrine organ was highly controversial. Despite greatly increased interest, many mysteries of its functions still remain to be unravelled.

The **pineal gland or body** (epiphysis cerebri, corpus pineale) lies near the centre of the brain. It is a cone-shaped structure resembling a pine cone. It is 7-10 mm long, 4-6 mm wide and 2-3 mm thick and weighs 0.2 gm. It is greyish-red in colour. It is hidden away at the base of the brain in a tiny cave behind and above the pituitary gland. It is composed, in part, of nerve-cells containing pigment similar to that present in the cells of retina.

Although it is located within the brain, the gland is innervated doubly by central and autonomic systems. Impulses from these nerve-fibres, transmitted to the gland by neuro-transmitter norepinephrine, stimulate the secretion of the pineal hormone—**melatonin.** It acts as a general supervisor over all the other glands, and its secretions act as a regulator for all endocrines. During the first two-three years of life, its chief duty is to give the baby time to grow in bulk and put on weight. An important effect of the pineal secretion is to inhibit the production of gonadotrophic hormones, thus reducing sexual excitation. Puberty (both in males and females) is delayed when melatonin production is high. Thus the pineal is believed to be the seat of the body's biological clock, which signals the onset of maturation.

Thus, in childhood, the pineal gland helps in holding the sex in abeyance, and later aids in the maturing processes of sex after puberty. In adult life, it regulates the proper nourishment to muscles and controls the action of light on the pigment of skin. It produces the normal physical and mental development of the brain cells. The rich blood supply to the pineal is suggestive of its significant functioning.

Some experimental evidence indicates that pineal hormones inhibit ACTH secretion, and thus indirectly help to regulate the secretions of the adrenal gland. Modern pineologists call pineal gland a regulator of regulators.

(ii) The Pituitary Gland

The **pituitary gland** (also called the hypophysis) is about the size of a pea, situated almost exactly in the centre of the head at the base of the brain and just behind the root of the nose. It hangs suspended from the underside of the brain in a little cup or cradle. It has a greyish yellow colour. It increases in size until about 30th year, and in the adult male, weighs about 600 mgms (slightly more in women). No part of the body is exempt from its influence.

To understand how the endocrine system works, we must look at the pituitary as well as the hypothalmus which controls it. Together they constitute a single interconnected system and control production of hormones from the other glands.

The pituitary is traditionally called the master gland or 'the conductor of the endocrine orchestra'. However, an even grander analogy must be found for the hypothalamus since it controls the pituitary. It is here that the nervous and the endocrine systems are co-ordinated.

The pituitary is composed of an anterior and a posterior part. The former produces six different hormones and is controlled by hormone-like releasing factors from the hypothalamus. Four of these are trophic hormones, that is, they regulate the action of other endocrine glands :

Thyroid-stimulating hormone (TSH) stimulates the thyroid.

Adrenocortico trophic hormone (ACTH) stimulates the adrenal gland.

Follicle-stimulating hormone (FSH) and luteinising hormone (LH) are both gonadotropins i.e. stimulate gonads (sex glands).

The hypothalamus receives inputs from parts of the body including the emotional centres of the brain. Whenever required it produces releasing factors which stimulates the pituitary to produce trophic hormones, which in turn stimulate the other glands to release the hormone needs for the occasion.

The other hormones are growth hormone and prolactine which stimulates the secretion of milk in the breasts. Growth hormone is still rather a mystery. Its job is to stimulate growth in the growing years but it works on many systems even after adolesecnce. At various times of life, the thyroid and sex-hormones also share a growth promoting role.

Functions of the two posterior pituitary hormones are more specific Antidiuretic hormone (ADH) is responsible for the regulation of water loss from the kidneys through braking effect.

The other hormone—oxytocine is most important during child-birth and breast-feeding. It causes the uterus to contract which will result in the expulsion of the fetus.

The posterior pituitary is not really an endocrine but a storage depot of the hormones secreted by the hypothalamus.

(iii) The Thyroid Gland

The **thyroid gland** consists of two lateral maroon-coloured masses astride the upper end of the trachea, close to the larynx. The two lobes are connected with a narrow strip of the same tissue just below the Adam's apple. Each lobe is about 5 cms. in length, 3 cms. in width and about 1 to 2 cms. thick. The normal thyroid of an adult weighs 25 to 40 gms. but its size fluctuates with age, habitation and diet. It is heavier in the female than in the male, and becomes enlarged during sex-excitement, menstruation and pregnancy. The vascular supply to this gland is by four main arteries and is exceptionally rich. Probably more blood flows through it in proportion to its size than through any other organ of the body with the possible exception of the adrenal gland; e.g., it receives four times as much blood as do the kidneys. This gland is innervated by sympathetic and parasympathetic nerves

Its most astonishing feature is its ability to take up and concentratel arge amounts of iodine which, within the gland, may be 50 to 300 times more than in the blood-plasma. Iodine ions are very effectively removed from the circulating blood by an active transport mechanism (an iodide pump). Iodine is used to produce hormones which regulate protein-, carbohydrate-, and fat-metabolism. They are essential for growth and mental development. Another hormone which does not contain iodine is concerned in the body's calcium metabolism.*

The rate of release of thyroid hormones is principally regulated by the thyrotrophic hormone—TSH—of the anterior pituitary. The role of thyroid hormones lies in growth and development.

