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HYGIENE

HYGIENE FOR TEACHERS

BY

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WITH PREFATORY NOTE

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THIRD IMPRESSION

LONDON
EDWARD ARNOLD

PREFATORY NOTE

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For scores and probably hundreds of thousands of years man has lived uncivilized as a wild animal, exposed to all the rigours of climate, and slowly evolved, structurally and functionally, to win as an individual in the struggle for existence and perpetuate his stock. In later times there has come about a vast revolution in his condition, brought about, first, by the acquirement of a dominion over fire and fashioning of implements; then by perfection of speech, writing, the printing-press, and the accumulation, sifting, and handing down of knowledge; and, finally, with enormously increased velocity by scientific invention of our age.

Geological evidence shows us that man, who lived twenty or thirty thousand years ago, had no less well-proportioned a body and no smaller a brain than ours. His cave drawings of animals in motion, his carvings and his stone implements, show that he was as cunning of hand as the best artist or artificer of modern days. If we could re-instil the spirit of life into some child of his, found, as the mammoth has been, perfectly preserved in ice, this child clothed and educated as one of us, would take an ordinary part in our world. But what a different world to his!

In place of the free range of forest, hill, seashore, and plain, confinement to an office desk or factory bench. In place of wind, rain, and sun beating upon his skin, and stimulating him to activity or repose, the uniformity of a windless atmosphere, often artificially lit, and the monotony of a sedentary occupation. In the place of fruit or flesh obtained by the hardest muscular effort, and eaten with the appetite bred of such exercise in the open air, and a spare diet, tinned food, white bread robbed of some of the vital principles of the fresh, whole foods of nature, and eaten with an appetite jaded by the long hours of monotonous sedentary occupation in confined places.

The wild man, like the wild animal, gained the perfection of bodily function and well-being at the expense of a maximum insecurity of life. Industrial man has sunk his individuality, lost the perfection of bodily function, and gained the security of a longer and tamer existence.

It is imperative that man should know how to regulate his life in industrial communities, so that his bodily functions may receive that exercise which is demanded by the history of man's evolution.

The happiness of the masses can only be obtained by the recognition of the working of the human body, by placing the foundations of physiological science on a sure footing. Some are unhappy because they do not know how to keep their bodies and minds in health; others because the industrial conditions do not permit them to live in accordance with those functional needs of the body which have been established by ages of evolution.

The spirit of man is not set above his body, so that he can afford to neglect the latter, and, allowing the disorder of bodily functions, yet triumph over all.

Such disorder inevitably leads to unhappiness and lessens efficiency. To mortify the flesh means to restrain the appetite and keep the body in perfect health by spare and clean living.

A man may be inherently weak or defective in some part and yet triumph over these defects, but it is by the discipline and through the perfect working of the vital organs. The spirit cannot overcome the defect of such organs—*e.g.*, defect of brain substance or of some organ essential to metabolism. Thus the idiot results from either the failure of the brain development or that of the thyroid gland.

From birth to the setting of the seal on a man's life, sensations, conscious or unconscious, stream into his nervous system from the world without and from the body within. The external sensations, such as the visual, enable man to project his spirit to the stars, and lead him to the contemplation of the universe.

His character, habits, and happiness, are moulded by his education, the ceaseless beating of myriads of impulses on the living substance of the brain. His consciousness should be filled with the changing play of external sensations, and the attention in perfect health should not be attracted to internal sensations arising from the body.

Modern conditions confine him to the murky atmosphere of a big city, to mean streets and houses—burrows which, in comparison with the immensity of nature, are no nobler and far less clean than the alleys of an ant-hill. Teaching, reading, and example may elevate the spirit above the conditions of modern life, but full happiness can only be secured by the recognition of the daily need of the body for open air, exercise, and exposure to wind and sunlight. These repel sensations of bodily discomfort and stimulate the metabolism, make us breathe deep, flood the lungs with air and blood, give us appetites, impel the blood to circulate faster in its course, and refresh the brain.

Open-air exercise and right feeding enable us to maintain our immunity, to resist the invasion of bacterial disease, and prevent errors of metabolism which result in degeneration of our tissues.

Man knows how to keep a horse in a perfect state of physical fitness, and in institutions children are no less well-disciplined to healthy happy lives. It is by discipline that sailors, soldiers, and policemen are kept in a state of physical fitness. The whole nation requires a disciplined life to secure any general measure of happiness.

The study of hygiene gives us the clue to the required happiness, but before we can understand hygiene we must know something of the structure and function of the body.

Our national life and progress depends on the diffusion of this knowledge, and the noblest function of the teacher is to acquire and instil that which will impel the younger generation to a better life.

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Osborne House,
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August 20, 1912.

AUTHOR'S PREFACE

The State has long realized that the power of the nation depends upon the physical and moral strength of the individuals composing it. Within the last few years the efficiency of the Public Health services has been increased. Medical inspection of schools and school-children has become one of the duties of the State, and all educational authorities have realized the importance of teaching physiology and hygiene in the schools and colleges.

This volume has been written mainly for the use of teachers in the training colleges, and when the student has mastered it, he should have no difficulty in answering any reasonable question on the work required by the Board of Education in the syllabus on hygiene and physical training; and a much more important attainment will be a good knowledge of hygiene and of the physiological principles upon which it is based.

My best thanks are due to Professor Leonard Hill, F.R.S., for guidance and help in the preparation of the manuscript and for the use of illustrations; to Dr. Drummond of Edinburgh and Mr. G. P. Mudge, Lecturer on Zoology at the London Hospital Medical College, for the use of some illustrations in their possession; to Mr. J. Watson Jerdan, who has drawn the illustrations on school con-

struction, planning, and drainage; and to Mr. W. Morris, of the London Hospital Medical College, who has drawn a large number of the illustrations. The correction of the proofs has been done by my friend and colleague, Dr. Martin Flack, to whom many thanks are due.

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September, 1912.

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CHAPTER I

INTRODUCTORY

Structure of an Animal Cell.—There are two methods of examining the structure of plants and animals. The *first* one is to dissect the organism and study its structure by the naked eye; this is called **macroscopic anatomy.** *Secondly*, its minute structure may be studied by magnifying it by means of a combination of lenses called a "microscope." This second mode of structural study is called **microscopic anatomy**, or **histology.** We can carry out a microscopic examination of any object which is sufficiently transparent to allow light reflected from the mirror of the microscope to pass through; thick objects therefore must be cut into very thin sections. To effect this, the living tissues are first killed and hardened by various reagents, such as alcohol.

Any form of tissue that is examined in this way is found to be composed of an aggregation of a number of small units. These to the earlier observers, who were not aided by modern methods of staining, appeared like empty spaces separated by fine strands of tissue; hence animal and vegetable tissues were said to be "cellular."

Though the term animal and vegetable "cell" is still retained, it conveys a different idea to the modern histologist to what it did to his predecessors; it is not an empty space enclosed by a cell wall, but is a structure of complex composition.

An **animal cell** may be defined as a unit mass of animal matter. Most of the simplest animals—*e.g.*, protozoa—

are single cells—egg cells and spermatozoa are single cells; but as the organism ascends in the zoological tree, the number of cells composing it are increased, and concurrently with this there is differentiation of structure in the cells by which they are accommodated to differences in function, and the cells which have the same function are aggregated to form tissues and organs.

When an animal cell is examined by the best histological methods, it is found to be made up of **cell substance,** or **cytoplasm,** which consists partly of the genuinely living substance, or protoplasm, and partly of complex materials not really living. This cytoplasm appears at first sight almost homogeneous, but higher magnification shows great complexity of structure. It is not amorphous, like raw white of egg, but shows a reticular, fibrillar, or vacuolar structure. There are often present obscuring granules of various kinds. It is a question how far the reticular or granular structures are produced by the action of the hardening reagents on the living cytoplasm, for these reagents produce reticular, fibrillar, or granular precipitate when added to white of egg.

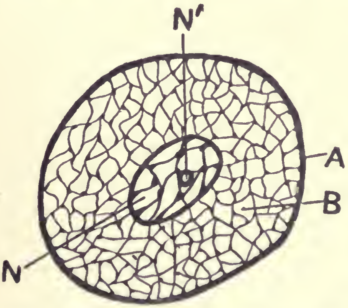

FIG. 1.—DIAGRAM SHOWING THE STRUCTURE OF AN ANIMAL CELL.
A, Cell-wall; *B*, protoplasm (cytoplasm); *N*, nucleus; *N′*, nucleolus.

Situated inside the cytoplasm of all living cells there is a small vesicle called the **nucleus**; it may be spherical, ovoid, elongated, annular, or irregular, in shape. The nucleus is bounded by a membrane which encloses a clear substance (nucleoplasm), and the whole of this substance is generally pervaded by an irregular network of fibres called the "nuclear reticulum." This reticulum undergoes a most remarkable series of changes when a cell divides into two cells.

Place of Man in the Animal Kingdom.—Man is the highest of all forms of animals, and in order to show his relation to the other forms of animal life it is necessary to give a general survey of the animal kingdom, its classification, and the factors on which it is based.

We naturally group together in the mind all things which are like one another, and here lies the beginning of all forms of classification. "The character of classifications will vary according to their purpose, or according to the points of similarity which have been selected as their bases. For instance, animals may be classified according to their diet or habitat, without taking any thought of their structure. A strictly zoological classification must be based on a real resemblance of structure, for it seeks to show the natural relationship of animals, to group together those which resemble one another in structure and nature."

Animals may be divided into two great groups—the **Invertebrates,** or backboneless animals, and the **Vertebrates,** or backboned animals. This distinction between the backboned and backboneless animals was to some extent recognized by Aristotle over two thousand years ago, and was probably more or less obvious to any who accurately studied various forms of animal life. It was not until 1797 that Lamarck definitely drew this line of separation.

The **Invertebrates** are the lower group of animals, and forming it there are a large number of diverse forms of animal life. The lowest members are made up of a single cell, and are called the "protozoa." Other members of this group are the sponges, jellyfishes, sea-anemones, corals, segmented and unsegmented worms, starfishes, insects, spiders, mussels, cockles, oysters, etc. The **vertebrates** include the fishes, amphibians, reptiles, birds, and mammalia.

The **Mammalia** include many different types of animals, such as men and monkeys, horses, cattle, cats, dogs, lions, tigers, mice, hedgehogs, bears, and so on ; but the common possession of certain characters unite them all in one class, readily distinguishable from all other forms of animals. These distinctive characters are " the milk-giving of the mother mammals, the growth of hair on the skin, the general presence of convolutions on the front part of the brain, and the occurrence of the muscular partition, or diaphragm, between the chest and abdomen."

Most mammals are suited for life on land, but some members of this group, such as seals, whales, and sea-cows, have taken to the water, while bats are structurally adapted for aerial life.

In the majority of mammals there is a close connection between the mother and the young during the early period of its development ; on the other hand, birds and reptiles lay eggs, and the young are developed from these when they have no organic connection between them and the mother.

The lowest group of mammalia, called the **Monotremes,** resemble birds and reptiles in bringing forth their young as eggs ; but after the eggs are hatched the young are suckled by the mother. The duckmole and porcupine ant-eaters are examples of this group, and they form an interesting link between the birds and reptiles on the one hand, and the higher mammalia on the other.

In the next group of mammalia the connection between mother and offspring has become closer. The embryo is born alive, but prematurely and after a short gestation. In most cases after birth the young are placed in an external pouch, within which they are sheltered and nourished.

In the highest forms of mammalia, or **Eutherians,** there is a close connection between the unborn embryo and the mother. The young obtains its food and oxygen from the blood of the mother, and this it does by means of a vascular sponge, which is partly maternal and partly embryonic in origin.

The various forms of human subjects are classified by the zoologist under the title of **Hominidæ,** which is the highest group of mammalia. "The great distinction between man and the anthropoid apes is his power of building up ideas and of guiding his conduct by ideals." But there are some structural peculiarities which are of great interest, such as more uniform teeth, forming an uninterrupted horseshoe-shaped series without conspicuous canine teeth, bigger forehead, smaller cheek-bones, a less protrusive face, and a true chin.

The brain of man is two or three times as heavy as that of an ape.

Darwin and others have sought to show that man has arisen from a stock common to him and the anthropoid apes. They have based their theory upon physiological, anatomical, and historical grounds.

The physiology of man is very similar to that of the anthropoid apes, and they are both subject to the same diseases.

Structurally man is very similar to the apes; the only great difference is the much heavier human brain.

The remains of primitive men are few, but most probably man could not have arisen from any of the known anthropoid apes, but he may have arisen from a stock common to them and to him.

Division of Labour.—It has been said above that the simplest animal is made up of a single cell, which has the ordinary structure of an animal cell. It is bounded by a cell wall, which encloses the protoplasm, situated in which there is a single nucleus. That single unit is able to perform all the functions that pertain to life. It will take in food, digest and absorb it, and will eliminate waste matter. It is also able to respond to stimuli, and has slight power of locomotion.

The higher animals are made up of a large number of cells; and if each unit remained in the primitive conditions similar to the unicellular animal, the whole organism would be a soft protoplasmic mass, and all its functions would be performed sluggishly. It is a well known fact that in the animal and vegetable kingdom there is a very great struggle

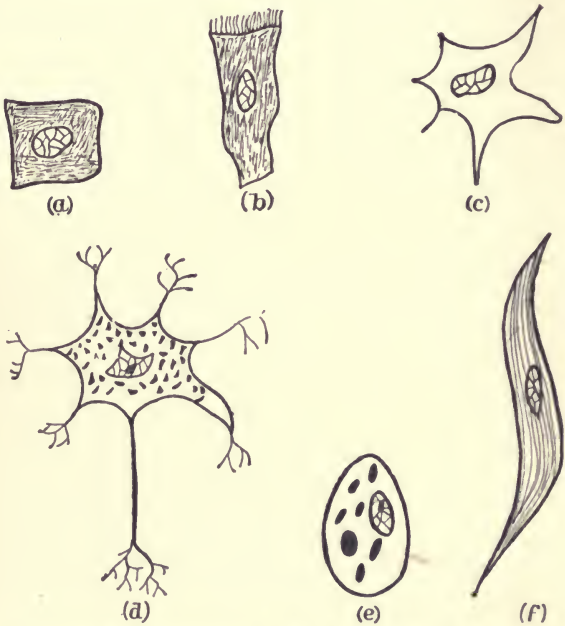

FIG. 2.—DIAGRAM ILLUSTRATING A FEW DIFFERENT FORMS OF CELLS FOUND IN THE HUMAN BODY.

a, Cell from lining of the mouth; *b*, ciliated cell from lining membrane of the trachea or windpipe; *c*, cell found in connective tissue; *d*, nerve cell; *e*, fat cell; *f*, involuntary muscular cell.

for existence. In order to survive, an animal must be able to compete successfully with its fellow-creatures, and this is only possible by its having a ready means of absorption of food and elimination of waste products, power of quick response to change in its environment, rapid means of locomotion, physical force for protection, and a good nervous system to control rightly all the other functions of the body. The only means of attaining this end is to set apart certain cells for certain physiological purposes. Thus, some of the cells of the body are set apart for the purpose of digesting food ; in some of the lower animals these simply form a layer of cells lining the body cavity, but in the higher animals they form the alimentary system, composed of gullet, stomach, liver, intestines, etc. In the lower animals—*e.g.*, protozoa—all the cell absorbs oxygen from the air, and eliminates carbon dioxide ; in the higher animals certain units are set apart for this function, and constitute the respiratory systems.

The protozoa reproduce by simply dividing into two, while in the higher animals certain cells are set apart for this function, constituting the ovaries in the female and the testes in the male.

In order to be able to respond more efficiently to external stimuli, certain cells are set apart which become sense organs, and these are so specialized that they can only respond to one form of stimulus ; thus, the eye can only respond to light stimuli, and the ear to sound, etc. The power of locomotion in a protozoan is very limited, and is effected by protruding its protoplasm in processes ; in the higher animals certain cells are set apart which develop great power of contractility, and become muscular tissue, and by this means they attain a more efficient means of locomotion.

Other examples may be enumerated how, as we ascend the animal tree, there is greater and greater specialization of function, and to attain this there must be adaptation in structure.

This setting aside of different functions to different organs and tissues, and a corresponding adaptation in structure, is called by the biologist **division of labour.**

Structure and Function.—It is readily seen that in the animal and vegetable kingdom there is structural adaptation in any portion of the organism to the kind of work which the organism requires of it. Thus, in the nerve layer of the eye there is a peculiar structure which is a very specialized means to respond to light stimuli. In the ear there are cells of peculiar structure, which are able to respond to sound stimuli, and convert these into impulses, which are carried along the auditory nerve to the brain.

Muscular tissue is made up of cells which have great power of contractility, and these cells have a very peculiar structure.

Bone serves the purpose of supporting and protecting the remaining more delicate tissues of the body ; consequently it is strong and rigid by its being made up of strong fibrous tissue with large deposits of lime salts.

The structure of the mouth is adapted for taking in, masticating, and mixing, the food with the saliva.

The stomach is adapted for the reception of food and its digestion by the gastric juice.

A large number of other instances of adaptation to function may be mentioned ; in fact, all the different parts of the body are structurally highly specialized for adaptation to the physiological functions which they perform.

Work and Rest.—Throughout life we find a large amount of work being done in the world around us, and it is comparatively few persons who realize what are the various factors concerned in this process called " work."

Let us take an example from the steam-engine. There coal is burnt, a large amount of heat is given off, and is mostly utilized to heat water and convert it to steam, which is kept at a high pressure. This high-pressure steam acts on the piston-rod, which causes movement of the axle of the wheels. The engine is thus able to move along and pull heavy weights behind it.

After a long journey large amounts of coal will have been burnt, and converted into carbon dioxide, water, and ashes.

Coal is made of vegetable material which has been subjected to very great pressure for a very long period of time. It is therefore a complex compound of the element carbon combined with hydrogen, oxygen, and inorganic material. The various elements which make up the coal are held together by what the chemist calls "chemical energy."

To the scientist the term "energy" means capacity for doing work. Energy takes various forms; heat, light, sound, mechanical movement, and electricity, are all forms of energy.

It is not within the power of man to destroy energy, but he can convert it from one form to another, and during this conversion he is able to use the energy to do what work he requires to be done. After it has been expended in doing work it is converted into a form of heat, which can no longer be utilized to do work.

In the steam-engine the capacity for doing work is stored up at first in the coal, as chemical energy. When this is burnt, the chemical energy is liberated as heat, which is used to heat the water in the boiler. The water is converted into steam, and on further heating the steam expands, like all bodies under the influence of heat. If the steam is prevented from expanding, it will exert great pressure on the structure which prevents its expansion. This pressure is utilized to move the piston, which in its turn causes movement of the wheels, and thus the engine moves along the rail and pulls the load behind it. The chemical energy of the coal has been converted by means of the engine into mechanical energy.

The human body may be looked upon as a kind of complicated engine, capable of converting chemical energy into various other forms of energy. Chemical energy is supplied to the body in the foodstuffs; these are very complicated organic compounds, and contain a large amount of chemical energy. The foodstuffs are oxidized or burnt (because burning is really a chemical reaction between the substance that is burnt and the oxygen of the air) into simpler substances, and the greater part of the chemical energy is liberated. This energy is used for various purposes—production of heat, mechanical movement, and all other activities of the body.

In the case of the steam-engine the best possible amount of work can only be obtained by having the best coal and the engine in the best condition.

Similarly for the human subject, work can only be done at its best when the body is in the best of health and has the best foodstuffs supplied to it.

It is very obvious that in our schools, in order to obtain the greatest amount of mental work, the health of the children must be in good condition, and they must be supplied with proper nourishment.

It is useless, therefore, for the teacher to try and instil knowledge into children that are physically unfit and are not supplied with proper nutrition. All forms of work involve a certain amount of wear and tear in the mechanism which acts as the converter of energy. The steam-engine has occasionally to be sent to the workshop for repairs. Similarly in the human body, all its activities involve a certain amount of wear and tear of the tissues, and these are repaired during periods of rest.

It is seen, therefore, how important rest is for continual good work. If it is insufficient, the repair does not keep pace with the wear and tear ; this will result in derangement of the tissues of the body, the amount and character of the work will be of a lower standard, and the resistance of the body to disease will be diminished.

Adequate rest for school-children is far more important than for adults, because they have to grow as well as work.

Development of the Child.—The young in mammalia during the first stage of its growth lies within the mother, and obtains its nourishment from her. The organic connection between mother and child is broken at birth, and even then the young is in rather a helpless condition, and only able to develop to maturity through the care of the mother.

The time that elapses between birth and maturity varies for different animals, and is longest in the case of the human subject, because it is the highest of all forms of living beings, and therefore requires greater time and care to develop. The success of the mammalia is attributed to the maternal sacrifice involved in the placental union between the mother and offspring, in the prolonged gestation, in the nourishment of the young on milk, and in the frequently brave defence of the young against attack.

The mother naturally provides the best form of foodstuff for its young, and it should be emphasized that the proper nourishment for the child is its mother's milk. If a mother, because of poverty, illness, or her own selfish interest, is unable to suckle her child, her offspring is likely to suffer, because artificial feeding can never be looked upon as a proper substitute for the mother's milk.

All the tissues and organs of the child at birth are anatomically and functionally undeveloped, and when we compare the anatomy and physiology of the child at birth with that of the adult, we find there is a great difference.

In the child the skeleton is small, soft, and weak; the muscular system is undeveloped and incapable of co-ordinate contraction, so that walking and other complex co-ordinate movements are impossible; the alimentary canal is only able to digest and absorb its natural form of foodstuff — namely, milk; the nervous system is undeveloped and incapable of generating impulses in proper sequence, and it cannot understand or appreciate the various stimuli that reach it by afferent paths. The respiratory and circulatory systems are undeveloped, and only able to supply the needs of the body at this stage of its growth.

The heat regulatory mechanism is very inefficient, and a child will therefore easily become too warm or too cold, unless very great care is taken to have it properly clothed.

Maturity is attained only by a very slow process of growth; and in a growing child not only has life to be maintained, but provision must be made for the development of the mind and body. A great characteristic of life is its power to respond to stimuli from its surroundings, and biologists tell us that environment has a great influence upon the development of all forms of life. This is even of greater importance in the case of the human race, because that part of the body—namely, the nervous system—that is specialized for the reception of outside stimuli is more highly developed.

The physical and moral surroundings of the child must be such as to aim at its highest mental, moral, and physical development.

The child should be allowed an ample supply of fresh air; it should not be kept in closed heated rooms, but should spend the greater part of its life in the open air.

Unsanitary conditions have a deteriorating effect upon persons of all ages, and is certainly most marked in the case of children, who should therefore be placed in the best possible hygienic conditions.

It is obvious that proper food is of the greatest importance to children; otherwise their growth and development are sure to suffer. This question will be discussed in Chapters III. and V.

The great ideal of most educationists is for all children to have a healthy mind in a healthy body, and proper physical and mental training are the only means of attaining such a condition.

Physical training will be discussed in Chapter II., and the nutrition and training of the nervous system in Chapter VI.

Characteristics of Children in Health.—The common characteristics of children in health are well known, and need only a very short description. They show great activity of mind and body; when at play they put their whole energy into their games, and when at work they are able to devote attention and concentration to their lessons. The memory is good in children, and the educational attainments of a child should be such as would be expected at that particular age. They are well nourished; their weight and height should correspond fairly closely to what it should be at their age. The following are the measurements given by the Anthropometrical Committee of the British Association:

Age.	Boys.		Girls.	
	Weight in Pounds.	Height in Inches.	Weight in Pounds.	Height in Inches.
5	39·9	41·00	39·2	40·55
6	44·4	44·00	41·7	42·88
7	49·7	45·97	47·5	44·45
8	54·9	47·05	52·1	46·60
9	60·4	49·70	55·5	48·73
10	67·5	51·84	62·0	51·05
11	72·0	53·50	68·1	53·10
12	76·7	54·99	76·4	55·66
13	82·6	56·91	87·2	57·77
14	92·0	59·33	96·7	59·80
15	102·7	62·24	106·3	60·93
16	119·0	64·31	113·1	61·75

The skin is clear and elastic, and has a good supply of subcutaneous fat. The size of the head proportionally to the body is larger than in the adult. The chest should be broad from side to side and show no deformity. The senses are very acute, and the time that elapses between the stimulation of a sense organ and the response is very short. The muscles have good tone and feel firm. In childhood the nervous system is characterized by its comparative instability; it has not yet settled down to the stable form characteristic of mature life. The higher centres are as yet imperfectly developed, and do not exercise such a good control over the lower centres; hence abnormal forms of nervous actions are common even in healthy children.

CHAPTER II

THE SKELETON AND MUSCULAR SYSTEM

I. The Skeleton

By the term "skeleton" is meant the parts of the body which remain after the softer structures have been disintegrated or removed, and includes not only the bones, but also the cartilages and ligaments which bind them together. In the restricted sense of the word, the skeleton denotes the bony framework of the body, and it is in this sense that it is generally used in human anatomy.

The skeleton supports the softer structures grouped around it, and also protects the many delicate organs lodged within its cavities. The connection of its various parts by joints converts its segments into levers, which constitute a means of locomotion and movement.

Bone may be regarded as white connective-tissue fibres which have become calcified tissue.

There are two methods of study applicable to bones, just the same as to all tissues of the body. The first method is by the naked eye, or macroscopically, and the second by means of the microscope, and it is by this method that we ascertain its minute or histological structure.

The naked-eye appearance of bones is known to everyone, and they have been classified by anatomists into four classes (according to their shape)—long, short, flat, and irregular.

Long Bones.—A long bone consists of a shaft and two extremities. The shaft is a hollow cylinder; the walls consist of dense, compact tissue, and the cavity in the

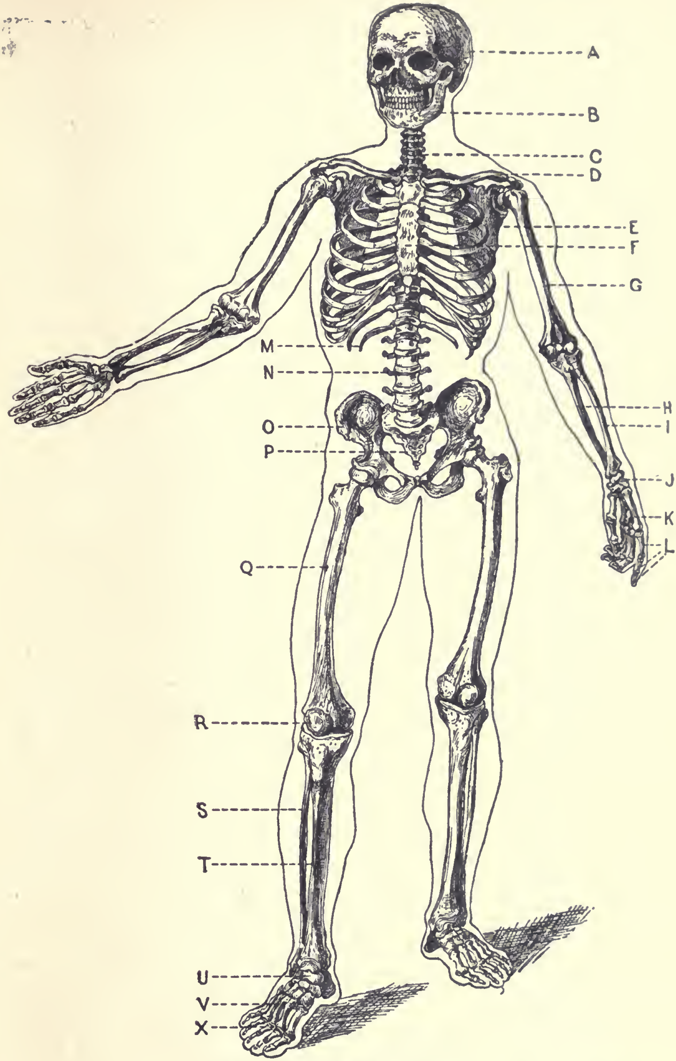

Fig. 3.—The Skeleton.

A, Skull ; *B*, lower jaw ; *C*, cervical vertebræ ; *D*, clavicle ; *E*, scapula ; *F*, sternum ; *G*, humerus ; *H*, ulna ; *I*, radius ; *J*, wrist or carpal bones ; *K*, metacarpal bones ; *L*, finger-bones ; *M*, floating ribs ; *N*, lumbar vertebræ ; *O*, hip-bone ; *P*, sacrum ; *Q*, femur ; *R*, patella ; *S*, fibula ; *T*, tibia ; *U*, tarsal or feet bones ; *V*, metatarsal bones ; *X*, toe-bones.

centre is called the "medullary canal." The extremities are generally somewhat expanded, for purposes of articulation, and afford a broad surface for muscular attachments.

The shaft is covered by a fibrous membrane—the periosteum. This contains bloodvessels which run by minute passages into the substance of the bone. The extremities, as they enter into articulation with other bones, are covered with a cap of smooth or hyaline cartilage.

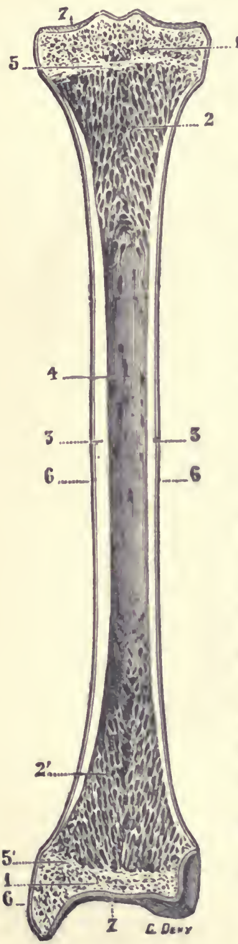

FIG. 4.—SHIN-BONE (TIBIA) SAWN IN TWO ALONG ITS LENGTH.

2, Struts and stays of spongy bone supporting 7, the upper and lower articular surfaces; 3, compact bone forming the shaft; 4, marrow cavity; 6, periosteum.

The interior of the long bones is hollow, in order that strength may be combined with lightness. The medullary canal is filled with spongy bone, fat, and cells, which cause the formation of the cells of the blood, all the contents being termed the "bone-marrow."

The marrow is well supplied with blood, and the vessels within the medullary canal communicate with those of the periosteum. The long bones are found in the limbs, and act as a system of levers, sustaining the weight of the body and conferring locomotion.

The bones belonging to the class of long bones are — Clavicle, or collar-bone; humerus, or arm-bone; radius and ulna—the bones of the forearm; femur, or thigh-bone; tibia and fibula, the bones of the leg; etc.

Short Bones.—Where a part of the skeleton is intended to be strong and compact, and is to be allowed a very small degree of movement, it is divided into a number of small pieces united together by ligaments. The separate bones

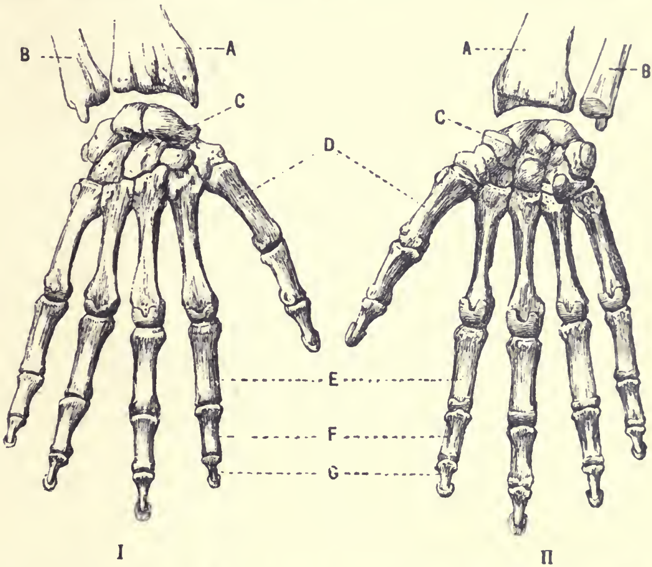

FIG. 5.—DIAGRAM OF SKELETON OF THE HAND AND FINGERS, SHOWING THE CHARACTERS OF SHORT BONES.

A, Lower end of radius; *B*, lower end of ulna; *C*, wrist or carpal bones; *D*, metacarpal bones; *E*, *F*, *G*, phalanges or finger bones (short bones).

are short and compressed, such as the carpal bones of the hand or the tarsal bones of the foot.

On section, the short bones are seen to be made of spongy bone, surrounded externally by a thin layer of compact bone.

Flat Bones.—Where a part of the skeleton is to provide either extensive protection or broad surfaces for muscular attachment, the bony structure is expanded into broad, flat plates, as in the bones of the skull and the shoulder-blade. These bones are composed of two thin layers of compact tissue enclosing between them a variable quantity of spongy bone.

The flat bones are—The occipital, parietal, frontal, nasal, lachrymal, vomer, scapula, os innominatum, and ribs.

Irregular or Mixed Bones are such as, from their peculiar form, cannot be classified in any of the preceding groups. They consist of a layer of compact tissue externally, and of cancellous tissue within.

FIG. 6.—PARIETAL BONE—AN EXAMPLE OF A FLAT BONE.

The irregular bones are — The vertebræ, sacrum, coccyx, temporal, sphenoid, ethmoid, malar, superior maxillary, inferior maxillary, and palate.

The **Microscopical Structure of Bone** can be studied by taking a piece of bone and placing it in dilute hydrochloric acid, which will dissolve its inorganic constituents, and then cutting the organic framework into very thin sections and staining them with various dyes, in order that their constituent cells should stand out more clearly.

A bone after it has been softened as described above can be readily torn into shreds by means of a pair of forceps. This is because bone is made up of white fibrous tissue impregnated with lime salts, which are most probably formed by the cells which remain in certain spaces called "lacunæ."

When a section of compact bone is examined, a number of small canals, called "Haversian canals," will be seen, and around each canal concentric layers, or lamellæ, of bone are placed. In between the lamellæ small spaces containing soft protoplasmic cells will be seen. The processes of the cells are contained in ramified passages which join contiguous cells. The cells are called the "bone corpuscles," the spaces in which they lie the "lacunæ," and the ramified passages in which the cell processes course are called the "canaliculi."

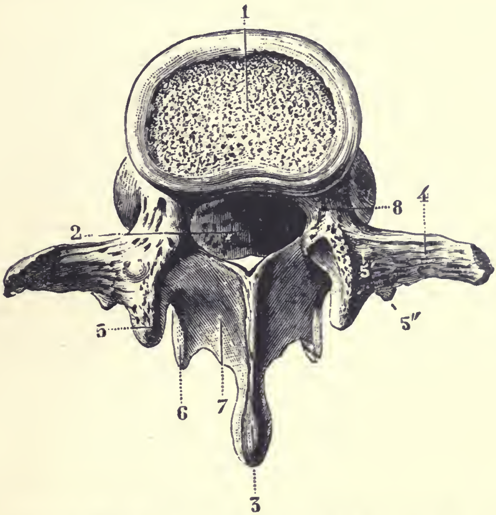

FIG. 7.—LUMBAR VERTEBRA—AN EXAMPLE OF AN IRREGULAR BONE.

The Haversian canals contain bloodvessels and marrow, and the nourishment of the bone is derived from these vessels. The canaliculi communicate with neighbouring cells and with the Haversian canals.

In spongy bone the regular Haversian systems are replaced by spicules of bone enclosing large irregular spaces filled with marrow. The lamellæ in the spicules contain lacunæ and canaliculi. Passing right through the lamellæ are certain fibres, called the "decussating fibres of Sharpey."

Ligaments or tendons when attached to any bone are joined to these fibres; the union thus becomes very strong.

A section of hard bone can be obtained with a fine saw, and the section is rubbed down to the required thickness on an oilstone, and then examined with the microscope. The Haversian canals would then be seen as holes, surrounded by lamellæ of bone, and the lacunæ and canaliculi, because they are filled with dust and air, appear as black dots and lines. The marrow and bone cells will have been destroyed by the process.

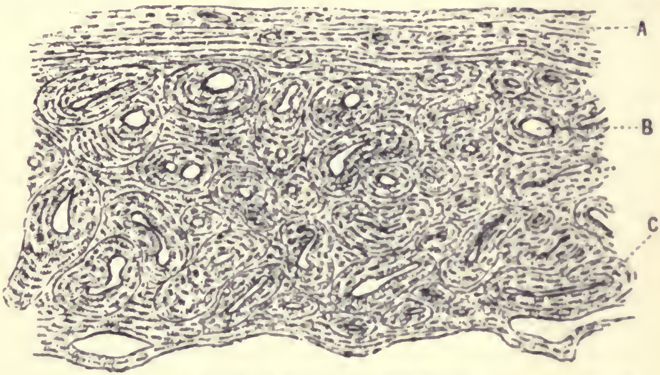

FIG. 8.—DIAGRAM SHOWING THE MICROSCOPIC STRUCTURE OF COMPACT BONE.

A, Outside layers; *B*, Haversian canal; *C*, lacunæ containing branching bone cell.

The **Chemical Composition of Bone** can be ascertained by igniting it in a covered porcelain dish in a blow-flame. The organic matter at first becomes charred, and finally disappears as carbon dioxide and water, and there remains a brittle white residue composed entirely of earthy salts, which by chemical test are found to be chiefly phosphates and carbonates of lime. The difference between the weight of the bone placed in the porcelain dish and the weight of the residue represents the weight of the organic matter.

The chemical composition of bone is found to be as follows:

Animal matter	33 per cent.
Calcium phosphate	57 ,,
Calcium carbonate	7 ,,
Other salts	3 ,,
	100

Development and Growth of Bone.—During the early stages of development the fertilized ovum divides into a large number of cells, and these cells become arranged into three layers—an outer layer, or *epiblast*, from which the skin and the nervous system is developed; an innermost layer, or *hypoblast*, from which the lining mucous membrane of the alimentary canal is formed; and a middle layer, or *mesoblast*, from which the bony and muscular constituents of the body are developed. Hence early in fœtal life a layer of cells is set apart to develop into the skeletal, supporting, and muscular tissue of the embryo.

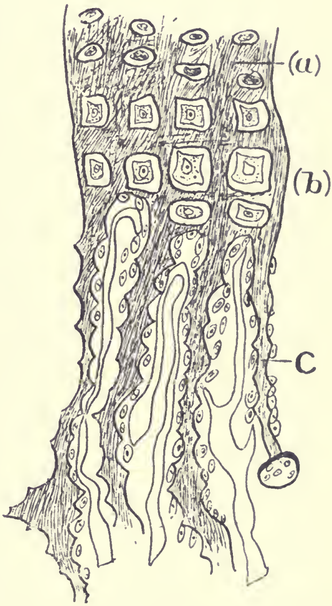

FIG. 9.—DIAGRAM SHOWING THE FORMATION OF BONE FROM CARTILAGE.

a, Cartilage cells arranged in rows; *b*, enlarged cartilage cells close to line of formation of bone; *c*, bone covered with bone-forming and bone-destroying cells.

The bony stage of the skeleton is preceded by either a membranous or cartilaginous stage. The flat bones are developed in membrane, and the long bones in cartilage.

In the *intramembranous form of osteogenesis, or bone* *formation*, bony spicules containing lime salts, together with bone corpuscles and cells, are formed within a proliferation tissue consisting partly of cells and partly of a more or less perfectly developed homogeneous ground substance.

The *intracartilaginous form of ossification* takes place in long bones, and in this process various definite stages may be identified. The cartilage cells at first become enlarged and arranged in rows; the matrix between the cartilage cells becomes calcified by the deposition of a large amount of calcium salts; the rows of cells become joined together, and into the spaces so formed extend the bloodvessels derived from the vascular layer of the fibrous membrane covering the outer surface of bone. Bone-forming and bone-destroying cells accompany these vessels, the former building up true bone at the expense of the calcified cartilage, the latter causing an absorption of newly-formed bone, and results in its conversion into a marrow cavity, and thus all the cartilage is replaced by true bone.

The Skull.

In order to understand the structure of the skull, it is advisable for you to have a skull before you, or, if that is not possible, a careful study of the figure of the skull should be made.

Some of the bones of the skull form the cranium, or brain-box, and others are the bones of the face. The cranium is made up of a **base,** upon which the brain lies, and a **vault,** which covers the sides and upper surface of the brain.

The bones of the **cranial vault** are the frontal, parietal, occipital, and temporal bones.

The anterior part of the cranial vault is formed by the frontal bone; this was originally made of two halves, which have joined by a bony suture.

The middle part of the cranial vault is formed by the two parietal bones, which are joined above in the middle line by a serrated suture.

The posterior part of the vault of the cranium is formed by the occipital bone, which is joined anteriorly to both parietal bones.

The lateral wall of the cranium is formed from before backwards by the frontal, temporal, and occipital bones.

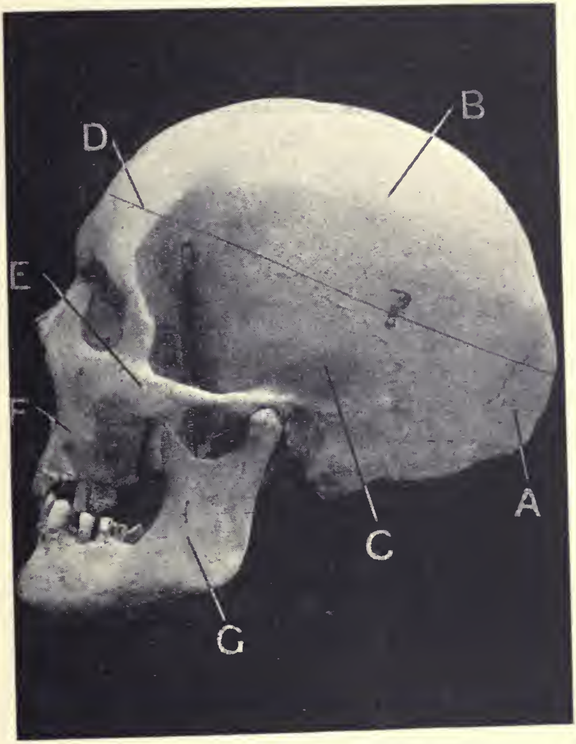

FIG. 10.—LATERAL VIEW OF THE HUMAN SKULL.

A, Occipital bone; *B*, parietal bone; *C*, temporal bone; *D*, frontal bone; *E*, malar or cheek bone; *F*, superior maxilla, or upper jaw-bone; *G*, inferior maxilla, or lower jaw-bone.

The **base** of the skull, when examined from the inner or cerebral surface, will present three cavities, or fossæ, which lodge different parts of the brain.

The **anterior fossa** is formed by the frontal bone and the anterior part of the sphenoid bone.

The **middle fossa** is made up of a narrow middle portion, with two wide lateral portions. It is formed by the sphenoid bone and the two temporal bones.

The **posterior fossa** is formed by the occipital bone and the posterior portions of the temporal bones. The floor of

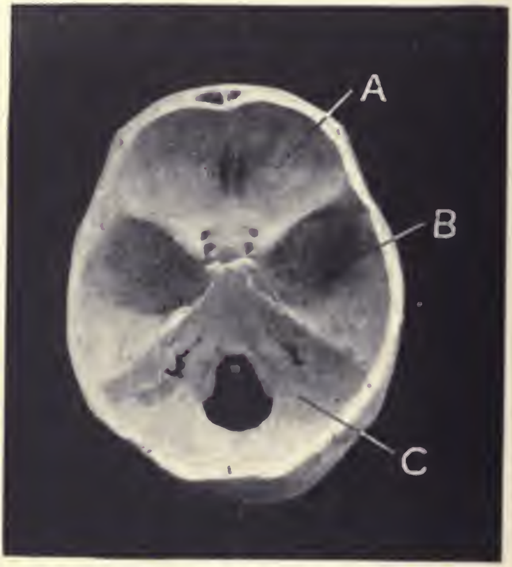

FIG. 11.—INNER SURFACE OF THE BASE OF SKULL.
A, Anterior fossa; *B*, middle fossa; *C*, posterior fossa.

the posterior fossa is perforated by an opening called the "foramen magnum," through which the brain becomes continuous with the spinal cord.

When the base of the skull is examined, a large number of small openings will be seen perforating it; these are called "foramina," and are for the passage of nerves and bloodvessels to and from the cranial cavity.

The facial part of the skull contains the following bones :

The **upper jaw** bones, right and left. Above they form the floor of the orbit (eye socket) ; behind they articulate with the cheek or malar bone. In front and below they join together to form the upper jaw and the bony palate ;

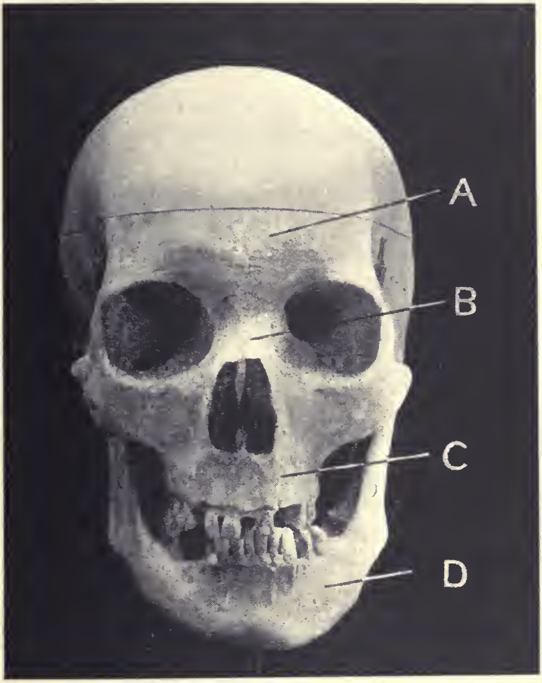

FIG. 12.—FACIAL ASPECT OF THE SKULL.

A, Frontal bone ; *B*, nasal bone ; *C*, superior maxilla, or upper jaw-bone ; *D*, lower jaw-bone, or inferior maxilla.

above and in front they are separated by the cavity of the nose.

The **lower jaw**, a single bone, is made up of a horizontal portion and two perpendicular portions ; the latter articulate with the temporal bone of each side.

The **nasal** bones—two small bones forming the roof of the anterior part of the nasal cavities.

The **lachrymal** bones are two small flat bones, one of which lies on the inner side of each orbit.

The **cheek** bones bound the orbits below and to the outer side.

The cavity of the nose should be carefully examined. A bony septum, formed by the **vomer** bone, divides it into two halves. The **ethmoid** bone separates the nose from the cranial cavity ; the lateral wall is formed by the upper jaw-bone, and projecting from this the scroll-like turbinate bones will be seen.

The skull is of great strength, in order that it may protect the brain, eye, and ear, from external violence, and at the same time it affords attachment for the powerful muscles of mastication.

The Backbone, or Vertebral Column.

The backbone is made up of a number of separate bones, called " vertebræ " (from *vertere*, to turn). The vertebræ are originally thirty-three or thirty-four in number, but during the growth of a child five of the lower ones fuse together to form a broad curved bone, called the *sacrum*, while the four lowest form a rudimentary tail, called the *coccyx*.

The vertebræ are named according to the position they occupy, and from above downwards they are called " cervical " (seven in number), " dorsal " (twelve in number), " lumbar " (five in number), " sacral " (five in number, and fused together to form the sacrum), " coccygeal " (four in number).

Structure of a Vertebra.—A short account will be given of the general structure of the vertebræ, and it may be noted that there are certain differences between vertebræ from different regions ; but it is not within the scope of this book to give any account of them.

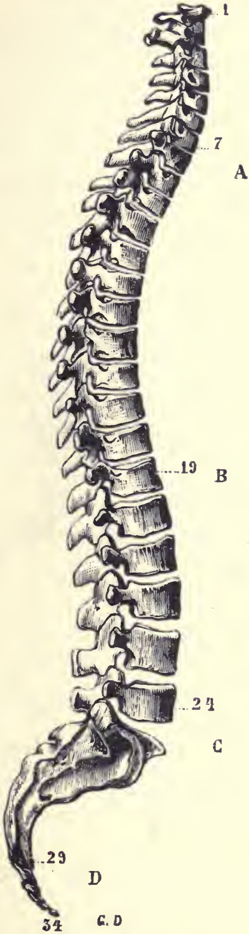

FIG. 13.—THE SPINAL COLUMN.

1-7, Cervical (7) ; 7-19, thoracic (12) ; 19-24, lumbar vertebræ (5) ; 24-29, sacrum (=5) ; 29-34, coccyx (=5). Notice the bends, or flexures, of the column.

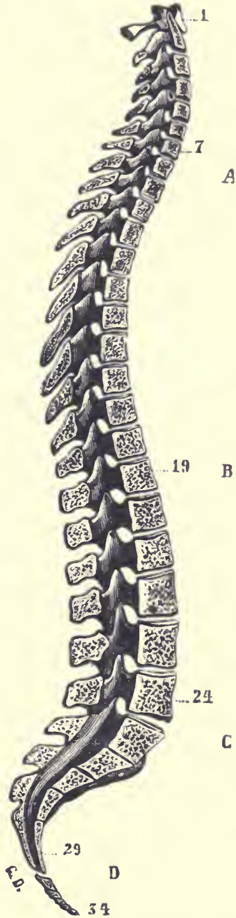

FIG. 14. — DIAGRAM SHOWING STRUCTURE OF VERTEBRAL COLUMN AFTER LONGITUDINAL BISECTION.

Note the spinal canal, which lodges the spinal cord, and the lateral openings, called "foramina," through which the spinal nerves pass out from the canal.

Each vertebra consists of a disc-like mass of bone, called the "body." Behind this is the vertebral arch, connected with the body by two pillars. From the back of the arch there projects backwards the spinous process, and from each side projects outwards a transverse process. The bodies of the vertebræ are united together by tough pads of fibro-cartilage, which are called *intervertebral discs.*

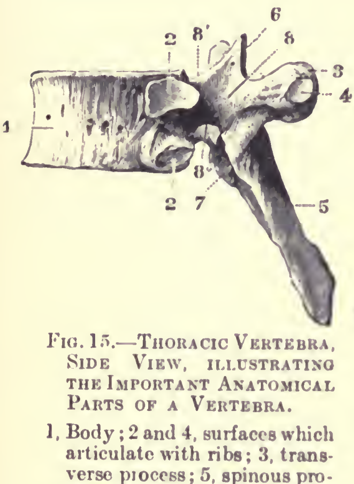

Fig. 15.—Thoracic Vertebra, Side View, illustrating the Important Anatomical Parts of a Vertebra.

1, Body; 2 and 4, surfaces which articulate with ribs; 3, transverse process; 5, spinous process; 6 and 7, surfaces which articulate with the next vertebræ above and below.

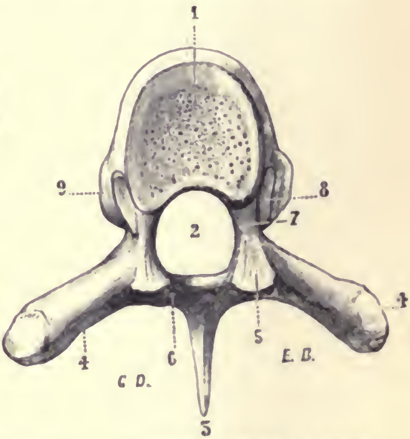

Fig. 16.—Thoracic Vertebra: View of Upper Surface.

1, Body; 2, vertebral canal; 3, spinous process; 4, transverse process; 5, surface articulating with vertebra above.

The arches of contiguous vertebræ articulate by definite joints.

By the joining together of the vertebræ there is formed a strong flexible column. The arches form a canal in which the spinal cord lies.

The Atlas and Axis.—These are the two upper cervical vertebræ, modified in structure so as to allow articulation with the skull.

The **atlas** is ring-shaped; it has no body, and on the upper surface of each half of its arch there are two oval depressed surfaces for articulation with the condyles of the skull.

The **axis**, or second cervical vertebra, has a pivot-like process projecting from its upper surface, and this articulates with the atlas, and it is by this joint that rotatory movements of the skull take place.

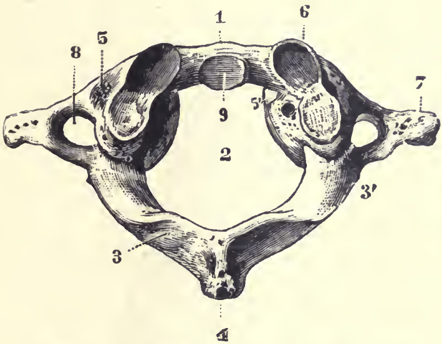

FIG. 17.—DIAGRAM SHOWING THE STRUCTURE OF THE ATLAS, OR FIRST CERVICAL VERTEBRA.

1, Anterior arch; 2, vertebral canal; 3, posterior arch; 4, spinous process; 6, surfaces articulating with condyles of the skull; 7, transverse process; 9, surface articulating with special process of axis.

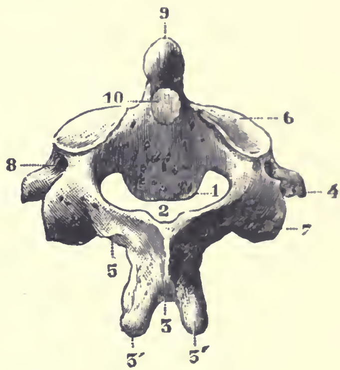

FIG. 18.—THE AXIS, OR SECOND CERVICAL VERTEBRA: VIEW OF UPPER SURFACE.

1, Body; 2, vertebral canal; 3, spinous process; 4, transverse process; 5, posterior arch; 6, surfaces articulating with atlas; 9, odontoid process.

The **sacral vertebræ** all fuse together to form the sacrum, which is wedged in between the two hip-bones.

The **coccyx** is the rudiment of a tail.

The **ribs** number twelve on each side. They articulate behind with the bodies and transverse processes of the dorsal vertebræ, and then sweep forward to meet the sternum, or breast-bone, in front. The upper seven are joined to the sternum by means of cartilages, called "costal cartilages." The cartilages of the next three ribs are connected indirectly to the sternum; they are first joined to one another, and then to the seventh rib. The last two are called "floating ribs," because they do not reach the sternum at all.

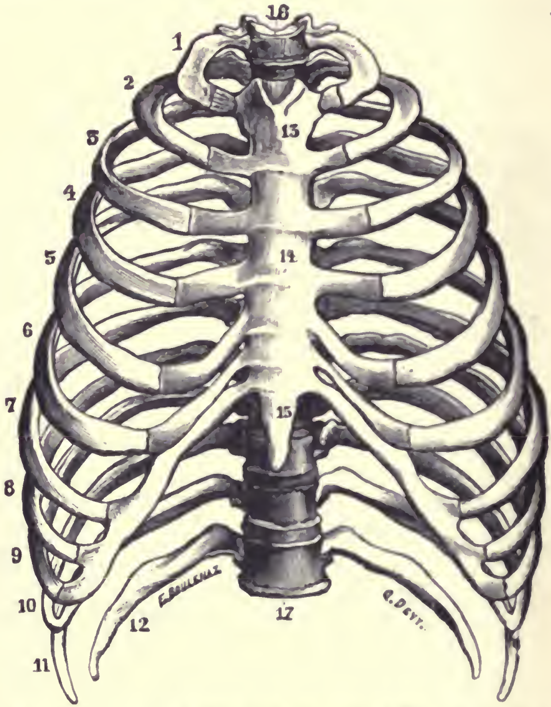

FIG. 19.—BONY FRAMEWORK OF THE CHEST, OR THORAX.
1-12, Ribs; 13-15, sternum; 16-17, the thoracic part of vertebral column (twelve vertebræ).

The **sternum,** or **breast-bone,** lies in the front of the chest. The dorsal vertebræ, sternum, and ribs, form the skeleton of the **thorax,** which contains the heart and lungs.

The bones of the upper limbs are—

1. The **clavicle**, or **collar-bone**, extends from the shoulder-blade to the upper part of the sternum. Feel it in your own body.

2. The **scapula**, or **shoulder-blade**, can be felt at the back of the upper

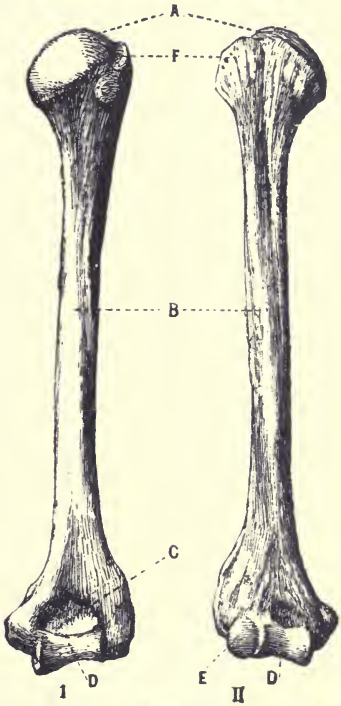

FIG. 20.—POSTERIOR (I.) AND ANTERIOR (II.) VIEW OF HUMERUS, OR UPPER-ARM BONE.

A, Head of the bone, articulating with the scapula, or shoulder-blade; *B*, shaft; *C*, cavity which receives the olecranon process, or upper part of the ulna; *D*, surface which articulates with ulna; *E*, surface articulating with radius; *F*, rough processes to which muscles are attached.

part of the chest. It is flat and triangular in shape, with a definite ridge running across it.

3. The **humerus**, or **arm-bone**, articulates above with the scapula, and below with the bones of the forearm. The head can be felt inside the axilla when the arm is moved. Its lower end is flattened from

FIG. 21.—ANTERIOR (I.) AND POSTERIOR (II.) VIEW OF RADIUS (*D*) AND ULNA (*E*).

A and *B*, Surfaces which articulate with humerus; *C*, olecranon process of ulna; *F*, surfaces which articulate with carpal bones of wrist.

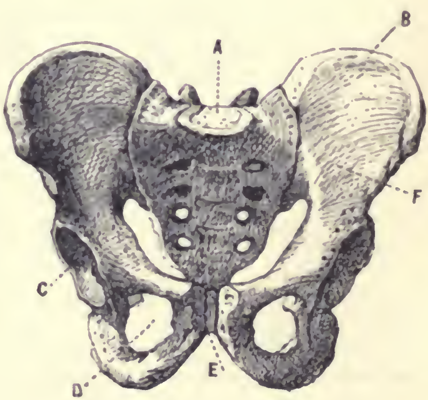

FIG. 22.—THE PELVIS.

A, The sacrum; *B*, crest of the hip-bone; *C*, the cavity (acetabulum) which receives the head of the femur; *D*, hole which lightens the weight of the bone; *E*, metal plate uniting the pubes (this is fibrous cartilage in life); *F*, right hip-bone.

before backwards, and on each side are projecting processes to which important muscles are attached.

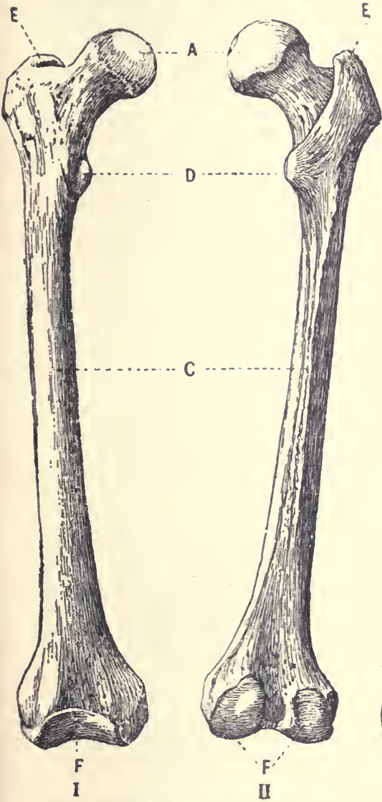

FIG. 23.—FRONT (I.) AND HIND (II.) VIEW OF FEMUR.

A, Head of the bone which articulates with the hip-bone; *C*, shaft; *D* and *E*, rough processes to which muscles are attached; *F*, surface which articulates with tibia.

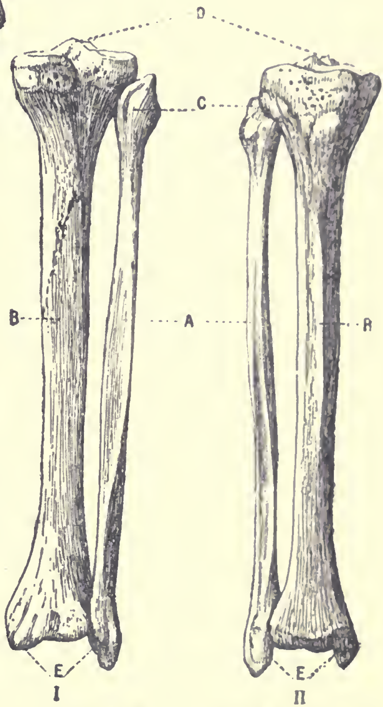

FIG. 24.—HIND (I.) AND FRONT (II.) VIEW OF TIBIA (*B*) AND FIBULA (*A*).

C, Head of the fibula articulating with tibia; *D*, surface articulating with lower end of femur; *E*, surfaces which articulate with astragalus.

4. The **radius** and **ulna** are the two bones of the forearm—the radius on the outer or thumb side, and the ulna on the inner side.

5. The **carpal** or **wrist bones** are eight in number; joined together by joints and strong ligaments.

6. The **metacarpal bones** lie in the palm, one for each thumb and finger.

7. The **phalanges** are fourteen in number, two to each thumb and three for each finger.

Fig. 5 shows the relationships of the bones of the hands.

The bones of the lower extremity are—

1. The **hip** or **innominate bone** has a very peculiar shape. It articulates with the sacrum behind, and with its fellow of the opposite side in front. The sacrum and both hip-bones form the pelvis, on each side of which there is a depression for the head of the thigh-bone to articulate.

2. The **femur**, or **thigh-bone**, is the longest bone in the body. It

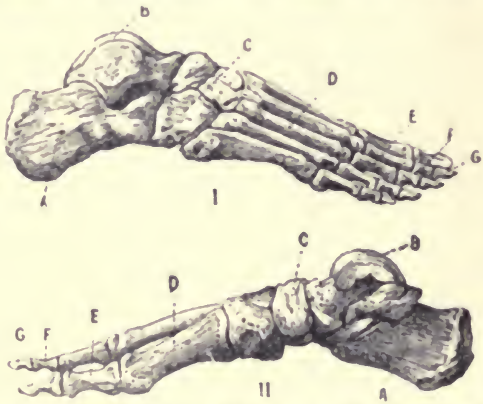

FIG. 25.—OUTER (I.) AND INNER (II.) VIEW OF FEET-BONES.

A, Heel-bone; *B*, surface on astragalus which articulates with leg-bones; *C*, tarsal bones; *D*, metatarsal bones; *E*, *F*, *G*, first, second, and third toe-bones, or phalanges.

articulates above with the hip-bone, and below with the upper surface of the tibia, or inner leg-bone.

3. The **tibia** and **fibula** are the bones of the leg—the tibia on the inner and the fibula on the outer side.

4. The **knee-cap**, or **patella**, is a small flat bone felt in front of the knee.

5. The **tarsal bones** are seven in number; the ankle-joint is formed by the articulation of one of these bones—namely, the astragalus—and the lower ends of the tibia and fibula.

6. The **metatarsal bones** and the **phalanges** correspond to similar bones of the hand.

Joints and Ligaments.

A **joint** is a mode of union between any two separate segments or parts of the skeleton. Joints are divided into two great groups—namely, the perfect, or movable; and the imperfect, or practically immovable.

Perfect joints, like the hip, shoulder, and knee, allow great freedom of movement; while **imperfect joints,** like the sutures of the skull or those between the vertebræ, allow very little movement. Entering into the structure of a joint, we generally find portions of two bones, which are covered by smooth hyaline cartilage. Each joint is enclosed in a bag made of white fibrous tissue, called the "capsule." Supporting the capsules there are generally some special bands of white fibrous tissue, called "ligaments," which tend to check excessive movement. The two bony surfaces are held in apposition by the tonic action of the muscles surrounding the joint. Even in the most movable joints there are certain limitations to its movements, brought about by the stretching of ligaments, interlocking of bony prominences, and the contact of surrounding muscles.

All the structures inside a perfect joint which are not lined by cartilage are covered by a smooth, glistening membrane, called the **synovial membrane.** This secretes a fluid called the "synovial fluid," which acts as a lubricant to the joint.

In the imperfect joints the bones are united by cartilage, and being bound together firmly by ligaments, only a very small degree of movement is allowed.

The imperfect joints are divided into two great classes: those which allow of no movement—*e.g.*, sutures of the skull-bones—and those which allow a small degree of movement—*e.g.*, pubic symphysis, joints between the bodies of the vertebræ.

The perfect or movable joints are of various kinds.

Ball-and-socket Joints allow movements to take place in all directions; such joints exist at the hip and shoulder.

Gliding Joints have nearly flat surfaces, and admit of only a limited amount of gliding movement, as in the articulation of the hand-bones, foot-bones, and the articular processes of the vertebræ.

Hinge Joints.—This form of joint allows movement only in one plane. The elbow-joint is the best example of a

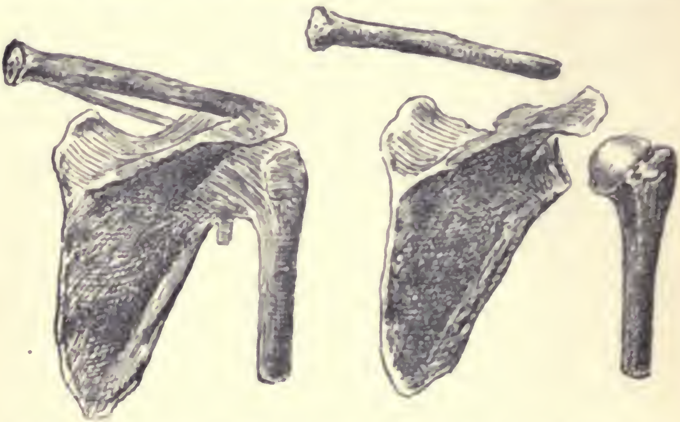

FIG. 26.—SHOULDER-JOINT, COLLAR-BONE, SHOULDER-BLADE, AND UPPER END OF HUMERUS, SHOWN SEPARATE AND BOUND TOGETHER BY LIGAMENTS.

hinge joint; the only movements allowed are those of flexion and extension.

The wrist, knee, and ankle, are also hinge joints, but they allow a slight amount of lateral movement as well.

Pivot Joints.—This type allows of only one form of movement—namely, rotation. A good example of this is the joint between the atlas and axis.

Condyloid Joints.—These allow all varieties of angular movement and circumduction, as in the metacarpo-phalangeal joints of the thumb.

Joints of the Skull.—The only movable joint in the skull is that between the lower jaw and temporal bone. It is covered by rather a loose capsule, and allows all movements concerned with mastication.

The Joints of the Trunk.—The vertebræ are joined together by intervertebral discs, and their articular processes by proper joints. In children the spine is very flexible.

The Joints of the Upper Limbs.—The **clavicle** articulates with both the sternum and scapula.

The **shoulder-joint** is formed by the articulation of the head of humerus with the glenoid cavity of the scapula. It allows very free movement.

The **elbow-joint:** The bones entering into the formation of this joint are the lower end of humerus and upper end of ulna and radius. The radius articulates with the humerus, and also above and below with the ulna. Flexion and extension are the movements of the elbow-joint, while the superior radio-ulnar joint allows pronation and supination.

The **wrist-joint** is formed by articulation of the lower end of radius and ulna with the upper row of carpal bones. It allows flexion, extension, and lateral movements.

Fig. 27.—Elbow and Wrist Joints shown strapped by Ligaments.

The **carpal joints** allow very little movement.

The movements of the fingers are flexion, extension, and lateral movements (adduction and abduction).

Joints of the Lower Limb.—The **hip-joint** is formed by the articulation of the head of the femur with the innominate bone. It is a ball-and-socket joint, and allows very free movement.

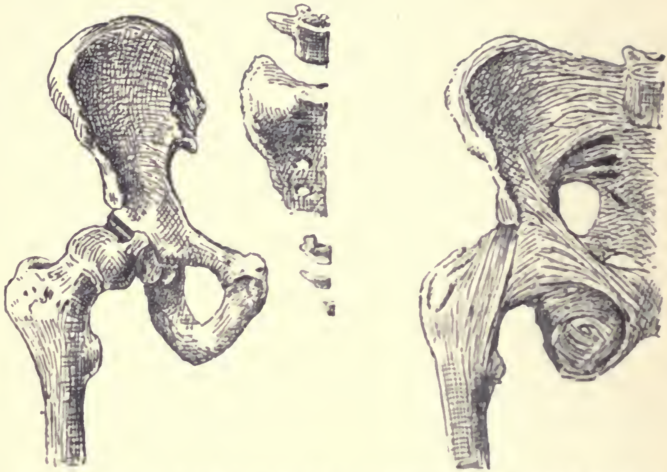

FIG. 28.—HIP-JOINT: THIGH-BONE, HIP-BONE, AND HALF THE SACRUM, SHOWN SEPARATE AND BOUND TOGETHER BY LIGAMENTS.

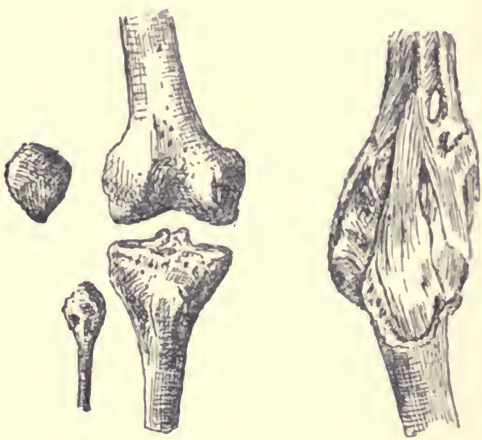

FIG. 29.—KNEE-JOINT: LOWER END OF FEMUR, UPPER ENDS OF TIBIA AND FIBULA, AND PATELLA, SHOWN SEPARATE AND BOUND TOGETHER BY LIGAMENTS.

The **knee-joint** is a hinge joint between the lower end of the femur and the upper end of the tibia. The concavities of the articular surfaces on the upper end of the tibia are deepened by two semilunar cartilages. The **patella,** or **knee-cap,** lies in front of the joint, and running from its lower border to the anterior surface of the upper end of the tibia is a strong ligament called the "ligamentum patellæ."

FIG. 30.—ANKLE-JOINT AND UPPER SURFACE OF FEET-BONES SHOWN STRAPPED TOGETHER BY LIGAMENTS.

The **ankle-joint** is a hinge joint, and permits of only flexion and extension. It is formed by the articulation of the upper surface of astragalus and lower ends of the tibia and fibula.

The **joints of the foot** are similar to those of the hand, except that movements are far more limited; this is especially the case with the big toe as compared with the thumb. The shape of the bones of the foot and their articular surfaces are such as to form various arches, and the integrity of these arches is very important for proper walking, because when some of them disappear, as in flat-foot, walking becomes difficult, and in some cases painful.

2. THE MUSCULAR SYSTEM.

The movements of the various parts and organs of the body are caused by the action of muscle cells, which are characterized by a special structure and by a special function of contracting under the influence of an appropriate stimulus.

There are three different forms of muscle cells :

1. **The striated or voluntary muscle cells, which make up the skeletal muscles.**

2. The non-striated or involuntary muscle cells, which are present in the walls of the intestine, bloodvessels, etc.

3. The cardiac muscle cells, which are striated, but involuntary, and form the heart muscle.

In this section we are only concerned with the skeletal or voluntary muscle.

Each voluntary muscle fibre or cell is an elongated, pale,

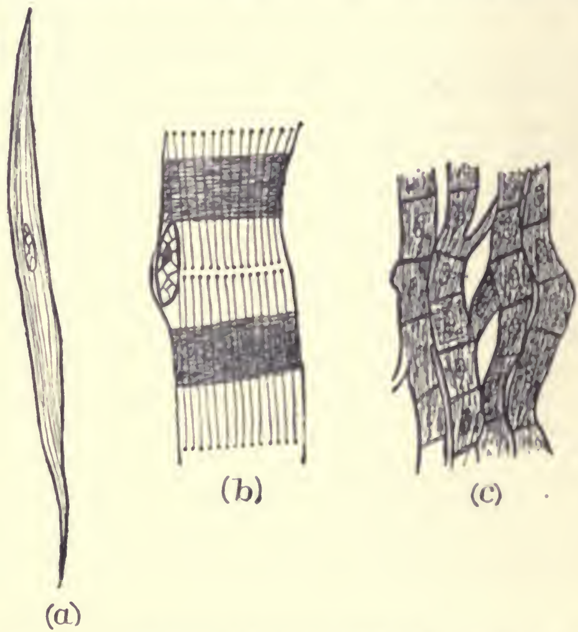

FIG. 31. DIAGRAM SHOWING STRUCTURE OF THREE FORMS OF MUSCULAR CELLS.

a, Involuntary or non-striated muscle cell; *b*, voluntary or striated muscle cell; *c*, cardiac or heart muscle cell.

transparent structure. Each has an elastic sheath, called the "sarcolemma," which encloses the contractile substance. The cytoplasm of the cell, or sarcoplasm, is characterized by alternate dark and light stripes, which run transversely across the fibre; hence it is called "cross-striated" or "striped" muscle. If the fibre be examined with a very strong microscope, it will be seen to be composed of a number of small fibrils. The nucleus of the cell is situated just within the sarcolemma.

A large number of these fibres become aggregated together, and are surrounded by connective tissue, and thus form a muscle.

Each muscle is composed of a number of fasciculi, or bundles, arranged together in different muscles in different ways, so as to give rise to the particular form of the muscles in question. Then each muscular bundle, or fasciculus, is composed of muscle fibres, and each fibre is made up of fibrils.

Each muscle, fasciculi, and fibres, are surrounded by connective tissue, by means of which they are brought into firm and intimate relation with the bony or other attachments of the muscle.

Each muscle arising from one bone is inserted into another, and in its course it passes over one or more joints. A muscle when excited to contract shortens in length and swells in girth; thus it pulls on the bones to which it is attached, and if one of these be fixed the other moves. The movement takes place at the joint over which the muscle passes. Muscles on contraction can move the bone from which they have origin or the bone to which they are inserted. A muscle is said to have *origin* from that bone which is the more fixed.

Tendons.—Tendons are the structures by which muscles become attached to bones. The fibres of the tendon run into and become part of the bone. Tendons are so securely attached to bones that it is easier to rupture a muscle or break a bone than to detach a tendon from a bone.

Tendons are generally long, slender white cords which run and become inserted into bones at some distance from the main portion of the muscle.

Properties of Muscle.—The physiological properties of muscle can be well studied in the frog. By one cut of the scissors decapitate a frog; and having done this, pass a pin down the vertebral canal and destroy the spinal cord. Divide the skin around the abdomen with a pair of scissors, and, taking hold of the skin below the cut, pull it from the lower limbs. The muscles will be thus exposed. Carefully separate the muscles at the back of the thigh; a white, glistening thread will appear. This is the main nerve of the thigh, and is called the sciatic nerve. It supplies the greater number of the muscles of the thigh and leg. Stimulate it by touching it with a pin or needle; the muscles contract. Further, show that the muscles themselves respond directly to stimuli by pricking them, when they will contract.

Normally, impulses pass along the nerves and cause the muscles to contract; but the muscles themselves are irritable and capable of being stimulated directly.

In a muscle freshly removed from the body there are three properties that can be easily shown. Remove one of the calf muscles of a frog, and if it is suspended by one end, and a small weight attached to the other, the muscle will be stretched; this is called *extensibility*. The muscle offers certain resistance to being stretched, and tends, when the weight is removed, to return to its former shape; this property is called *elasticity*.

When the muscle is pinched, pricked, or if an electric spark is passed into it, it will contract sharply; it becomes shorter and thicker for a moment, and then returns to its original condition. This is *contractility*, and it is by means of this property that a muscle is able to do its work.

Muscle contains 75 per cent. of water, and combined with it are the proteins myosinogen and paramyosinogen, glycogen, certain organic waste products, and mineral salts.

Some of these substances are combined to form the living contractile substance; others form the food or waste products of the same. A resting muscle is alkaline in reaction, but when fatigued or dead it is acid in reaction. This is due to the formation of sarcolactic acid—an acid similar to that formed in milk when soured by bacteria.

When at rest there is a certain amount of oxidation going on in the tissues, and therefore oxygen is absorbed and carbon dioxide eliminated; but during contraction there is a far greater amount of oxygen absorbed and carbon dioxide eliminated. During this process energy is evolved by the breaking up of complex substances, and the formation of simple products, like carbon dioxide. Some of this energy is used up in doing work, some takes the form of heat and warms the body, while a small portion is converted into electricity.

Rigor Mortis.—The condition of stiffness into which muscles enter after death is called *rigor mortis.* It comes on much more rapidly when the muscles are fatigued; thus, soldiers in battle and hunted animals stiffen almost as soon as they drop dead. The stiffness lasts for some hours, and then disappears, when putrefaction commences. This stiffness is due to the clotting of one of the proteins present in muscle, the soluble myosinogen being converted by the action of a ferment into the insoluble myosin.

Muscular Action.—The action of some of the muscles of the body should be studied in the living subject.

Muscles of the Head and Neck.—Note how facial expressions are caused by the contraction of various muscles of the face.

Place a finger on the outer surface of the angle of the lower jaw-bone; it will be found to be covered by a muscle. When the teeth are clenched, this muscle will be felt to harden. This is called the **masseter** muscle, and will be found to be attached above to a ridge of bone in front of the ear, and below to the outer surface of the angle of the jaw. If a finger is placed deep or slightly below the angle of the jaw, the tongue and lower jaw moved, various muscles will be felt to contract. These are muscles which pass from the tongue or jaw-bone to be inserted into the hyoid bone.

At the back and sides of the neck important muscles will be felt. On each side of the neck a long muscle will be found to run from the upper surface of the sternum and inner end of the clavicle to a bony process behind the ear, called the "mastoid process." This muscle is therefore called **sterno-mastoid,** because it passes from the sternum to the mastoid process.

Muscles of the Upper Limbs.—Examine the shoulder while the arm lies by the side. On the outer border of the shoulder the sharp bony projection formed by the spine of the scapula, or shoulder-blade, will be felt. Just below this the **deltoid** muscle will be felt. It arises above from the outer border of the spine of the shoulder-blade and anterior border of the outer end of the collar-bone, and is inserted below into the bone of the arm, or humerus. Its action is to pull the arm from the side to the horizontal position.

In front of the arm the **biceps** muscle will be seen, while on the posterior aspect of the upper limb lies the **triceps** muscle. The biceps is a flexor, while the triceps is an extensor, of the elbow; therefore the triceps has quite the opposite action to that of the biceps, and is called its "opponent." While the biceps contracts, the triceps slackens, and *vice versa.*

In front of the forearm a number of muscles will be felt; they are the flexors of the wrist and the joints of the hand and fingers. Behind the forearm are their antagonists, the extensors.

Muscles connecting the Upper Limbs with the Trunk.—The armpit is a pyramidal-shaped structure bounded by muscles, and containing arteries, nerves, veins, and connective tissue. The anterior border of the armpit is formed by the **great pectoral,** or breast muscle, which arises from

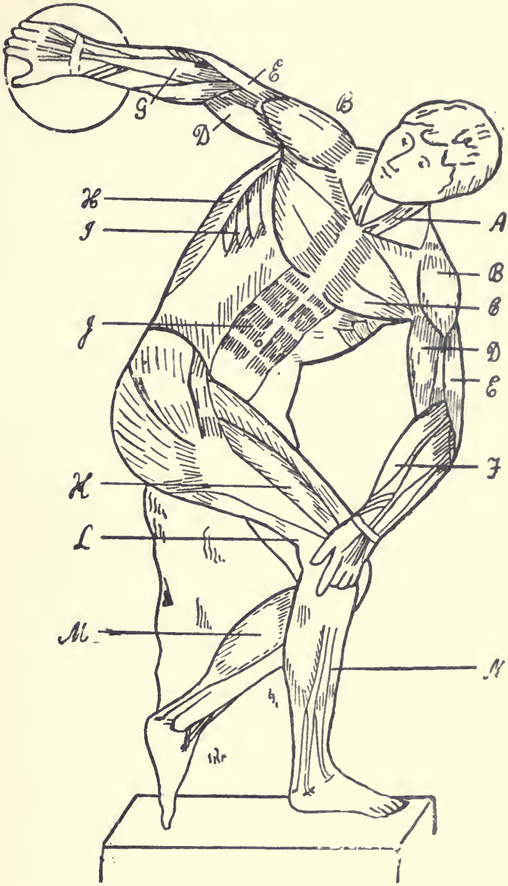

FIG. 32.—SUPERFICIAL MUSCLES.

A, Sterno-mastoid; *B*, deltoid; *C*, pectoralis major; *D*, biceps; *E*, triceps; *F*, supinator of forearm; *G*, extensors of fingers; *H*, latissimus dorsi; *I*, serratus magnus; *J*, rectus abdominis; *K*, flexors of thigh (extensors of knee); *L*, hamstring muscles; *M*, calf muscles (extensors of foot); *N*, flexors of foot (extensors of toes).

the breast-bone, costal cartilages, and collar-bone, and is inserted into the humerus, or arm-bone.