Thyroxine is the main secretion of this gland. It is a gelatenous substance. Besides a large percentage of iodine, it also contains iron, arsenic and phosphorous—iron for the general system and to aid in the electric energy and conductivity of the system ; phophorous for the nerve and brain centre ; and arsenic for the skin. The hormone is the builder of the nerve and brain tissue. **Tri-iodo-thyronine** is the other hormone which regulates the metabolic rate of the body.

Thyroid gland is essentially an energy producing organ and its output is the controller of the rate of metabolism or the speed of living. Any disturbance in the thyroid secretion in quantity, i.e., too much or too little, or in quality, i.e., an abnormal change in the chemical composition, produces serious results. Thyroid is very closely related to other glands. It is the other great link between the brain and the organs of generation; and its acceleration is necessary to give balance to the brain.

*The body has a double system for regulating calcium-metabolism. Calcitonin—recently discovered hormone from the thyroid—seems to act as a short-term regulator, preventing acute excess of calcium in the body-fiuids, while the parathyroid hormone sets the long-term level of calcium ions in them.

The effects of thyroid gland on other functions are widespread :

—aids in normal mental and physical development;
—secretes the iodine-containing hormones which combats the poison of the body;
—gives nerve stability;
—helps to control the amount of fat stored in the body and the basal metabolic rate;
—prevents and cures goitre.

(iv) The Parathyroid Glands

Parathyroids are four minute yellowish brown ovoid bodies about 6 mm long and 3 mm wide, embedded in the lobes of the thyroid gland (two in each lobe). Sometimes the lower two are found much further down and in the chest. The hormone secreted by these glands is called parathormone (PTH). Its action sets the long term calcium levels in the body.

The overall effects of parathyroid hormone are to increase the calcium levels in the extra-cellular fluids and decrease the phosphate concentration. The hormone is secreted in a self-regulating feedback system, independent of pituitary control. In exerts its effects in three major sites :

(i) In the bones, where it promotes reabsorption of calcium and phosphate into the extra-cellular fluid by increasing the number and activity of the osteoclasts.

(ii) In the intestine, where it enhances the absorption of calcium and phosphate, and

(iii) In the kidneys, where it increases the reabsorption of calcium but enhances excretion of phosphate with the urine.

The functioning of the hormone PTH is dependent on adequate supply of Vitamin-D.

(v) The Thymus Gland

Unlike other glands, the thymus gland is not universally

*Osteoclasts (lit. bone-breakers) are cells which dissolve away inner bony tissue adjacent to the marrow-cavity, thus enlarging it to keep pace with the overall growth of the bone.

accepted as a member of the endocrine system. It is generally described under "organ of uncertain endocrine function". However, there cannot be much doubt that it is the source of one or more hormone-like factors.

A lymphoid, two lobed structure, this gland is situated in the chest between the two lungs and extends up into the neck. It descends and comes to the upper portion of the heart. A brownish mass, it reaches its largest size at the begining of puberty, when it is about 5 cms. long, 3.5 cms. wide and 6 mm. thick. and weighs 25-35 gms. It grows rapidly during the first two years of the child's life and it gradually shrinks after the 20th year. By the age of 75 years, it weighs only 6 to 10 gms. Some of the secreting cells, however, remain throughout life. This gland is believed to control the physical growth of children, the greater part of which takes place before the 14th year of age. During this time, it holds other glands, particulary the sex-glands, in check, delays puberty and furthers normal brain development.

The thymus is a lymphoid organ, since it contains closely packed lymphocytes. Besides the function mentioned above, the thymus exerts an influence on the lymph nodes, spleen and other lymphatic tissues so that they too gain the ability to produce lymphocytes and foster the development of immuno-competent cells by means of a hormone.

An interesting correlation that has recently attracted the attention of researchers is the fact that there is a dramatic increase in auto-immune diseases such as arthritis, anemia, (conditions in which the body attacks its own useful cells as a result of errors in recognition mechanism) with increasing age precisely at the time when the thymus is losing its functional capacity.

It is believed that this is the gland that keeps children childish and sometimes makes adults childlike. During childhood, it promotes growth of bones, but at puberty, its functioning begins to decrease, i.e., rise in the functioning level of sex-glands exerts restraining influence on the thymus, but many times the thymus gland does not cease its action. The continuance of its activity after puberty causes peculiar actions of sex-development and stops the process of transforming into positive sex-expression, either of male or female.