The posterior border is formed by the **latissimus dorsi,**

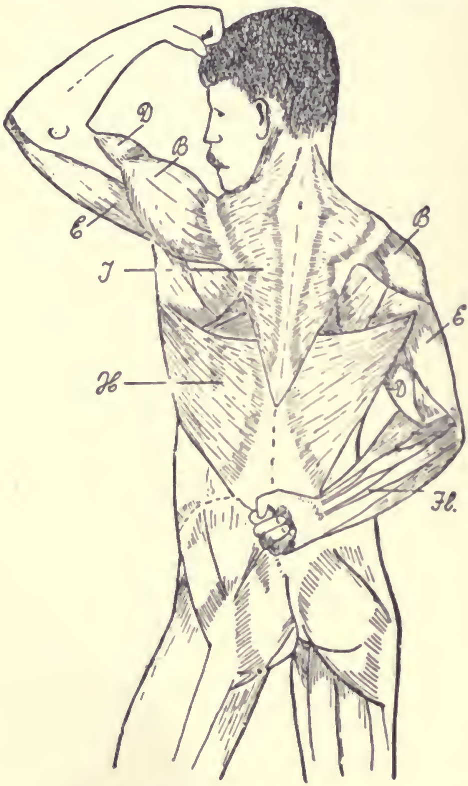

FIG. 33.—MUSCLES OF BACK.

T, Trapezius ; *Fl*, flexors of fingers ; other letters as in Fig. 32.

which arises from the hip-bone and the lumbar vertebræ, and is inserted into the humerus, its action being to pull the humerus downwards and backwards.

There are two other large muscles connecting the upper limb with the trunk. The **serratus magnus** arises from the ribs at the side of the chest, and is inserted into the inner border of the shoulder-blade, and its action is to pull the shoulder forward. The **trapezius** arises from the skull and vertebræ of the neck and back, and is inserted into the outer part of the posterior border of the collar-bone and the upper border of the spine of the shoulder-blade; its action is to pull the shoulder-blades back.

Muscles of the Trunk.—The powerful muscle of the back is called the **erector spinæ.** It is made up of several smaller muscles, which cover the whole length of the spine from the sacrum to the back of the head.

The abdominal wall is made up of several muscles which arise from the ribs, bones of the pelvis, and lumbar vertebræ, and are inserted into a fibrous layer in the middle line, called the "linea alba."

Muscles of the Lower Limbs.—The muscles of the thigh may be divided into three great groups. In front are the muscles which flex the thigh on the abdomen; and since these muscles gain insertion to the patella and the anterior surface of the tibia, their contraction will also result in extension of leg on the thigh. Behind are the opponents of these muscles, which extend the thigh at the hip-joint, and, by their insertion in the bones of the leg, flex the leg on the thigh at the knee-joint. On the inner side are the adductors, running from the pelvic bone to the inner side of the femur and tibia, and their action is to pull the lower limb towards the middle line.

In the leg there are two sets of muscles. The extensors lie anteriorly, and arise from the anterior surface of the tibia and fibula. They have long tendons which are inserted into the metatarsal bones or phalanges of the toes. Their action is to extend the toes, and one of them is a powerful invertor of the foot.

On the posterior surface of the leg there are two groups of muscles. The superficial group is inserted into a strong tendon, called the **tendo Achillis,** which is attached to the posterior surface of the heel-bone, or os calcis. The deeper group of muscles on the posterior aspect of the leg have long tendons, and are inserted in the under-surface of the phalanges of the toes; they cause flexion of the toes.

Relation of the Muscular System to the Nervous System.—All the striated or skeletal muscles can be controlled voluntarily in the execution of movements, but we are so accustomed to perform various movements that they are done by us quite unconsciously. The non-striated musculature is controlled by the sympathetic nervous system, and is not under voluntary control.

A certain part of the brain is set aside to govern the action of the voluntary muscles. The posterior part of each frontal lobe of the brain contains the nerve cells which generate impulses that travel along nerve fibres and stimulate the muscles to contract.

Two groups of nerve cells are involved in the nerve path from the brain to the muscle; the first or upper group is situated, as said above, in the posterior part of the frontal lobe, whence the *efferent* nerve fibres travel to the base of the brain. When these fibres reach the lower part of the brain, or medulla oblongata, they cross to the opposite side, then run down in the spinal cord, and end here by forming connections with the second or lower group of motor cells situated in the spinal cord. The nervous path is continued by efferent fibres arising in the motor cells of the cord, which finally end in the muscle fibres in special end organs called the "muscle plates." It is seen, therefore, that in the motor nervous path two groups of nerve cells and their fibres are involved. The upper group of motor nerve cells is situated in the frontal lobe of the brain, while the lower is situated in the spinal cord.

For proper muscular action it is essential that these two groups of nerve cells should be intact; injury to nerve cells in either of them results in paralysis of corresponding muscles.

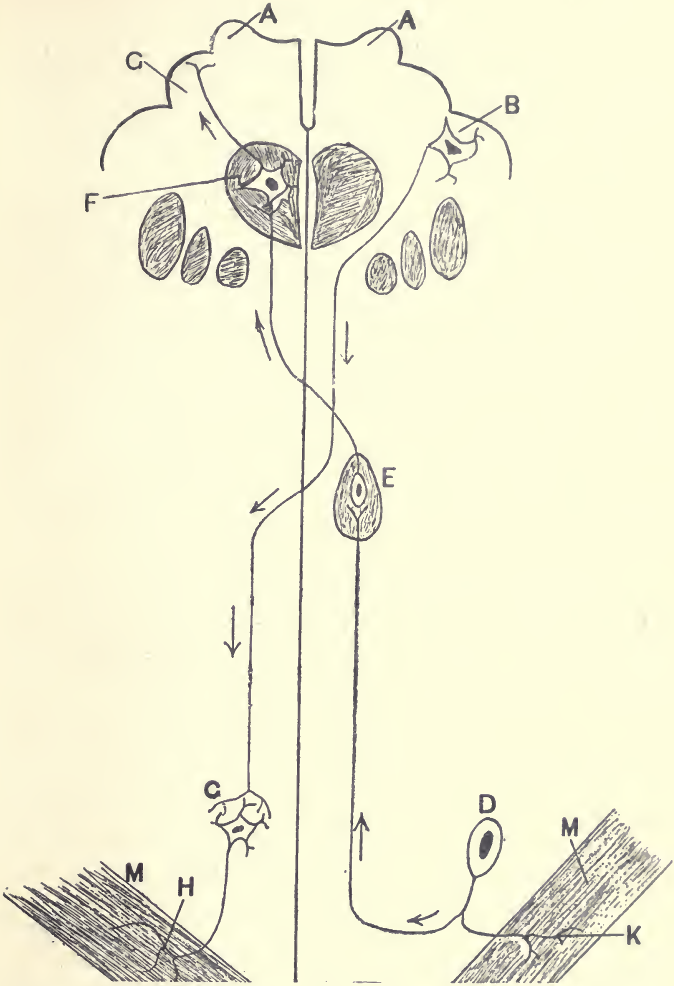

FIG. 34.—DIAGRAM SHOWING THE CONNECTIONS BETWEEN MUSCULAR AND NERVOUS SYSTEMS.

A, Cerebral cortex ; *B*, motor cortex, containing the upper motor nerve cell ; *C*, anterior horn cell of spinal cord (lower motor nerve cell) ; *D*, posterior nerve root cell ; *E*, nerve cell in medulla ; *F*, nerve cell in optic thalamus ; *G*, motor sense area of cerebral cortex ; *M*, muscle ; *H*, motor nerve-ending in muscle ; *K*, sensory nerve-ending in muscle ; *B*, *C*, *H*, represents motor nervous path ; *K*, *D*, *E*, *F*, *G*, represents the path along which muscular sensation is carried in the nervous system.

There are also *afferent* nerve fibres running up from the muscles and joints to the central nervous system. These tell us of the condition and position of our muscles and joints, and the integrity of these is essential for co-ordinated muscular contraction.

Muscular Fatigue.—If the sciatic nerve is exposed in the frog, as described above, and placed on two electrodes attached to an induction coil and battery, the nerve will receive a series of rapidly repeated electric shocks on closing the circuit. These will be conducted to the muscles, which will give correspondingly rapid contractions, and this will go on for some time until the muscular response gradually decreases, and finally there will be no muscular contraction at all. Such a condition is called *muscular fatigue*, and may be defined as a more or less complete loss of irritability and contractility brought on by functional activity.

The seat of exhaustion in a fatigued muscle is in the nerve endings or in their connections with the contractile substance of the muscle. This is proved by the fact that, though a muscle will *not* contract when its nerve is stimulated, it will respond when it is directly excited.

The site of fatigue when caused by voluntary muscular contraction has not been definitely settled. Certain experiments seem to prove that it is due to central changes, and not entirely to changes in the muscles and nerves themselves; thus, electrical stimulation of a "tired" muscle or of its nerve is readily responded to at a time when a weight cannot be raised by voluntary contraction.

It has also been shown that the injection of the blood of an animal exhausted by running or other muscular effort into the circulation of a normal animal produces in the latter all the symptoms of fatigue. It seems that certain substances are produced in the muscles during activity, and if these accumulate to a certain point they produce the sense of fatigue. The products causing this action are probably acid-reacting substances, such as sarcolactic acid ; thus, the muscle's own waste products serve to limit its responsiveness to stimulation, forming a protective mechanism that saves it from complete exhaustion.

Locomotion.—In walking, one leg—say the right—is slightly bent at the knee, and planted down in front of the other. The weight of the body is thrown on to this leg, while the left leg, raised on to the toes by the action of the calf muscles, forms a straight stiff rod. The left leg, by giving a push to the ground, next throws the body forwards. Thereupon the right leg straightens up, while the left, slightly bent at the knee, swings forward as a pendulum, and comes down in front of the right. It is now the turn of the right leg to push off, and of the left leg to bear the weight of the body. The length and rapidity of the step in walking will, of course, depend on the length of the leg.

It is far more difficult to analyze the exact changes that take place in running, but this has been done by taking a succession of instantaneous photographs by means of a cinematograph arrangement. Both feet are momentarily off the ground during each step, and therefore much more powerful contractions of the muscles are necessary to propel the body forwards ; and this is brought about by the combined action of the calf muscles and the extensors of the thigh.

Postures and Attitudes.—Some writers state that bad positions in writing, drawing, reading, and standing, are common causes of deformity. It is doubtful whether these factors are able to produce deformities, except when they are combined with other conditions, such as bad nutrition, rickets, etc.

If deformities are to be avoided, it is most important that children should be properly fed and the muscles brought into good tone by suitable exercises ; also such attitudes and postures as tend to produce deformities should be avoided.

The ideal sitting posture for the child while receiving instruction in school should be such that the force of gravity would largely replace muscular exertion. The child should sit in such a position that it would be in stable equilibrium, though all the muscles of the body are at rest. The body should be symmetrically placed, and the pelvis resting equally on the seat of the desk; the spinal column must be erect, the head balanced so that the muscles of the neck are at rest; the thighs horizontal, and the hands resting upon them. It is very difficult to maintain such a position for any length of time because of the lack of support to the back; and since the legs of all children in the classes are not of equal length, it is impossible to have this ideal posture unless the height of the seat is adjusted for each pupil.

Postures which involve twisting of the body should be avoided, because they may result in curvature of the spine.

When seated, the children should be taught to sit up straight, and not to bend the body forward, or slide downwards on their seat, so that they sit on their sacrum and coccyx instead of on their ischial tuberosities.

When the pupil sits with the body bent forward, there is compression of the chest, and proper expansion during inspiration is impossible; the amount of oxygen absorbed would be diminished, and this would have a bad effect on all the activities of the body. The dorsal spinal curve is increased, while the lumbar curve is reversed. The anterior abdominal wall is folded, and the contents of the abdomen are unduly pressed upon. When a child slips forward on his seat equally bad results follow.

A very common posture taken by the child when writing is to support the right arm and hand on the desk, while the left arm hangs down unsupported. This tends to produce curvature of the spine, with the convexity to the right.

Writing produces fatigue readily in children, because it is such a complicated muscular movement; and many of the injurious postures assumed are the direct result of an attempt to relieve this fatigue.

The best position for standing is when the chest is thrown forward with the head well back, and the heels placed slightly apart and opposite each other, so that the body is symmetrically placed and the weight of the body is equally divided between the two legs. Such position cannot be maintained for long, because the circulation in the legs is impeded when they are held in one position. The force of gravity opposes the return of the blood, and muscular movement is required to pump the blood up the veins.

For longer periods the best position is when the trunk is held as above, but one leg is placed in front of the other; the posterior one is held rigid, and supports the weight of the body, while the anterior one is relaxed and the knee slightly flexed. The position is varied from time to time, so that the anterior leg is placed posteriorly and supports the weight of the body, while the previously posterior leg becomes anterior and is relaxed and rests.

Lateral Curvature of the Spine, or **Scoliosis,** arises in several ways: (1) It is said to occur very rarely as a congenital affection, owing to deformity in the formation of the vertebræ. (2) It may commence in young children as the result of rickets, owing to softened condition of the bones, and partly to irregular growth. (3) Any cause of asymmetry of the body will give rise to scoliosis; shortness of one leg will cause tilting of the pelvis, and to compensate for this a lateral curvature of the spine is produced. (4) The most common form is the scoliosis of adolescents due to excessive muscular fatigue, bad nutrition, and unhygienic surroundings, met with in young people about the age of puberty.

The first sign is inequality in the level of the shoulders or some awkwardness in the gait. Slight cases may be treated at home, but children with marked deformity should be sent to special schools for a course of educational treatment by means of remedial exercises and movements.

Angular Curvature of the Spine, or Pott's Disease.—This is due to tuberculous disease of the vertebræ, originating almost invariably in their bodies, which are more or less destroyed, and leading to the so-called "angular curvature."

The exact signs and symptoms will vary considerably in different situations, but generally there are some symptoms in common.

Pain is a constant and invariable accompaniment of the disease, and in the early stages it can only be elicited by careful examination. The pain is either local over the site of the disease, or, by involvement of the sensory roots of nerves, it may be referred to different regions—*e.g.*, down the legs, over the buttocks or abdomen.

Rigidity is present, due to muscular spasm at first, and then to bony deformity.

Deformity arises from destruction of the vertebræ. The disease process often results in abscess formation, which may form tracks to various regions.

Physical Training.

The educational legislation and administration of this country during the last few years has been characterized by the efforts made to improve and develop the physical condition of the children in our elementary schools. These are certainly steps in the right direction, because a healthy physique is the greatest asset a nation can possess. A healthy body is absolutely necessary for the development of an active intelligence and a sound character.

The muscular system plays a very important part in the physiological processes in the body; and if this system be undeveloped, not only is the physical power of the individual weakened, but the vital processes upon which life depends are performed in a sluggish manner. In the sections on

Physiology it is shown that the muscles are the main site of the oxidative processes in the body, and muscular tone and contraction are the most important causative factors in the venous return of blood to the heart. The proper development of the musculature of the body can only be attained by adequate physical exercises.

The Board of Education has paid great attention to this subject, and has issued an excellent syllabus of physical exercises suitable for children in elementary schools.* It is the duty of every teacher to procure a copy and make a careful study of it.

In the introductory chapter of the above syllabus, the objects, effects, and general physiology, of muscular exercise are very well explained, and we cannot do better than quote here some of the facts recorded there, together with some additions that seem necessary.

It is stated that the *object* of physical training is to help in the production and maintenance of health in body and mind.

It is pointed out that physical training has, or should have, a twofold effect : on the one hand a physical effect, and on the other a mental and moral effect, which for convenience may be termed "educational" in the popular sense. The direct results upon the health and physique of the child may be described as the *physical effect.* "Exercises, if rightly conducted, also have the effect, not less important, of developing in the children a cheerful and joyous spirit, together with the qualities of alertness, decision, concentration, and perfect control of brain over body. This is, in short, a discipline, and may be termed the *educational effect.*" These two elements are obviously blended in varying degree in every suitable exercise, and, according to circumstances, now the one aspect of the exercise, now the other, is to be regarded as the more important. The difference consists rather in the stage at

* "The Syllabus of Physical Exercises for Public Elementary Schools," 1909 (Wyman and Sons).

which, and the manner in which, the exercise is taken, than in actual difference of movement."

Physical Effect.—This is considered under three headings, according as the effect is (1) on the general nutrition, (2) corrective, (3) developmental.

1. *Effect on General Nutrition.*—The exercises which have the most beneficial influence on general nutrition are those involving a large number of muscles. Such exercises consist chiefly of massive movements, and are of two kinds —general and special.

"*General Massive Movements* are those of the limbs and trunk, which involve the whole bony and muscular structure of the body, and quickly and powerfully affect both respiration and the circulation. Types of such exercises are to be found in the natural play movements of children, such as running, leaping, and skipping; also in marching, dancing, cycling, and games of all kinds. It is chiefly through such movements, given a sufficient supply of fresh air and suitable food, that the structure of the body is built up during the growing period, and the artificial conditions of school life make it of the first importance that adequate provision should be made for such exercises."

"Among the *Special Massive Movements* may be included the various balance movements, shoulder exercises, and lungs. These have a beneficial effect upon the nervous system, and strengthen the control exercised by the nerve centres over the muscles."

2. *Corrective Effect.*—"This term is used to denote the remedy or adjustment of any obviously defective or incorrect attitude or action of the body, or any of its parts. Exercises employed for their corrective effect do not usually involve the whole body, but the trunk or limbs taken separately, in order to encourage local development."

3. *The Developmental Effect.*—"One of the aims of physical training is to promote the development of the muscular system and the body as a whole, in order to attain the highest possible degree of all-round physical

fitness. Physical training has also an equally important influence on the development and specialization of the brain cells.

"There are in the brain certain 'centres,' or masses of brain matter, which preside over co-ordinated movements of all kinds. These centres begin to perform their functions in early life, when the child learns to stand, to walk, or to talk. As new movements are attempted, new centres become active, certain nerve impulses become more or less habitual, and thus new nerve paths are opened up and established, and the connections between the centres in different parts of the brain become increasingly well defined and co-related. It has been found that, within reasonable limits, the greater the scope of the physical education, the more complex and highly specialized and developed do these centres become.

"There should be no demand for accurate movements in the infant school, and but little in the lower standards. It is only in the upper school, with children from eleven to fourteen years of age, that real precision and smartness of execution should be required."

Educational Effect.—The educational effect is of great importance, especially as the child grows older. Exercises have not only a physical effect on the body, but also a strong mental and moral influence, which is a powerful agent in the formation and development of character. The child learns to respond cheerfully and promptly to the word of command, and thus unconsciously acquires habits of discipline and order.

Physiology of Muscular Work.

Effects of Exercise on the Muscular System.—In all living tissues there is an adaptation of structure to function; hence, if the muscles of the body are called upon to do a greater amount of work, their structure is adapted to perform such new duties. Muscles on being regularly and suitably exercised become larger, stronger, and more capable of doing work. Muscular work increases the chemical changes going on in the muscles, and a greater amount of food and oxygen is used up.

Effects on Bones and Joints.—Physical training causes the skeleton to become bigger and heavier. Joints become more flexible and supple, as well as stronger, by exercise.

Effects on Heart and Circulation.—The heart beats more quickly during muscular work, because a more rapid circulation is necessary to meet the various demands of muscular activity ; this is brought about by the nervous impulses passing out of the brain having an effect on the nerve cells which govern the rate of the heart-beat. The products of muscular activity also affect the heart and cause it to beat quicker.

The heart is a muscle, and resembles the skeletal muscles in its response to work. Gradually increasing work with good nutrition and periods of rest strengthen it. If excessive work be done when the heart muscle is untrained, it may be overstretched and injured ; such a damage is far less easily repaired than in the case of skeletal muscle.

Muscular tone and contraction aid the return of blood to the heart, and so help to maintain the circulation in the veins and lymphatics.

Effects on Respiration.—Muscular work causes increased absorption of oxygen and elimination of carbon dioxide. In order to meet the greater demand for the supply of oxygen and the removal of carbon dioxide, there is an increased respiratory exchange and increased ventilation of the lungs. All parts of the lungs are opened out and well circulated with blood owing to the deep breathing.

Effects on the Temperature of the Body.—Muscular exercise results in a greater formation of heat, and in order to keep the temperature of the body constant the heat loss must be correspondingly increased. There is dilatation of the vessels of the skin, a greater amount of blood reaches the surface of the body, which results in greater loss of heat from the skin. Further, the sweat glands are stimulated to activity, and the evaporation of this moisture causes rapid cooling of the surface of the body. There is also increased evaporation of water from the surface of the lungs, resulting in greater loss of heat. In spite of the far greater loss of heat, hard muscular exercise may at the time raise the temperature of the body one or two, or even three, degrees (Fahrenheit).

Effect on the Digestive System.—Muscular activity involves greater oxidation of food in the muscles, and to keep up a proper supply there must be an increased absorption from the intestine. The functional activity of the digestive tract is improved, the appetite is sharpened, and digestion and absorption of food increased. The vigorous movements of the diaphragm aid the circulation through the liver and other abdominal organs. The metabolic functions of the liver are greatly improved by exercise.

Effect on the Nervous System.—The developmental effect on the brain centres has been referred to above. There is a close connection between the nervous and muscular systems, and physical training must result in an improvement in the tone and condition of the nervous system. The increased circulation of blood through the brain brought about by exercise has a very beneficial effect.

Physical Condition of the Child and Physical Exercises.—There are few children who do not benefit by physical exercises of the right kind, when not excessive in amount; but in certain cases the demands may be too great on the physique of the child, and a good deal of harm may be done. Medical inspection of schools will do much to obviate this.

The teacher should watch for certain signs during physical exercises—namely, marked breathlessness, early signs of general fatigue, pallor, fainting, and mouth breathing. The frequency of the pulse is greatly increased during hard exercise. On resting, the frequency ought to lessen very rapidly. If the pulse remains frequent, it is a sign cf overfatigue.

Children showing any of the above signs should be sent to the medical officer for examination.

Clothing.—Physical exercises can only be carried out satisfactorily when suitable clothing and proper shoes are worn. At present, unfortunately, this is impossible in our elementary schools, unless special provisions are made by the local educational authority.

Open Air.—All exercises should be carried out in the open air, for the cooling effect of the wind is very beneficial.

Games.—Physical exercises must not replace school games. Playing-fields should be provided for every school, and proper games should be organized for the children by certain members of the teaching staff. The older boys should play football, cricket, tennis, etc. These games undoubtedly improve the mental, moral, and physical condition of the children.

The amount of physical exertion required by the games should be graduated according to the age and strength of the child. This is done most satisfactorily by the co-operation of the teacher and the medical officer.

CHAPTER III

THE DIGESTIVE SYSTEM

Digestion is the means by which food is taken into the organism and changed into a form ready for absorption. In the simplest form of animals—the protozoa—food is taken in by the organism throwing out a protrusion of its protoplasm, and surrounding the particle of foodstuff. After the particle of food is taken into the protoplasm, it is acted upon by certain substances, and broken up into simpler compounds, which are absorbed, and the waste products are thrown out. In the unicellular animal no one part of the organism is specialized for this work, but as we ascend the animal kingdom there is greater and greater division of labour, until in the higher animals a very special part of the body is set aside for the taking in of the food and its conversion into simpler and more soluble substance, more suitable for absorption into the blood-stream. This specialized part of the body is called the " alimentary system."

We shall first describe the chemistry of the foodstuffs, and then treat of the anatomy and physiology of the various parts of the digestive system.

Chemistry of Foodstuffs.—The food of man may be divided into three main classes—the proteins, fats, and carbohydrates.

The **Proteins** are substances which contain carbon, oxygen, hydrogen, and nitrogen, sometimes sulphur and sometimes phosphorus. They are the most important group of substances, because without them no animal can survive, as they are absolutely essential for the building up of the tissues. Since during the processes of life a certain amount of wear and tear of the tissues always takes place, it is readily seen how important these substances are to the organism.

The chief proteins that we eat are the vegetable protein found in flour, oatmeal, peas, beans, and potatoes; albumin and globulin, found in white of egg and blood-plasma; myosin and myogen, found in lean meat; casein, found in milk and cheese; gelatin, obtained from bones and ligaments by boiling.

As they exist in Nature proteins are amorphous substances, but it is possible in the laboratory to change some of them into a crystalline condition.

Some of the proteins are soluble in water (*e.g.*, the albumins), while others (*e.g.*, the globulins) are insoluble in water, but soluble in dilute salines. The solutions so obtained are not true solutions, but simply a very fine suspension of the particles of the protein in water; hence, when neutral salts are added to the solution, they cause an aggregation of the particles of the protein, and result in its precipitation. This serves as an important test for protein; when neutral salts are added to a solution of protein, they cause precipitation of the protein, and the amount of salt that is required to attain this result varies for different proteins.

The more modern view held about the composition of proteins is that they are made up of an aggregation of simpler bodies, called "amino-acids." Proteins can be readily broken up into amino-acids through the intermediate products of proteoses and peptones. About eighteen of these amino-acids have been definitely isolated on breaking up various proteins. These amino-acids undergo chemical reaction with various reagents, and hence these serve as tests for proteins. We will mention two of these tests here.

1. *Biuret Test*, so called because it is given by a substance called biuret, which is obtained by heating urea in a test-tube. When it is applied for proteins, it is done in the following way: To a solution of protein (*e.g.*, solution of egg-white) add caustic soda solution, and then, drop by drop, dilute copper sulphate solution (1 per cent.), mixing after each addition: a violet colour appears.

2. *Xanthoproteic Test.*—Heat a little egg-white solution with concentrated nitric acid; a yellow colour is formed; cool, and add ammonia or soda in excess: the colour changes to orange.

Fats.—Chemists tell us that bases and acids combine together to form a new compound, and this new compound is called a "salt"; *e.g.*, sodium hydroxide (base) will combine with sulphuric acid (acid) to form sodium sulphate. The reaction can be stated thus:

$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O.$$

When we study organic chemistry, we find there are reactions comparable to the above, and one of these is the combination of alcohols and acids.

Alcohols combine with acids to form a new compound, called an "ester." Thus, ethyl alcohol combines with acetic acid to form ethyl acetate:

$$\underset{\text{ethyl alcohol}}{C_2H_5OH} + \underset{\text{acetic acid}}{CH_3COOH} = \underset{\text{ethyl acetate}}{CH_3COOC_2H_5} + H_2O$$

Fats are esters, and therefore are a combination of alcohol and acid. Animal and human fat is generally a mechanical mixture of three esters. The alcohol present in these esters is the same (namely, glycerine), but there are three different acids—namely, stearic, palmitic, and oleic acids. Hence animal and human fats are a mechanical mixture of glycerine tristearate, glycerine trioleate, and glycerine tripalmitate.

Animal fats are semisolid at body temperature. Fats are insoluble in water, but soluble in ether, chloroform, and hot alcohol. Another important physical property of fats is their power to emulsify—that is, they are capable of being broken up into very small globules. A natural form of emulsion is milk. Fats are readily broken up into their components—namely, glycerine and fatty acids. When treated with caustic potash or soda, they are split up into glycerine and a soap ; and if the products of their reaction are treated with sulphuric acid, the soaps are broken up, with the formation of fatty acid and sodium sulphate, and the free fatty acids float to the surface. Fats are an important group of foodstuffs, and before they are absorbed they are broken by one of the digestive enzymes into fatty acids and glycerine, and then resynthesized during absorption.

Carbohydrates are compounds containing carbon, hydrogen, and oxygen. In this group must be included the sugars, starches, dextrine, glycogen, and cellulose.

Sugars.—For our purpose in this book we may state that the sugars are divided into two main classes—the simple sugars, or monosaccharides; and the more complicated, the disaccharides.

MONOSACCHARIDES.—There are three monosaccharides which are of importance in human physiology—glucose, fructose, and galactose.

They are all soluble in water, and are capable of reducing the salts of heavy metals in alkaline solution. A large number of tests that are used for sugars depend on the latter property—*e.g.* :

Trommer's Test.—Add a few drops of copper sulphate to a sugar solution, and then some caustic potash solution. A blue solution of cupric hydrate is formed, which on heating yields a yellowish-red precipitate of suboxide of copper.

Fehling's Test, is only a modification of Trommer's test. Fehling's solution is made by mixing solutions of copper sulphate, caustic potash, and Rochelle salt. The object of the addition of Rochelle salt, which is a crude form of sodium tartrate, is to keep the cupric hydrate in solution. When a sugar solution is heated with Fehling's solution, a yellowish-red precipitate of suboxide of copper is formed.

Disaccharides, or Compound Sugars, are formed by combination of two monosaccharide sugars, with the elimination of a molecule of water. Three disaccharides are important in human physiology—namely, maltose, lactose, and cane-sugar.

Maltose is made up of two molecules of glucose, and these are so combined that their reducing property still remains, and hence maltose gives Trommer's and Fehling's tests. Maltose is important physiologically as an intermediate product of hydrolysis of starch, and industrially as an intermediate product in the preparation of ethyl alcohol from barley.

Lactose, or sugar of milk, is made up of a molecule of glucose combined with a molecule of galactose. It also gives Trommer's and Fehling's test.

Cane-sugar, or *sucrose*, is a combination of glucose and fructose, and these are so combined as to have no reducing properties, and hence cane-sugar will not give a Trommer's or Fehling's test. It will, after warming with dilute acids, give Trommer's and Fehling's test, for the acid hydrolyzes cane-sugar and splits it into glucose and fructose.

Starches are the most important reserve forms of foodstuffs in the vegetable kingdom They exist in plants as small granules, made up of alternate layers of cellulose and starch.

Starch is insoluble in cold water, but dissolves into an opalescent solution on heating. On the addition of iodine solution starch gives an intense blue coloration, which disappears on heating and reappears on cooling.

Starch can be hydrolyzed to glucose by means of dilute acids or enzymes. In the human body starch must be converted into glucose before it can be absorbed by the small intestine.

The Digestion of Food.—The foodstuffs which we have discussed above cannot be absorbed as such from the intestine, hence they must be broken up to simpler and more soluble forms. The cleavage of these foodstuffs is brought about by the action of certain specialized substances, called "ferments" or "enzymes." These bodies are formed in special tissues called "glands." The products of activity of a gland are called its "secretion." After the food has been broken down to the simpler products, these are carried through the living membrane of the intestine into the bloodvessels and lymphatics present in the intestinal wall. The process of taking the food into the blood or lymphatic vessels is called "absorption."

After absorption the food is carried in the blood-stream to the tissues, and now serves to nourish all the body. "Metabolism" signifies the use of the food by the tissues, and the chemical changes it undergoes therein. Oxygen is carried by the blood to the tissues from the lungs, and there oxidizes the food, liberating its chemical energy; on this life is sustained. After this process of oxidation there are left the waste products, and the body gets rid of these substances by a process of excretion. Hence in digestion and metabolism there are three great processes, called "secretion," "absorption," and "excretion."

The processes of secretion, absorption, and excretion, are distinguished from one another only by their object or physiological function, and not by anything intrinsically different in their nature or in the mechanism by which these processes are carried out in the body.

Secretion.—The purpose of secretion is to prepare an active substance in solution for use in assisting a process which is of service to the organism in some other part (*e.g.*, digestive secretion) or a secretion of a substance which has a guiding influence upon chemical change in other tissues, and hence affects the state of activity of those tissues (*e.g.*, internal secretion: adrenalin, secretin, etc.; *vide* pp. 102-105); or a secretion which acts by mechanical means (*e.g.*, secretion of lachrymal glands, mucous secretions of mucous membranes, and also secretions of serous membranes).

Absorption is for the purpose of taking up for the service of the body generally, and of the absorbing cells, the materials in solution which have been prepared and modified by the secretions.

Excretion is for the purpose of removing from the body materials which have been passed through, or been formed in the cycle of metabolism in the body, and have become waste products for which the body has no further use. In addition, the purpose of excretion is to maintain in normal amount and concentration in the circulating fluid of the body — the blood — those products which are of service; for in abnormal concentrations these useful bodies become as injurious to the living cells as effete products of metabolism or foreign substances of actively poisonous nature.

Ferments or Enzymes.—It would be advisable at this stage to learn some of the general properties of ferments or enzymes, because the chemical changes wrought in the food as it passes along the alimentary canal are due to the secretions of various glands which line its cavities, which pour their juices into it through special ducts. These secretions owe their power for the most part to the presence of these substances called "enzymes" or "ferments." Enzymes or ferments are bodies capable of producing certain changes in some substances without undergoing any change themselves. Enzymes are protein-like substances, and are generally soluble in salt solutions, water, or glycerine. They are destroyed by heat (80 °C.), and their action is inhibited by cold. They all have an optimum temperature—*i.e.*, temperature at which they work best—and for those which are present in the body this is the body temperature. Ferments are precipitated by alcohol, and carried down by flocculent precipitates — *e.g.*, calcium phosphate. Their action is always incomplete; *e.g.*, yeast cannot convert a certain weight of glucose entirely to carbon dioxide and alcohol, nor can pepsin hydrolyze completely a certain weight of protein. Their action is always inhibited by the products of their reactions—*e.g.*, when yeast acts on glucose. If the amount of alcohol rises above 14 per cent., the action stops ; then, if some of the alcohol be removed, the action will go on until the strength of alcohol again rises to 14 per cent. Enzymes are most often secreted in an inactive form, called the "zymogen," then acted upon by a substance called the "activator," or "kinase," and changed to the active form.

Various theories have been formed as to the mode of action of ferments, but we are still rather far from understanding the exact nature of enzyme actions.

Ferments are classified according to the nature of the chemical changes which they bring about—*e.g.* :

1. *Proteolytic or protein-splitting ferments* are those which hydrolyze proteins, breaking them up into proteoses, peptones, and amino-acids —*e.g.*, pepsin of the gastric juice, trypsin of the pancreatic juice, and erepsin of the intestinal secretion.

2. *Amylolytic or starch-splitting ferments* are those which break up starch, converting it into glucose—*e.g.*, ptyalin of the saliva, amylopsis of the pancreatic juice.

3. *Lipolytic or fat-splitting ferments* are those which split fats into glycerine and fatty acids—*e.g.*, steapsin of pancreatic juice, and lipases present in the liver and connective tissue and other parts of the body.

4. *Sugar-splitting enzymes* are those which break up sugars :

   (*a*) Those which change disaccharides to monosaccharides ; *e.g.*, maltase converts maltose to glucose, invertase changes cane-sugar to a mixture of glucose and fructose.

   (*a*) Those which split up the monosaccharides.

5. *Coagulative enzymes* are those which act on certain substances, changing them from a soluble to an insoluble form ; *e.g.*, thrombin changes soluble fibrinogen to insoluble fibrin, and brings about the coagulation of blood ; rennin changes the soluble calcium compound of caseinogen to the insoluble calcium compound of casein, and hence brings about the clotting of milk.

6. *Oxidizing enzymes, or oxidases*, are those which bring about the oxidation of substances in the tissues.

Physiology of the Mouth.

Anatomy.—The **alimentary canal** is a long muscular tube lined by a mucous membrane. It is about 30 feet in length. Its upper expanded portion is called the "mouth," and is specially adapted for the reception and mastication of food. When the mouth is examined, we can distinguish in it various parts—the aperture of the mouth, the vestibule, and the cavity of the mouth proper.

The **aperture of the mouth** is the upper or anterior opening of the alimentary canal, and is bounded above and

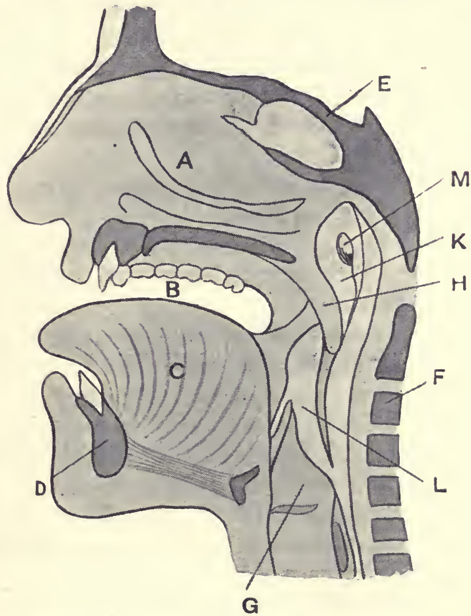

FIG. 35.—DIAGRAM SHOWING STRUCTURES SEEN WHEN A LONGITUDINAL SECTION IS MADE THROUGH THE MOUTH, TONGUE, NOSE, AND PHARYNX.

A, Cavity of the nose; *B*, cavity of the mouth; *C*, tongue; *D*, lower jaw; *E*, base of skull; *F*, vertebral column; *G*, larynx; *H*, palate; *K*, naso-pharynx; *L*, oral pharnyx; *M*, opening of Eustachian tube.

below by the corresponding lips, which by their junction at the sides form the angles of the mouth.

The **vestibule** is a slit-like space bounded anteriorly and externally by the lips and cheeks, posteriorly and internally by the dental arches and gums. Its roof is formed by the reflection of the mucous membrane from the deep surface of the upper lip and upper part of the cheeks on to the gum of the upper jaw. The floor is formed by the reflection of the mucous membrane covering the deep surface of the lower lip and lower parts of the cheek on to the gum of the lower jaw. You should ascertain the boundaries of the vestibule by placing the finger in the mouth between the lips and teeth and pushing it upwards and downwards.

Lips are composed of a stratum of muscular tissue covered superficially by skin, and on their deeper surface by a mucous membrane.

Cheeks.—The cheeks resemble the lips in structure, being formed of corresponding layers.

Cavity of the Mouth Proper.—This is the space situated within the dental arches, which with the gums separate it from the vestibule.

Posteriorly the cavity of the mouth opens into the throat, or pharynx, through an aperture bounded by two folds of mucous membrane containing muscular tissue. These are called the " pillars of the fauces."

The **roof** is formed by the hard palate and by the anterior part of the soft palate.

The **floor** is formed by the tongue. When the tip and marginal portions of the tongue are raised, a limited surface, formed of mucous membrane and muscular tissue, is exposed, and is called by anatomists the " floor of the mouth."

Gums.—These are made up of firm connective tissue covered by a mucous membrane. They form the outer covering of the bony ridges carrying the teeth in the upper and lower jaws. They are continuous on the outer surface with the mucous membrane lining the floor and roof of the vestibule, and on the inner surface with the mucous membrane covering the floor of the mouth and the hard palate.

The **palate** is the structure which separates the mouth from the cavity of the nose; it projects posteriorly into the pharynx, incompletely dividing that cavity into an upper nasal and lower oral portion. The anterior half is composed of bone covered by a mucous membrane on each side; this is called the "hard palate." The posterior part is formed of muscular tissue covered by a mucous membrane, and is called the "soft palate." The soft palate ends posteriorly in a conical projection, called the *uvula*.

The **tongue** is an organ composed chiefly of muscular tissue covered by a mucous membrane. It occupies the floor of the mouth, and forms part of the anterior wall of the pharynx.

The muscular part of the tongue is made of voluntary muscular tissue, the fibres of which go in various definite directions. The mucous membrane is made of stratified epithelium; it is also covered with numerous papillæ, which give the tongue its most characteristic appearance.

The papillæ of the tongue are formed by projections of the upper part of the mucous membrane, covered by thick caps of epithelium. Some of the papillæ are furnished with taste-buds (*vide* Special Senses).

The **teeth** are specialized portions of the mucous mem brane of the mouth. Each tooth may be looked upon as a papilla of such mucous membrane undergone calcification. Just as the mucous membrane of the mouth is made up of two portions—namely, a substratum of connective tissue and a superficial layer of epithelium—so each tooth is also composed of two layers—namely, dentine and enamel.

The **dentine** is modified connective tissue, and forms the greater part of each tooth. The **enamel** is derived from the epithelial layer, and forms a cap for the portion of the tooth that lies above the gum. Another special form of hard tissue, called the "cement," or "crusta petrosa," surrounds the portion of a tooth that lies in the socket.

The enamel is the hardest and densest substance in the body, and is made up almost entirely of phosphate and carbonate of lime. Dentine is made up of a large amount of calcium salts combined with organic matter.

Anatomists designate various parts to each tooth. The **crown** is the portion of the tooth that lies above the gum. This varies in shape in different teeth. In the anterior teeth—namely, the incisors and canines—this portion is shaped like the edge of a chisel, while the grinding surface of all the other teeth bears either two or three cusps, or tubercles. Those which have two cusps are called the "bicuspids" or "premolars," while those which have three cusps are called "tricuspids" or "molars."

The **neck** of a tooth is the portion that comes in contact with the gum.

The **root** is the part of a tooth which lies in the bony socket of the upper and lower jaws. In the incisor, canine, and bicuspid teeth the root is a single process, while in the tricuspids the root is made up of two or three processes. When a longitudinal section is made of a tooth, its various parts can be easily recognized and studied. The **crown** will be seen to be made up of a superficial portion of enamel, and a deeper part composed of dentine. The enamel will be seen to end at the site where the gum comes in contact with the teeth. The **neck** is made up of dentine with an outer layer of cement substance with which the gums come in contact. The **root** is made up of dentine with an outer covering of cement, or crusta petrosa, which is attached to the bony socket by a vascular layer of connective tissue.

In the centre of each tooth there is a cavity, called the **pulp cavity.** It contains connective tissue, bloodvessels, and nerves, all the contents being termed the **tooth pulp.** The pulp cavity extends down to the root, whether it is single or made up of two or three fangs. It finally terminates in the small foramina at the apices of the roots, through which nerves and bloodvessels enter the pulp cavity. Nourishment is carried to the dentine along small branching canals which radiate through it from the pulp cavity.

The human subject is provided with two sets of teeth, which make their appearance at different periods of life.

Those of the first set appear in childhood, and are called the "temporary," "deciduous," or "milk" teeth. Those of the second set, which also appear at an early period, continue until old age, and are named "permanent."

The temporary teeth are twenty in number: four incisors, two canines, and four molars, in each jaw.

The permanent teeth are thirty-two in number: four incisors (two central and two lateral), two canines, four bicuspids, and six molars, in each jaw.

In each half of a jaw the teeth are arranged in the following manner from before backwards—central incisor, lateral incisor, canine, two premolars, and three molars.

The **salivary glands** are six in number, three on each side, and these are called the "parotid," "submaxillary," and "sublingual."

The parotid gland is situated in a deep recess at the side of the head, below and in front of the ear. Its secretion is carried to the mouth by a duct, called "Stenson's duct." It passes superficially to the masseter muscle, and then pierces the mucous membrane of the mouth, where it opens opposite the second upper molar tooth.

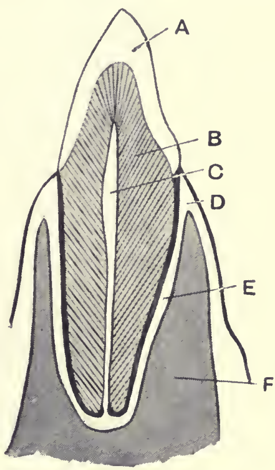

FIG. 36.—DIAGRAM SHOWING THE STRUCTURE OF A TOOTH: (LONGITUDINAL SECTION).

A, Enamel; *B*, dentine; *C*, pulp cavity; *D*, gum; *E*, root membrane; *F*, bony socket.

The submaxillary gland is placed just below and under cover of the angle of the lower jaw.

The secretion of the submaxillary gland is carried to the mouth by means of Wharton's duct, which opens on the floor of the mouth on each side of the frenum of the tongue.

The sublingual gland lies on the floor of the mouth, on each side of the frenum linguæ, which is a ridge of mucous membrane seen on the under surface of the tongue. The secretion of the sublingual gland is carried to the mouth

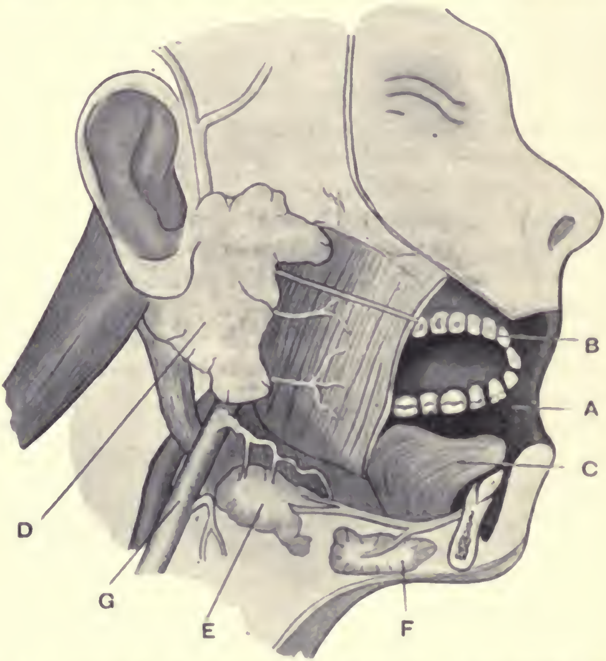

FIG. 37.—DIAGRAM SHOWING SOME IMPORTANT STRUCTURES IN A LATERAL DISSECTION OF THE LOWER PART OF THE FACE AND UPPER PART OF NECK.

A, Mouth cavity ; *B*, teeth of upper jaw ; *C*, tongue ; *D*, parotid salivary gland ; *E*, submaxillary salivary gland ; *F*, sublingual salivary gland ; *G*, carotid artery.

by a number of ducts which open on each side of the frenum linguæ, and these are called the " ducts of Rivinus."

Composition of Saliva.—Saliva is a watery, alkaline fluid containing inorganic and organic constituents. The inorganic substances present are various salts—*e.g.*, sodium chloride, sodium carbonate, calcium phosphate, magnesium phosphate, and calcium carbonate. The organic substances are mucin, a protein of the nature of a globulin, potassium sulphocyanide, and ptyalin.

The secretion of the parotid gland is very watery, and contains a good percentage of inorganic salts, but is poor in organic constituents. The secretion of the submaxillary and sublingual glands is thick and viscid, being rich in organic substances. The presence of the above substances

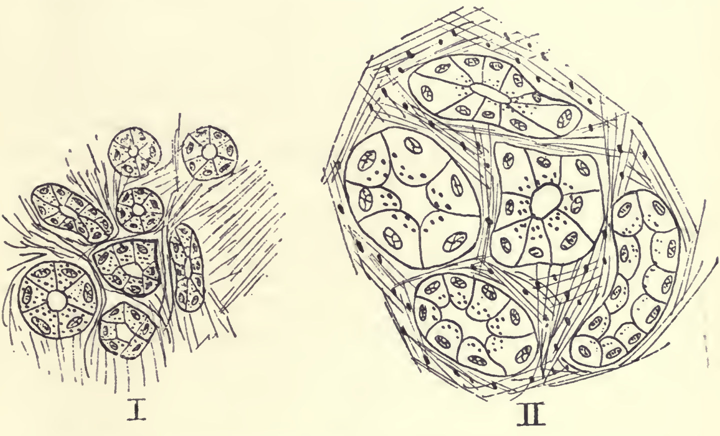

FIG. 38.—DIAGRAM SHOWING MICROSCOPIC STRUCTURE OF SEROUS SALIVARY GLAND (I.) AND MUCOUS SALIVARY GLAND (II.).

in saliva can be easily demonstrated. The salts can be identified by the ordinary tests used in inorganic analysis. Mucin is a slimy, viscid substance, and gives various protein tests; it is also precipitated by acetic acid, and is insoluble in excess of that acid. Mucin acts as a lubricant to the bolus of food.

Pytalin is the only ferment present in saliva; its action is to convert starch into maltose. This can be easily proved by making a solution of starch in boiling water, allowing it to cool, and then test a little of it with iodine, when an intense blue coloration will be produced. Then some of the starch solution is placed in the mouth and held there for a minute; it is then returned to a test-tube, and the iodine test again applied, when no blue colour would be produced. If another portion of the starch that has been held in the mouth be tested with Trommer's solution, a precipitate of cuprous oxide would be produced on heating, showing the presence of a reducing sugar.

The saliva has several important functions. It has a digestive enzyme which acts on starches, and hence it helps in the digestion of this class of foodstuffs. It moistens the food, and when a bolus has been formed the mucin forms a slimy covering to it, and in this way saliva helps mastication and swallowing. Saliva is also protective, because, if any irritant—*e.g.*, dilute acetic acid or caustic potash—is placed in the mouth, it reflexly causes a great secretion of saliva, which dilutes the irritating substance, and therefore lessens its corrosive action.

Hygiene of the Mouth.—It is very important to keep the mouth and teeth clean, because various micro-organisms thrive readily in the mouth. They become mixed with the food and are swallowed; the poisons which they produce are absorbed into the body tissues, and give rise to serious results. Anæmia may be caused by bad teeth, and there is a fatal form of anæmia which may probably arise from this infection from the mouth. Very serious joint affections may have the same cause. Indigestion, and possibly appendicitis, may be results of bad teeth.

The causes of decay of teeth are predisposing and determining. Heredity may play a part, because some persons are, unfortunately, provided by Nature with a weak set of teeth.

Malnutrition from wrong feeding is a very important predisposing cause to dental caries; this is most important in the poorer classes of the community. The eating of sweets may be a predisposing cause.

An acute illness may arrest the development of the teeth.

The determining cause is the action of micro-organisms, which produce an acid fermentation of food particles between the teeth. Decay of the teeth can be prevented by regular and thorough cleansing of the teeth and mouth. The meals should be regular, and no food eaten between meals. The eating of fruit, like an apple, at the end of a meal will excite the flow of saliva and clean the mouth. Sweet, sticky substances which cling to the teeth should not be eaten last. The teeth should be cleansed every night by a stiff brush and water. Some simple tooth - powder should be used; carbonate of soda or powdered borax will serve very well.

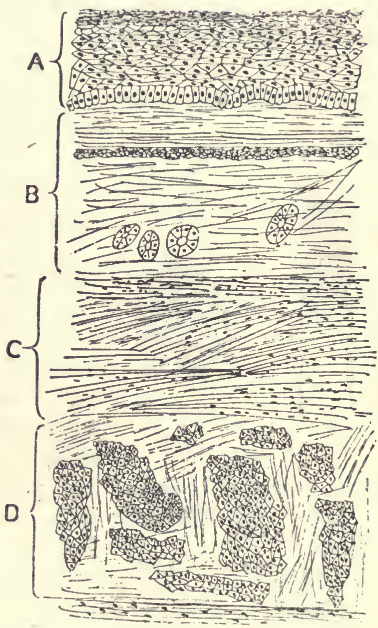

FIG. 39.—DIAGRAM SHOWING MICROSCOPIC STRUCTURE OF THE WALLS OF THE ŒSOPHAGUS.

A, Mucous membrane formed of stratified epithelium; *B*, submucous layer made up of connective tissue, and containing a few mucous glands; *C*, circular muscular coat; *D*, longitudinal muscular coat.

The Pharynx and Gullet. —The **pharynx** is the part of the alimentary canal which lies behind, and communicates with the mouth, the larynx, and cavities of the nose. It is a passage for air and food; the former is carried downwards along the windpipe to the lungs, and the latter along the œsophagus to the stomach.

The **œsophagus, or gullet,** is the part of the digestive canal which communicates with the pharynx above and the stomach below. It extends from the termination of the pharynx to the cardiac orifice of the stomach.

The function of the gullet is to carry the food from the mouth into the stomach. This is done by the process of swallowing, or deglutition. The food, having been broken up by the teeth and mixed with saliva, is gathered up by the tongue into a mass, or bolus, and forced between the pillars of the fauces into the pharynx. At the same moment the larynx is drawn upwards, so that the epiglottis covers its upper opening, and respiration for a short time ceases, and thus the food is prevented from entering the larynx and windpipe. The muscles at the floor of the mouth then contract and force the tongue backwards, which pushes the food before it into the pharynx. When the food enters the pharynx, the muscles of this tube contract and surround the bolus closely. The contraction of the pillars of the fauces and elevation of the soft palate prevent the regurgitation of the bolus to the nose or mouth, and therefore it is forced along the gullet to the stomach.

FIG. 40.—DIAGRAM SHOWING THE MECHANISM OF PERISTALSIS.

I., Diagrammatic representation of bolus of food in the alimentary canal; II., diagrammatic representation of a peristaltic wave. There is constriction above and dilatation below the bolus.

Throughout the alimentary canal food is moved along by a special form of movement of the digestive tube, and this is called "peristalsis"; it is a complex co-ordination of contraction and relaxation, so that above the bolus there is always contraction, and below it there is relaxation. Wherever in the body we find such a co-ordination of movements, they are found to be under the influence of certain groups of nerve cells. Those for the process of swallowing are situated in the central nervous system, or, to locate them more exactly, in the medulla oblongata of the brain. This is proved by cutting the nervous connection—namely, the vagi nerves—between the central nervous system and the œsophagus, when all swallowing movements will be stopped entirely. The act of swallowing is therefore brought about by a reflex action. The sensory nerves, stimulated by the presence of food, carry messages from the mouth and throat to the medulla oblongata, and there excite the motor nerve cells, which form impulses that cause the muscles of the pharynx and gullet to contract co-ordinately.

Physiology of the Stomach.

Anatomy.—The stomach is the dilated portion of the alimentary canal as soon as it enters the abdominal cavity. Its exact shape varies from time to time, according to the amount of food present and its relative position to surrounding organs. Anatomists generally describe it as being an irregularly pyriform - shaped structure. The broad portion is called the "cardia," and is directed backwards and to the left; while the narrow portion is called the "pylorus," and passess to the right to join the duodenum, or first portion of the small intestine. The stomach has two surfaces, superior and inferior; the former comes in contact with the diaphragm and under-surface of the left portion of the liver, and the latter lies on a portion of the diaphragm, left kidney, pancreas, and other important neighbouring organs.

The lesser curvature of the stomach is directed towards the liver, and the greater curvature is directed downwards and to the left. The stomach has two orifices: the cardiac orifice, by which it communicates with the œsophagus; and the pyloric orifice, through which it communicates with the small intestine.

Structure of the Stomach.—The stomach wall is composed of four coats—namely, from without inwards: (1) Peritoneal; (2) muscular; (3) submucous; (4) mucous.

The **peritoneal** or **serous coat** is made up of pavement epithelium lying on a basement membrane. This coat gives the outer surface of the stomach its smooth and glistening appearance.

The **muscular coat** is composed of involuntary muscle. The fibres are disposed of in three incomplete layers—an external or longitudinal, a middle or circular, and an internal or oblique. In the region of the pyloric orifice the circular layer becomes much thickened, and forms the pyloric sphincter.

The **submucous coat** is a layer of strong and loose con-

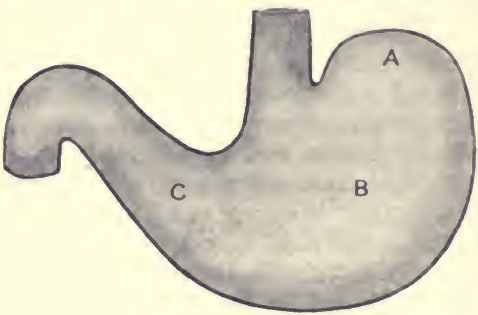

FIG. 41.—DIAGRAM SHOWING VARIOUS ANATOMICAL PARTS OF THE STOMACH.

A, Fundus ; *B*, cardia ; *C*, pyloric portion.

nective tissue, which connects the muscular and mucous coats. Bloodvessels, nerves, and lymphatics, ramify in this layer.

The **mucous coat** of the stomach is a soft thick layer. It is lined by columnar non-ciliated epithelial cells, and contains a large number of glands, which form the secretion of the stomach called the "gastric juice." On examining the inner surface of the stomach with a lens, a large number of small pits will be seen ; these are depressions of the mucous membrane, and are lined by the same kind of cells as those which cover the general inner surface of the

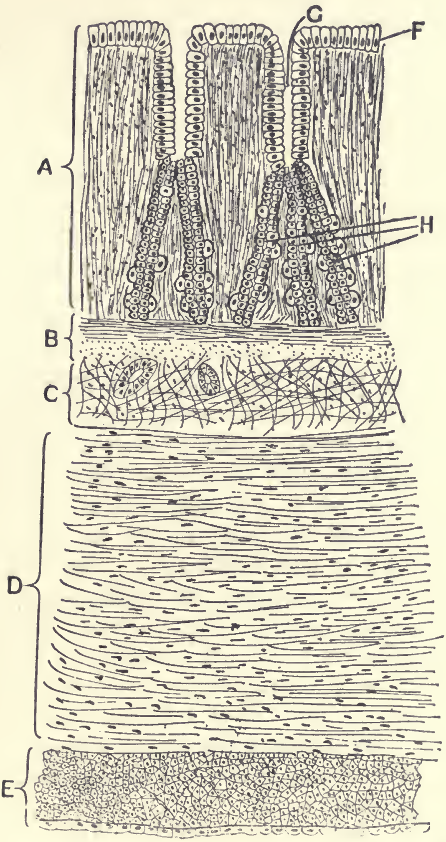

FIG. 42.—DIAGRAM SHOWING HISTOLOGICAL STRUCTURE OF THE WALL OF THE STOMACH.

A, Mucous coat, lined on the inner surface by columnar non-ciliated epithelium, and containing gastric glands, and their ducts supported by connective tissue; *B*, muscularis mucosæ; *C*, submucous coat made up of connective tissue, and containing a few mucous glands; *D*, circular muscular coat; *E*, longitudinal muscular coat; *F*, columnar non-ciliated épithelium; *G*, duct of gastric glands; *H*, gastric glands.

stomach. They form the ducts of the glands, and when a microscopic section is studied, one to four small tubular glands will be seen to open into each duct. In the spaces between the glands and the ducts there is connective tissue, containing a number of lymphocytes, or white blood-cells.

The **gastric glands** are small tubules, and are formed of a layer of secreting cells lying on a basement membrane. These cells are of two kinds : (*a*) The chief or pepsin cells are cubical in shape and granular in appearance ; these form the ferments that are present in the gastric juice. (*b*) The oxyntic or parietal cells are rounded in shape, and have acid properties ; they secrete the hydrochloric acid present in the gastric juice. The columnar lining, the general surface, and ducts, of the stomach secrete mucus.

Bloodvessels of the Stomach.—The arteries of the stomach are all derived ultimately from the cœliac axis, a branch of the aorta, as soon as it enters the abdominal cavity.

The veins follow the same course as the arteries, and finally all drain to the portal vein. The glands are surrounded with a close network of capillaries.

Nerves of the Stomach.—The stomach has two nerve-supplies : (*a*) Fibres which are connected with cells in the central nervous system : these run in both vagi nerves, sometimes called the "pneumogastrics"; (*b*) fibres connected with cells in the sympathetic system : these come from the solar plexus in the abdomen, and run in the sheath of the bloodvessels.

The Gastric Juice.—The digestive secretion of the glands of the stomach is called the "gastric juice," and the following are its most important constituents : Water, salts (chiefly chlorides of sodium, potassium, magnesium, and calcium), hydrochloric acid, pepsin, and rennin.

Activity of the Gastric Glands.—The gastric juice is not secreted continuously, except in animals, such as the rabbit, whose stomachs are never empty. There are two methods by which the gastric glands are stimulated to activity :

The idea or sight of food, and the tasting and mastication of it, act as a stimulus to the gastric glands. This is done reflexly through the nerves of special sense and the vagi. The second mode of stimulation is by the direct action of the food on the gastric mucous membrane, and this is due to the formation of a chemical substance—a hormone, or messenger—which is absorbed into the blood-stream, and acts as a stimulus to the gastric glands.

Chemistry of the Gastric Juice.—The hydrochloric acid is present in the free state, and is formed in certain special cells of the cardiac portion of the stomach. It forms an acid medium for the pepsin to act in. *Pepsin* is a proteolytic enzyme, splitting up the proteins of the food into proteoses and peptones, and, if continued long enough, into amino-acids.

Rennin is a ferment present in gastric juice, which causes the coagulation of milk. It acts on caseinogen, a protein in milk, converting it into casein, and this combines with calcium to form calcium caseinate, which constitutes the clot.

A *fat-splittng ferment*, or *lipase*, is said to be present in the gastric juice. This breaks up fat into fatty acids and glycerine.

Changes undergone by the Food in the Stomach.—When the food, which has been broken up by the teeth and mixed with alkaline saliva, reaches the stomach, the ptyalin ferment continues to act upon the starch for some little time. The food which entered the stomach first is in contact with the stomach wall, and absorbs the gastric juice; while the food which entered last lies in the middle, and is acted on by the saliva. As soon as the gastric juice is secreted in sufficient amount to make the food acid, the ptyalin is destroyed and its action stopped.

The starchy constituents of food are therefore hydrolyzed in the stomach by action of the ptyalin of the saliva.

The proteins of food are digested by the action of pepsin.

The fats of the food are melted by the heat of the stomach, and hydrolyzed to a certain extent by its lipase.

Absorption in the Stomach.—It is doubtful how much of the food is absorbed from the stomach. It is possible that there may be absorption of the following substances : Salts, sugars, and dextrins, that may have been formed by the action of saliva on starches of the food, or that may have been eaten as such ; the proteoses and peptones formed as the result of digestion of proteins in the stomach itself. There is also some evidence that certain drugs—*e.g.*, alcohol —are absorbed from the stomach. It was formerly assumed that the stomach absorbs easily such things as water, salts, sugars, and peptones. Experimental work performed under conditions as nearly normal as possible tends to prove that absorption does not take place readily in the stomach—certainly nothing like so easily as in the intestine.

Movements of the Stomach.—It can be readily proved that the stomach exhibits certain definite muscular movements. This can be seen in animals, by killing them and opening the abdomen quickly and examining the stomach. In man, under certain diseased conditions, when there is obstruction at the pyloric orifice, the movements of the stomach are exaggerated, and can be seen through the abdominal wall.

The muscular part of the stomach is made of involuntary or unstriped muscle ; hence the movements are not under the control of the will, as are movements of the skeletal or striped muscle. Even when the stomach is cut off from all connection with the central nervous system the movements still continue ; hence the contractions of the stomach wall have their origin in the stomach itself. There are networks of nerve fibres and cells in the coats of the stomach which maintain its movements. The nerves which supply the stomach may reinforce or check these movements.

The stomach may be divided anatomically and functionally into two parts—the fundus and the pylorus. The fundus serves as a receptacle for the food, and its movement is peculiarly adapted to its function ; that is, during the taking in of food it gradually dilates, and as digestion goes on it tonically contracts upon its contents, and pushes them towards the pylorus.

In the pyloric portion the food is further broken up and mixed thoroughly with the gastric juice, and here we have a *series of waves of contraction*, which start about the junction of the pylorus and fundus and pass towards the pyloric orifice. The effect of these waves is to force the food, which has been digested by the gastric juice and detached from the surface of the mass of food in the fundus, towards the pylorus. The pyloric sphincter remaining closed, the food cannot escape, and therefore is squeezed back, forming an axial reflux stream towards the fundus.

The opening and closing of the pyloric orifice is regulated by the local nervous mechanism, and the adequate stimulus for its opening is a certain consistency and a certain acidity of the contents of the stomach. Acidity on the stomach side of the pyloric sphincter makes it open, while acidity on the duodenal side makes it shut. Thus the acid chyme passes slowly into the intestine in a succession of squirts.

When the food has passed from the stomach to the small intestine, it then comes in contact with a series of alkaline digestive secretions. These neutralize the acid chyme. The pancreatic juice comes from the pancreas, the bile from the liver, and the intestinal juice is formed in the glands of the small intestine. We shall have to deal separately with these three secretions.

Physiology of the Pancreas.

Anatomy of the Pancreas.—The pancreas is an elongated glandular structure which lies transversely on the posterior abdominal wall. Its right end, or head, rests in the concavity of the first portion of the small intestine, which is called the "duodenum," and its left end, or tail, touches the spleen, an organ on the left side of the upper part of the abdominal cavity. The intervening part, or body, lies in front of the great vessels of the abdomen, and behind the stomach and intestines.

Histology of the Pancreas.—The pancreas is made up of a large number of branching tubes ending in dilatations

FIG. 43.—ABDOMINAL VISCERA DISPLAYED SO AS TO SHOW THE PORTAL VEIN CARRYING THE BLOOD FROM THE VISCERA TO THE LIVER.

l., Liver; *gb.*, gall-bladder; *st.*, stomach; *du.*, duodenum. These have been divided from each other. *p.*, Pancreas; *sp.*, spleen; *ac*, *cd*, large intestine. The bile-duct is shown sending off a side-branch to the gall-bladder on its way to the duodenum.

called "alveoli," which are lined by secretory cells. It resembles the salivary glands in its general structure, but its alveoli are more tubular and elongated in shape; the connective tissue is looser in character, and small groups of epithelioid cells are distributed amongst the alveoli, and are called the "islets of Langerhans."

Pancreatic Juice.—The pancreatic juice is a colourless alkaline fluid. It contains a little protein, salts, and ferments. The chief salt is sodium carbonate, which renders the juice alkaline. The ferments present are trypsin, which breaks up protein; amylopsin, which converts starch to maltose; steapsin, which hydrolyzes fats to fatty acids and glycerine; and in some animals there is a milk-curdling

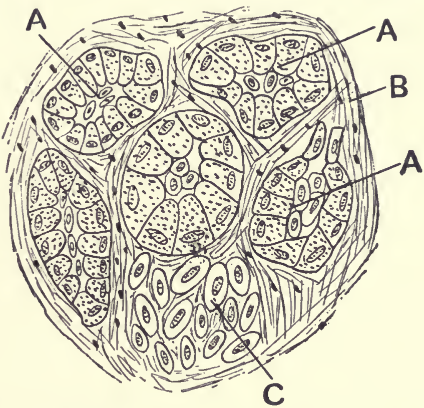

FIG. 44.—DIAGRAM SHOWING HISTOLOGICAL STRUCTURE OF PANCREAS.
A, Pancreatic alveoli; *B*, connective tissue; *C*, islets of Langerhans.

ferment. All these ferments will only act in the presence of dilute alkali.

Hence we may tabulate the composition of pancreatic juice as follows:

Water	97·6 per cent.	
Inorganic salts ..	0·6 ,,	Sodium chloride. Sodium carbonate. Potassium chloride, etc.
Organic solids ..	1·8 ,,	Trypsin. Amylopsin. Steapsin. Milk-curdling ferment. Traces of other substances.

Mechanism of Secretion in the Pancreas.—Pancreatic juice does not flow continuously into the small intestine, but only at certain definite intervals. It was noticed, by experimentation in animals, that the flow of pancreatic juice was always greatest about three hours after the taking of food, and this coincides with the time at which there is the greatest flow of chyme from the stomach to the duodenum ; hence physiologists thought that there was some association between these two phenomena.

The question arose, What constituent of the chyme acted as the requisite stimulus to the pancreas ? It was easily proved that it was the acid present in the gastric contents that acted as the adequate stimulus to the secretory activity of the pancreas.

The next question to be answered was, How did the acid act ? The first theory regarding its mode of action was that the acid stimulated certain nerve endings in the mucous membrane of the small intestine, nerve impulses passed from it to the central nervous system, and here impulses were generated that passed back to the pancreas and excited it to activity. For such a process to take place, all the nervous connections between the pancreas, small intestine, and the central nervous system, should be intact. It was shown that, if a loop of the intestine was entirely devoid of all nerve connections, the introduction of acid into this loop still caused a secretion of pancreatic juice ; and, further, the introduction of acid directly into the blood-stream through the jugular vein did not excite a secretion. The only difference was that in the first case the acid comes into contact with the mucous membrane of the loop of intestine. It was further proved that, on treating the mucous membrane of the upper part of the small intestine of any animal with hydrochloric acid, and filtering, the injection of the filtrate into the jugular vein of another animal caused a profuse secretion of the pancreas. Hence here we have a chemical mode of stimulation : the hydrochloric acid of the gastric juice acts on the mucous membrane of the upper part of the small intestine, and liberates from it a chemical substance called "secretin," which is absorbed by the blood, carried to the pancreas, and stimulates its alveoli to activity.

Action of the Pancreatic Juice.—The digestive action of the secretion depends upon the three enzymes—trypsin, amylopsin, and steapsin.

Trypsin converts proteins into proteoses, peptones, and finally amino-acids.

Amylopsin acts on starch and breaks it up into dextrins, and finally maltose.

Steapsin is the name given to the fat-splitting ferment; it breaks up fat into glycerol and fatty acids.

The following experiments should be performed to show the action of the pancreatic juice: Obtain the pancreas of a pig from a butcher. Chop it up and soak it in a weak solution of sodium carbonate (1 part by weight in 100 of water). Keep the mixture warm for some hours, and finally strain off the liquid.

Add some of this artificial pancreatic juice to egg-white or a piece of meat, and keep it on a water-bath at the temperature of the body for half an hour. The trypsin will break up raw or coagulated protein first into soluble peptone, and later into amino-acids. Apply the biuret test to the protein solution at various stages in the reaction. At first, when the protein is unchanged, a violet coloration will be formed; later it will be pink in colour, showing the presence of proteoses and peptones; and finally no colour will be given, when the protein has been completely hydrolyzed to amino-acids.

Add some of the juice to a solution of starch, and keep this also at body temperature. The starch will be turned by the starch-splitting ferment, or amylopsin, into sugar. Test with iodine; no blue colour will result. Then apply Trommer's test by boiling a sample with a little copper sulphate solution rendered alkaline by caustic potash; a yellow-red precipitate will be obtained.

Bile.

Another digestive fluid that comes in contact with the food in the small intestine is the bile. It is formed in the liver, and carried from there to the duodenum by means of a series of tubes called the "bile-ducts."

From a physiological standpoint bile is partly an excretion carrying off waste products, and partly a digestive secretion playing an important rôle in the absorption of fats, and possibly in other ways. Bile is continuously formed in the liver, but in animals that possess a gall-bladder its ejection into the duodenum is intermittent.

Composition of Bile.—The following are the most important constituents of bile :

Water.
Inorganic salts : Sodium chloride, sodium carbonate, etc.
Sodium taurocholate.
Sodium glycocholate.
Mucin.
Bile pigments : Bilirubin and biliverdin.
Cholesterin.
Lecithin.
Soaps.

Sodium Taurocholate and Glycocholate.—These are the bile salts ; the digestive function of bile is due to their presence, because they facilitate the splitting and absorption of fats in the small intestine ; and they also serve as a menstruum for dissolving the cholesterin and lecithin, which are constantly present in bile, and are excretions to be removed.

Bile Pigments.—There are two pigments generally present in bile, called "bilirubin" and "biliverdin." These pigments are derived from the hæmoglobin, and are therefore waste products of the red corpuscles of the blood. In the intestine these pigments are reduced to a substance called "stercobilin," which is the colouring matter of the fæces. A portion of these pigments are absorbed, and give rise to the pigments of the urine.

Cholesterin is found in all animal cells, and is an important constituent of the cell walls of animal tissue. It is said to be an alcohol of the terpene series. It is soluble in chloroform, and can be readily crystallized.

Lecithin is a complex compound containing glycerol, fatty acids, phosphoric acid, and an organic base called "cholin."

Mucin is formed by the living membrane of the gall-bladder and bile-ducts. It makes the bile viscid and

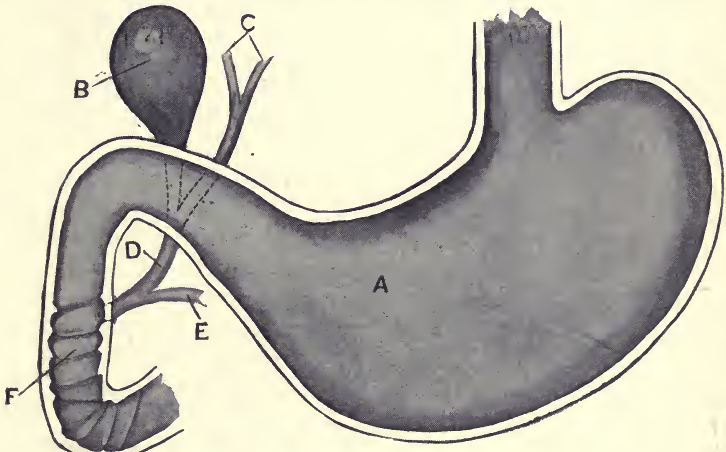

FIG. 45.—DIAGRAM SHOWING ANATOMICAL RELATIONS OF THE STOMACH, GALL-BLADDER, BILE-DUCT, PANCREATIC DUCT, AND DUODENUM.

A, Stomach; *B*, gall-bladder; *C*, right and left hepatic bile-ducts; *D*, common bile-duct; *E*, pancreatic duct; *F*, duodenum.

slimy. Mucin is readily precipitated on the addition of acetic acid, and is insoluble in excess.

Tests for Bile.—Obtain some bile from a butcher, and perform the following experiments:

1. Note its colour and slimy nature.

2. Add some acetic acid or vinegar to a portion of bile. A stringy precipitate of mucin is formed.

3. Pour a little bile into a white basin, and add to this a few drops of fuming nitric acid. A display of colours will result. This is called "Gmelin's test," and is due to the presence of bile pigments.

4. Place a little bile in a white basin, and dilute it with water; add a little solution of cane-sugar and sulphuric acid. On warming, a beautiful purple colour results. This is called "Pettenkofer's test," and is due to the presence of bile salts.

Physiological Rôle of Bile.—Bile has both excretory and secretory functions. It is of importance as an excretion in that it removes from the body waste products of metabolism, such as cholesterin, lecithin, and bile pigments.

Its most important secretory function is the part it takes in the digestion and absorption of fats. It accelerates greatly the action of the fat-splitting ferment of the pancreatic juice in breaking up the fats into fatty acids and glycerol, and it further helps in the absorption of the products of this reaction.

Whenever bile is prevented from reaching the intestinal canal, a large portion of the fat of the food escapes absorption, and is found in the fæces. This occurs in human subjects when the bile-passages are blocked by stones or new growth; then we find the fæces are very pale, due to absence of pigment, and are very offensive, due to decomposing fatty acids. The bile is then absorbed into the blood-stream, and gives rise to yellow pigmentation of the skin, called "jaundice."

The older physiologists thought that bile prevented excessive putrefaction in the intestine. This idea is probably erroneous, because bile has very weak, if any, antiseptic properties. The addition of bile or bile salts to the contents of the stomach causes precipitation of the unaltered native protein, and it has been suggested that by thus precipitating the constituents of the chyme, which have not been carried to the peptone stage, bile prepares them for the action of pancreatic juice.

Physiology of Small and Large Intestine.

Anatomy.—The small intestine is the portion of the digestive tube which lies between the stomach and the beginning of the large intestine. It commences at the pyloric orifice of the stomach, and ends at the ileo-cæcal opening, where it joins the large intestine. It occupies the greater portion of the abdominal cavity below the liver and stomach.

Structure of Small Intestine.—The wall of the small intestine, like that of the stomach, is made up of four coats.

The **outer** or **serous coat** is formed of peritoneum, and is complete throughout the small intestine, except for part of the duodenum.

The **muscular coat** is composed of two layers of muscular tissue, an outer longitudinal and an inner circular, and between the two there is a gangliated plexus of nerves.

The **submucous coat** is made up of connective tissue, and in it the blood-vessels and lymphatics ramify before entering or after leaving the mucous membrane. It also contains a gangliated plexus of nerve fibres.

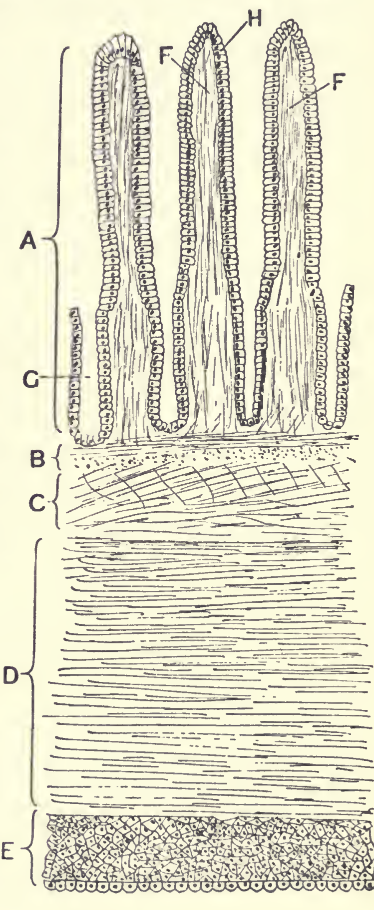

FIG. 46. — DIAGRAM ILLUSTRATING THE MICROSCOPIC STRUCTURE OF SMALL INTESTINE.

A, Mucous coat; *B*, muscularis mucosæ; *C*, submucous coat; *D*, circular muscular coat; *E*, longitudinal muscular coat; *F*, villus; *G*, intestinal gland, or crypt of Lieberkühn; *H*, layer of columnar non-ciliated epithelium.

The **mucous coat** is lined with a layer of columnar epithelium lying on a basement membrane of connective tissue. It also contains simple tubular glands, called the "crypts of Lieberkühn."

The lining membrane of the intestine between the glands is thrust out in the form of finger-like processes; these are called "villi," and serve to increase its area of absorption. Inside this protrusion of mucous membrane we find a framework of connective tissue, a few lymphocytes, an artery, vein, network of capillaries, and a lymphatic or lacteal.

Secretion of Glands of Small Intestine.—The following are the most important constituents of intestinal juice:

Water.
Salts: Sodium chloride, potassium chloride, sodium carbonate, etc.
Erepsin, enterokinase.
Invertase.
Maltase.

Erepsin is a ferment which breaks up proteoses and peptones into amino-acids. It is said not to have any action on native proteins.

Invertase is an enzyme which converts cane-sugar to a mixture of glucose and fructose.

Lactase breaks up lactose into galactose and glucose.

Maltase hydrolyzes maltose into glucose.

Enterokinase is a substance which activates trypsinogen, the inactive form of trypsin.

Changes undergone by Food in the Small Intestine.—In the small intestine food is acted upon by three digestive secretions—namely, the pancreatic juice, intestinal juice, and the bile.

The proteins of the food, after being partly digested in the stomach, are further hydrolyzed into amino-acids by the action of trypsin and erepsin.

The starchy constituents of the food which have escaped the action of ptyalin of the saliva are converted into maltose by the action of amylopsin of the pancreatic juice.

Maltose is broken up into glucose by the action of the maltase of intestinal juice.

Lactose is hydrolyzed by the action of lactase into galactose and glucose.

Cane-sugar is split up into glucose and fructose by the action of invertase.

Fats by the action of bile and steapsin are emulsified, and then hydrolyzed to glycerol and fatty acids.

Large Intestine. — The large intestine extends from the termination of the ileum to the anus. It is about 5 feet in length, being about one-fifth of the whole extent of the intestinal canal. It is largest at its commencement at the cæcum, and then diminishes as far as the rectum, where there is a dilatation of considerable size just above the anus.

FIG. 47.—THE VALVE BETWEEN THE LARGE AND SMALL INTESTINE.

a, Small intestine; *b*, large intestine; *e*, *f*, valve; *g*, appendix.

Absorption. — Absorption is the process by which the foodstuffs are taken up from the lumen of the gut into the blood or lymphatic stream.

One of the great functions of the small intestine is to absorb the digestive products of the food, which have been formed by the action of the gastric juice, the bile, pancreatic juice, and the intestinal juice. The columnar cells which line its walls perform the work of absorption, and, since they must absorb sufficient food for the whole body, the small intestine is about 20 feet long, and its absorbing surface is greatly increased by the folding in of mucous membrane in the form of valvulæ conniventes and villi.

The columnar cells which line the intestine have the power to take up the various products of hydrolysis of the foodstuffs, and to pass them along into the capillaries or

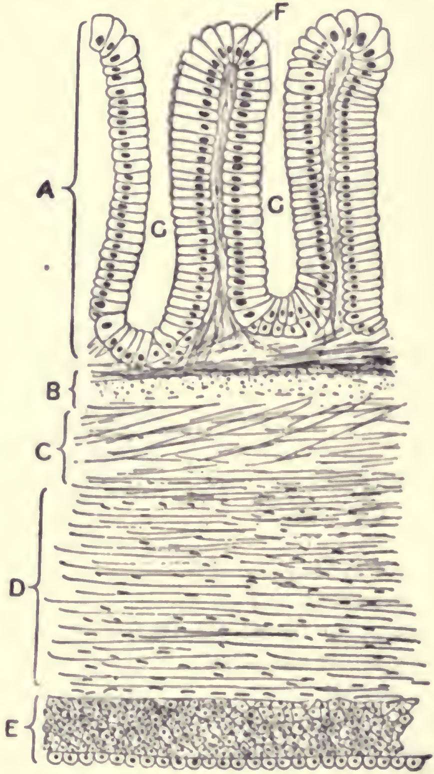

FIG. 48.—DIAGRAM SHOWING THE MICROSCOPIC STRUCTURE OF LARGE INTESTINE.

A, Mucous coat; *B*, muscularis mucosæ; *C*, submucous coat; *D*, circular muscular coat; *E*, longitudinal muscular coat; *F*, layer of columnar non-ciliated epithelium lining the large intestine; *G*, glands of large intestine.

lacteals. By some extraordinary means the products of hydrolysis of proteins—namely, amino-acids—and those of the carbohydrates—namely, sugars—are carried to the blood-capillaries; while the products of hydrolysis of fats are re-formed into fats and carried along the lymphatics or lacteals.

Absorption is no mere physical process of diffusion and filtration. It must be taken into account that the cells through which the absorbed substances pass are living, and, in virtue of their vital activity, not only select materials for absorption, but also change these substances while in contact with them. Also, when the cells lining the intestine are removed or rendered inactive by sodium fluoride. absorption practically ceases, though the opportunities for simple filtration or diffusion would by such means be increased.

Absorption of Carbohydrates.—All the starches and compound sugars are hydrolyzed to the simple sugars before absorption, and the carbohydrates are mainly absorbed as glucose.