Islets of Langerhans

Endocrine tissue making up the **islets of Langerhans** accounts for about 1 to 2 % of the total weight of the **pancreas.** They are supplied with blood more abundantly than other parts of the pancreas. Three kinds of cells are distinguished in the islets : (i) **beta-cells**—located near the centre of the islets and comprising 60 to 70 % of all its cells; (ii) **delta-cells** which are predecessors of other cells (2 to 8 %); (iii) **alpha-cells**—located near the periphery.

Glucagon is formed in the alpha-cells, **insulin** in the beta-cells, and **somatostatin** in the delta-cells. We have already discussed about the glucagon and insulin in the 8th chapter.[1] **Somatostatin** is one of the regulators of the secretion of insulin and glucagon.

(vi) The Adrenal Dlands

Adrenals are a pair of three-cornered hat-shaped glands capping the upper end of the kidneys. They are about as big as the ends of one's fingers. The weight of both adrenals ranges from 6 to 12 gms. Their langth is 40-60 mm, breadth 20-35 mm, and thickness 6-10 mm. Each adrenal is a double gland, composed of a cortex—an outer layer, and a medulla—an inner layer. The cortex makes up the bulk of the gland, which is bright yellow outside and reddish brown inside. The medulla is much thinner and grey in colour. Cortex itself is divided into three zones :

(a) a narrow outer,
(b) a wide heavier middle, and
(c) an irregular inner.

In childhood and youth, the glands are relatively larger and more prominent than in the adult life. At all ages, the amount of blood passing through the adrenals is very great compared to their size. They are supplied with blood by the superior, middle, and inner adrenal arteries. The tremendous importance of these glands is better understood when it is known that death occurs very quickly after removal. They are innervated by sympathetic and

1. See pp. 94-95.

parasympathetic nerves.

Adrenal Cortex

Probably more hormones—more than three dozens—are produced by the **adrenal cortex** than by any other endocrine gland of the body. A number of these hormones are essential to life. The cortex is closely related to the organs of reproduction. The secretions of the cortex stimulate the healthy growth of the brain and sex-cells, develop great mental concentration and physical endurance and generate a vigorous muscular and nervous constitution. So close are the brain and adrenal cortex related that a normal human brain never develops without a normal adrenal cortex.

Fifty steroid compounds have been isolated from the adrenal cortex to date. Functionally, the adrenal-cortical hormones can be grouped into three major classes :

(i) **Mineralocorticoids** which influence primarily the electrolytes of the extra-cellular fluids, regulate the quantity of salt and water and maintain the electrolyte balance in the body.

(ii) **Glucocorticoids** which act primarily on the carbohydrate-, protein- and fat-metabolism and help fight stressful conditions (infection toxicosis, injury etc.) by raising the blood-glucose-level. They are secreted in response to ACTH released from the pituitary.

(iii) The sex hormones (both male and female).

Two of the most important hormones are :

(a) **Aldosterone**, belonging to the first group, and

(b) **Cortisone** which is converted to hydrocortisone, from the second one. Cortisone is nowadays synthesized and used in treatment of many different disorders mostly to suppress inflammation. Pain in muscles and joints are often dramatically affected and relieved by the use of this drug.

The Adrenal Medulla

The adrenal medulla has a loose structure; it is about one-tenth the size of the cortex. It secretes two important hormones :

(i) **Epinephrine**—also called **adrenaline.**

(ii) **Norepinephrine (noradreealine).**

Noradrenaline is the precursor of adrenaline.

Fear, pain, exposure to cold, low blood-pressure, emotional upsets and other challenging experiences stimulate the release of these hormones.

They are secreted in response from sympathetic nerves. Their effects are basically similar, but there are some key differences. Norepinephrine which is also a neuro-transmitter is also released by the ends of the sympathetic nerve-fibres.

The secretion of these two hormones is controlled by the sympathetic nervous system and the higher centres in the cerebral cortex and hypothalamus. Thus the functioning of the adrenal medulla is intimately linked with the sympathetic nervous system. Both the release and re-synthesis of the hormones are triggered by nerve impulses. The amount of adrenaline, in circulation in general, is about 1 part to 20 millions, while a hundred thousand times more is stored in the glands as reserve.

Adrenaline has been called the emergency hormone. Its entry into the blood causes a tremendous heightening of vigour and tensing of the nervous system. More sugar is sent into the blood from the liver and more red blood-cells are forced into circulation from the blood reservoirs of the liver and spleen. The heart beats more strongly, the blood-pressure and temperature rises, breathing is more rapid, and the blood rushes in the brain as well as to the skeletal muscles of the limbs. On the other hand, the digestion and everything non-essential is inhibited, arrested and suppressed. All this is in preparation of 'fight or flight' in response to the emergency.