After absorption the glucose is carried along the portal vein to the liver, and there stored up temporarily as glycogen.

Absorption of Proteins.—The proteins of the food are converted by the proteolytic enzymes of the digestive juices into amino-acids, and are absorbed as such. They are taken up by the blood-capillaries of the intestines, carried along the portal vein to the liver, where the nitrogenous moiety is often broken off and converted to urea, and the other moiety changed to glycogen. Some of the amino-acids are allowed to pass through the liver, and are used in the building up and repair of the tissues.

Absorption of Fats.—Fats are hydrolyzed during the process of digestion into glycerol and fatty acids. The columnar cells of the intestine resynthesize the fats after absorption from their components. The lymphatic vessels or lacteals of the villi take up the fat, and it is carried along the main lymphatic vessels, which open into the great veins at the root of the neck.

Fæces are the waste products of the digestive system. They differ greatly in amount and in composition with the character of the food. Their amount is greatest on a vegetable diet containing large quantities of cellulose; with a protein diet, on the other hand, they are small in amount and dark in colour.

The most important constituents of fæces are—

1. Indigestible material, such as ligaments of meat or cellulose from vegetable.
2. Undigested material, such as fragments of meat, starch, or fats, which have in some way escaped the action of the digestive juices.
3. Products of bacterial decomposition, such as indol and skatol. They possess a disagreeable fæcal odour.
4. Pigments—stercobilin and urobilin.
5. Inorganic salts—salts of sodium, potassium, calcium, magnesium, and iron.
6. Bacteria, which form a large proportion of the weight of fæces.

Movements of the Small Intestine.—In the small intestine two kinds of movements are to be seen:

1. Segmentation movement. Both the longitudinal and the circular muscular coats contract, causing alternating segment of constriction and dilatation. This type of movement may originate at any part of the gut. The function of these movements is to break up the food into smaller particles, and mix it thoroughly with the digestive juice of the intestine.
2. Peristaltic movements — waves of constriction preceded by a wave of relaxation of the muscular coat of the intestine. These are the movements which carry the food along the alimentary tract.

Movements of the Large Intestine.—These differ from those of the small intestine mainly in the great frequency of antiperistalsis—that is, a wave of peristaltic movement running in the opposite direction to what it does in the small intestine. It is to prevent the contents of the large intestine passing along too quickly, and therefore allow time for the absorption of water, which is one great function of the large intestine.

Defæcation is partly a voluntary and partly a reflex act. But in the infant the voluntary control has not yet been developed; in the adult it may be lost by disease.

The fæces gradually accumulate in the pelvic colon and rectum, and by their presence stimulate the sensory nerves of the rectum and produce a distinct sensation and desire to defæcate.

The involuntary factor is found in the contractions of the strongly-developed musculature of the rectum, especially the circular layer, which serves to force the fæces onwards; and there is also relaxation of the internal sphincter.

The voluntary factor in defæcation consists in the inhibition of the external sphincter, a muscle which closes the anus, and the contraction of the abdominal muscles.

Physiology of the Liver.

The liver is one of the most important organs in the body. It is situated in the upper part of the abdomen; its upper convex surface fills the dome of the diaphragm on the right side. Since it is situated near the diaphragm, it is pushed down and compressed by its contraction. Muscular exercise increases respiratory movements; it will quicken the circulation in the liver, and therefore prevent its congestion. It is a very vascular organ, and contains about one-fourth of the blood in the body. It is divided into five lobes by five fissures. Into one of these fissures, called the "transverse fissure," pass the portal vein, the bile-duct, and an artery—the hepatic artery.

At the upper edge of the posterior surface two large veins issue, called the "hepatic veins"; these carry blood away from the liver, and after a very short course open into the inferior vena cava, which passes in close relationship to the posterior surface of the liver.

If a section of the liver be examined microscopically, it will be found to be made up of polyhedral masses, composed of cells, separated from one another by connective tissue.

Each of these masses, or lobule, is penetrated by a fine network of connective tissue, which helps to support the

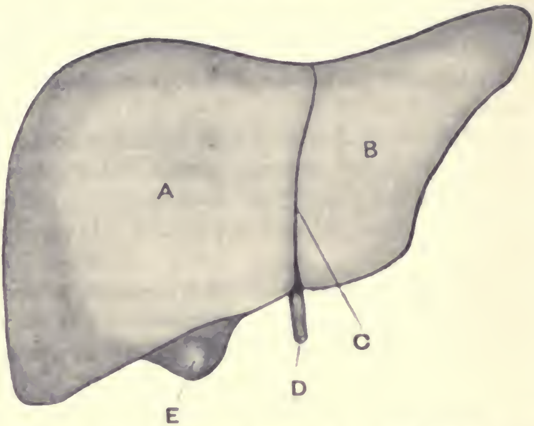

FIG. 49.—ANTERIOR SURFACE OF THE LIVER.

A, Right lobe; *B*, left lobe; *C*, longitudinal fissure; *D*, round ligament; *E*, gall-bladder.

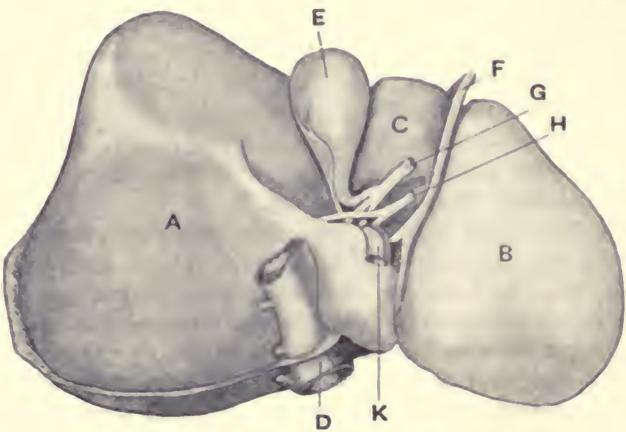

FIG. 50.—UNDER-SURFACE OF THE LIVER.

A, Right lobe; *B*, left lobe; *C*, quadrate lobe; *D*, inferior vena cava; *E*, gall-bladder; *F*, round ligament; *G*, bile-duct; *H*, hepatic artery; *K*, portal vein.

columns of cells within the lobule. The bloodvessels which enter the liver through the portal fissure—namely, the portal vein and hepatic artery—finally break up to very small branches, which penetrate to the intervals between the hepatic lobules.

On leaving the hepatic lobules, these bloodvessels are joined together, and finally form the hepatic veins.

The bile-ducts commence as very small channels in between the liver cells ; these finally join up and form one

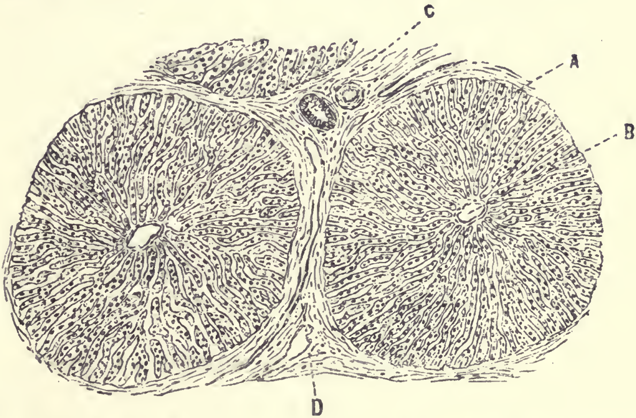

FIG. 51.—MICROSCOPIC SECTION THROUGH A FRAGMENT OF THE LIVER SHOWING TWO LOBULES.

A, Liver cells ; *B*, branch of hepatic vein ; *C*, branch of bile-duct; *D*, branch of portal vein.

duct, which leaves the liver by the portal fissure, and opens into the first stage of the duodenum.

Functions of the Liver.—It has been said above that the carbohydrate of the food is converted to grape-sugar or glucose by the action of the digestive juices, and carried as such in the portal vein to the liver.

If this sugar is not required in other parts of the body, it is converted by the liver cells into glycogen ; this is a carbohydrate similar to starch, but gives a red coloration with iodine. Therefore the liver is a temporary storehouse for carbohydrate food after absorption.

The proteins of the food are converted by the action of the enzymes of the alimentary canal into amino-acids, and are absorbed as such into the portal vein and carried to the liver. The amino-acids are made up of nitrogenous and non-nitrogenous moieties. The greater part of the nitrogenous moiety is cut off from the amino-acids in the liver and converted to urea, while the non-nitrogenous moiety is converted to glycogen. The liver is the most important site of formation of urea.

The red cells of the blood are continually being formed in the red marrow of bone, and after a certain period of activity they are destroyed in various parts of the body; their pigment or hæmoglobin is discharged, and carried to the liver, and there converted into the pigments which are found in the bile.

The liver also manufactures the bile, which is partly a digestive secretion and an excretion. (For properties and function of bile, see pp. 92.)

Ductless Glands.—There are a number of glandular structures in the body which have no ducts, but their secretion is poured into the blood-stream and carried to all parts of the body. Their secretory products have various important functions. The spleen, the thyroid, and the suprarenal capsules, are examples of the ductless glands.

The Thyroid Gland.—This gland lies on the anterior aspect of the neck. It consists of two lobes lying on each side of the trachea, and an isthmus which passes in front of the trachea. It is surrounded by a capsule of connective tissue, and the glandular portion is made of minute sacs; each sac is lined by a layer of cells, and contains a glassy-looking substance.

If the gland is not developed, the child grows up a cretin. Bodily and mental growth is arrested, and an adult cretin will remain the size of a child and behave like a child. If a cretin be fed on thyroid glands taken from sheep, his condition will greatly improve, and he may develop like a normal child, but he will have to take thyroid continuously. If the thyroid degenerates prematurely in older people, a very peculiar condition called "myxœdema" results; there is mental dulness, physical inactivity, increase in the fat under the skin; the hair falls out.

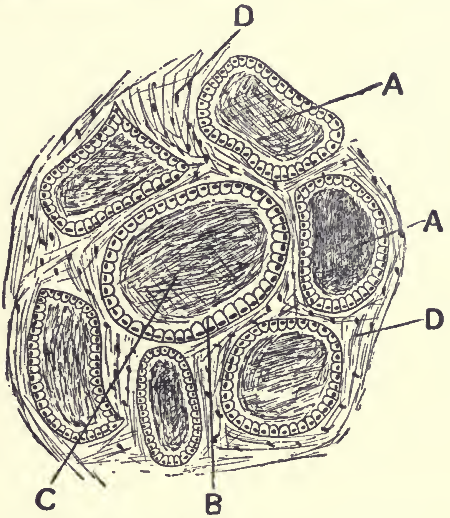

FIG. 52.—DIAGRAM SHOWING MICROSCOPIC STRUCTURE OF THYROID GLAND.

A, Alveoli; *B*, cubical cells lining alveoli; *C*, colloidal material inside alveolar cavity; *D*, connective tissue.

It is therefore evident that the thyroids produce a substance that is essential for the proper growth and the tissue changes of the body.

Suprarenal Capsules.—These are two small structures situated in the abdomen. One rests on the top of each kidney. If they are both removed in an animal, death results in a few days. Man rarely suffers from a diseased condition of these glands. The symptoms and signs are very characteristic: pigmentation of the skin, vomiting and diarrhœa, great physical exhaustion. If an extract of the central portion of the suprarenal capsule be injected under the skin, it causes great rise in blood-pressure; or if it is applied to the external surface of a wound, it causes constriction of the vessels and stops bleeding. It is thought that the suprarenal gland secretes an active substance called "adrenalin," which keeps up the tone of the sympathetic nervous system.

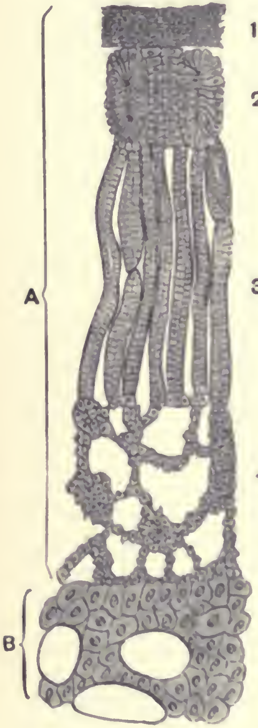

Fig. 53. — Microscopic Structure of Suprarenal Capsule.

A, Cortex; *B*, medulla; 1, 2, 3, 4, various layers making up the cortex.

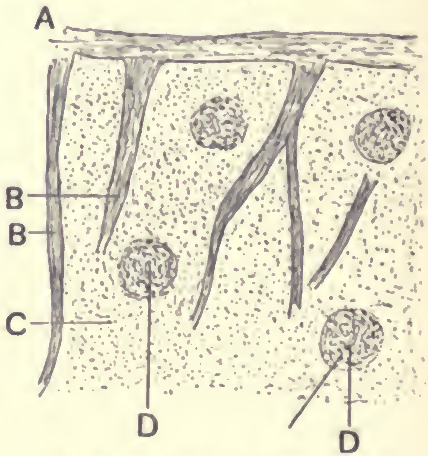

Fig. 54.—Microscopic Structure of Spleen (Low Power).

A, Capsule; *B*, trabeculæ; *C*, spleen pulp containing various cells; *D*, aggregation of lymphocytes around some small arterioles.

The Spleen.—This is another ductless gland, and is situated in the upper part of the abdomen, on the left side and behind the stomach.

The exact function of it is not known; it can be removed from the body without any deleterious results. It is probably a site of destruction of red blood-corpuscles; it certainly forms certain kinds of white blood-corpuscles. It undergoes rhythmic expansion and contraction, and this is said to help the movement of the blood along the portal veins.

Food and Nutrition.

It has been said above that life is maintained by the oxidation of the foodstuffs in the tissues. Such oxidation results in the formation of water, carbon dioxide, and other waste products, which are eliminated. Concurrently with this oxidation we should expect a loss in weight, and this is found to be the case. Thus, if a man be weighed by means of a sensitive balance, loss of weight will be registered, which gradually increases as the interval of time from the last meal lengthens. When a meal is taken, the weight will suddenly increase by an amount equal to the weight of the food taken in; but immediately afterwards the weight will commence to decrease, and continue to do so until the next meal, when the weight will again go up by a corresponding amount.

At the end of twenty-four hours a man will be found to have much the same weight as he did at the beginning, for practically all the food taken in has been oxidized and its waste products eliminated.

If the same experiment were performed with a child, it would be found that he would have gained in weight, for in it the intake is greater than the loss.

On the other hand, if the weight of a man that was starving or doing very hard muscular work were taken at the beginning and end of twenty-four hours, it would be found that there would be a loss in weight.

In a healthy adult the main objects of a diet are to furnish sufficient nitrogenous and non-nitrogenous foodstuffs, salts, and water, to maintain the body in equilibrium of material and energy; that is, the diet must furnish the material for the regeneration of tissue, and the material for the heat produced and the muscular work done.

The diet of a child must supply the necessary amount of energy for the production of heat and all activities of the body, the repair of the tissues and the building up of new tissues, which take place during growth.

At the beginning of this section it was said that foodstuffs may be divided into three main classes—the carbohydrates, fats, and the proteins.

Carbohydrates have three main uses to the body:

1. They furnish a source of energy for muscular work. All the carbohydrates are converted to grape-sugar before they can be absorbed, and this, when it passes to the liver, becomes converted to glycogen; or it may be stored in the muscles as glycogen. It has been proved that the glycogen of a muscle disappears in proportion to the work done by the muscle. Under normal conditions this material furnishes the main, if not the sole, source of energy for muscular work.

2. The oxidation of the sugar results in the formation of heat. The heat of the body is produced by the oxidation of these substances in the muscles.

3. The oxidation of the sugar protects the proteins of the body. It will be shown later on that proteins are absolutely essential to the body. Man could live on protein food alone, but life could not be sustained on a diet made up of starches and fats entirely.

It would not be advisable for man to live on a protein diet alone, because the amount of protein that he would have to take would be so large that it would throw too much work on some of the internal organs—namely, the liver and the kidneys. Life can be properly sustained on a much smaller amount of protein if carbohydrate food is increased, and therefore physiologists state that the starches and sugars act as protein-sparers, in addition to being a source of heat and energy.

Fats have important nutritive functions, which correspond very closely with those of the carbohydrates:

1. During their oxidation in the body they give rise to a large amount of heat, because 1 gramme of fat yields 9,300 calories of heat, twice as much as 1 gramme of carbohydrate or protein. (A calorie is the amount of heat necessary to raise 1 gramme of water through 1° C.) Hence

we find inhabitants of cold regions choosing a diet that is very rich in fat.

2. Fats are protein-savers, because their oxidation protects the protein from consumption ; but in this respect fat is not so effective as an equivalent amount of carbohydrate food.

Another very important function of fat is that it provides a store of reserve food, which is used up by the body in case of deficiency of food or complete starvation. The fat in the skin acts as a natural garment, keeping in the body heat, and rounding off the figure and giving beauty and softness of form.

Proteins are absolutely essential for the maintenance of life, and their functions may be briefly summarized as follow :

1. They are the essential factors in the building up of tissues, and repairing the changes due to the wear and tear of the body.

2. They serve as a source of body heat and other forms of energy, but for this purpose carbohydrates and fats are better, because they are cheaper and do not throw such stress on the digestive organs.

Since childhood is the period at which there is the greatest amount of building up of the tissues, it is impossible to exaggerate the importance of a sufficiency of protein in the diet of children. No doubt much of the feebleness, flabbiness, and pallor, of the children of the poorer classes in large towns are due to a lack of it.

The following figures have been quoted from Dr. Robert Hutchison's "Diet and Dietetics." They show the amount of each nutritive ingredient required at different ages.

Age.	Protein.	Fat.	Carbohydrates.
1½ years ..	42·5 grammes	35 grammes	100 grammes
2 ,, ..	45·5 ,,	36 ,,	110 ,,
3 ,, ..	50 ,,	38 ,,	120 ,,
4 ,, ..	53 ,,	41·5 ,,	135 ,,
5 ,, ..	56 ,,	43 ,,	145 ,,
8–9 ,, ..	60 ,,	44 ,,	150 ,,
12–13 ,, ..	72 ,,	47 ,,	245 ,,
14–15 ,, ..	79 ,,	48 ,,	270 ,,

Nutritional Disorders.

Overeating.—There is no doubt that under conditions of modern civilization a large number of people eat too much. This involves greater work on the digestive system, the liver, and the kidneys. For some years they are able to cope with this extra work, but later on we find the organs of the body prematurely decay, the bloodvessels become thickened, the blood-pressure is increased, and great work is thrown on the heart, which prematurely becomes exhausted. Dyspeptic troubles in young adults are very often due to overfeeding.

It is said that many men used to a luxurious life are enormously improved in health by the hard diet and hard labour of a prison. Centenarians are not found among the luxurious, but among those who have lived sparingly and have worked hard throughout their lives.

Underfeeding amongst the poorer classes is a very common cause of a weak physique, and predisposes the body to all forms of disease. Unless the body is supplied with sufficient food to carry out its functions and build up new tissues during growth, the individual will grow up having a weak constitution, will be attacked by various diseases, and will not become a useful member of the community.

Decomposing Foods give rise to irritation of the alimenmentary system, resulting in vomiting, diarrhœa, and pain in the abdomen. Fortunately, Nature, as it were, applies the remedy, expels the noxious food from the body, and the person then recovers; the young, the old, and the infirm, may, however, be so prostrated by excessive vomiting and purging that they may sink from exhaustion.

Alcohol.—The Board of Education has issued an excellent syllabus of lessons on temperance for scholars attending the public elementary schools, and the teacher should procure a copy and make a close study of it.

Healthy persons are better without taking any form of alcoholic beverages; if alcohol be taken, it should not be more than a glass of wine or beer at meals. Spirits should only be given on the advice of a physician.

The degeneration of the tissues and the great loss of nerve power produced by alcohol-drinking should be forcibly impressed upon all.

Malnutrition.—The common signs of malnutrition are arrested growth, anæmia, and sallow skin; flabby and deficient muscles; emaciation; digestive troubles—diarrhœa and vomiting; mental dulness, inattention, and lassitude.

Good nutrition is not synonymous with stoutness, nor bad nutrition with thinness, though at the same time the majority of children who are well nourished are also children who are well up to the standard as regards weight, while the majority of children poorly nourished are proportionally below the standard. A flabby, rickety child may be above the standard in regard to weight, and yet be, strictly speaking, of poor nutrition; while a muscular child of slender build may be below the weight standard, and yet of good nutrition. Thus, although stoutness or thinness of a child are important indications of the nutrition of the child, they should be taken in conjunction with other signs, such as the presence or absence of anæmia, the character of the complexion, the condition of the eyes and skin, and the character of the hair.

Rickets is a very common disease due to bad nutritive condition, and the results of this disease are frequently met with in schools of the poorer districts.

Sir William Jenner said many years ago that "Rickets is the most common, and in its indirect results the most fatal, of the diseases which peculiarly affect children."

The great cause of this disease is the substitution of artificial and improper feeding in place of breast feeding. It occurs in children who are fed in infancy on condensed milk, or have a deficiency of fresh milk and fats and an excess of starchy food.

The signs of rickets are readily recognized. There is pallor and general weakness; bones are very brittle and easily fractured; there is a characteristic square head; the ribs are beaded; the upper part of the chest is narrow and constricted; the ends of all the long bones are enlarged —consequently there is enlargement of the wrists, ankles, or knees; the spine may be curved and the legs bent; knock-knee and flat-foot may arise from rickets.

Rickety children in schools should be sent to the medical officer, who will advise proper treatment and give the right instruction to the parents. They should be excused from standing too long, because the bones are soft and give way under the weight of the body; and for the same reason these children are very liable to bony deformity, and greater care should be taken that their postures and attitude do not tend to produce deformities.

Feeding of the School-Child.—A large number of the children in our elementary schools are underfed, and this is due to the social conditions under which the poorer members of the community live in the large towns.

Since the education of the child has been made compulsory, it is the duty of the State to see that the physical condition of the child is such that it will benefit from the education that is provided for it.

Up till 1906 voluntary associations had undertaken to feed the necessitous school-child.

In 1905 the Relief (School-Children) Order was issued by the Local Government Board, by which certain provisions of the Poor Law were adapted to the relief of elementary school children in a state of destitution from want of food.

At the end of the year 1906 the Education (Provision of Meals) Act came into operation. It permits of the formation of a school canteen committee, composed entirely of members of the local education authority, or of such members in combination with the committee of any voluntary association for the provision of school-meals. In certain cases the education authority may defray the cost of food from the rates, provided that the sum expended does not exceed the amount which would be produced by a halfpenny rate in the pound.

The adoption of this Act is permissive, and not obligatory.

If the local authority are going to take advantage of the provisions of this Act, they must first of all adopt it ; and if the voluntary funds are insufficient, the local educational authority must pass each year a resolution that there exist in the schools children unable to take advantage of the education provided because of lack of nourishment. The Board of Education will then sanction the spending of a definite sum on food. A committee is formed to which is entrusted the organization of school-meals and the selection of suitable children.

An application is made by the parent to the teacher, attendance officer, school-nurse, or medical officer, and each case is investigated by the canteen committee. The degree of poverty which entitles the child to receive free meals varies in different localities ; generally it is taken as three shillings weekly per member of the family.

The drawing up of the menu should be left to the school doctor. The meals should be economical, easily cooked, satisfying, and based on scientific principles.

The dietary will vary in different localities.

CHAPTER IV

CIRCULATORY AND RESPIRATORY SYSTEMS

FUNCTIONS, MORPHOLOGY, AND PROPERTIES, OF BLOOD.

BLOOD is the most important fluid in the body, and the functions that it performs are numerous and most essential to the maintenance of life. A healthy condition of the body is impossible unless the blood performs its duties properly. We will first of all enumerate some of its important functions, and then give a short account of its composition, morphology, and properties.

The **functions of the blood** are—

1. To carry nourishment from the digestive system to all parts of the body.

2. To absorb oxygen from the lungs and distribute it throughout the tissues, and also to carry carbon dioxide away from the tissues to be eliminated by the lungs.

3. To remove the waste products from the tissues, and carry them to the excretory organs.

4. It is by the blood that the heat of the body is equally distributed throughout.

5. To convey substances from certain organs that are essential for the proper working of all other parts of the body—*e.g.*, secretions from ductless glands.

6. To protect the body against the invasion of micro-organisms, and, if they gain entrance to the body, to destroy them and neutralize their poisonous effects. The study of this question—namely, immunity—has received very great attention during the last ten years.

7. A very large percentage of the body is made up of water, and one very important function of the blood is to keep this percentage constant.

Composition of Blood.—Blood is made up of a large number of small cells, which float in a liquid of complex composition.

The cells which are present in the blood are called the "blood-corpuscles," while the liquid in which they float is called the "blood-plasma."

The corpuscles of the blood are of two kinds—namely, red and white. We must consider the structure and function of each.

Red Blood-Corpuscles.—These are very small disc-shaped cells; they can only be seen by means of a microscope. They are thicker in the periphery than in the centre, and contain no nucleus; thus, the general way of describing

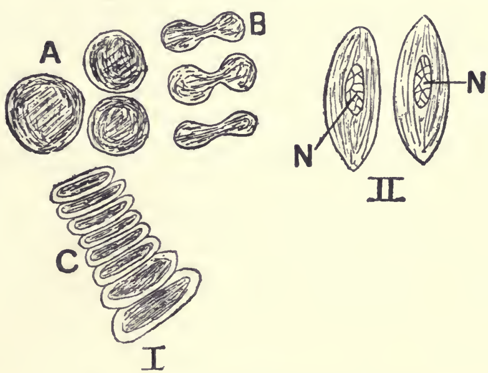

FIG. 55.—RED BLOOD-CORPUSCLES.

I. Mammalian cell: *A*, surface view; *B*, side view; *C*, rouleaux formation. II. Red blood-corpuscle of frog: *N*., nucleus.

the structure of the red corpuscle is to say "that it is a biconcave, non-nucleated disc." It has a cell body, or stroma, which is permeated by a peculiar protein substance called "hæmoglobin." Each red blood-corpuscle measures about $\frac{1}{3000}$ inch in diameter. Their shape is easily changed, as happens when they pass through small tortuous vessels.

In order to examine the blood-corpuscles, you should perform the following experiments:

Experiment A.—Prick your finger near the base of the nail by a needle, which has been previously sterilized by being passed through the flame of a match. Place a drop of blood on a slide, and examine it with the microscope. You will notice the red corpuscles as small circular bodies floating in an almost colourless liquid medium. These corpuscles are straw-coloured, and it is only when there is an aggregation of a large number of them that they result in the red colour characteristic of blood. Note also that the red corpuscles tend to aggregate together in a peculiar fashion, similar to a distorted pile of coins; this is called "rouleaux formation," and is brought about by the peculiar consistency of these bodies.

Experiment B.—Again prick your finger, with the above-mentioned precautions, and place a drop of blood near one end of a slide which has been thoroughly cleaned and rubbed with fine emery paper. The drop of blood is now drawn into a film, by the edge of a second slide, which is held at an angle of 45 degrees to the first one. This should be done by one light movement, which should not be repeated unless the slide is cleaned and a fresh drop of blood placed upon it. Having obtained a good even film, allow it to dry in the air. Then place upon it some staining reagent; the commonest one used is called "Leishman's stain"; it is made of a mixture of methylene blue and eosin dissolved in methyl-alcohol. Pour on the film a few drops of Leishman's stain, and allow it to remain there for thirty seconds, during which the film is fixed and prepared to take up the stain; then dilute it with three times its volume of distilled water, and allow it to stain for four or five minutes. Then wash the slide in distilled water and dry between two pieces of blotting-paper. Examine the film with the high power of the microscope. All the corpuscles of the blood will stand out much more clearly; the red cells will be stained red by the eosin, and the white cells can be readily distinguished by their nuclei being stained blue, and the protoplasm of the cells stained blue or terra-cotta colour, according to its staining property.

Of these red cells, there are 5,000,000 in the male and 4,500,000 in the female in each cubic millimetre of blood—a droplet about the size of a small pin's head. In the study of various conditions of anæmia it is very important for the physician to know how many corpuscles are contained in each cubic millimetre of his patient's blood. The red cells are enumerated by an instrument called a "hæmocytometer," which is shown in Fig. 56. One cubic millimetre of the patient's blood is drawn up into a small pipette; this is diluted a hundred times by drawing up a certain special salt solution. After thorough mixing of the two fluids, a drop of the resultant mixture is made to fall into a small trough on a microscopic slide. The bottom of this trough is divided out into small squares of known area, generally $\frac{1}{400}$ square millimetre, and the height of the trough is generally $\frac{1}{10}$ millimetre; therefore each square would enclose a volume of $\frac{1}{4000}$ cubic millimetre. By placing it under a microscope the corpuscles in each square can be enumerated; this is done for a large number of squares, and the average taken; since we know the volume of each square and dilution of the blood, the number of red corpuscles in each cubic millimetre of undiluted blood can be calculated.

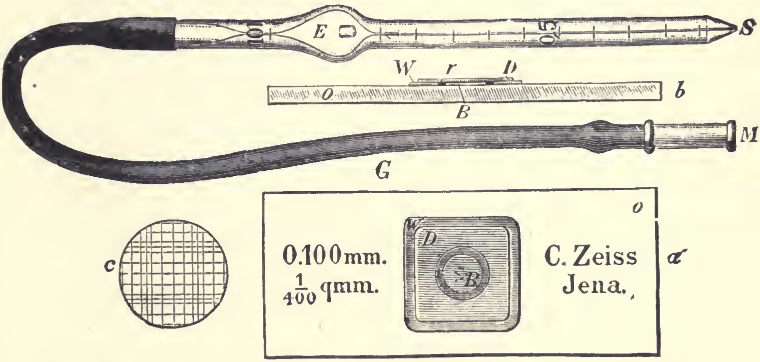

FIG. 56.—HÆMOCYTOMETER, OR INSTRUMENT FOR ENUMERATING THE CORPUSCLES OF THE BLOOD.

The important function of the red cells is to carry oxygen from the lungs to the tissues, and carbon dioxide away from the tissues to the lungs. This is performed by means of the red pigment, called "hæmoglobin," that is present in the red corpuscles.

Hæmoglobin is the most important constituent of blood, to which it gives its characteristic colour and forms 13 per cent. of its weight. It is a very complex substance, made up of a protein combined with hæmatin, an iron-containing pigment. It is able to combine loosely with oxygen when it is brought into contact with it, forming oxyhæmoglobin, and on reaching the tissues it will give up its oxygen to them, where the oxygen combines with the foodstuffs in the complex processes called "metabolism." One resultant product of metabolism is carbon dioxide, and both the corpuscles and the plasma combine with this and carry it to the lungs. The scarlet colour of arterial blood is due to oxyhæmoglobin, and the dark colour of venous blood is due to hæmoglobin which has given up oxygen.

If distilled water be added to blood, it causes the red corpuscles to swell up and finally burst, and the hæmoglobin is taken in solution, and the only remnant of the corpuscle will be a colourless protein shell, representing the stroma on which the hæmoglobin was deposited. By certain processes hæmoglobin can be obtained in a crystalline condition from the above solution. It is of great importance that hæmoglobin forms only a *loose* compound with oxygen. The oxygen is easily combined and easily given up to the tissues. There is another gas, carbon monoxide, which forms a very stable compound with hæmoglobin, and then it becomes of no use to the body. This is what happens in coal-gas poisoning.

Most other pigments, such as those of the bile, urine, and fæces, are derived from hæmoglobin.

Origin and Life-History of Red Cells.—The red blood-corpuscles are formed in the embryo in the parts which give rise to the bloodvessels. The liver, the spleen, and the red bone-marrow, are also sites of their formation at this period of life.

In the adult they are formed only in the red bone-marrow.

It is not known exactly what is the life-history of the red blood-corpuscles, but it is certain that they are destroyed in various parts of the body. The hæmoglobin is liberated and carried to the liver, where it is converted into bile pigments, and from these the pigments of the urine and fæces are formed.

The White Blood-Corpuscles.—In order to study the white blood-corpuscles, you should make a blood-film as described in Experiment B. Take great care to obtain a good film, and stain it well. The white cells of the blood are not so numerous as the red corpuscles—only about 7,000 to 10,000 per cubic millimetre of blood. They are enumerated by a method similar to that applied in the case of red corpuscles, except that the blood is diluted five or ten times by very dilute acetic acid with methylene blue added to it. When you study them closely, you will find that they are of two kinds—namely, lymphocytes and leucocytes.

Lymphocytes are oval-shaped cells, with a similarly-shaped nucleus which nearly fills the whole cell. In the blood-film the whole cell will appear blue, because the nucleus and the protoplasm readily stain with the methylene blue constituent of your stain. Lymphocytes are divided into two groups according to their size—namely, the small and the large.

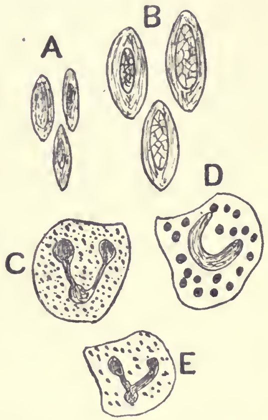

Fig. 57.—Various Forms of White Blood-Corpuscles.

A, Small lymphocytes; *B*, large lymphocytes; *C*, *D*, *E*, three forms of polymorphonuclear leucocytes.

Leucocytes are irregularly-shaped cells, containing a nucleus that is divided into several parts, joined together by strands of nucleus tissue. The protoplasm of the cell is granular, and the staining properties of these granules serve to classify these cells into three different groups. In some the granules will be small and numerous, and stained a terra-cotta colour; others will have a few coarse granules of the same colour, while another group will have the granules stained blue. These cells have great power of independent movement.

Function of the White Blood-Corpuscles.—The white blood-corpuscles may be looked upon as the protective army and the scavengers of the body. Wherever micro-organisms gain access to the body, they cause, by the products of their metabolism (toxins), a certain amount of irritation to the tissues; the blood carries away the toxins which act as a stimulus to the formation of the white cells, and these are carried by the blood to the site of invasion. Then they will surround the germs and kill them, and carry away their bodies and lay them aside, or destroy them *in situ*. There are certain substances called "opsonins," present in the blood-plasma, which act on the bacteria and aid their destruction by the white corpuscles. In this struggle some of the white cells are killed, and if this happens to a large extent their dead bodies in the tissue fluids form matter, or pus.

Formation of White Blood-Corpuscles.—The two main forms of white corpuscles have different modes of origin.

The leucocytes, or granular cells, are formed in the bone-marrow, and there we find several different forms of cells developing into adult leucocytes. From the bone-marrow they are carried to the tissues.

The lymphocytes are formed in the lymphatic glands. There we find certain cells dividing and giving rise to lymphocytes, which are passed to the blood-stream.

Lymphatic Glands and Lymph.—The lymphatic glands are small oval structures about the size of hazelnuts, and are distributed through various parts of the body. They are found at the side of and in front of the neck, at the root of the lungs, in the mesentery (a membranous structure by means of which the intestines are tethered to the posterior wall of the abdomen), in the armpits and groins, and other parts of the body.

When a section of a lymphatic gland is examined microscropically, it is found to be made up of a capsule and framework of connective tissue, in the interstices of which lie a large number of lymphocytes. The manner of aggregation of the lymphocytes is such as to divide each gland into a cortical and medullary portion. In the former they are accumulated to form lymphatic nodules, while the latter has a loose structure, and the lymphatic cells are aggregated into small cords.

Passing in and out of the lymphatic glands we find the lymphatic vessels. In between all the cells of the body there are potential cavities, which are called the "connective-tissue spaces." The lymphatic vessels take their origin in these connective-tissue spaces, and pass along to the lymphatic glands, from which vessels arise which pass to another set of lymph glands, and finally into one

FIG. 58.—SECTION THROUGH A FRAGMENT OF A LYMPH GLAND.

A, Fibrous coat sending partitions into *C*, the pulp of the gland; *B*, denser masses of lymph cells; *D*, bloodvessel in fibrous partition.

of the two main lymph channels which reach the bloodstream. The lymph inside the vessels flows in one direction —*i.e.*, towards the veins. This is due to the action of the valves which are present in the lymphatic vessel, and which allow the lymph to flow only in that direction.

It will be seen that blood is carried to all parts of the body by means of bloodvessels, which, as they recede from the heart, branch repeatedly until very minute plexuses of vessels are formed, called the "capillaries." These are made up of a single layer of flattened epithelial cells. The fluid constituents of the blood pass from the capillaries to the tissue spaces around, and this fluid is then called "lymph."

Contraction of the muscles in all forms of movements, and the action of the valves, are the two important factors which cause the circulation of the lymph ; by these means the connective-tissue spaces are pressed upon and their contents squeezed out.

The amount of lymph in the connective-tissue spaces is regulated by the activity of the cells lining the capillaries. When these cells are injured by any form of irritant, such as a blister, burn, or a bee-sting, the amount of fluid poured out into the connective-tissue spaces is very much increased at the site of injury, and results in a blister. In some people a diffuse nettle-rash will appear when they have partaken of certain things, such as crabs or mussels ; this is due to the toxic effect of such diet upon the cells lining the capillaries. The rashes of scarlet fever, measles, etc., are caused by the toxic action of the organisms which produce these diseases.

When germs or dust gain access to the tissue, they pass into the connective-tissue spaces, and are then carried in the lymph-stream to the nearest set of lymphatic glands, where most often the germs are killed and the dust laid aside. If the germs are so numerous that the glands cannot cope with them, they cause irritation and reaction on the part of the glands. The lymphocytic cells are increased in number and the connective tissue is hypertrophied, and we have an inflammatory condition of the glands. Everyone has experienced some form of inflammatory condition of glands. After a sore throat the glands of the neck are often enlarged and tender. The germs which cause consumption often gain access into the body through the tonsils, and are carried along lymphatic vessels into the lymphatic glands of the neck, giving rise to the tuberculous condition of these structures. The infection may be so severe as to cause the death of the cells in the lymphatic glands, thus resulting in an abscess formation. The greater part of the lymph that passes from the blood-capillaries into the tissues returns into these vessels; it is only a small part which passes through the lymphatic glands to the veins.

Blood-Plasma.—Plasma is blood that has been deprived of its corpuscles. It is in the blood-plasma that the food-stuffs are carried to the tissues and the waste products conveyed to the excretory organs. It will contain the three blood-proteins—fibrinogen, serum albumin, and serum globulin—fats, traces of sugar, urea and uric acid, inorganic salts, various enzymes and substances involved in the means of protecting the body from bacterial invasion.

In order to obtain a specimen of plasma, some means must be taken to prevent the clotting of the blood. One method is to pass the blood, when the animal is being killed, into a vessel containing strong salt solution, and leaving the vessel to stand; the corpuscles will drop to the bottom.

If the blood is allowed to be in contact with the vessel, it will not clot; hence plasma can be prepared by exposing a large vein and after tying it at each end, cutting it out. If the vein is suspended, the corpuscles will fall to the bottom, and the plasma above can be removed by a pipette.

Coagulation, or Clotting of Blood.—The phenomenon of clotting of blood is well known to everyone. In a few minutes after its escape from the bloodvessels it becomes viscous, and then sets into a soft jelly, which contracts and becomes firmer, pressing out some clear, faintly yellow liquid called "blood-serum."

Obtain a drop of blood from your finger, and allow it to fall on a clean porcelain dish, and follow the changes that take place during the clotting of blood.

In order to make a further study of the coagulation of blood, you should have a greater supply of blood at your disposal.

Take three vessels to a butcher on the day he kills; in one place a strong solution of salt, and just rinse the other two with 0·9 per cent. salt solution. In one of the last two vessels place a small bundle of bristles or twigs from a broom. Ask the butcher to collect some blood in each; two of the samples he must put aside undisturbed, while the one with the twigs in it he should be told to whip vigorously for a few minutes immediately after collection.

It will be found that one of the samples has clotted, so that the vessel can be turned upside down without spilling, and clear straw-coloured serum will have escaped from the clot.

The one with the strong salt solution will be fluid, but on dilution and placing it on a water-bath at the temperature of the body, it will clot.

The blood that has been whipped will be fluid, and entangled on the bristles will be found shreds of material. Wash these under the tap, and the shreds will be seen to be made up of a white fibrous substance, called *fibrin*.

The essential factor in the coagulation of blood is the conversion of a soluble protein called "fibrinogen" into an insoluble protein called "fibrin." This is brought about by the action of a ferment, and the sequence of events in the formation of a clot after injury to the body is as follows: When the tissues are injured, some of the white blood-corpuscles are killed, and during this process a ferment is liberated. But the ferment is then in an inactive form. Certain substances from the tissues and the lime salts from the blood activate the ferment, which is then able to convert the fibrinogen into fibrin. This is deposited irregularly in fine strings, and entangles the red corpuscles in its meshes. These fibrin filaments contract, and the fluid constituents and white corpuscles are squeezed out of its meshes, forming the serum; while the red cells are entangled, forming the clot.