Through repeated excitement, anger, fear etc. the adrenal glands may be exhausted of their reserve supply of adrenaline secretion. If enough time is not allowed for the glands to recuperate, amount of the secretion will be insufficient to meet the demand. The result would be temporary or chronic adrenal deficiency. It is characterized by indecision, a tendency to worry and an inclination to weep for the slightest provocation

(vii) The Gonads (Sex-glands)

The term **"gonad"** literally means **"seed"**, and the male and female sex-organs—**the gonads**—produce the seeds of the new generation. The main gonads of the female are the **ovaries** and in the male they are the **testes**. Their principal function is to produce the germ-cells (ova and sperm) that can fuse with the germ-cells of the opposite sex to produce a new life. Elaborate system of ducts and glands, for the conveyance of the germ-cells towards the exterior, has been evolved. These systems constitute accessories.

The gonads also double as potent endocrine glands, secreting hormones that condition the functional state and influence the psycho-biological phenomena involved in the sexual act. Thus besides producing the ovum, ovaries also produce endocrine substances that vitalize a woman and make her feminine.

The testes have semen as their external secretion which carries the sperm and which is stored at the prostate gland. Its internal secretions are the male energising forces and what makes him really male. They are the male endocrines. These hormones have profound influences not only on the sexual lives but also a number of body-organs and functions of an individual.

The Ovaries ;

The ovary is one of the paired organs situated in the pelvis. It is 3-4 cms. long 2-2.5 cms. wide and weighs 6-7 gms.

Secretions of a woman's sex-hormones are in a large measure responsible for the characteristics that distinguish her from a man. These are secreted mainly by the ovaries which are two small glands of the size of a bean which lie inside the pelvis supported by ligaments. They are touched by the fronded ends of the fallopian tubes—the ducts for the passage of ova to uterus.

The major hormones produced by the ovaries are **estrogens** and **progesterone.** At or about the age of 10, the biological clock (pineal gland) in the girl's body seems to set off an alarm that wakes up a specific portion of the hypothalamus. Releasing factor is despatched to the anterior pituitary and the secretion of follicle-stimulating hormone (FSH) begins. Now the dormant endocrine function of the ovaries awakens and they begin to secrete their own hormones, estrogens.

The Testes

Testes are the chief male gonads like the ovaries in the female, having two major functions : they produce the germ cells that act in reproduction and they also are powerful endocrine organs secreting male sex hormones. The testes in the adult are small ovoid structures about 3 to 5 cms. long, 2-3 cms. wide and weighs 20-30 gms. suspended in the **scrotum.**

The male sex hormones are called **androgens** and **testosterone** is the major androgen produced by the testes. Other androgens are produced by testes as well as adrenal glands but all of them are slight in comparison with testosterone. The function of the testes is controlled by the hypothalamic-pituitary system, and its regulation by the gonadotrophic hormones is accomplished according to the feedback principle. As in the case of female, pituitary hormones play a profound role in controlling the functions of the testes in male. At least some differences in the typical behaviour and personality between men and women seem to be linked with the secretion of testosterone.

The secretion of testosterone begins in the male foetus. Small quantities of testosterone continue to be secreted during childhood, but there is a dramatic increase at puberty. This sparks a furious growth—spurt along with the development of the mature sexual organ.

Testosterone is responsible, to some degree, for sexual interest and sex drive, but an intricate complex of psychological factors is superimposed on this underlying endocrine mechanism.

Hormone and the Life Cycle

The growth and changes in the body are largely under hormonal control. So also is the variation that repeats its cycle regularly everyday the so-called 'circadian rhythms' to wake during the day and sleep at night.

Several hormones are active before birth e.g. those controlling metabolism. Growth hormone and thyroxine are especially influential in the period of rapid growth and development both in the womb and outside. On the other hand, sex hormones are inactive before puberty and again in old age. At puberty, the first signal is given by hypothalamus through gonadotropins from pituitary which stimulate the major producers of sex hormones—the testes and ovaries —to grow and begin to secrete. The effect is dramatic In boys, hair grows on the face and elsewhere and the muscles strengthen. In girls, the breasts develop and menstruation begins. Both sexes become capable of reproduction. The endocrine rhythm is in-built.

For homeostasis, hormones are vital. Science cannot hope to mimic the fine control exercised by this powerful band of chemical messengers.

Intersction of Feeling and Behaviour

Having dealt with physical functions of the endocrine system, we shall now, briefly, discuss its action on the mental states and behavioural patterns of man.

The nervous system and the endocrine system are the two major control-systems of the body. The co-ordinating effects of the nervous system are transmitted nearly instantaneously by electro-chemical impulses; the endocrine glands secrete chemical regulators (hormones) which are carried through the body by the blood-stream. The action of the latter is more slowly established, but longer lasting than that of the former. While nerve-action is measured in milliseconds, some hormones need several days to get started and then last for weeks, months or even years. Nerve-impulses control the function only of muscles and glands, while hormones may act on all the cells of the body.

A serious study of the endocrines and their hormones commenced about the beginning of the century. It has now been known that besides the old method of chemical intercommunication between the two systems, another method by nerve-action also exists. Lately, it has been realised that nervous and endocrine systems, both functioning to integrate the organism, are not as divergent as was formerly supposed. Many endocrine glands act on the nervous system through their hormones ; on the other hand, endocrines are stimulated or inhibited by products of the nervous system.

Within the central nervous system, there are groups of nerve-cells, which are capable of functioning as glands. The chemical messengers released by these neuro-secretory cells are called neuro-hormones. These cells serve as link between the central nervous system and the endocrine system. With the help of these dual cells acting as go betweens, the central nervous system can control the functional activity of many endocrine glands, and adjust their activity in accordance with the requirements of varying internal and external environments. Equally important is the reverse relationship by which the endocrine system can influence the central nervous system. This concept of the reciprocal inter-relation of the two system is now generally accepted.

Recent studies on neuro-secretions leave no doubt that the nervous system has its own endocrine specialization for the release of hormones. The functional interlocking is so remarkable that nervous and endocrine elements are coming to be regarded as constituting a single integrated system called 'neuro-endocrine system'. As research deepens our knowledge of co-ordinate systems, it becomes increasingly apparent that their products participate not only in every bodily function, but have profound influence upon the mental states and behaviour of individuals.

The neuro-endocrine system is the seat of instincts and impulses of man. Impulses and urges not only generate feelings but also command appropriate action that satisfy the need. Animals just act out instinctive rituals of eating, courtship and fighting because they do not possess a reasoning mind. Man, on the other hand, because he has conscious reasoning, can control his responses to the insistence of the impulsive drives. Of course, man also does feel angry, hungry and sexually aroused. But he can modify his action. He could, for example, channel an erotic mood on to another creative track.

Love, hate and fear are endocrine impulses. It is the primitive urge of aggression from the endocrine, that will start war and not the brain because no reasoning mind will ever wish to kill or injure. All the passions, emotions and impelling forces are the actions of the endocrine expressions. The reasoning mind itself has no emotions but many a time the powerful impulses from the endocrine can overwhelm and continue to tinge the supposed reasoning.

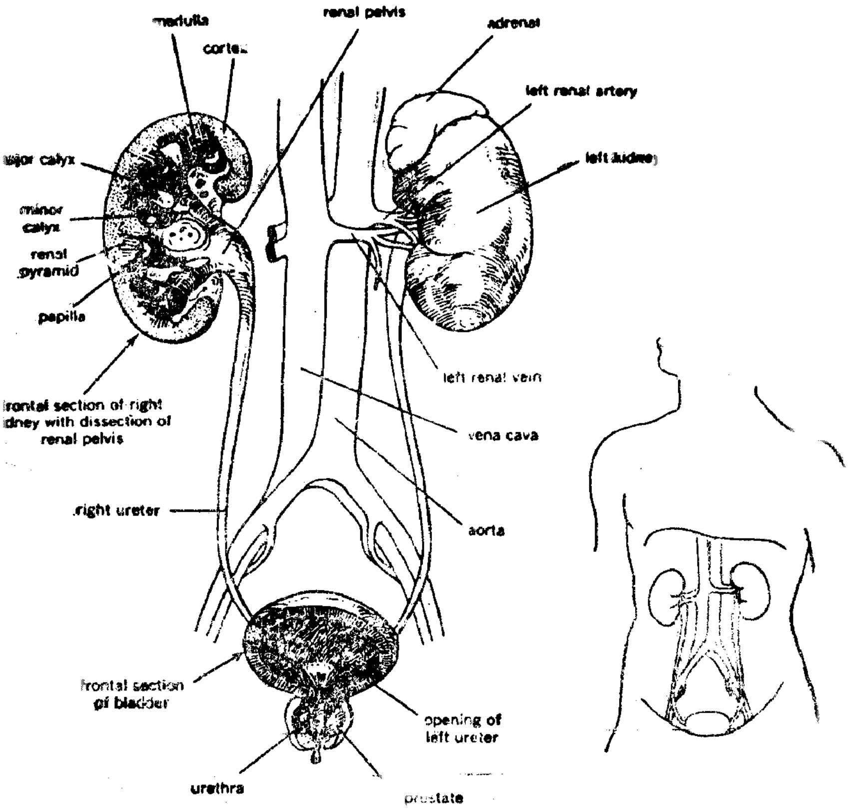
10
The Urinary System

The function of the excretory organs is just as essential to the well-being of the body as those of the other body systems.