Clotting is a means devised by Nature to stop hæmorrhage after an injury has been inflicted on any part of the body. In some persons the blood has very weak power of coagulating, and in them a slight injury will result in a severe loss of blood.

Circulation of the Blood.

From what has been said in the latter pages, it is seen that the important function of the blood is to carry oxygen and nourishment to the tissues, and to convey the waste products from the tissues to the excretory organs. It cannot perform such duties unless it comes into intimate connection with the tissues; and, further, it must come into similar relationship with the lungs and intestine, in order to absorb respectively oxygen and nourishment therefrom. Such varied functions performed in distant parts of the body can only be adequately fulfilled by a movement of the blood through the various tissues; this movement is called the "circulation of blood."

Let us consider some of the most important factors concerned in the circulation of the blood. It is brought about by the pumping of the blood by the heart through a series of elastic tubes, called the "bloodvessels." When such a vessel conveys blood away from the heart, it is called an **artery,** but when the direction of flow in a vessel is towards the heart that vessel is called a **vein.** The small bloodvessels which permeate the tissues are called the **blood-capillaries.**

The cause of the circulation of the blood is the pumping action of the heart, but several other factors modify and aid the flow of blood in the peripheral tissues and its return to the heart—namely, the peripheral resistance, muscular contraction, respiratory movements, etc.

It is therefore essential that we should know a little about the anatomy of the heart and its great vessels in order to understand the very elements of the circulation.

Anatomy of the Heart and its Great Vessels.—There is very little difference between the main anatomical features of a sheep's heart and that of the human subject. Therefore ask your butcher to give you "a sheep's heart, with the heart-bag and pluck attached, and the tubes cut long." If he follows your instructions, you will be able to obtain the heart, lungs, and large vessels, in an undamaged state. Then carefully note the following facts :

The heart and lungs will be seen to be closely associated, and passing from the heart to the lungs are several tubes or

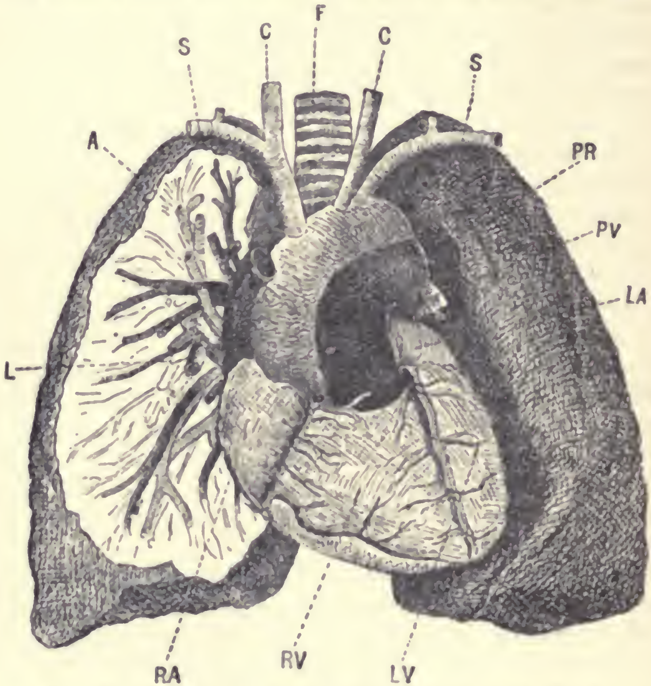

Fig. 59.—Heart and Lungs removed from the Body.

A., Aorta ; *C.*, carotid arteries ; *F*, trachea; *L.*, lung cut open to show branches of pulmonary artery, vein, and air-tubes ; *L.A.*, left auricle ; *L.V.*, left ventricle ; *PR*, pulmonary artery ; *P.V.*, pulmonary vein ; *R.A.*, right auricle ; *R.V.*, right ventricle ; *S.*, subclavian arteries.

bloodvessels. You will also notice that the heart is enclosed in a strong fibrous bag, which is called the " pericardium."

The Pericardium.—This is a strong fibrous bag enclosing the heart. By means of a pair of scissors and dissecting forceps, open the pericardium along its anterior surface (the posterior surface is readily recognized, because passing from it will be two vessels—one to each lung—and surrounding these will be a large amount of connective tissue and fat). On section the pericardium will be seen to be made up of two layers—an outer thick and tough layer, made of white fibrous tissue ; and an inner smooth, glistening layer, which on microscopical examination will be found to be made of a layer of flattened epithelium lying on a thin bed of connective tissue. It will be seen that this glistening layer is reflected on and covers the outer surface of the heart. The fibrous layer of the pericardium is attached below to the central tendon of the diaphragm, whilst above it merges with the outer coats of the bloodvessels which leave the heart at its base. The pericardium has two functions : the fibrous layer protects the heart, and prevents its over-distension with blood; the inner layer, by its smoothness and secretion of a small amount of fluid, diminishes friction, and allows the contraction and relaxation of the heart to take place with greater ease.

The Heart.—Now direct your attention to the heart itself. It will be seen to be a conical muscular organ, with the apex downwards and the base above, where the great vessels leave and enter it. A groove will be found running along its anterior surface from above downwards, and in a slight oblique direction, so that it passes a little to the right side of the apex ; it will contain a small amount of fat and a bloodvessel ; this is called the "interventricular groove," Corresponding to it there is a septum, which divides the cavity of the heart into a right and left portion, and is called the "interventricular septum." A second groove, containing more fat, will be seen running transversely across the heart, a little nearer the base than the apex ; it divides each half of the heart into an upper auricular and a lower ventricular portion ; this groove is called the "auriculo-ventricular groove," and corresponds to a perforated septum called the "auriculo-ventricular septum." Thus the heart is divided into four chambers—the right and left auricles above, and the right and left ventricles below.

Now carefully remove all the connective tissue and fat which surrounds the large vessels as they leave and enter the base of the heart. Find a large elastic vessel which can be seen anteriorly at the base. One arises from the right ventricle, and lies more anterior; it will be seen to divide very soon into two branches—one for each lung. This vessel is called the "pulmonary artery." The other arises from the left ventricle, and at first is more posterior; it thus curves forward to form an arch on the right side of the pulmonary artery. This second vessel is called the "aorta," and is the chief artery of the body. Large branches supplying the head and neck will be seen to arise from the upper or convex surface of the arch.

Now turn your attention to the right and left auricles; note their shape and structure, and the vessels which enter them. Both auricles are small, thin-walled bags, prolonged anteriorly to crinkled projections lying close to the pulmonary artery and aorta; these projections are called the "auricular appendices."

Two vessels enter the right auricle—the superior vena cava above, and the inferior vena cava below; they carry all the venous or impure blood from the tissues to the heart.

If you dissect on the posterior wall of the auricular portion of the heart, two short vessels, one from each lung, will be seen passing to the left auricle; these are called the "pulmonary veins," and carry oxidized blood from the lungs to the left auricle. In man there are four pulmonary veins—two from each lung.

Now take a probe or penholder, and pass it along all these vessels, and find out to which chamber of the heart it passes in each case. The superior and inferior venæ cavæ will be seen to end in the right auricle; the pulmonary artery and aorta arise respectively from the right and left ventricles; while the pulmonary veins will be seen to end in the left auricle.

Next turn your attention to the cavities of the heart. Place one blade of your scissors into the superior vena cava, and cut right through down to the inferior vena cava. The cavity of the right auricle will be exposed; it is lined by a smooth, glistening membrane, and in the auricular appendix there are bands of muscle called the "musculi pec-

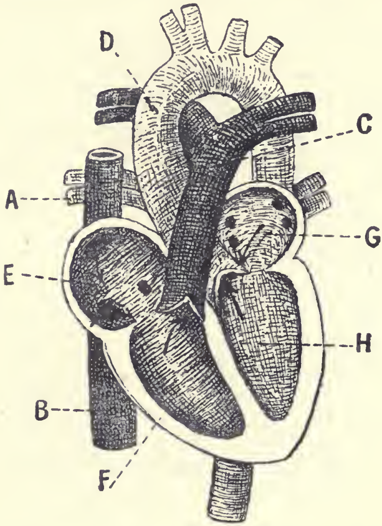

FIG. 60.—DIAGRAM OF THE CAVITIES OF THE HEART AND BLOODVESSELS.

A, Vena cava superior; *B*, vena cava inferior; *C*, pulmonary artery; *D*, aorta; *E*, right auricle; *F*, right ventricle; *G*, left auricle, with four pulmonary veins opening into it; *H*, left ventricle. The arrows show the direction of the circulation.

tinati." The right auricle opens into the right ventricle by the right auriculo-ventricular opening, which is guarded by a valve made of three flaps or cusps, and hence called the "tricuspid valve."

Now make an incision into the anterior wall of the right ventricle; further examine the right auriculo-ventricular opening and valve. Also note the smooth character of the membrane lining its inner wall, and deep to this membrane are bars of muscle called the "columnæ carnæ"; some of these are hypertrophied to form special muscles called the "musculi papillares," which by tendinous cords become attached to the cusps of the valves. In the right ventricles there are three sets of musculi papillares; by their contraction during ventricular systole, they prevent the valves

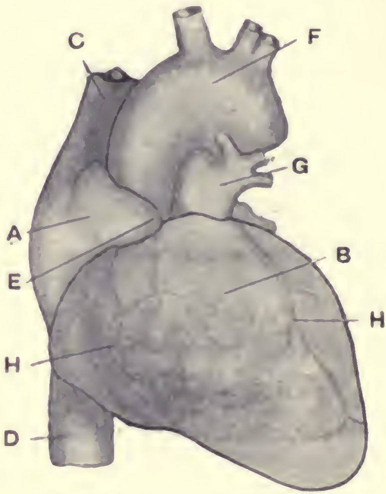

Fig. 61.—Anterior Surface of the Heart.

A, Right auricle; *B*, right ventricle; *C*, superior vena cava; *D*, inferior vena cava; *E*, right auricular appendix; *F*, aorta; *G*, pulmonary artery; *H*, coronary arteries.

being pushed into the auricles. In the upper part of the right ventricle the pulmonary artery will be seen to arise. Now cut the pulmonary artery transversely just above where it leaves the right ventricle, and look downward to the ventricle; the opening will be seen to be guarded by a valve made of three semilunar cusps—hence called the "pulmonary semilunar valve"; then lay open the pulmonary artery and make further studies of its valves.

Make an incision into the anterior wall of the left ventricle; study its cavity. It will be found to communicate with the left auricle by an opening called the "left auriculo-ventricular opening," which is guarded by a valve made of two cusps, and hence called the "bicuspid" or "mitral" valve.

Columnæ carnæ will also be seen in the left ventricle, and two sets are specialized to form musculi papillares,

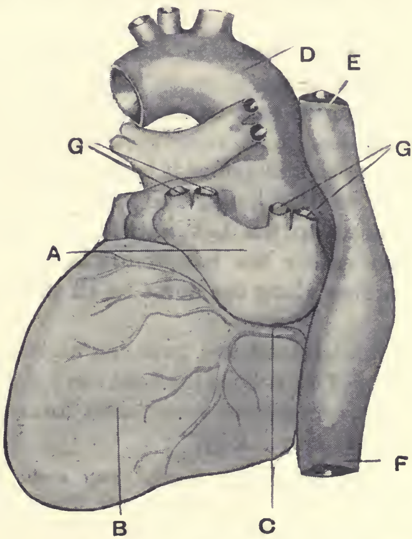

Fig. 62.—Posterior Surface of the Heart.

A, Left auricle; *B*, left ventricle; *C*, coronary artery; *D*, aorta; *E*, superior vena cava; *F*, inferior vena cava; *G*, *G*, pulmonary veins.

which are attached to the two cusps of the mitral valve by means of chordæ tendineæ.

Cut the aorta transversely just above where it leaves the left ventricle, and look within. Its opening will be found to be guarded by a valve made of three semilunar cusps—hence it is called the "aortic semilunar valve"; then lay open the aorta and further study its valve.

At the bottom of two of the pouches formed by these semilunar cusps small openings will be seen; it is here that the coronary arteries arise. These are of great importance, because these vessels supply the musculature of the heart.

Place the blade of your scissors in the left auriculo-ventricular opening, and open up the left auricle; the openings of the two pulmonary veins (four in man) will be seen. Also examine the musculi pectinati of the left auricle.

From the above dissection the course of the blood through the heart can readily be followed. It enters the heart by the superior and inferior venœ cavæ, and passes through the right auriculo-ventricular opening to the right ventricle. From this chamber it is pumped along the pulmonary artery to the lungs, and passing through their capillaries returns to the left auricle by the pulmonary veins; it then enters the left ventricle, and is pumped from this chamber along the aorta to all the tissues of the body.

In order to understand the pumping action of the heart and the working of its valves, perform the following instructive experiment, which has been taken from Dr. Leonard Hill's "Manual of Physiology":

The Action of the Heart as a Pump.—Buy a sheep's heart, and perform the following instructive experiment: Obtain two glass tubes about 18 inches long and ½ inch in diameter. Insert one into the right auricle through the superior vena cava; tie it firmly within with a piece of string. Take another piece of string, and tie the opening of the inferior vena cava. Tie the other glass tube into the pulmonary artery in such a position that the end of this tube lies just above the semilunar valves. Now, holding up the heart by the two glass tubes, fill with water the tube attached to the superior vena cava, and then rhythmically squeeze the right ventricle with the hand.

With each squeeze the water will shrink in the vena cava tube and rise in the pulmonary artery tube. This proves that the heart is provided with valves, that fluid can be pumped only in one direction—namely, from auricles to ventricles, and from ventricles to arteries. The water in this experiment runs in the following way:

1. From superior vena cava through the right auricle to the right ventricle.

2. On squeezing the right ventricle the pressure inside its cavity is raised, and causes the tricuspid valves to come together and prevent the return of the water to the auricle.

3. At the same time the increased pressure inside the ventricle forces the semilunar valves open, and the water is drawn into the pulmonary artery.

4. On ceasing to squeeze, the water runs again into the right ventricle from the tube in the vena cava; but it cannot return from the pulmonary artery to the right ventricle, because the semilunar valves become closed.

The above experiment tells us how the living heart works. Blood flows from the superior and inferior venæ cavæ to the right auricle, and from thence through the auriculo-ventricular opening to the right ventricle; the muscular wall of the latter then contracts, and expels the blood within its cavity to the pulmonary artery; then the ventricle dilates and is refilled. Simultaneously with the above processes blood flows from the pulmonary veins to the left auricle, and thence into the left ventricle, which in its turn contracts and expels the blood to the aorta. The two ventricles fill together and empty together with perfect co-ordination, and hence we have at first a simultaneous contraction of both auricles, then an interval during which the muscular contraction passes from the auricles to the ventricles, followed by the simultaneous contraction of both ventricles. This process goes on about seventy to eighty times a minute during all our lives, and it is wonderful that the heart is able to do its work so regularly and effectually for so long a period.

Arteries, Capillaries, and Veins.—Blood is carried away from the heart by means of a system of elastic tubes. There are only two of these tubes leading from the heart itself—one the pulmonary artery, carrying the blood to the lungs; and the other the aorta, which carries the blood from the left ventricle to all other parts of the body. These tubes, as they recede from the heart, give off a number of branches, which in their turn subdivide, until the whole body is penetrated by small vessels which are called the "capillaries." These small vessels unite to form venules;

these, again, join to form veins ; and finally all the blood in the human subject is returned to the heart by means of two large veins, which open to the right auricle, and are called the "superior and inferior venæ cavæ."

Structure of an Artery.—When a section of an artery is examined by the microscope, it is found to be made up of

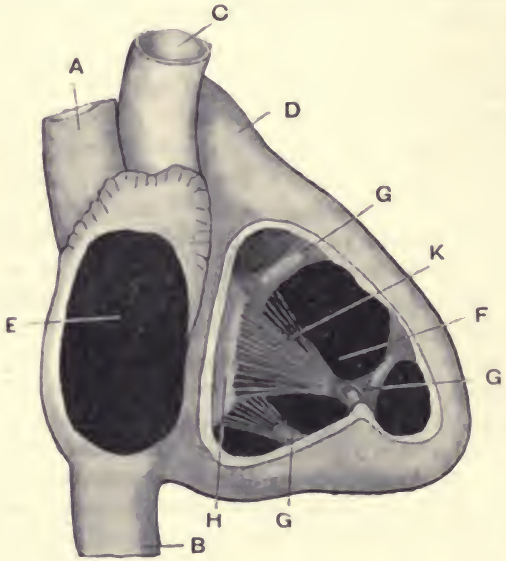

Fig. 63.—Diagram showing the Structures seen when the Anterior Wall of the Right Auricle and Right Ventricle has been dissected away.

A, Superior vena cava ; *B*, inferior vena cava ; *C*, aorta ; *D*, pulmonary artery ; *E*, cavity of right auricle ; *F*, cavity of right ventricle ; *G*, *G*, *G*, musculi papillares ; *H*, right auriculo-ventricular valve ; *K*, chordæ tendineæ.

three coats. The *inner coat* is composed of a layer of endothelial cells lying on a layer of connective tissue. The *middle coat*, or *tunica media*, consists mainly of circularly-disposed plain muscular fibres intermingled with elastic fibres. In the larger arteries—*e.g.*, aorta and pulmonary artery—there is more elastic than muscular tissue, while the middle coat of the smaller arteries is mainly composed of muscular tissue. The *outer coat* is formed of connective tissue with a good many elastic fibres, especially next to the middle coat. The strength of an artery largely depends upon this coat; it is far less easily cut or torn than the other coats, and it serves to resist undue expansion of the vessel.

Structure of a Vein.—The veins on the whole resemble the arteries in structure, but they present certain differences. The middle coat contains far less elastic and muscular tissue, but there are present a large number of white connective-tissue fibres, and the outer coat is relatively better developed in the veins than in the arteries.

The walls of the smaller arteries differ from those of the larger arteries by a great increase in the number of muscle cells and a decrease in the elastic fibres. Hence the larger arteries are essentially extensile and elastic, while the smaller arteries are muscular, contractile tubes.

As the smaller arteries branch into capillaries, the muscular constituent of their walls becomes less and less, until in the capillaries there is nothing left but a layer of flattened cells separating the blood within from the tissues without. It is through this layer of cells that the tissues absorb their nourishment and oxygen from the blood, and also eliminate their waste products to the blood-stream.

It has been said above that the great function of the blood is to carry nutriment and oxygen to all parts of the body. All the tissues are bathed in a continuous stream of blood, which is moved along by the force of contraction of the heart. This continual movement of the blood is called its "circulation." Thousands of years were spent in study and observation before this fact was discovered, and that was because the older students of medical science studied the dead more than the living body. After death the arteries constrict and force the blood into the veins, and so the old anatomists found the arteries always empty.

after death, while the veins were full of blood. They therefore came to the conclusion that it was the same during life, and the arteries were said to contain "animal spirits." It was reserved to the genius of an Englishman, Harvey, by means of a few simple experiments, to prove that the blood moves in a circle; thereby he laid the foundation of the modern science of physiology.

Harvey first observed the action of the valves in the veins of the limbs. These can be noticed when you stroke your arm downwards towards the hand ; little knots or swellings will at once rise up in the course of the veins. If such vessels were dissected, there would appear at each knot small membranous flaps or valves placed within so as to allow the blood to flow in one direction only—towards the heart. Harvey concluded from this that the blood in the veins could flow only in one direction—that is, from the limbs towards the heart.

Harvey also made a large number of observations on the direction of flow of blood in the heart and bloodvessels of snakes, frogs, and fishes, and definitely proved the circulation of the blood.

Microscopical Study of the Circulation.—If any transparent living membrane—*e.g.*, web of a frog's foot or a tadpole's tail—be examined by means of a microscope, the blood can be seen circulating from the smallest arteries, through the capillaries, to the venules.

The easiest way to see the circulation is to obtain a tadpole ; wrap the body of it in wet blotting-paper, place it on a glass slide, and examine the tail by means of the microscope. The circulation can also be seen in the web of a frog's foot. The digits must be spread out over a hole in a sheet of cork. The frog can be put in a linen bag with one leg left out.

It will be found that the flow is very rapid in the small arteries, so much so that the shape of the corpuscles cannot be readily detected ; in the capillaries the passage is so narrow and tortuous that the corpuscles have to pass along in single file. The red corpuscles move in the central axis of the stream ; to the outside there moves a layer of transparent plasma, and in this the white corpuscles move along, sticking now and again to the wall ; the outermost layer of plasma is practically stationary.

If a slight injury is inflicted to the web of the frog, it will be found that there is a certain reaction on the part of the tissues to this injury, and such reaction is called "inflammation." The smaller vessels would dilate, the blood-flow would quicken in rate, then become slower, and finally come to a standstill ; the white corpuscles would pass out in large numbers to the surrounding tissue.

Course of the Circulation.—The general course of the circulation can be studied by dissection of a dead rabbit or cat, after a warm solution of gelatin stained with carmine has been injected into the arteries. The path and direction of flow of blood is practically the same in these animals as in man, except there are a few differences in the anatomical distribution of the bloodvessels.

In man the blood is pumped from the left ventricle into the arches of the aorta. From the top of the arch there arises on the right side the innominate artery, and on the other side the left common carotid and left subclavian arteries. The innominate artery soon divides into right common carotid and subclavian arteries. The common carotid arteries ascend on each side of the neck, and about the level of the upper border of the larynx they divide into internal and external carotid arteries. The external carotids supply the tissues of the head that are outside the skull cavity, and the internal carotids enter the cranium, and are the most important blood-supply of the brain. The subclavian arteries pass behind the collar-bone to the armpit, where they are called the "axillary arteries," and thence are continued as the main arteries of the upper limb. The blood is returned from the head and neck by means of the jugular veins ; these join with the subclavian veins to form the innominate veins, and the right and left innominate veins unite to form the superior vena cava, which opens into the right auricles.

The aorta courses down the thoracic cavity near the vertebral column; here it gives off a few branches which supply the wall of the thorax; one runs under each rib, and a few twigs to the gullet and bronchi. It passes to the abdominal cavity, where it gives off a large number of branches. As soon as it has pierced the diaphragm, it gives off a large artery called the "cœliac axis," and this subdivides to branches which supply the stomach, liver, and spleen.

Fig. 64.—Section through a Small Artery and Vein.

A, Artery lined with flat, scale-like cells; *B*, elastic membrane; *C*, muscular coat; *D*, connective-tissue coat (the vein is much thinner, and has less muscle and elastic tissue); *E*, capillary supplying outer coat with blood.

A little lower down it gives off the superior mesenteric artery, which divides into a large number of branches to supply the small and large intestines. At the level of the kidneys the aorta gives off two renal arteries, one to each of these organs. It also gives off a branch called the "inferior mesenteric artery," which supplies the lower part of the large intestine.

At the level of the fourth lumbar vertebra the aorta ends by dividing to two terminal divisions, called the "right and left common iliac arteries." These run for a short course in a downward and outward direction, and divide into external and internal branches. The latter supplies the buttocks, the lateral walls of the pelvis, and back of thigh; while the former passes down the anterior

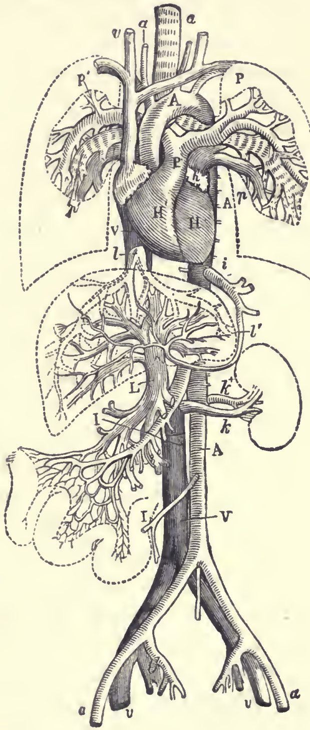

FIG. 65.—DIAGRAM OF THE CIRCULATION.

H', Right ventricle; P', pulmonary artery; P, lung; the branches of the pulmonary artery and vein, p', and the air-tubes, p, are seen entering the lungs; h, left auricle; H, left ventricle; $A.$, aorta; a, carotid arteries to head; next to these arise the subclavian arteries which supply the upper limbs; $I.$, intestine; $k.$, kidney. The aorta is shown giving off branches to these organs. Finally the aorta divides into branches which supply the pelvic organs and the lower limbs. V, vena cava inferior; receiving blood from lower limbs, pelvic organs, kidneys, and liver, it enters the right auricle. The portal vein, L, is shown carrying the blood from the intestines to the liver; l, hepatic vein; l', hepatic artery; v', superior vena cava bringing blood from head and upper limbs to right auricle.

aspect of the thigh, and forms the main blood-supply of the lower limb. The femoral artery can be felt pulsating in the upper part of the thigh; after giving off branches to the thigh, it winds round the lower part of the shaft of femur to reach the back of the knee, and thence sends branches to supply the leg and foot.

Blood is returned from the lower limb and pelvis by veins which join the external and internal iliac veins; these unite in the common iliac veins, and the right and left common iliac veins join to form the inferior vena cava. This runs up in front of the vertebral column, and receives tributaries from the kidneys, the abdominal wall, and the liver; it then pierces the diaphragm, and after a very short course within the thorax it enters the right auricle. The veins from the intestines do not enter directly into the inferior vena cava. Blood from the small intestine and parts of the large intestine is drained into the superior mesenteric vein; the blood from the lower part of the large intestine is carried along the inferior mesenteric vein, which opens into the splenic vein. The superior mesenteric and the splenic veins unite to form the portal vein, which enters the liver, and there breaks up into a number of capillaries, which reunite to form the hepatic veins, and these we have previously seen to join the inferior vena cava, just as it pierces the diaphragm.

The superior and inferior venæ cavæ open into the right auricle, and from thence the blood passes to the right ventricle, which pumps it along the pulmonary artery to the lungs, whence, after traversing their capillaries, it reaches to the left auricle. Then it passes through the mitral orifice to the left ventricle, which by its contraction forces it along the aorta.

The Beat of the Heart and Cardiac Cycle.—You should study the contraction of the various parts of the heart in an animal. This may very well be done in the case of a frog. The anatomy of the heart of this animal differs to some extent from that of the mammalian heart, but it will serve very well to study the co-ordinate contraction of its different parts.

Obtain a frog, flex its head, and then push a stout pin into the space separating the base of the skull and the upper part of the spinal cord. Turn the frog on its back, and fix it to a cork tray by passing pins through its four legs. Now take a pair of scissors and dissecting forceps, cut through the skin covering the chest, and remove the breast-bone. The heart will now be exposed enclosed in the pericardium, which in this animal is a thin membrane and should be removed with care. Make a careful study of the anatomy of the frog's heart; the veins conveying the blood to the heart will be seen to end in a small chamber called the "sinus venosus." Note also the auricular portion of the heart divided by a vertical septum into a right and left half. The ventricular portion will be seen as a single conical structure, not divided into two, as in the case of mammalia. Now study the sequence of contraction of the various chambers of the heart. Blood will be seen flowing along the veins to the sinus venosus and auricles; the sinus venosus will then contract, followed by a synchronous contraction of the auricles, and later by contraction of the ventricle. It is thus seen that each heart-beat in all animals is composed of co-ordinate contraction of various parts of the heart. The necessary stimulus that excites the muscles of the heart to activity is generated in the region of the mouths of the great veins; it passes to the auricles and causes them to contract; then it is conducted to the ventricles along certain special bands of muscle connecting the auricles and ventricles; finally the ventricles are excited to contract. For a short period after contraction of the ventricle the whole heart remains at rest.

The period of contraction of any portion of the heart is called its **systole,** while the period of relaxation is called **diastole**, and thus we speak of auricular systole and diastole, and ventricular systole and diastole. The series of changes that take place in the heart with each inflow and output of blood is called the **cardiac cycle.** Above we have only described the various phases of contraction of the heart; let us discuss the flow of blood through the heart, and the relation of the time of opening and closing of the different valves of the heart to the periods of the cardiac cycle. The following description is applicable to mammalian hearts : For nearly half a second after the contraction of the ventricle the whole musculature of the heart is in a condition of relaxation, and its cavities are being filled with blood. Blood is pouring into the right auricle along the superior and inferior venæ cavæ, and into the left auricle along the pulmonary veins. The auriculo-ventricular valves of both sides are in apposition since the last ventricular systole. As the auricles are filled, the pressure of the blood on the auricular side of these valves becomes greater than on the ventricular side ; consequently the valves open, and blood can now pass from the auricles to the ventricles. Auricular systole now sets in, and the contents of the auricles are pushed through the auriculo-ventricular openings into the cavities of the ventricles. As the ventricles are filled with blood, the valve cusps float on its surface, and a fifth of a second after contraction of the auricles the ventricles enter into systole. During this period the pressure inside the ventricular cavities is greatly increased, and results in a closure of the auriculo-ventricular valves. Since the last period of contraction of the ventricles the semilunar valves of the pulmonary artery and aorta have been in apposition ; very quickly after the closure of the auriculo-ventricular valves the pressure of the blood inside the cavities of the ventricles becomes greater than that in the pulmonary artery and aorta, and this results in the opening of the semilunar valves. When the cavities of the ventricles have been emptied, they enter into diastole, and then the pressure of the blood in the pulmonary artery and aorta becomes greater than that in the ventricles ; consequently the semilunar valves are closed and the whole heart is at rest. The above changes are again repeated. Thus, the auriculo-ventricular valves of both sides open at the beginning of ventricular diastole, and close at the beginning of ventricular systole ; while the semilunar valves of the aorta and pulmonary artery open very early in ventricular systole, and close at the beginning of ventricular diastole.

Causation of the Heart-Beat.—The cause of the heart-beat has naturally constituted one of the fundamental objects of physiological inquiry. In the heart-heat we have really a contraction of a special form of muscle. Physiologists first studied the structure and properties of voluntary or skeletal muscle, and the facts which they ascertained about skeletal muscle were applied to cardiac muscle. One of these properties is that the contraction of voluntary muscle within the body depends upon the integrity of its nerve-supply ; hence the older physiologists said that the heart-beat depends upon the integrity of, and arises in the nerve cells of, the heart. This statement is the basis of the nervous or "neurogenic theory of the heart-beat."

A special study was then made of the heart muscle, and its properties were found to differ greatly from those of voluntary muscle. Heart muscle was found to be automatic—that is, capable of generating its own stimuli—when separated from all parts of the body. Some time after death a heart can be resuscitated by transfusing it with warm saline, and in the embryo of certain animals the heart has been seen beating before any growth of nervous tissue has reached it. Hence the more modern view on this subject is that the stimulus which excites the heart to contraction arises in the musculature of the heart itself. This is called the "myogenic theory of the heart-beat."

The Frequency of the Heart-Beat.—You can count the number of times the heart beats per minute by feeling the pulse at the wrist. In a normal adult, when resting, the pulse-rate is about 60 to 70 per minute. In young infants the pulse-rate is much faster, about 130 per minute. The rate of the heart-beat is accelerated under various conditions: nervous excitement will cause the heart to beat quickly, any form of fever is accompanied by an increased pulse-rate, and exercise causes great acceleration of the heart.

Time Relations of Systole and Diastole.—The duration of the separate phases of the heart-beat depends, naturally, on the rate of the beat. Assuming a pulse-rate of 70 per minute, the average duration of the different phases may be estimated approximately as follows :

		Second.
Ventricular systole	=	0·379
Ventricular diastole and pause	=	0·483
Auricular systole	=	0·100
Auricular diastole and pause	=	0·762

When the rate of the pulse is increased, it is the diastolic and pause periods that are shortened ; and since it is during these periods that the musculature of the heart receives its nourishment, it is clearly seen how dangerous it is for the heart to continue to beat very rapidly during a fever or overstrain.

The Heart-Sounds.—Two sounds are produced during each beat of the heart. These sounds will be readily heard if you place your ear against a friend's chest over the region of the left nipple. The first sound has a deeper pitch and is longer than the second, and their relative pitch and duration are represented frequently by the syllables "lūbb-dŭp." The first sound is heard at the beginning, and the second sound at the end, of the ventricular systole.

If the heart of a sheep or ox be cut out immediately after the death of the animal, the first sound of the heart will be heard as long as the heart muscle continues to contract. There are two factors which play a part in the formation of the first sound : the contraction of cardiac muscle and the closure of the auriculo-ventricular valves both set up vibrations which give rise to the first sound.

The second sound is caused by the tension of the semilunar valves. As the ventricles cease to contract, eddies of blood shut the valves. The greater pressure of the blood on the arterial side of the semilunar valves at the beginning of ventricular diastole throws the valves into a state of tension, and the vibrations set up by it are the cause of the second cardiac sound.

Blood-Pressure.—When an artery is cut, the outflow of blood is not uniform and smooth, but takes place in *jerks* which correspond to each beat of the heart. Moreover, the blood spurts out with considerable force, which, although it is greater at each jerk, is still persistent and large between the jerks. The obvious conclusion to be drawn from the above observation is that the blood in the artery is always under considerable, though variable, pressure. This pressure is called **arterial blood-pressure.**

The smallest arterioles and capillaries offer a considerable frictional resistance to the flow of blood through them into the veins. This is generally called "peripheral resistance." Owing to this resistance, of the total amount of blood forced into the arteries at each beat of the heart only a portion can during the actual beat, apart from the pause between it and the next beat, pass on into the veins. The remainder is lodged in the arteries. This volume of blood distends the arteries, and in between the beats the elastic wall of the arteries recoils and presses forward the blood ; hence there is a storing-up of the force of the heart-beat by the elasticity of the arterial walls. We have seen that the flow in the arteries is intermittent, but in the veins the blood-flow would be continuous. This is explained by the fact that the arterioles store up the force of the heart-beat by the elasticity of their walls, and during diastole the blood-flow in the veins is continuous.

As the blood passes along the arteries, capillaries, and veins, there is a continual fall of blood-pressure, because the force of the heart and the elastic recoil of the arteries are used up to overcome the resistance to the flow of blood. The greater the resistance that is overcome, the greater the fall of pressure. The greatest amount of resistance is offered by the capillary area, and hence the greatest fall of blood-pressure occurs in this area.

Hence the blood-pressure is highest in the arteries, where it is intermittent, and lowest in the veins, where the flow of blood is continuous.

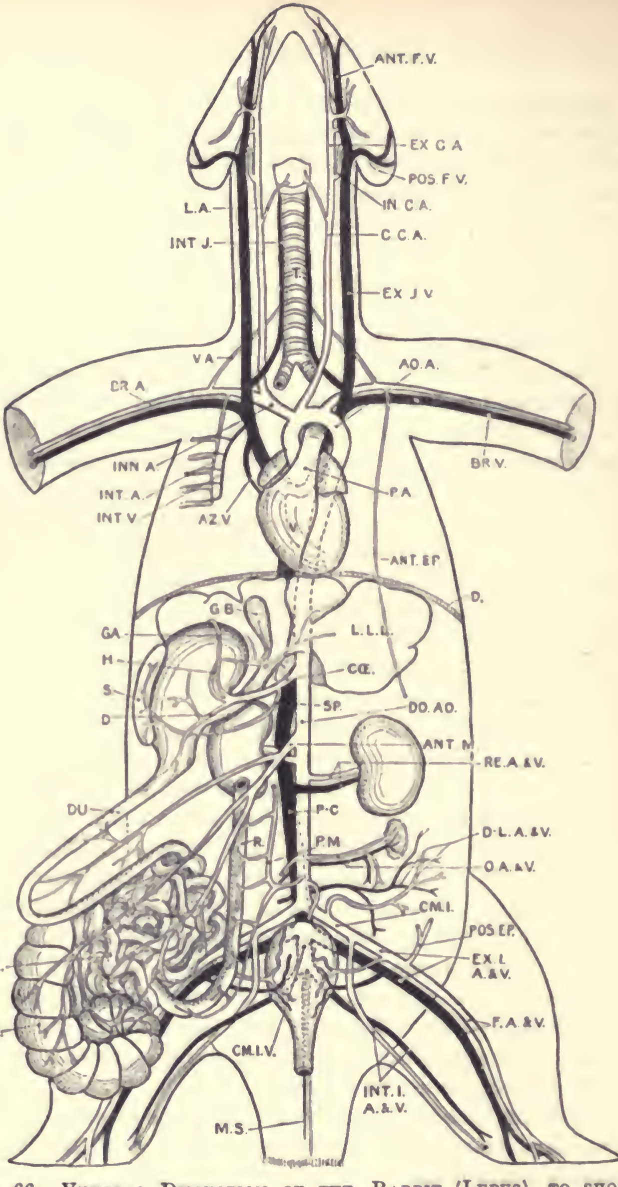

FIG. 66.—VENTRAL DISSECTION OF THE RABBIT (LEPUS), TO SHOW MAIN ARTERIAL AND VENOUS VESSELS.

[*Continued at foot of page* 145.

The arterial blood-pressure can be measured very easily by an instrument called a "sphygmometer." This consists of a broad rubber bag enclosed in a leathern armlet. The armlet is strapped round the arm above the elbow. The rubber bag is connected with a pressure gauge or mercurial manometer, and with a syringe-bulb. The pressure is raised in the bag by pumping air into it, a finger is placed on the radial artery at the wrist, the pressure in the bag is raised so that it is able to prevent the pulse-wave travelling to the wrist, and the pressure which is just able to do this gives the measure of the blood-pressure.

Velocity of Blood.—The rate at which the blood flows varies in different parts of the vascular system. In order that there should be no stasis of blood in any part of the body, the same amount of blood must enter and leave the heart in a certain interval of time. Therefore the rate of flow in any set of vessels will vary inversely as the area of

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FIG. 66 *continued:*

The arteries are represented in line, and the veins in solid black. The ventral portion of the pelvic and pectoral girdles has been removed, as well as the body wall and ribs. The viscera have been turned over to the animal's right. *AO. A.*, Aortic arch ; *ANT. F. V.*, anterior facial vein ; *ANT. EP.*, anterior epigastric ; *ANT. M.*, anterior mesenteric artery ; *AZ. V.*, azygos vein ; *BR. A.*, brachial artery ; *BR. V.*, brachial vein ; *C. C. A.*, common carotid artery ; *CŒ.*, cœliac artery ; *CÆ.*, cæcum ; *CM. I.*, common iliac artery ; *CM. I. V.*, common iliac vein ; *D.* (to reader's right), diaphragm ; *D.* (to reader's left), duodenal branch of cœliac artery ; *DO. AO.*, dorsal aorta ; *DU.*, duodenum ; *D-L. A.* and *V.*, dorso-lumbar artery and vein ; *EX. C. A.*, external carotid artery ; *EX. J. V.*, external jugular vein ; *EX. I. A.* and *V.*, external iliac artery and vein ; *F. A.* and *V.*, femoral artery and vein ; *G. A.*, gastric artery ; *G-B.*, gall-bladder ; *H.*, hepatic artery ; *IN. C. A.*, internal carotid artery ; *INT. I. A.* and *V.*, internal iliac artery and vein ; *IL.*, ileum, or small intestine ; *INT. A.*, intercostal artery ; *INT. V.*, intercostal vein ; *INN. A.*, innominate artery ; *INT. J.*, internal jugular vein ; *L. A.*, laryngeal artery ; *L. L. L.*, left lobe of liver ; *M. S.*, median sacral vein ; the artery of the same name is immediately to the left of it ; *O. A.* and *V.*, ovarian artery and vein ; *P. A.*, pulmonary artery ; *P. M.*, posterior mesenteric artery ; *P.-C.*, postcaval vein ; *POS. EP.*, posterior epigastric artery ; *POS. F. V.*, posterior facial vein ; *R.*, rectum ; *T.*, trachea ; *V. A.*, vertebral artery. The pre-caval veins are not lettered, but they are the two veins entering the heart from above, and formed by the union of *BR. V.* and *EX. J. V.*

cross-section of the vessels. When a river passes through a gorge its velocity is very great, but when it widens out in the plains the rate of flow is greatly diminished, and this is because, if there is increased area of cross-section in the river-bed, a smaller velocity will allow a volume of water to pass which in the narrow gorge would require a greater velocity for its passage in the same interval of time. The same principle holds with the blood-flow. The area of cross-section of an artery is always smaller than the total area of cross-section of its branches, and, similarly, the total cross-section of tributaries of a vein is always greater than that of the vein itself.

As we pass from the aorta to the capillaries, there is greater and greater increase in the area of cross-section of the bloodvessels, and in the capillaries we have the greatest cross-area. As the capillaries join into veins, and the smaller veins into larger veins, the bed again becomes narrowed; finally, in the two venæ cavæ the capacity is not much greater than that of the aorta.

In the aorta the channel is narrow and the flow fast; through the capillaries the blood moves slowly, for here the total bed through which the stream flows is far wider than that afforded by the aorta. As the capillaries unite to form veins, and these to form larger veins, the bed again becomes narrowed, and hence the velocity increased.

Relation of Circulation to the Nervous System.