Like the world in which we live, the human body has its pollution problems. Nutrients, taken in through the digestive system, and oxygen, supplied by the inhaled air, are utilised to provide the energy needed to power the activities of the body. But the metabolic processes, like those in huge factories, generate by-products and wastes. To prevent the body from polluting itself-with its own waste products they, must be eliminated as they are produced. The excretory organs and the major substances they eliminate are summarized below :

Excretory Organs	Substances Excreted
Lungs	Gaseous wastes, carbon dioxide, water vapour
Skin (sweat glands)	Water, salts, nitrogenous wastes
Alimentary canal (large intestine)	Solid wastes of digestion
Kidneys	Water, nitrogenous wastes, soluble salts, bacterial toxins, infested drugs and poisons, etc.

We have already dealt with the excretory functions of the lungs, skin, and large intestine. We shall, therefore, discuss here the kidneys together with the other organs of the urinary system. The alimentary canal is not the main waste disposal system, but the urinary system is. The former may become inactive for quite some time without



General organization of the urinary system.

any grave danger, but if the latter closes down, it may spell disaster.

Urine is produced in the **kidneys.** A pair of narrow tubes, the **ureters,** carry it from the kidneys to the baglike **bladder,** in which it is stored temporarily. A single muscular tube, **the urethra**, leads to the exterior.

Organs of Urinary System

The Kidneys : The major excretory organs for the elimination of nitrogenous wastes are the kidneys. A pair of bean-shaped organs, they are among the hardest working organs in the body. The normal adult kidney is about 10 to 12 cms. long, 5 to 6 cms. wide and about 3 to 4 cms. thick.

They are located under the diaphragm, just above the waist line, one on each side of the spine against the posterior body wall. They are embedded in a heavy cushion of fat which both protects and supports them. Both kidneys are capped by adrenal glands.

Microscopic examination of the kidney reveals a complex system of tubes, capillaries, arteries and veins, carefully packed together to form approximately one million identical units called **nephrons.** They are the structural and functional units of the kidney. Being miniaturized chemical filtration plants, they balance the composition of the blood and form urine.

The Ureters : The urine that is formed continuously in each kidney trickles out through the ureters. Each ureter is a long muscular tube, about 25 to 30 cms. long and 4 to 5 cms. in diameter. There are three constricted areas along the course of the ureter. These three bottlenecks have no particular effect on the flow of the urine, but they may become trouble spots if stones are formed in the kidneys and pass into the ureters. They may become lodged in the narrow portions producing excruciating pain and a blockage of urine flow.

The Bladder : It is an expandable baglike structure, situated mainly in the pelvic cavity. As it fills up, it expands upward into the abdomen. The two ureters enter the bladder and travel for a few centimeters under the bladder wall. This helps to prevent a backflow of urine.

The Urethra: In both sexes, urine is emptied from the bladder through a pencil size tube, the urethra, which emerges at the exterior surface of the body in an opening.

In females, the urethra is a short tube about 2.5 to 3 cms. long. The male urethra takes a much longer, tortuous course. It goes through the prostate gland and has a total length of about 20 cms. It serves the double function of carrying urine as well as seminal fluid. Enlargement of prostate gland (in old people) can restrict the flow of urine making urination difficult and painful.

Urine Composition : **Urine** is a watery solution of nitrogenous wastes and salts. Usually, it is a transparent liquid of light yellow colour. It is normally 96 % water and 4 % inorganic and organic waste products. Inorganic wastes include sodium chloride and other salts. Organic wastes are urea, uric acid, etc. Urea which is nearly half of all solids is the end product of protein digestion. The average amount of urine excreted daily is 1.5 to 2 litres containing 25 gms. of inorganic and 35 gms. of organic wastes. The amount can, however, vary considerably even under normal conditions and even more in various pathological conditions. Abnormal constituents of urine include glucose, albumin, blood, pus, bile pigments and stones etc. Various poisons, bacterial toxins and drugs are also excreted through urine. Laboratory examination of urine, provides valuable diagnostic indications of the functioning of the body.

The Formation of Urine

Urine is produced continuously, 24 hours a day. It is formed in the kidneys from the copious blood flow that passes through them.

Three processes are employed by the nephrons of the kidney in the production of urine :

(1) filtration
(2) reabsorption
(3) selection.

Filtration

This is a simple physical process. Water, salts and other substances are filtered through the membranes from blood plasma holding back formed elements of the blood and large proteins.

Absorption

Each day, the kidneys filter about 180 litres of fluid (about 18 buckets full). If all this fluid were excreted as urine, there would be a serious loss of valuable materials, apart from the need of replacing, by drinking, about 400 pounds of fluid each day. But urine production is not a simple filteration process. As the fluid moves into the nephron, water and solutes are transported out and selectively reabsorbed into the circulation

Selection

Finally the process of selection between the unwanted and wanted substances takes place. The unwanted urea and excess materials pass into the collecting duct where they are then known as urine. A certain amount of water is essential to keep all these unwanted substances dissolved and expelled as urine.

Besides water, glucose, vitamins, proteins, amino acids and various inorganic salts are sent back for the body's use. Thus, the fluid that finally trickles down the ureters has a quite different composition from the initial filterate and the blood from which it was formed. About 1200 ml. of blood (about one-quarter of the total cardiac output) passes through the kidneys every minute. Out of this, only 1 ml/min. flows into the bladder. Drinking large amounts of liquids results in dilution of plasma and the filtration rate is increased. Dehydration, on the other hand, decreases this rate.

At night, during sleep, under the influence of ADH, the reabsorption of water is greatly increased and smaller amounts of more concentrated urine are produced. As a result, the bladder is usually able to cope with a night's urine production allowing the person to sleep undisturbed. Occasionally, the dissolved salts in the urine may solidify to form kidney stones—either small gritty particles or large stones, which require surgical removal.

Regulation : The organs of urinary system are linked in an effective feedback system with the hypothalamus and pituitary gland. The amount of water excreted by the system is controlled mainly by the hormone ADH (anti-diuretic hormone) produced by the hypothalamus and secreted by the posterior pituitary. In the absence of ADH, the urine output can rise to as high as 15 to 18 ml. per minute ; under the influence of the hormone, the urine output may be reduced to 0.35 ml/min. Thus the hypothalamus-pituitary-kidney link maintains a precise balance of the tissue fluids by conserving water for the body and returning the concentration of the fluids to the optimum values.

Urination (Micturition)

Micturition is the act of emptying the bladder or passing the urine. Control over urination is twofold. There is an internal sphincter which is controlled by the autonomic nervous system and has no voluntary control. It is normally in a state of contraction and relaxes when accumulation of urine in the bladder makes voiding necessary. An additional external urethral sphincter permits voluntary control over urination and the voiding reflex can be consciously suppressed. In the very young children, urination is a completely reflex action. Normally in an adult, the presence of about 300 ml. of urine in the bladder will stimulate a desire to urinate, which is primarily a reflex act but the reflex stimulation can be inhibited and urine will continue to accumulate. When the contents reaches a volume of about 700 ml. the average person will have difficulty in controlling the reflex. Emotional stress may prevent the bladder to relax after urination and stimulate an urge to urinate.

Failure of the kidneys can lead to a severe toxic condition called uremia or urine in blood. Toxic wastes build up in the blood and tissues and ultimately poison the body. An artificial kidney utilizing the principle of dialysis can be used to prolong patient's life. Two to three treatments a week are required and each treatment takes five to twelve hours. Home dialysis units are now available.

Besides cleaning and filtering the blood, kidneys encourage production of red blood cells. They regulate the proportion of sodium and potassium salts, water and other substances in the blood. A little too much or a shade too little of any of them can be fatal they control vital water balance. It also keeps blood neither too acidic nor too alkaline.

Thus, kidneys are very discriminating processing plants, carefully regulating our sea of internal fluids. Survival of the whole body relies on the delicate balancing processes of these two organs, no bigger than the size of a clenched fist.

: 11 :

The Reproductive system

Gamete (Sex cell)

The ability to reproduce is one of the essential characteristics of life. In human beings the process is one of sexual reproduction. That is, it involves two sexes, each contributing a **gamete** (mature sex cell) for the formation of the new individual. The female produces an egg-cell or **ovum** which is fertilized by the germ cell (**spermatozon**) produced by the male. The nucleus of every human cell contains 44 **somatic** and 2 sex chromosomes. Each gamete undergoes a special type of cell division called **meiosis**, so that each contains twenty-three chromosomes (22 somatic and one sex chromosome). Thus the zygote resulting trom the fusion of an ovum and a sperm results in a cell with forty-six chromosomes.

The reproductive organs of the male and the female differ anatomically and physiologically, each being adapted to the functional activities they are required to perform. They are stimulated by the gonadotrophic hormones from the anterior pituitary gland.

The function of the **male** system is to form and transmit spermatozoa and implant them in the female so that they can meet the ova. The female system is adapted to form ova which, if fertilized by the sperm, remains in the cavity of the uterus where it is nurtured until it is born.

THE MALE REPRODUCTIVE SYSTEM

The Testes and Their Functions

The testes are small ovoid glands suspended in the scrotum. They are the reproductive glands or gonads of the male. Each testis consists of from 200 to 300 lobules composed of tubules. They provide the spermatogenic cells with nutrition.

The function of the testes is controlled by the hypothalamic-pituitary system. The follicle-stimulating hormone (FSH) stimulates growth of seminiferous tubules.

Two of the important function of the testes are :

(1) **Spermatogenesis** is the process by which primitive male gametes (spermatogonia) become mature sperm. At puberty, spermatogonia begin to divide under the influence of FSH, and will continue to do so throughout life with a decrease in the later years.