The amount of blood passing through an organ is proportional to the amount of physiological activity going on in that organ. The total amount of blood that is normally present in the body would not be sufficient to supply adequately all the organs if they were in an active condition at the same time. Since it is absolutely necessary that the parts of the body that are in activity should receive a good supply of blood, Nature has elaborated effectual means of governing the blood-supply to various organs according to their physiological requirements. This is done by increasing or decreasing the rate and strength of the cardiac beats, and varying the calibre of the bloodvessels. So that, if any part of the body requires a greater amount of blood, it will receive it by a dilatation of its own bloodvessels and constriction of vessels supplying the parts that are not in activity; and if this will not suffice, the heart will beat quicker and stronger, and still further increase the amount of blood passing through the site of activity.

Vasomotor Nerves.—When describing the structure of arteries, we said that their walls were made up of muscular elastic tissue. The muscular tissue contracts and relaxes like all forms of muscle, and these phenomena are under the influence of a special set of nerves, which are called the "vasomotor nerves." They run along the course of the arteries, and end in a network of filaments in contact with the muscle cells. These nerves emerge by the anterior roots of the spinal nerves, and have their origin in the spinal cord. The vasomotor nerves are of two kinds—vaso-constrictor and vaso-dilator. The vaso-constrictor nerves cause contraction of the muscular coat of arteries, and therefore a decrease in their lumina; while the dilator fibres cause relaxation, and thus bring about an increase in the calibre of the arteries.

All the vaso-constrictor nerves arise from the nerves which issue from the spinal cord in the thoracic and upper lumbar regions. From the spinal cord they pass to the sympathetic system, which is a series of nerve ganglia connected by a nerve cord, lying in front of the vertebral column, and from the ganglia the fibres are carried on to the wall of the bloodvessels.

Vaso-dilator fibres are present in most of the cranial and spinal nerves. When certain precautions are taken to prevent a constrictor effect, the stimulation of nerves containing these fibres brings about vaso-dilatation of the organs which they supply.

Vasomotor Centre.—The vaso-constrictor fibres are generally in tonic activity, while the vaso-dilator fibres are not in tonic activity; in other words, impulses are continually passing along the vaso-constrictor fibres, keeping the musculature of the arteries in a certain state of tonic contraction, while such impulses do not continuously travel along the vaso-dilator fibres, but only at certain special periods. All the vaso-constrictor fibres are in connection with a special group of nerve cells situated in the lower part of the medulla oblongata of the brain, and this group of cells is called the **vasomotor centre.** The vaso-dilator fibres, on the other hand, are not connected with any special group of nerve cells, and, as said above, they are not in tonic activity. This generation and passage of impulses from the vasomotor centre along the vaso-constrictor nerves are the factors that govern the relative amount of blood-flow through the different tissues of the body, and it is by such means that the parts of the body which are in physiological activity receive a greater blood-supply at the expense of such tissues as are not in activity. This greater blood-supply is obtained by either stimulation of the vaso-dilator fibres or inhibition of the vaso-constrictor fibres which supply the active organ, and by stimulation of the vaso-constrictor fibres supplying the rest of the body. Thus, during mental activity, in order to have a good supply of blood to the brain, there is constriction of the arteries of the other parts of the body.

During digestion there is great activity going on in the stomach and intestines, resulting in dilatation of their blood-vessels, and increase in the amount of blood in the abdominal viscera. Consequently not so much blood is left to supply the brain and other tissues; hence mental work is performed with difficulty after heavy meals.

Similarly, during muscular exercise there is greater flow of blood to the muscles.

Various emotional conditions influence the activity of the vasomotor centre; thus, fear or fright causes constriction of the peripheral vessels, while feelings of shame or embarrassment cause vaso-dilatation.

The vasomotor nerves also counteract the effect of gravity upon the weight of the blood, and when the body is in the erect posture the constriction of the bloodvessels prevents the stagnation of blood in the arteries of the lower limbs and abdomen. When, however, this influence is removed the bloodvessels dilate, and the stagnation of blood in the abdomen and lower limbs is such that the amount going to the brain is so diminished that it results in fainting. It is evident that the rational treatment of such a condition is to lay the patient flat on the ground, or place him with his feet up in the air, and the force of gravity will then help the flow of blood to the brain.

Nerve-Supply of the Heart, and its Actions.—The heart is richly supplied with nerves, which arise from two sources —namely, from the vagi and the sympathetic systems.

The vagi, or tenth cranial nerves, arise from the medulla. One runs on each side of the neck between the carotid artery and the internal jugular vein; they both run through the thorax, and pass to the abdomen, where they end by joining various abdominal nervous plexuses. During their course in the neck each vagus gives off three cardiac branches, which pass down to supply the heart.

The sympathetic nervous chain will be found on each side of the neck behind the carotid artery, and three cardiac branches are given off on each side, which also go down to supply the heart. Stimulation of the vagi causes the heart to beat more slowly, or stop for a short time altogether. The cardiac fibres of the vagi are connected with a group of nerve cells in the medulla oblongata, called the "cardio-inhibitory centre," and this centre is always in tonic activity; this is proved by the fact that if the vagi be cut the heart will beat more rapidly.

Stimulation of the sympathetic supply of the heart will cause it to beat more rapidly and more forcibly; hence their influence is entirely opposite to that of the vagi.

There are also two nerves, one on each side, which carry impulses from the heart to the medulla. In part of their course the fibres ascend in the vagi. If these fibres are separated from the vagi and stimulated, the vasomotor centre will be depressed, and consequently there will be great vaso-dilatation. The blood will escape more easily to the capillaries, and the heart, owing to the consequent fall of pressure in the aorta, expels the blood at each systole with less effort.

The medulla oblongata has complete nervous control over the circulation. The heart can be made to work more quickly or slowly, and each organ can obtain the blood it requires during activity or rest.

Respiration.

Respiration in its widest sense is the means by which the tissues of the body gain the oxygen they require, and eliminate the carbon dioxide they produce.

Oxygen must be supplied to the protoplasm in order that the energy of life may be maintained.

In the lowest animals, which are made of a single cell; no special mechanism of respiration is needed ; the oxygen diffuses in and the carbon dioxide diffuses out through the general surface.

In some multicellular animals — *e.g.*, sea-anemones — oxygen is obtained by diffusion through the ectoderm from the surrounding water. In animals of more complex structure special adaptation for this important process becomes necessary, and respiration may be divided into two stages :

1. *External respiration* is the means by which the gaseous exchange takes place between the air or water and the circulating fluid.

2. *Internal respiration* is the means by which the interchange takes place between the circulating fluid and the cells of the tissues.

In the lower kinds of worms gaseous exchange takes place almost entirely by the skin, under which plexuses of blood-vessels often exist.

In crayfish there are special organs called "gills," where the circulating fluid absorbs oxygen from the surrounding water.

The bodies of insects are traversed by minute tubes, which carry air from the outside to the tissues within.

Fishes and other water animals possess gills. By means of these organs water is rhythmically swept over these membranous sheets of tissue, which contain networks of capillaries full of blood.

The respiratory organs of birds are complicated; in addition to small lungs they possess large and membranous air-sacs. These sacs surround the lungs, and extend between the organs of the body. They are connected with the windpipe and its branches, and with the hollow medullary cavities of the bones.

In man and the higher animals we have in the lungs complicated organs, specially devised for the absorption of oxygen and the elimination of carbon dioxide.

Physiological Anatomy of the Respiratory Apparatus.

In man the respiratory apparatus consists of the nose, pharynx, larynx, trachea, bronchi, bronchioles, and air-sacs.

The **nose** is a cavity that is bounded above by the bone of the skull, below by the soft and hard palate, and laterally by the upper jaw-bone. The nasal cavity is divided into two by the nasal septum, which is made up of a framework of bone covered by a mucous membrane.

The upper part of the nose is covered by a special form of mucous membrane, which constitutes the organ of smell.

The remaining surface of the nasal cavity is lined by ciliated epithelium, and the air in its passage to the lungs comes in contact with this, and is filtered free from dust particles and bacteria. Hence it is important that one should always breathe by the nose, for the air is rendered warm and moist, and is also purified to a large extent from bacteria and dust particles.

Ask a butcher for the head of a sheep which has been sawn through the middle line, and study in it the general anatomy of the nasal cavities.

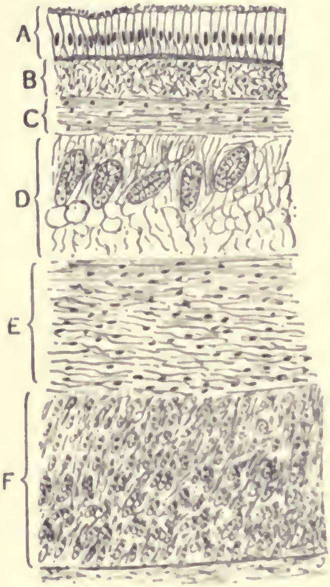


FIG. 67. — MICROSCOPIC STRUCTURE OF TRACHEA.

A, Mucous membrane formed of ciliated epithelium; *B*, layer of loose connective tissue; *C*, layer of yellow elastic fibres; *D*, submucous coat made up of loose connective tissue, and containing mucous glands; *E*, layer of involuntary muscular tissue; *F*, supporting cartilage.

The structure of the **pharynx** has been described in Chapter III. It is divided into two portions by the soft palate—an upper nasal pharynx, and a lower oral pharynx, which is a passage common to food and air.

At the lower end of the pharynx there commence two tubes, the œsophagus or gullet behind, and the trachea in front. At the upper part of the trachea is the larynx, which is a cartilaginous box specialized for the production of voice. In order to study the structure of the trachea, larynx, and lungs, ask the butcher for the pluck of a sheep.

For the structure of nose and pharynx, study Fig. 35, etc.

The **trachea, or windpipe,** will be found to be formed of C-shaped rings of cartilage covered within by mucous membrane; the rings are incomplete behind where the trachea rests on the gullet, which in its turn lies on the vertebral column. Owing to the rings of cartilage the trachea remains open always, and cannot be compressed except by considerable force. The rings of cartilage imperfect behind are completed by a band of non-striated muscle. The cartilage rings themselves are embedded in and connected together by connective tissue. The mucous membrane is lined by ciliated epithelium resting on a basement membrane; beneath it there is a layer of elastic tissue and a deeper layer of loose connective tissue containing a large number of mucous glands.

Bronchi and Bronchioles.—The trachea divides below into right and left bronchi; one goes to each lung. The bronchi are similar in structure to the trachea.

Bronchial tubes are formed by the subdivision of the bronchi; they are in structure similar to the bronchi, but pieces, not rings, of cartilage strengthen the walls, and there is a complete ring of muscular tissue.

The bronchial tubes subdivide into bronchioles, and these pass to all parts of the lung, and end finally in the air-sacs.

The Structure of the Lung.—Each bronchiole ends at length in an elongated dilatation about $\frac{1}{30}$ inch in diameter on an average, and known as an **infundibulum.** The wall of an infundibulum sends flattened projections into its interior, and thus forms a series of thin partitions by which the cavity of the infundibulum is divided up into a large number of little sacs or chambers. These sacs are the alveoli, or air-sacs.

The very thin walls which separate these alveoli are supported by much delicate and highly elastic tissue, and carry the wide and close-set capillaries into which the ultimate ramifications of the pulmonary artery pours its blood.

Thus the blood contained in these capillaries is exposed on both sides to the air, and separating the blood from the air we have only two layers of endothelial cells; through these the gaseous interchange takes place. The air-sacs are bound together by connective tissue to form lobules, and these are further bound to form lobes. In the human subject there are three lobes in the right lung, and two in the left lung.

Circulation of Blood through the Lungs.—Venous blood is returned to the heart from all parts of the body by the superior and inferior venæ cavæ. It first of all reaches the right auricle, and from there it passes through the right auriculo-ventricular orifice to the right ventricle. The pulmonary artery arises from the right ventricle, and carries

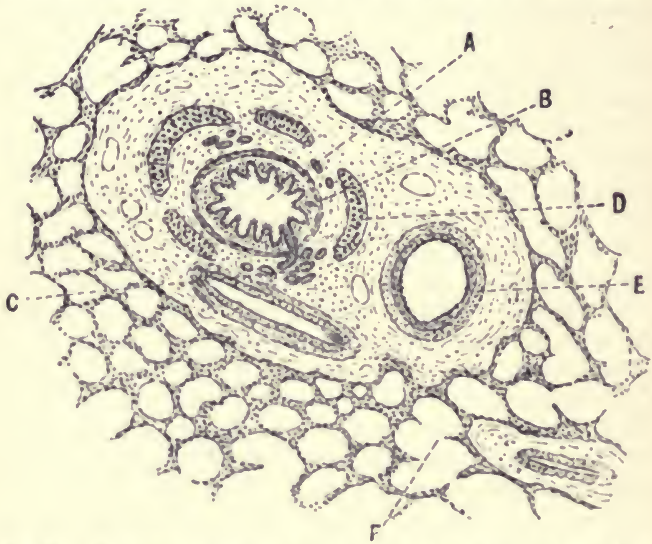


Fig. 68.—Microscopic Section through a Fragment of the Lung. *A*, Bronchial tube lined with ciliated cells; *B*, layer of unstriped muscle; *C*, mucous gland with duct; *D*, cartilage stiffening the walls; *E*, branch of pulmonary artery; *F*, air-cells in which the bronchial tubes end.

the venous blood to the lungs. It divides into branches which pass to the lobes and lobules, and finally ends in a network of capillaries surrounding the wall of each air-sac. The tissue of the lung itself is supplied with some arterial blood by branches of the aorta—the bronchial arteries.

The respiratory movements draw air to the lungs until the cavities of the air-sacs are filled with air, and in their walls the venous blood is contained in the capillaries, and separating the two is nothing but the thinnest membrane, composed of two layers of flat pavement epithelial cells. Here the interchange of gases takes place ; the blood gives off carbonic acid, and absorbs oxygen from the air within the air-sacs.

These capillaries unite to form venules, and the blood re-enters the heart by two pulmonary veins from each side, four in all, which open into the left auricle.

The blood during its passage through the lungs has changed greatly in colour. As it enters the lung it is bluish and dark, while on its return its colour has changed to a bright red. This is due to the oxygenation of the hæmoglobin. Oxyhæmoglobin is bright red, while reduced hæmoglobin is very dark red in colour.

Since the capillary area of the lungs is less than that of the systemic system, the peripheral resistance must also be less ; and therefore the pressure of the blood in the pulmonary system is smaller, but the velocity is greater, than in the systemic system.

In order that the blood may continually acquire oxygen and yield up carbon dioxide, it is necessary that the air in the lungs should be renewed. This is effected by the act of respiration, which occurs about fifteen to twenty times a minute.

The Thoracic Cavity.—The thorax is the part of the body in which the lungs and heart are situated. It also contains the great vessels entering and leaving the heart and lungs ; the gullet passes through it on its way to the abdomen.

The whole structure is supported by a bony framework ; this is made up of the backbone or vertebral column behind, the breast-bone or sternum in front, and the ribs pass obliquely between these structures.

Various muscles take origin from, or are inserted into the outer surface of the ribs and sternum. Some come down from the neck, others pass to the abdominal wall or upper limbs, while behind the great muscles of the back are situated. On the outer surface of these muscles there lie subcutaneous tissue and the skin. In between the ribs there are two thin sheets of muscle called the "internal and external intercostal muscles."

The contraction of all the muscles attached to this bony framework either tend to expand or diminish the dimensions of the thoracic cavity ; the former are called "inspiratory" and the latter "expiratory" muscles.

The thorax is bounded above by the connective tissue which passes from the neck on the great vessels, gullet, and windpipe, as they enter it. It is separated from the abdominal cavity by a muscular partition called the "diaphragm."

The pericardium and its contents more or less divide the thoracic cavity into two, and each is occupied by a lung, covered by a glistening membrane called the "pleura."

The pleuræ are two membranous sacs, each surrounding a lung. It must not be thought that each lung is placed inside each sac, but the walls of each sac are in apposition, and the whole structure then surrounds a lung. Thus the whole lung is surrounded by a pleura, except in a small area on the inner surface, where the bronchi and bloodvessels leave and enter it ; this area is called the "root of the lung." It is seen that the cavities of the pleural sacs are in normal persons only potential spaces. Since the lungs are always in a condition of distension, and fill all the available space in the thoracic cavity, the outer layer of the pleura becomes attached to the inner surface of the thoracic wall, while the inner is intimately connected with the outer surface of the lung. The surfaces of the pleuræ which are in contact with each other are smooth and glistening ; they also secrete a small quantity of fluid, which lubricates the surfaces, and hence the alternate expansion and contraction of the lungs are allowed to take place with the least possible amount of friction. When the pleuræ become inflamed, the surfaces become sticky, and may result in adhesions ; the expansion of the corresponding lung would be limited, and the inflammatory stage accompanied by pain.

The lungs may be looked upon as two large membranous, elastic sacs, the interior of which communicates freely with the air through the trachea, while the outside is protected from atmospheric pressure by the walls of the chest. When the chest is opened, the lungs are found shrunk up and far smaller than the thoracic cavity.

The atmospheric pressure on the interior surface of the lungs expands these structures under normal conditions until they fill every part of the thoracic cavity not occupied by other organs. When the dimensions of the chest cavity vary, that of the lungs will follow suit, until they again fill up every part of the thorax. If the thoracic cavity communicates with the outside air, or if the wall of the lung is punctured so that air can communicate with the pleural cavity, the pressure is equalized on the inner and outer side of the sac, and the lungs, owing to their elasticity, at once collapse.

The Normal Position of the Thorax—*Inspiration and Expiration.*—The size of the thorax continually changes with the respiratory movements. The position taken at the end of a normal expiration may be regarded as the normal position of the thorax, and in this position all the muscles of respiration are at rest. Any enlargement of the thorax from this position constitutes an *active inspiration*, while any decrease in the size of the thorax would be an *active expiration*. It is easily seen how after an active inspiration the thorax may, by its own elasticity and without any muscular effort, return to its normal position, giving what may be called a "passive expiration."

Normally the respiratory movements consist of active inspirations followed by passive expirations.

Respiratory Movements. — Air is constantly renewed in the air-sacs of the lung by alternate expansion and decrease in the cavity of the thorax.

It is readily seen, on studying the shape of the thorax, that expansion of its cavity might occur in three directions—vertical, antero-posterior, and from side to side.

An increase in the vertical diameter can only be brought about by contraction and descent of the diaphragm ; hence the importance of abdominal breathing, because it is the only way by which the vertical diameter of the thoracic cavity may be increased. In the adult the only way in

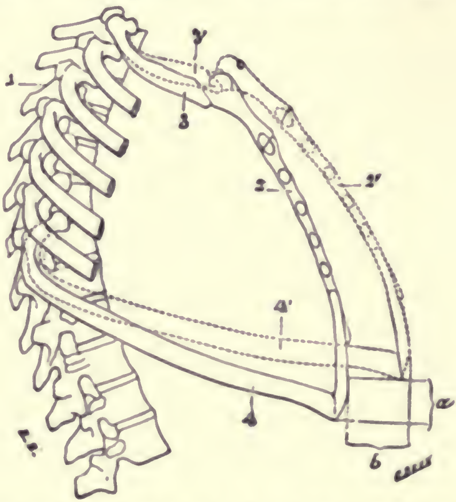


FIG. 69.—DIAGRAM TO SHOW HOW, AS THE RIBS MOVE UPWARDS, THE STERNUM GOES FORWARD, AND SO INCREASES THE SIZE OF THE THORAX DURING INSPIRATION.

1, Spinal column ; 2, sternum ; 3, first rib ; 4, seventh rib ; 2′, 3′, 4′, position in inspiration ; *a*, *b*, indicate the extent of movement.

which aeration of the apices of the lungs can take place is by abdominal breathing. Consumption generally starts at the apices, and lack of aeration is one important predisposing factor. The germs which cause this disease usually invade these regions.

The diaphragm is prevented from pulling inwards the lower ribs by the action of antagonistic muscles, which draw the same ribs outwards. The increase in the antero-posterior diameter is caused by the lifting up of the ribs, which run, in the position of rest, in an oblique direction around the thorax. Each pair of ribs forms one ring of the thoracic cage, and each ring slopes downwards. By pulling each ring into the horizontal position, the thorax must be made larger and the sternum thrust forwards.

The increase in the side-to-side diameter of the thorax is due to the obliquity of the axis around which the ribs move.

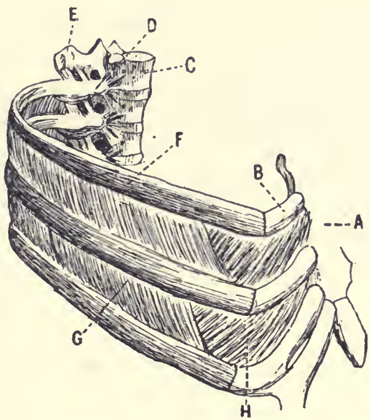


FIG. 70.—FIGURE SHOWING THREE RIBS, THEIR ATTACHMENT TO SPINE AND STERNUM, AND THE MUSCLES COMPLETING THE THORACIC WALL.

A, Sternum; *B*, rib cartilage; *C*, vertebral column; *D*, *E*, attachment of ribs to spine; *F*, rib; *G*, *H*, outer and inner intercostal muscles.

The ribs are fixed to the vertebral column by means of two joints. The head of the rib articulates with the bodies of the vertebræ, while the capitellum is jointed to the top of the transverse process. These two regions are the most fixed points in each rib, and therefore movement takes place around the line which joins these two points. The line is set obliquely, and the increase in the side-to-side diameter of the thorax depends upon this obliquity.

A combination of abdominal and costal movements results in expansion of the thoracic cavity in all directions. and this type of breathing should always be practised.

When the diaphragm descends and the ribs ascend, air rushes down the trachea and bronchi, and distends each lung so as to fill up the enlarged thoracic cavity.

The descent of the diaphragm is necessarily accompanied

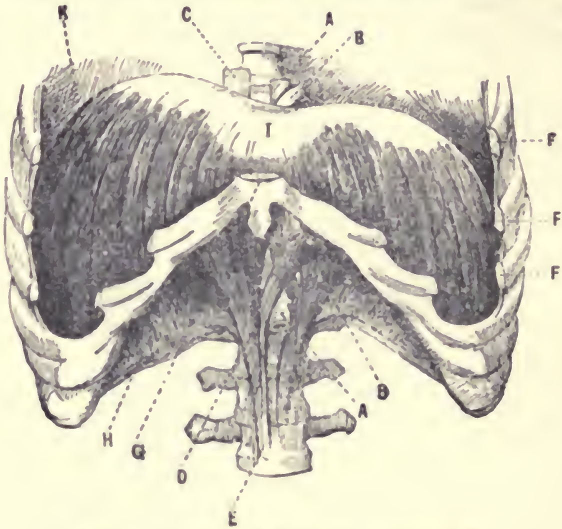


FIG. 71.—THE DOME-SHAPED DIAPHRAGM.

A, Aorta; *B*, œsophagus; *C*, vena cava inferior; *D*, muscular pillars of the diaphragm arising from the spinal column; *E*, *F*, ribs, and *G*, sternum, sawn through so as to allow removal of the front of the thorax; *H*, hind, and *K*, front, muscular sheet, and *I*, central tendinous part, of the diaphragm.

by a descent of the liver and other abdominal contents. This causes an increase in the intra-abdominal pressure, which is associated with a decrease in the thoracic pressure. It is readily understood that during inspiration there would be a greater flow of blood from the abdomen into the thorax. Since blood is sucked into the right heart in great amount, and the capillary area of the lungs is increased, during an inspiratory movement, there is greater volume both of air and blood drawn into the lungs, and hence the gaseous exchange between them is favoured.

The Volume of Air respired in the Capacity of the Lungs.—The volume of air respired varies, of course, with the extent of the movements and the size of the individual.

The amount of air that is taken in and given out at each normal breath is for an adult man about 500 c.c. (a little less than a pint), and is called the *tidal air*.

The amount of air that can be breathed in over and above the tidal air by the greatest possible inspiration measures about 1,600 c.c., and is called the *complemental air*.

By the term *supplemental air* is meant the amount that can be breathed out, after a quiet expiration, by the most forcible expiration. This is about 1,600 c.c.

By "vital capacity" is meant the amount of air that can be breathed out by a most forcible expiration after making the deepest possible inspiration. It is made up of tidal, complemental and, supplemental air. It measures in an adult man about 3,700 c.c.

After the most forcible expiration there still remains about 1,000 c.c. of air, which is called the "residual air."

During natural quiet respiration there are within the lungs about 2,600 c.c. of air, and at each inspiration 500 c.c. of air is taken into the trachea and larger bronchial tubes. The actual ventilation of the air within the alveoli of the lungs depends upon the size of the bronchial tree. It has been found that the area of the bronchial tree amounts to 140 c.c.—therefore 360 c.c. of air actually reach the alveoli during each quiet inspiration; and since there is already present in the lungs about 2,600 c.c., the ventilation would be $\frac{360}{2000} = \frac{1}{6}$ approximately.

Inspired and Expired Air.—Expired air differs from the air inspired in the following manner:

Whatever the temperature of the inspired air may be, that of the expired air tends to be nearly as hot as the blood—that is, it has a temperature about 98·6° F., or 37° C.

However dry the inspired air may be, the expired air is nearly or quite saturated with aqueous vapour. This water is derived from the outer air-passages, so that the inspired air is saturated with aqueous vapour before it reaches the alveoli of the lungs. This is more effectually done when the air is taken in through the nostrils.

The expired air differs in chemical composition from inspired air.

In 100 volumes we find in inspired or atmospheric air—

Oxygen	20·96
Nitrogen	79·00
Carbon dioxide	0·04
Water	variable

In 100 volumes of expired air we find, on the average—

Oxygen	16·40
Nitrogen	79·19
Carbon dioxide	4·41
Water	saturated

Thus, speaking roughly, in air that has been breathed once the amount of nitrogen remains constant; there is a great increase in the amount of aqueous vapour, the amount of carbon dioxide has increased 4 per cent., and the amount of oxygen has decreased about 4 per cent.

Experiment.—Buy some lime-water from a chemist, place at the bottom of a bottle, and shake it up with the air above. The lime-water remains clear. Now place a glass tube into the lime-water, and blow through it. The expired air will immediately make the lime-water milky; this is due to the fact that the carbonic acid of the expired air combines with the lime-water to form carbonate of lime, which is insoluble.

You can prove the presence of moisture in expired air by simply breathing on to any cold surface, when the water vapour will be condensed, and will appear as small droplets of water.

Gas Analysis.—A specimen of air may be obtained by taking a special form of tube, and filling it with acidulated water. On opening one of the taps attached to it, the water will run out and the air will rush in; the taps are then closed. The chemical composition of the sample can be ascertained by an apparatus which is diagrammatically shown in Fig. 72. *A* is a graduated mercurial pump, and

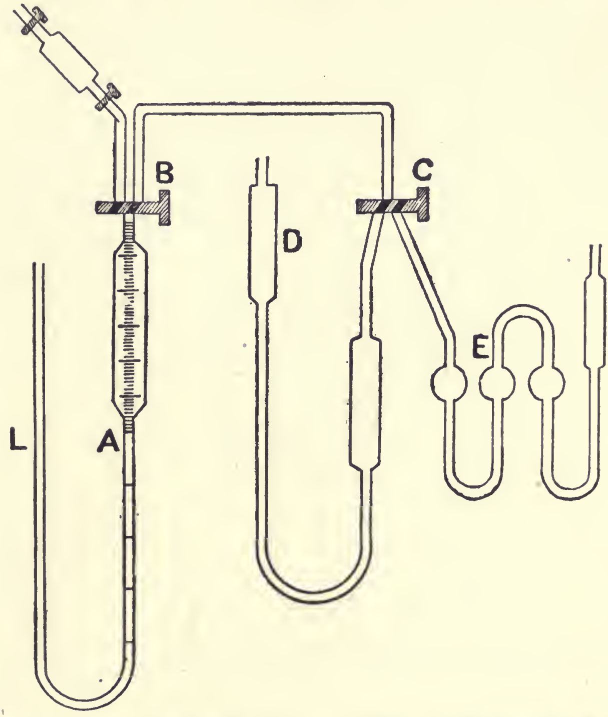


FIG. 72.—DIAGRAM OF APPARATUS USED TO DETERMINE THE COMPOSITION OF AIR.

therefore the contents of the tube can be drawn into *A* by lowering its distal limb, *L*. The amount of air taken is measured. By arranging the taps *B* and *C*, and raising *L*, the contents of *A* are pushed over to *D*, which contains a solution of caustic potash; this absorbs all the carbon dioxide. By lowering *L* the gases are withdrawn into *A*, and the change in volume noted; the difference gives us the amount of carbon dioxide absorbed.

Now, on turning the tap *C*, the contents of *A* may be pushed over to *E*, which contains a solution of pyrogallic acid in caustic potash. This absorbs the oxygen. On returning the contents back to *A* and reading the volume, we find by difference the amount of oxygen absorbed. The remaining volume represents the amount of nitrogen.

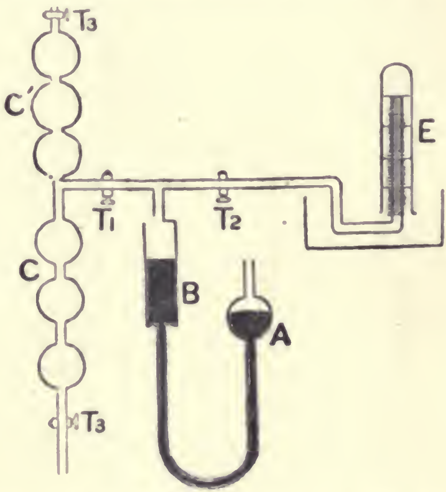


Fig. 73. — Diagram showing the Apparatus used to determine the Gaseous Constituents of Blood.

Knowing what volume of air we started with, we can easily render in percentages the amount of carbon dioxide, oxygen, and nitrogen. To obtain expired air for analysis one requires a large rubber bag fitted with inspiratory and expiratory valves and a mouthpiece. The bag is squeezed empty, and one breathes in the outside air, and expires into the bag.

Gases of the Blood.—If a known quantity of blood be taken from a vein, and the same quantity from an artery, of an animal, the gases contained in each can be analyzed by means of the blood-pump. The blood contains a great deal of gas, for from every 100 pints of blood there can be obtained about 60 pints of gas.

The following is a rough method of performing the analysis (see Fig. 73):

The bulb C is placed in position C'. The reservoir A is raised until C' is full of mercury. On closing the tap T_3 and lowering A, the mercury will fall in C', leaving a vacuum. After producing a vacuum in C', it is placed in the dependent position C. The tap T_3 is immersed in a measured vessel containing defibrinated blood, and this opened for a moment. Blood will rush up into C, and its volume is then observed. The reservoir A is still lowered until there is a greater vacuum in B. The blood in C will begin to froth and bubble, especially if C be warmed. The gases in B can be analyzed by methods similar to that described above.

The difference between the gaseous content of venous and arterial blood is as follows:

	100 Volumes of Arterial Blood would yield about—	100 Volumes of Venous Blood would yield about—
Carbon dioxide	40 volumes	46-50 volumes
Nitrogen	1-2 ,,	1-2 ,,
Oxygen	20 ,,	8-12 ,,

Condition of the Oxygen and Carbon Dioxide in the Blood.—Sugar or salt when brought into contact with water will disappear by entering in solution. Gases can also enter into solution, and animals living in water obtain their oxygen from that which is dissolved in the water. It is found that the amount of gas that can dissolve in a given volume of water is directly proportional to the pressure exerted by the gas in contact with the surface of the water. On the other hand, the amount dissolved will vary inversely as the temperature. A small amount of the oxygen is held in solution in the blood, and this portion will obey the above laws of solubility of gases. But the greater portion of the oxygen is combined chemically with the hæmoglobin, and will therefore not obey the gaseous laws.

The carbon dioxide is present in a small amount in solution, but the greater part is chemically combined with the alkalies of the plasma and the red blood-corpuscles.

The nitrogen is held only in solution, and therefore its amount will vary according to the pressure, and inversely as the temperature.

Gaseous Exchange between the Blood and the Air inside the Alveoli of the Lungs.

The gaseous exchange between the blood and the alveolar air depends on the concentration of the gases. The oxygen and carbon dioxide diffuse from the place where there is more to the place where there is less of each. There is a higher concentration of oxygen in the air than in the blood, and a higher concentration of carbon dioxide in the blood than in the air.

Tissue Respiration.—The term "tissue respiration" is applied to the gaseous exchange taking place between the blood and the tissues. The cells of the body cannot live without oxygen, and the blood is the carrier of oxygen; hence in the capillaries the tissues absorb oxygen from it. The maintenance of life depends on complex chemical changes, and without oxygen these cannot take place. One of the resultant products of these chemical changes is carbonic acid, and this the tissues yield to the blood. Carried away by the blood, it is eliminated from the lungs.

The greater the extent of the tissue changes in the body, the greater will be the amount of oxygen absorbed and the carbon dioxide eliminated. Thus, the amount of carbon dioxide breathed out by a man during muscular exertion may be five times as great as during an equal period of rest.

Like most chemical changes, those of the body are accompanied by the formation of heat, and all the heat of the body is formed in this way. In cold weather the amount of oxygen absorbed and carbon dioxide eliminated is greater than in hot weather. When cold a man moves about actively and contracts his muscles, while in hot weather he is not inclined to do any form of work.

The chief seat of combustion is not in the lungs or blood, but in the tissues, and especially in the muscles.

Relation of Respiration to the Nervous System.—Respiratory movements consist of co-ordinate contraction and relaxation of special sets of muscles. Such phenomena in the body are always under the influence of a special group of nerve cells. The group of nerve cells which controls the respiratory movements is situated in the medulla oblongata, very close to the cardio-inhibitory centre. This is proved by the fact that, if this part of the brain is destroyed in animals, the respiratory movements cease at once. The centre is automatic—that is, it is capable of generating its own stimuli, which pass along the efferent nerves to the muscles concerned in inspiration.

The chief efferent nerves of this centre are the two phrenics, which pass, one on each side, to the diaphragm. If these nerves are cut the diaphragm ceases to contract. The intercostal nerves which supply the other respiratory muscles are also connected with this centre.

Various sensory impulses have a profound effect on the respiratory movements, and this is due to their having either a stimulative or inhibitory effect on the respiratory centre. Irritation in the nose produces a sneeze ; a cough results from a similar process in the larynx or windpipe. A dash of cold water on the skin produces a deep breath. Sharp pain or fright often compels a man to stop breathing. Respiration comes to a standstill for a short time whenever a man swallows.

Sighing is a deep inspiration ; it helps the circulation, because the negative pressure in the thorax is greatly increased, more blood gets to the right heart, and therefore more to the brain.

Yawning is a deep inspiration associated with the contraction of various muscles, which by pressing the capillaries and venules throws more blood to the veins, and therefore improves the circulation.

Crying, shouting, and laughing, are all good exercise and improve the circulation, and they should not always be suppressed in children.

A person to a certain extent has voluntary control over his respiratory movements ; this is because there are nervous connections between the cortex of the brain, where consciousness resides, and the respiratory centre.

A group of nerve cells can be influenced not only by impulses travelling along its nervous connections, but also by a change in the composition of the blood which supplies it, and this has been found to be the case with the respiratory centre. Physiologists argued that, since respiration had to do with the gaseous exchange of the blood, it would be very likely that a variation in the percentage of the gaseous contents of the blood would act as a stimulus to the respiratory centre, and this was found to be the case. The slightest increase in the amount of carbon dioxide in the blood acts as a strong stimulus to the respiratory centre. The carbon dioxide in the blood regulates the respiratory centre, so that its percentage is always kept the same. Owing to this fact, any increased percentage of carbon dioxide in the air of a room only makes the breathing a little deeper. It cannot have any poisonous effect. A great diminution in the amount of oxygen in the air affects the breathing. Small differences, such as occur in close rooms, have no effect. The ill-effect of badly-ventilated and crowded rooms is due to the excessive heat and moisture and absence of movement in the air.

The sensory nerve fibres of the respiratory tract run in the vagi, and impulses passing up these help to co-ordinate the respiratory rhythm and make the movements work smoothly.

Effect of Respiratory Movements on the Circulation.—It has been said above that the respiratory centre and the cardio-inhibitory centre are situated close together in the medulla oblongata. The generation of an impulse and its passage from the respiratory centre has an influence upon the neighbouring cardio-inhibitory centre, and it tends to depress it; therefore the heart generally beats quicker during inspiration than during expiration.

During the first part of inspiration the arterial blood-pressure falls, while during the later stage the blood-pressure is raised a little.

During the first stage of expiration the blood-pressure rises, while during the later stage it falls a little.

Breathing Exercises.—The first important fact that must be realized regarding breathing exercises is that the respiration can only be properly carried out when the air enters through the nose. A large number of children habitually breathe through the mouth. This may arise as a bad habit, and is often followed by nasal obstruction.

But children may be unable to use the nose because it is partly or wholly blocked by adenoid vegetations, other forms of growths, or catarrhal condition. Such children are usually weakly developed and of low vitality, and they soon give up all attempt to breathe through the nose. It is obvious that breathing exercises will be of no use to the child unless the mechanical obstruction is removed; therefore if the teacher suspect a member of a class to be suffering from nasal obstruction, he should be sent to the medical officer for examination.

Breathing exercises can be given at short, odd intervals between lessons. It is very advisable to have all the windows open all the time, so that there is a good supply of pure air.

The following is a type of breathing exercise that can be readily performed by members of a class: The children should be taught to stand at attention, the shoulders well pulled back and the hands resting on the hips. They should then take a slow, steady breath through the nose, the mouth being firmly closed, raising the chest to accommodate the intake of air, and keeping the shoulders fixed. This should be practised several times a day, but not for long at a time. When the movements of respiration were described, it was said that in the adult the apex of the lung is aerated only by contraction of the diaphragm, so it is also important for abdominal breathing to be practised. Many authorities maintain that breathing exercises, if generally and thoroughly carried out in every school and by all children, would do more than anything else to cause a rapid diminution in the number of cases of adenoids in children and consumption in young adults.

Only general principles that should guide the teacher when instructing a class in breathing exercises have been indicated. For the exact performance of the exercises the teacher should consult the Syllabus of Physical Exercises issued by the Board of Education.

A very important objection to these breathing exercises is that, unless there is a general activity of the body musculature, they embarrass the circulation, so that walking and running and outdoor sports are far better respiratory exercise than the kind of exercises that have been described above.

Advantages of an Open-Air Life.—In the open air our bodies are surrounded by layers of air which are continually changing; the molecules of air on coming in contact with our bodies take away some of our body heat, and the greater the rate at which the layers of air in contact with our body surface are renewed, the greater will be the loss of our body heat. This will excite a greater production of heat in the body, and therefore all the processes involved in the production of heat will be accelerated—that is, there will be an increase in the consumption of food and oxygen and a greater production of carbon dioxide. There will be greater movement of the body, the muscular contractions will improve the circulation in the veins, the inflow of blood to the heart will be greater, and this will stimulate the cardiac muscle to contract more efficiently; hence the circulation of the blood will be greatly improved to what it will be if the person habitually stays indoors.

Since the circulation is improved, and there is vaso-constriction of the skin vessels excited by the cold, the blood-pressure will be raised, a better quality and greater amount of blood will pass to the brain, the condition of the nerve cells will be improved, and therefore all forms of mental work will be done better and with greater ease.

When treating of the functions of the blood, it was said that it possesses substances which protect the body against the invasion of micro-organisms, and there is no doubt that by leading an open-air life these substances are increased in amount.

The white blood-corpuscles are also in better condition, and are able to cope more effectually with any form of invading germs.

It is a well-known fact that a person who lives an out-door life is far less liable to contract disease, when exposed to infection, than a person who lives a sedentary life and is always indoors.

The mental and moral condition of persons is improved by outdoor exercises.

Adenoids.—At the back of the nose, where the nasal passages open into the pharynx, nodules of lymphatic glandular material are situated. These may cause trouble by becoming enlarged.

Repeated attacks of cold may result in a chronic inflammatory condition of this adenoid tissue. A vicious circle is set up, the child takes cold more readily than ever, and eventually the adenoid growths become of a size sufficient to cause the characteristic signs of obstruction.

Mouth breathing is the most characteristic sign of adenoids, and it may lead to serious consequences. The air as it enters the bronchi and lungs has not been warmed and filtered through the nose; consequently it acts as an irritant to the mucous membrane of the bronchi, and may set up bronchitis.

Children so affected are more liable to infectious disease, and when such disease develops they are more liable to bronchial and pulmonary complications.

Snoring is another sign of adenoids, and it seldom occurs in children apart from the presence of adenoids or some other form of nasal obstruction. Nasal discharge is frequently present, and leads to excoriation outside the nose.