The gametes undergo mitotic division to form primary spermatocytes, each containing 44 somatic and 2 sex chromosomes. By a meiotic division it produces a pair of secondary spermatocytes, each containing 22 somatic and one sex chromosome. The sex-chromosomes are called X and Y. They can be distinguished from the others, which are somatic (body) chromosomes. An ovum has two X chromosomes (XX), whereas a sperm has X and X chromosome (XY). The fertilized cell will have either an 'X' or a 'Y' chromosome, but not both, from the sperm. The sex of a child clearly depends on whether it inherits an X or a Y chromosome from its father.

(2) **Secretion of Testosterone.** Very little testosterone (the principal male hormone) is secreted in childhood. At puberty, hormone from the anterior pituitary stimulates its production. Its secretion promotes maturation of the reproductive organs and causes the appearance of secondary sexual characteristics (hair over the chest, pubis and on the face). Its secretion is essential for development of the spermatozoa beyond the primary stage.

Functions of the System

The male system is concerned with spermatogenesis and the introduction of spermatozoa into the female system during sexual intercourse. Erection of the male organ, emission of spermatozoa and other constituents of semen into the urethra and ejaculation of the semen out of the urethra are performed by the male system.

THE FEMALE REPRODUCTIVE SYSTEM

The Ovaries and their Functions

The Ovaries are the female gonads or sex glands.

They are small ovoid structures, lying one on either side of the uterus. Each ovary is suspended from below by an ovarian ligament.

(1) Oogenesis

Oogenesis is the process by which primitive female gametes become mature ova. Very little development takes place between childhood and puberty. During puberty the internal organs reach maturity, become active and menstruation begins. The mature ovary has a cycle of activity which occupies approximately 28 days.

At birth, the ovaries of every girl contain about 2 million primordial follicles, each containing a primary oocyte. During the reproductive years, some 500 of the follicles will mature and expel their ova.

The secretion of follicle stimulating hormone (FSH) by the anterior pituitary gland stimulates primordial follicle, which begins to grow and develop. By the time ovulation occurs, the oocyte undergoes the first phase of meiosis.

2. Ovulation

Luteinizing hormone (LH), also from the anterior pituitary, assists FSH to promote final follicular growth and ovulation. The follicle ruptures expelling the ovum which enters the uterine tube.

If the ovum is fertilised by the male sperm, it implants itself in the uterus. Large amount of oestrogen and progesterone are produced during the early months of pregnancy. If the ovum is not fertilized, production of hormones ceases, menstruation occurs and the next cycle begins.

3. Secretion of Hormones

Ovarian endocrine activity is mainly concerned with the secretion of oestrogen and progesterone. Oestrogen is a collective name for a group of hormones which are of similar structure. It is responsible for the development of secondary sexual characteristics, female reproductive tract and mammary glands.

Progesteron acts in close collaboration with oestrogen and affect tissues which have already been influenced by the latter. Its principal function is to prepare the system for pregnancy.

Uterus and Its Functions

The uterus is a hollow, pear-shaped organ situated in the pelvic cavity. It is held in place by four pairs of supporting ligaments and by the muscles of the pelvic floor. Two uterine tubes open into the cavity.

During the reproductive years each menstrual cycle prepares the uterus to receive the fertilized ovum, and to retain and nourish the developing fetus throuhout the duration of pregnancy. At the end of pregnancy the muscular walls of the uterus contract to expel the fetus.

The uterine tubes (Fallopian tubes) are about 10 cm long. They extend from the uterus to curve round the ovaries. These tubes serve as ducts to convey the ovum from the ovary to the uterus. The ovum is prepelled towards the uterus by peristaltic contractions of the smooth muscles.

Fertitization of an ovum by a sperm usually occurs in one of these tubes, and the fertilized ovum normally continues its journey towards uterus where it implants. Occasionally a tubal pregnancy occurs put rarely proceeds beyond six weeks and is aborted.

Mammary Glands (The Breasts)

The breasts are accessory organs of the female system. They begin to enlarge and develop at puberty due to the influence of the ovarian hormones. During pregnancy there is further growth and development and changes occur in preparation for lactation. After childbirth release of prolactin from the posterior pituitary stimulates the process of lactation while oxytocin (from the same gland) causes the expulsion of milk to the ducts. The secretion of oxytocin is stimulated by the infant sucking at the breast. Regular sucking is necessary to maintain lactation.

Menopause

The child-bearing period usually lasts for about 35 years. After that the processes which occured at puberty are reversed. The changes are caused by the change in the concentration of the sex hormones. The ovaries gradually become less responsive to the FSH and LH. Ovulation and the menstrual cycle become irregular and eventually stop altogether. This is called menopause. Several other phenomena may also occur at the same time including episodes of unpredictable behaviour sometimes.

In the male, fertility and sexual ability tend to decline gradually with ageing. There is no period comparable to the menopause in the male.

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