There are important ear signs which arise from adenoid vegetation. Deafness is very common. This is due to blockage of the Eustachian tube. The inflammatory condition may spread up the Eustachian tube, and lead to inflammation of the middle ear. Pus may be formed here, the tympanic membrane perforated, and a discharge from the ear result.

The speech of children with adenoids is altered. There is marked nasal intonation, and in younger children the speech is thick and indistinct, and pronunciation defective. This is due to defective action of the soft palate and the general catarrhal condition of the nose and pharynx.

There are certain nervous conditions usually associated with adenoids. There is a curious condition of mental dulness characterized by marked loss of power of concentration. There are various theories about the way it is brought about ; it is certainly partly due to deafness.

Night terrors are often present. Nocturnal incontinence of urine is another condition associated with adenoids.

Tight Clothing.—Tight clothing hinders the respiratory movement and the taking of exercise. It also causes displacement of organs ; tight corsets cause the liver to be pushed up towards the thorax, and the stomach is often displaced, and this certainly interferes with the functional activity of these organs.

It causes compression of the muscles beneath, and therefore they tend to atrophy.

CHAPTER V

THE EXCRETORY SYSTEM

Care of the Body.—The life of the members of the human race may be divided up into various periods, and the mode of living will vary to a great extent in each period.

Certain broad principles may be laid down, which apply to all periods of life, such as the necessity of nourishing food, suitable clothing, adequate periods of work and rest, appropriate exercises in the open air, etc.; but the quality and quantity of these necessities vary according to the age of the individual, so that it is impossible to lay down any strict rules that apply equally to persons of all ages, and not even to those of the same age.

A few words must be said in a general way on personal cleanliness, habits, clothing, etc.

Personal Cleanliness.—The importance of personal cleanliness must be instilled into the children. The hair, face, and hands, should always be clean, and the nails kept short. The skin must be kept clean, because dirt predisposes to infection by bacteria and the formation of blackheads, pimples, boils, and abscesses, and it harbours parasites. A weekly change of underclothing and frequent baths are essential.

The benefits of school baths have been extolled by teachers and doctors; there is great reduction in skin diseases and vermin, increased self-respect among the scholars, disappearance of unpleasant odours in classrooms occupied by the children, and good moral influence on the homes. Cold baths and swimming have a splendid tonic effect on the body.

The hygiene of the mouth and teeth has been discussed in Chapter III.

Habits.—Children are very sensitive to every form of external impression, and habits are formed very early in life. Since children are so imitative, it is very important that the teacher should give them a good example of character and personal cleanliness.

The children should be taught the importance of cleanliness of the skin, care of the teeth, regular action of the bowels, sufficient sleep, adequate exercise, and the avoidance of tobacco and alcohol. Constipation is one of the commonest diseases in this country, and this is largely due to the fact that parents do not teach their children that the daily regular action of the bowel is a necessity for health, and this regularity can only be attained by keeping to the same hour every day. For most people the most convenient time is just before or after breakfast. Children should be taught that to allow waste products to accumulate in the body causes the absorption of putrefactive substances, which poison all the tissues.

Another very bad habit is spitting. This should be suppressed in the schools, not only on account of its filthiness, but because it is often a potent factor in spreading disease ; for instance, there is no doubt that spitting by consumptive persons is a very important factor in the spreading of this disease.

There are other bad habits that children may attain in schools, and it is the duty of teachers to do all in their power to suppress them.

The children should also be taught their duty in helping to keep their homes, the streets, and open spaces, parks, and gardens, clean and tidy.

Nutrition.—In order to develop a healthy body and mind, an adequate amount of food is absolutely necessary. Foodstuffs may be divided into three great classes : starches, fats, and proteins. The uses of food in children are—(1) To build up the tissues during growth ; (2) to supply the energy for the formation of body heat and all the work of the body—*e.g.*, contraction of muscles, secretory processes, brain work, etc.; (3) to repair the damage due to wear and tear of the body tissues.

The proteins, starches, sugars, and fats, all serve as sources of energy to the body, but the proteins are necessary for the building up and repair of the tissues.

The tissue-forming food, or protein, is the most expensive foodstuff, and is therefore amongst the poorer classes deficient in quantity and quality, and this results in poor physical and mental development.

Fats seem very essential for children, and deficiency in fat is one cause of rickets.

Unless children are properly fed, it is unprofitable to attempt to teach them. The mental apparatus of such children is unfit for work, and if work is insisted upon, the nervous system is readily exhausted, and this results in all sorts of evil.

The Regulation of the Heat of the Body.—The temperature of the human body remains practically constant in all conditions of normal health.

Temperature is registered by means of a thermometer, and the special form of instrument that is used to ascertain the temperature of the body is called a "clinical thermometer."

The organs of a man's body work at a temperature of 98·5° F. If the temperature either rises or falls a few degrees, the functions are disordered, and if continued for some time life becomes endangered.

The temperature is kept uniform by the control (1) of heat production, (2) of heat loss.

Heat Production.—In order to maintain life, certain complex chemical changes are going on in all forms of living tissues, and such changes always produce heat. The contraction of the muscles results in the breaking down of complex contractile substances and the formation of heat and simple waste products—carbon dioxide and water. When a person gets cold, he voluntarily increases the activity of his muscles by moving about; *e.g.*, a coachman or policeman beats his chest and stamps his feet on the ground, and this results in greater production of heat, and tends therefore to maintain the body temperature constant.

Each contraction of the heart produces heat, and the force that is spent in driving the blood through the circulatory system is also turned into heat.

The liver, stomach, and all other organs, during activity produce heat.

In cold weather man naturally eats more and shows greater activity, while in hot weather he eats less and avoids effort.

The circulation of the blood distributes the heat evenly to all parts of the body.

Heat Loss.—Heat is lost in the urine, fæces, expired air, but mainly from the skin. Heat is lost from the skin by conduction, convection, radiation, and evaporation.

When one end of a poker is placed in a fire, the distal end very soon becomes hot, and the heat is carried along the poker by a process called "conduction"—that is, it is carried from one molecule to its neighbour, and this gives up some of its heat to the molecule that is next to it, and so on.

Convection is only possible in liquids or gases. The air in contact with the body is heated, its molecules expand and become lighter, these move away and are replaced by molecules of lower temperature, these, again, are heated, and thus the body will continually go on losing heat as long as its temperature is higher than that of the surrounding air.

Heat may be carried from one body to another without heating the intervening medium, and such process is called "radiation."

Evaporation is the conversion of water from its liquid to its gaseous state. This takes place on the surface of the body; sweat is secreted by the sweat-glands, and this is evaporated on the surface of the body, and in order to convert water to steam a large amount of heat is required.

This is one of the most important means by which the heat of the body is lost.

All the above processes are made more effectual by increasing the rate at which the air in contact with the body is changed. They are also increased by a greater blood-supply to the skin.

On the other hand, the heat loss is diminished by the stagnancy of the air in contact with the body, and a decreased supply of blood to the skin.

It is thus seen why in cold weather the skin is pale, the excretion of sweat is decreased, and more clothes are put on, while in warm weather the skin is flushed, there is greater formation of sweat, and the amount of clothing is diminished.

Clothes.—The function of clothing is to prevent a too rapid loss of body heat, and this it does by entangling air within its meshes. Clothes prevent the loss of heat by convection, for the air, when warmed by the body, cannot rise owing to the garments which entangle it. Air is also a bad conductor of heat.

Woollen clothes are warmer than cotton, owing to their spongy texture. White reflects away most sunlight, and is therefore coolest; black absorbs most.

The following are the most important facts that should be considered in the selection of material and type of clothing:

1. The clothes should offer ample protection to the body against heat and cold, and should be such that the surface of the body is held at about the same temperature during summer and winter.

2. They should not interfere with the function of the skin or any of the internal organs.

3. They should be light, and it is easy to obtain warm clothing though it may be light.

4. They should not constrict any part of the body; further, a loose clothing is much warmer, because the amount of air entangled is greater than in the case of tight clothing.

5. They should allow efficient evaporation of sweat from the surface; otherwise the underclothing will become soaked in perspiration, and the skin be sensitized and very liable to be chilled.

The underclothing of children should be made of flannel. It is the best absorber and retainer of moisture, and the worst conductor of heat; it therefore prevents any sudden change of temperature of the skin. Flannel does not catch fire, and is safest for children. Flannelette, on the other hand, is very inflammable. Some children are overclothed, and their skin becomes very sensitive and delicate, and loses its power to react when chilled. Great care should be taken to afford ample protection to the feet. Woollen socks or stockings should be worn; the boots should be made of good leather, fit well, and be protective against cold and damp.

Waste Matter.—The waste matter of the body is made up of the portions of food that remain unabsorbed from the intestine, and also certain chemical compounds that are formed during the chemical changes going on in the tissues of the body. These latter compounds are formed from the food that is absorbed, and result from their oxidation in the tissues.

The undigested foodstuffs remaining in the intestine constitute the fæces, and their composition has been dealt with in the chapter on digestion.

The waste products that are formed in the tissues are mainly carbon dioxide, water, mineral salts, urea, and uric acid; these are expelled either in the urine, the sweat, or from the lungs.

The Kidneys and the Excretion of Urine.—The urine is the most important excretory product of the body. It contains in solution the substances that result from the chemical changes going on in all the tissues. In order to learn some of the most important properties of urine, you should perform the following simple experiments:

1. Collect all the urine passed in twenty-four hours. Measure the quantity, note its colour, and determine its density by means of a hydrometer.

2. Determine whether it is acid, alkaline or neutral in reaction, by placing a piece of red or blue litmus-paper in it.

3. Place a little in a test-tube, and heat it over a spirit-lamp or Bunsen's flame. Healthy urine will remain unchanged, or a slight cloudiness may be produced, which disappears on the addition of acetic acid.

On the other hand, if a cloudiness or coagulum is formed which does not disappear, it is a sign of diseased condition of the kidney, allowing the proteins of the blood to pass through.

4. If some of the urine be evaporated to dryness, a residue will remain, consisting mainly of inorganic salts, urea, and uric acid.

5. Evaporate some urine to about a fourth of its volume, and then add strong nitric acid to it. The acid will combine with urea in the urine, forming an insoluble crystalline precipitate of urea nitrate. Place a little of the liquid containing the crystals under the microscope, and examine their structure.

6. Add a few drops of a solution of copper sulphate and some caustic potash to a small volume of urine in a test-tube, and heat to boiling on a spirit or Bunsen's flame. No red or yellow precipitate is formed in the case of a healthy urine, because sugar is not present. When a person is suffering from diabetes, his urine readily reduces the copper sulphate, and a red or yellow precipitate forms. It must be remembered that this is not an infallible test for sugar.

7. Add some hydrochloric acid to some urine in a glass vessel, and allow it to stand for twenty-four hours. A pinkish precipitate of uric acid will be formed, and deposited at the bottom of the vessel.

8. To some urine in a test-tube add a little nitric acid and solution of silver nitrate. A white precipitate of silver chloride will result. This shows the presence of chlorides in the urine.

9. To show the presence of sulphates, take a little urine in a test-tube and add to it some hydrochloric acid and barium chloride. A white precipitate of barium sulphate will result.

10. The presence of phosphates can be proved by adding solution of ammonium molybdate and nitric acid ; a yellow crystalline precipitate will be formed.

Properties and Composition of Urine. — In a healthy subject the urine is a clear amber-coloured liquid, acid in solution, and its density is higher than that of water. If the specific gravity of water be represented by 1000, that of the urine will be 1020 to 1025. It consists of various inorganic and organic substances dissolved in water. The specific gravity is a good indicator of the amount of solids dissolved in the urine. Thus, after copious drinking the specific gravity is lowered, while after hard muscular work or copious sweating for any reason it is increased. A person suffering from diabetes passes much urine of high specific gravity, due to the sugar present.

Two or three pints of urine are passed every day by a healthy man. Of course the volume will vary with the amount of fluid taken into the body, and the amount of water that is eliminated through other channels, such as the skin, bowels, or lungs.

The inorganic constituents of the urine are the chlorides, sulphates and phosphates of sodium, potassium, calcium, and magnesium, but the salt that is present in largest amount is common salt, or sodium chloride. The presence of these salts can be shown by means of the tests given above. The chief organic constituents of urine are urea, uric acid, and creatinin.

Urea is the chief nitrogenous excretory product of the body. It is partly derived from the wear and tear of the tissue, and partly from the proteins that are absorbed from the alimentary canal. In the chapter on digestion it was said that the proteins of the food are broken down to amino-acids by the action of ferments in the alimentary canal. After absorption they are carried along the portal vein to the liver. If more protein is taken in the food than is required to repair the tissues, the amino-acids which result from this excess are broken up in the liver, and the nitrogenous portion is converted into urea, while the other moiety is changed to glycogen. The urea is carried in the blood-stream to the kidneys and excreted, while the glycogen may remain as such in the liver, or be converted into glucose and carried to the muscles, and there stored as glycogen. If the non-nitrogenous portion is not required for muscular work, it is converted into fat, and stored as such in the body.

The liver, and not the kidneys, is the great site of formation of urea; this we know because, after extirpation of the kidneys in animals, urea still continues to be formed in the body, and finally poisons the animal. If blood containing some of the amino-acids or a solution of ammonium carbonate be circulated artificially through an excised liver, the amount of urea in the blood is increased on its passage through the liver. Diseased conditions of the liver in man will cause an increased amount of ammonium salts, and a diminution in the amount of urea in the urine. In the body uric acid is formed by the breaking up of certain special forms of proteins called "nucleo-proteins." The amount of uric acid in the urine, however, does not tell us anything about the extent of the decomposition of nucleo-proteins going on in the body, because the greater part of the uric acid is converted into urea by the liver, and it is only a small portion that escapes such conversion which appears in the urine. In certain diseased conditions (gout) uric acid is deposited in the capsule of joints, but there is no evidence of an excess of uric acid in the blood in this condition, or that excess of uric acid is the cause of the disease.

Some of the constituents of urine, such as phosphates, uric acid, or urates, may crystallize out and give rise to gravel, or they may be aggregated together to form a stone; this may take place in the kidney or in the bladder, resulting in a kidney or bladder stone respectively. Phosphates are deposited in an alkaline urine, while urates and uric acid are precipitated from an acid urine. Stones give rise to great pain and other troublesome symptoms, and when once formed they can be removed only by the surgeon.

Anatomy of the Kidneys.—The kidneys are two organs of characteristic shape, placed on each side of the vertebral column in the lumbar region. The last rib passes behind each kidney at the junction of the upper with the lower two-thirds. Each kidney is embedded in a capsule of connective tissue containing large quantities of fat.

The outer border of the kidney is convex, while the inner is concave and directed towards the vertebral column. This concavity is called the "hilum of the kidney," and here we find entering and leaving the kidney the renal artery and vein, and also a muscular tube, called the "ureter," which carries the urine from the kidney to the bladder. The relative positions of these structures is the vein in front, the ureter behind, and the artery in between. The renal arteries come from the abdominal aorta, while the renal veins join the inferior vena cava. The blood-supply to the kidney is very large.

On section the kidney will be seen to be made up of a peripheral dark red granular portion called the "cortex," and an inner pale striated portion called the "medulla";

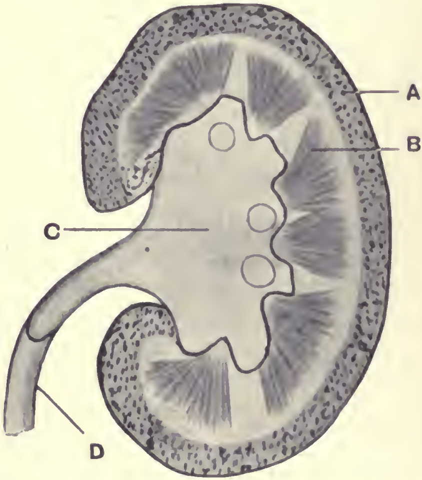


FIG. 74.—DIAGRAM TO SHOW STRUCTURE SEEN ON LONGITUDINAL SECTION OF THE KIDNEY.

A, Cortex; *B*, medulla; *C*, pelvis; *D*, ureter.

this is divided into a number of processes called the "pyramids."

Obtain some sheep's kidneys from a butcher, and make dissections to show their chief anatomical features.

Remove all the fatty connective tissues which surround the kidney, its bloodvessels and ureter. Make a careful dissection to show the relative position of the renal artery and vein and the ureter. Then, with a long sharp knife, bisect the kidney, starting at the convex border. Note the character of the cortex and medulla.

If a section be made of the kidney and examined microscopically, or if a piece of the same organ be unravelled under the microscope, it will be found to be made up of a large number of small tubules lined by secreting cells.

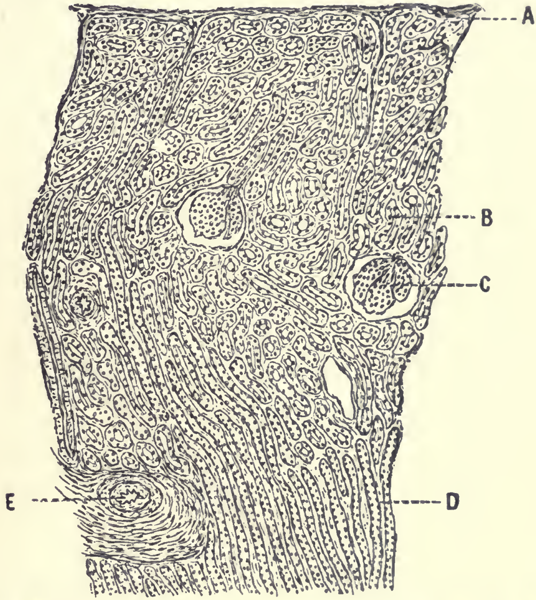


FIG. 75.—MICROSCOPIC SECTION THROUGH A FRAGMENT OF THE KIDNEY.

A, Connective-tissue coat, or capsule; *B*, convoluted tubules; *C*, glomerulus; *D*, loops and collecting tubules; *E*, artery.

These tubules are held together by connective tissue, and supplied by a rich capillary network of bloodvessels.

When each tubule is examined by itself, it will be found to have a long and complicated course. It commences in a dilated portion, called the "capsule," which surrounds a tuft of blood-capillaries called the "glomerulus"; this is situated in the cortex. The first portion of the tubule courses irregularly in the cortex, then runs down into the medulla, where it forms a loop, and returns to the cortex, to again take an irregular course ; finally it opens into a collecting tube which passes straight through the medulla, to open into the pelvis of the kidney at the apex of the pyramids.

The striated structure of the pyramids is due to its being made of straight-coursing tubules, while the granular appearance of the cortex results from the presence of the glomeruli and the irregular course of the tubules.

Blood-Supply of the Kidney.—The right and left kidneys are supplied by the right and left renal arteries, which arise from the abdominal aorta.

Each artery enters the hilum of the kidney, and there divides into branches, which pass in between the pyramids towards the junction between the cortex and medulla Here the branches form a series of arches in the substance of the kidney. From these arches small arteries run outwards into the cortex to supply the glomeruli, and on the inner side branches are given off to the pyramids. Each glomerulus is supplied by its own artery, which breaks up into a number of branches. These join into an efferent vessel which, on issuing from the glomerulus, breaks up into a network of capillaries which surround and supply the convoluted tubes.

The blood is returned by a series of veins, which join together finally to form the renal vein.

Secretion of Urine.—The urine is formed by the secretory activity of the cells lining the capsule and tubules. The water and salts are secreted through the glomeruli, while the organic constituents are thrown out of the blood through the activity of the cells lining the renal tubules.

The amount and character of the urine is influenced by a large number of factors, which act by varying the amount or character of the blood supplying the kidneys.

If the amount of blood passing through the kidneys is increased, there will be a greater amount of urine secreted.

Thus, on a cold day the arteries of the skin are constricted, less blood passes through the periphery of the body, more

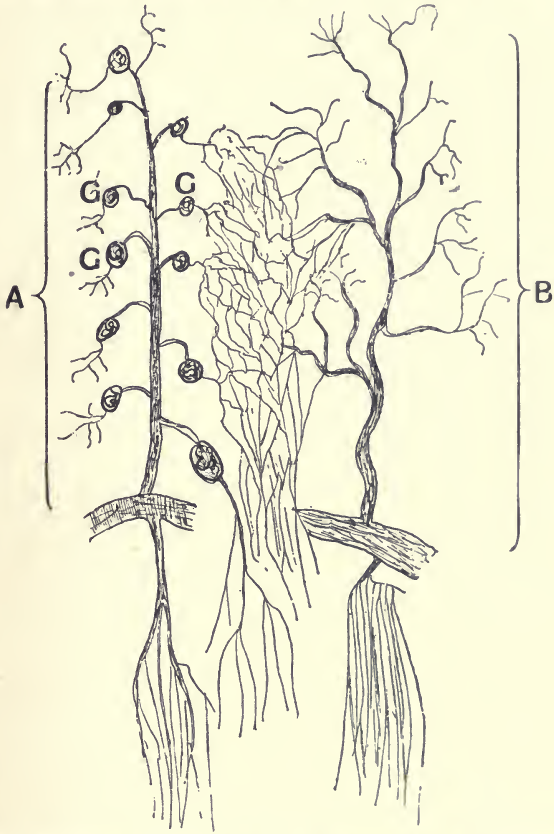


Fig. 76.—Diagram showing the Arrangement of the Bloodvessels in the Kidney.

A., Arteries supplying the glomeruli ; *B*, vein ; *G.*, glomeruli.

circulates through the viscera, and this increased visceral blood-flow is shared by the kidneys, which respond and secrete more urine. On the other hand, on a hot summer's day the bloodvessels of the skin are dilated, a greater amount of blood passes through the periphery and a smaller amount through the viscera ; this results in a decreased secretion from the kidney, and the urine becomes concentrated.

When a person takes large quantities of fluid, it is absorbed into the blood, which becomes diluted and increased in volume. Such a condition excites the kidneys to greater activity ; they excrete copious amounts of dilute urine, and thus restore the blood to its proper composition.

Certain drugs, such as nitrate or acetate of potash, by direct action on the cells of the kidney, excite them to greater activity, and thus increase the amount of urine excreted. Certain other drugs—*e.g.*, digitalis—by improving the general circulation through the kidneys, increase the amount of urine excreted.

Ureter.—This is the small muscular tube by means of which the urine is carried from the hilum of the kidney to the bladder. The muscular coat is made up of an outer circular and an inner longitudinal layer ; it is lined by a mucous membrane. The urine is passed along the ureter by repeated contraction of its muscular wall.

The Bladder.—The bladder is a structure into which the urine flows along the ureter from the kidneys, and where it is lodged until its expulsion from the body.

It is really a muscular bag, lined by a mucous membrane. Its muscular coat is made of involuntary fibres, which are disposed in three layers. The ureters pass into the bladder in an oblique direction, and thus their orifices are covered by a fold of mucous membrane, which prevents the backward flow of the urine from the bladder to the ureter. The bladder opens below the pubic arch (formed by the junction of the anterior parts of the two ossa innominata) into the urethra. Certain fibres of the bladder coat are aggregated at the base to form a sphincter. The urine continuously flows along the ureter from the kidneys. When the bladder has been filled to a certain amount, the pressure is sufficient to arouse a sensation of fulness or desire to micturate. The pressure of the urine inside the bladder stimulates the sensory nerve-endings in the mucous coat; the impulses are carried to the spinal cord, where they initiate reflex motor impulses, which cause contraction of the musculature of the bladder. The pressure of the urine inside is still further increased, and there is a corresponding increase in the sensation of wanting to micturate. These impulses cause relaxation of the sphincter.

There is another sphincter or compressor of the urethra situated just below the pubic arch; this muscle is under voluntary control. The impulses set up in the bladder are passed to the spinal cord, and they also reach the cerebral cortex, which exercises a certain voluntary control over the process. When the occasion is fitting, the voluntary part of micturition comes into play—namely, relaxation of the sphincter and increased abdominal pressure, brought about by closure of glottis and contraction of the abdominal muscles.

The Skin.—The skin consists of two parts—an outer layer, or epidermis, resting on a deeper layer, the dermis.

The skin as a whole is connected to the tissues it covers by a layer of loose connective tissue called "subcutaneous tissue."

The *epidermis* is made of stratified epithelium. It is composed of a number of layers of cells, the deeper of which are soft and protoplasmic, and form the rete mucosum, whilst the superficial layers are hard and horny.

The *dermis* is composed of dense connective tissue, which becomes more open and reticular in texture in its deeper part, where it becomes connected with the subcutaneous tissue.

Sweat-Glands.—If the skin of the palm be examined with a lens, minute pits may be seen, placed in rows on the ridges. These pits are the pores, or ducts, of the sweat-glands. Each gland is composed of a coiled little tube, and lies in the deeper parts of the skin. The sweat-glands, like most glands in the body, are supplied with secretory nerves, which run in the sympathetic system.

The presence of these secretory nerves can be shown by severing the nerve of the leg of a cat, when on placing the cat in a warm chamber the pad of the foot on that leg will not sweat, while the other three feet will.

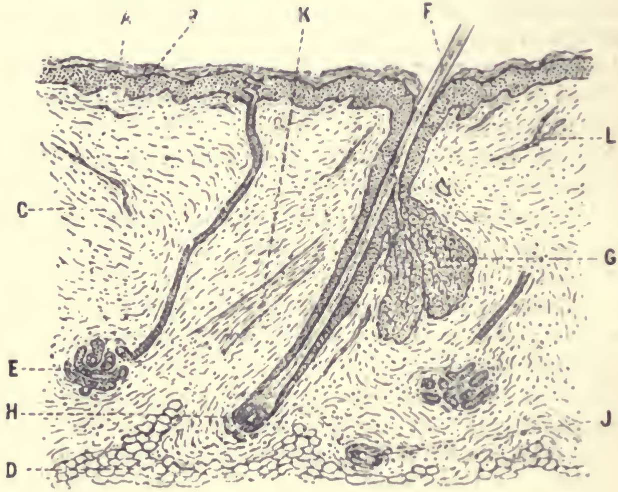


FIG. 77.—MICROSCOPIC SECTION THROUGH THE SKIN.

A, Horny layer of cells ; *B*, layers of soft-growing cells ; *C*, thick connective-tissue coat ; *D*, fat layer ; *E*, sweat-gland and duct ; *F*, hair ; *G*, sebaceous gland ; *H*, papilla of hair ; *J*, small artery ; *K*, muscle of hair ; *L*, capillaries.

Composition of Sweat.—It is very difficult to determine the precise composition of sweat, because, as it is usually obtained, it is mixed with the secretion of the sebaceous glands.

It is made up of water having small quantities of inorganic and organic substances dissolved in it. The larger part of the inorganic salts consists of sodium chloride. Small quantities of the alkaline sulphates and phosphates are also present. The organic constituents, such as urea, are present in mere traces. Usually the amount of urea excreted by the skin is very small, but when the kidneys are diseased the amount found in the sweat is greatly increased. There are sebaceous glands attached to the roots of the hairs, which secrete a fatty substance—the sebum.

Functions of the Skin.—The skin in man has many important functions to perform. (1) It protects the internal organs from injury and access of bacteria ; (2) it regulates the loss of heat from the body ; (3) it has many important sensory functions (these will be dealt with in Chapter VIII.) ; (4) it acts to a small extent as an excretory organ.

The most important excretory product of the skin in a normal person is water. The quantity of water excreted by the skin of a man in twenty-four hours varies so much that it would be impossible to quote any exact figures. It is enough to say that the excretion of water from the skin is about as much as the amount excreted by the kidneys in the same interval of time. The water is excreted by the skin in order to keep it supple and to cool the body by evaporation. The sebum helps to keep the skin and hair supple and sleek, and prevents these being penetrated and softened by water. It also prevents the invasion of bacteria. It is unwise to wash away the sebum by the too free use of soap.

The amount of solids excreted by the skin in a normal person is very small, but under diseased conditions the amount may be greatly increased.

The **Lungs** act as excretory organs, because they get rid of carbon dioxide and water. The older physiologists believed that there were volatile poisonous organic compounds given off by the lungs, but modern research work disproves such a theory.

CHAPTER VI

THE NERVOUS SYSTEM

THE nervous system is the most highly developed portion of the body. In the lower animals it is represented by a layer of cells which have specially developed the function of responding to changes in the environment of the organism.

In the higher animals, man included, the nervous system controls all the functions of the body, and converts to consciousness all the impulses that the organism receives from its surroundings by means of its sense organs.

The nervous system is made up of a number of units, each of which is called a **nerve cell** or **neurone,** and this, like all other animal or vegetable cells, possesses a cell wall, protoplasm, and a nucleus. The nerve cell is irregular in shape, due to the presence of a number of small protrusions, which divide to a number of branches, and one long process, which as it leaves the cell attains a fatty sheath, and often travels for a long distance before it divides into its terminal divisions. The smaller processes are called **dendrites,** while the single long process is called an **axon.** In the nerve cell, after it has been fixed in alcohol, may be seen a number of granules, called "Nissl's granules," after the man who first described them; these are thought to be a special nutritive material for the cell. This has been proved by experimentation in animals. In the resting animal the cells contain a large number of granules, while after exhaustion all the granules disappear. The above description applies to the commonest form of nerve cell, and is the form found in the anterior horn cell of the spinal cord. There are two other forms of nerve cells found in the body. One form differs from the above in that the axon has a very short course, and then divides into a large number of terminal twigs; this serves to connect other nerve cells together, and is called an **association cell.** Another form of cell is one in which the dendrites are replaced by a single process forming a second axon; the

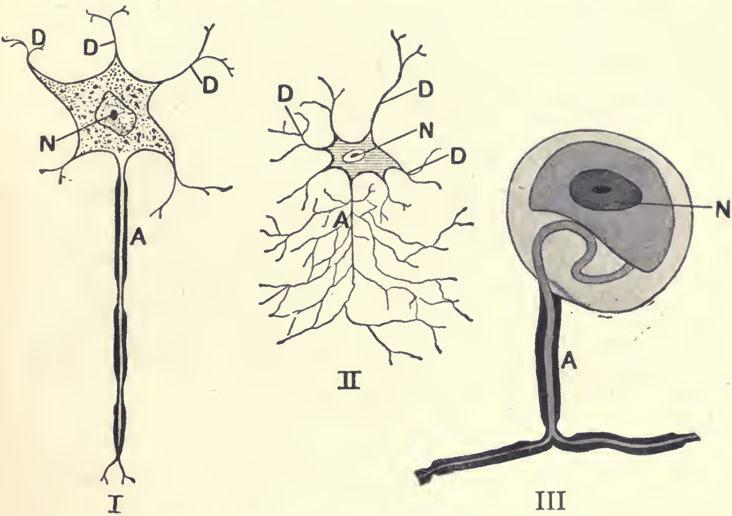


FIG. 78.—THREE FORMS OF NERVE CELLS.
I., Multipolar cell; II., association cell; III., unipolar cell: *N.*, nucleus; *D.*, dendrites; *A.*, axon.

two axons come out of the cell together as a single process, which bifurcates. This is the type found in the ganglia of the sensory root of nerves. The nervous system is made up of—

1. Central portion, comprising the brain and spinal cord.
2. Peripheral portion, made up of nerves and ganglia.
3. Sympathetic system, which governs the activity of internal organs and the tone of the bloodvessels.

The peripheral portion of the nervous system is made up of nerves and ganglia. A ganglion is simply a collection of nerve cells, which are bound together by connective tissue; nerve fibres enter and leave it; they are found mainly on the posterior roots of nerves and in the sympathetic system.

Nerves are, as it were, the telegraph-wires of the body, because they carry messages from one part of the body to another. They are divided into two classes, according to whether they carry messages to or away from the central nervous system. The first class carry impulses from the

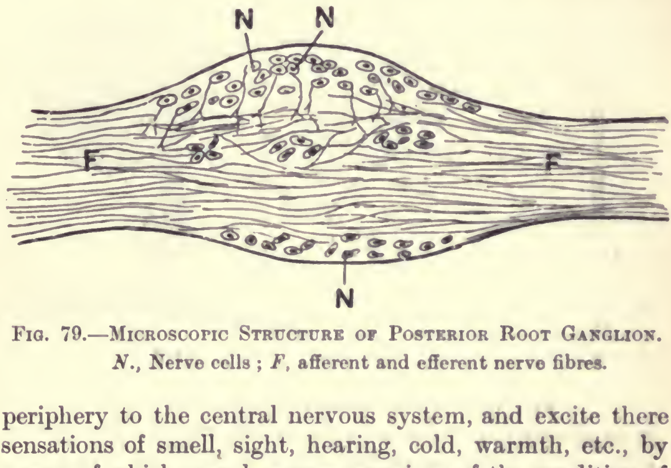
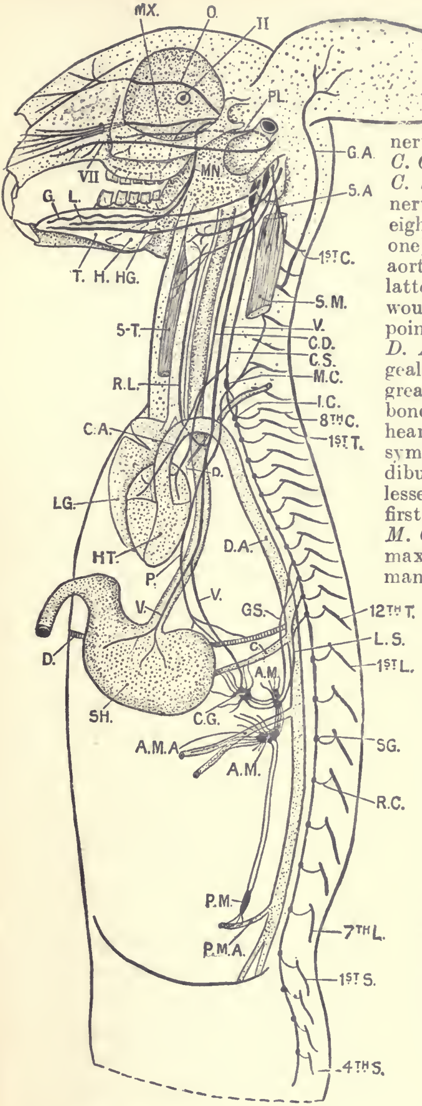


Fig. 79.—Microscopic Structure of Posterior Root Ganglion. *N.*, Nerve cells ; *F*, afferent and efferent nerve fibres.

periphery to the central nervous system, and excite there sensations of smell, sight, hearing, cold, warmth, etc., by means of which man becomes conscious of the condition of the world around him. The second class carry impulses away from the central nervous system to the periphery, and these govern the activity of the skeletal muscles, glands, etc.

The Distribution of Nerves in an Animal.—Obtain a rabbit, and kill it by poisoning it with chloroform. Dissect away the skin, and during this process fine white threads will be seen in the subcutaneous tissues; these are the nerves supplying the skin. On separating the muscles similar



A. M., anterior mesenteric ganglion of sympathetic; *A. M. A.*, anterior mesenteric artery; *C.*, cœliac artery; *C. A.*, cardiac accelerator nerve; *C. D.*, cardiac depressor nerve; *C. G.*, cœliac ganglion of sympathetic; *C. S.*, cervical portion of sympathetic nerve chain; 1st and 8th *C.*, first and eighth cervical spinal nerve; *D.* (upper one), ductus arteriosus; it joins the aortic and pulmonary arches, but the latter is not represented; the ductus would join it just where the index line points; *D.* (lower one), diaphragm; *D. A.*, dorsal aorta; G., glossopharyngeal; *G. A.*, great auricular nerve; *G. S.*, greater splanchnic nerve; *H.*, hyoid bone; *H. G.*, hypoglossal nerve; *HT.*, heart; *IC*, posterior cervical ganglion of sympathetic; *L.*, lingual branch of mandibular nerve; *LG*, right lung; *L. S.*, lesser splanchnic nerve; 1st and 7th *L.*, first and seventh lumbar spinal nerve; *M. C.*, middle cervical ganglion; *MX.*, maxillary division of trigeminal; *MN.*, mandibular division of trigeminal; *O.*, ophthalmic branch of trigeminal; *P.*, phrenic nerve; *PL.*, palatine division of facial nerve; *P. M.*, posterior mesenteric ganglion of sympathetic; *P. M. A.*, posterior mesenteric artery; *R. C.*, rami communicantes; *R. L.*, recurrent (posterior) laryngeal nerve; *S. A.*, spinal accessory nerve; *S. M.*, stylo-mastoid muscle; *SH.*, stomach; *ST.*, sterno-thyroid muscle; *S. G.*, sympathetic ganglia; 1st and 4th *S.*, first and fourth sacral spinal nerves; *T.*, tongue; *V.*, vagus; 1st and 12th *T.*, first and twelfth thoracic spinal nerves; *II.* and *VII.*, second and seventh cranial nerves. The trachea lies just behind the sterno-thyroid muscle (*ST.*), and its top dilated part represents the larynx. The dotted tube behind it is the œsophagus.

FIG. 80.—CRANIAL AND SPINAL NERVES AND THE SYMPATHETIC NERVOUS SYSTEM OF RABBIT (LEPUS). A SIDE-DISSECTION, SEMI-DIAGRAMMATICALLY REPRESENTED.

threads will come into view. Now separate the muscles on the back of the thigh. A white cord will be found; this is the main nerve of the lower limb, and called the "sciatic nerve." Follow it upwards, cutting through each successive structure that conceals it from view. The hip-bone will have to be cut through, for the nerve passes through the pelvic bone, and finally extends to the lower part of the backbone. Here the nerve will be found to divide into several branches, which disappear into the vertebral column, where they join the lower part of the spinal cord.

Having removed the skin from the back of the rabbit, and also the muscles which cover the vertebral column, take a strong pair of scissors and cut away the spinous processes of the vertebræ; then insert the point of one blade between the arches of any two vertebræ about the middle of the spine, and cut away the arches of the vertebræ; this must be done with great care, and the blade that lies inside the vertebral canal must be kept very close to the bony arches, so as not to injure the spinal cord. This dissection will expose the spinal cord. At the level of the lumbar vertebræ the spinal cord tapers to a filament, and is surrounded by a leash of white nerves; this part is called the **cauda equina**, or horse's tail. Above the spinal cord joins the brain.

On either side of the spinal cord nerves are given off in pairs, and there are in man altogether thirty-two pairs of spinal nerves; these pass out of the spinal canal by apertures between the vertebræ, called the "intervertebral foramina."

Roots of the Nerves.—If a nerve be examined as it leaves the spinal cord, it will be found to arise by two roots. One of these issues from the back, and the other from the front, of the cord, and they are called respectively the "posterior" and "anterior" roots. These two roots join together as they leave the vertebral canal, and just at their junction there lies on the posterior root a small swelling, called the "posterior root ganglion."

It has been found that, if the anterior roots of nerves are severed in an animal, then all the muscles supplied by these nerves will be paralyzed. For instance, if the anterior roots of the nerves supplying the legs are cut, the animal will be unable to move them, but it will be able to feel

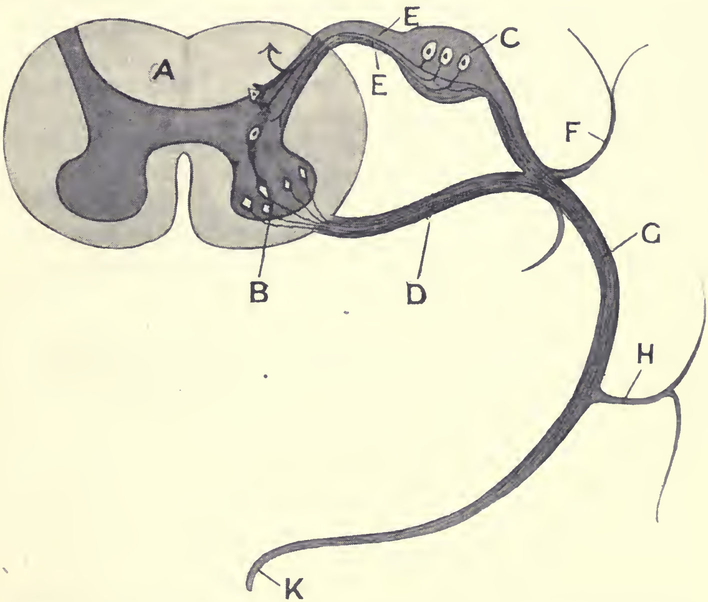


FIG. 81.—DIAGRAM SHOWING THE ORIGIN AND COURSE OF A SPINAL NERVE—*e.g.*, INTERCOSTAL NERVE.

A, Spinal cord; *B*, anterior horn cells; *C*, posterior root ganglion; *D*, anterior motor root; *E*, posterior or sensory root; *F*, posterior division of nerve; *G*, anterior division; *H*, lateral cutaneous branch; *K*, anterior cutaneous branch.

anything that is cold or hot, and a prick or touch, in the legs. On the other hand, if the posterior roots of the nerves are severed, the animal will be unable to feel any prick or touch or anything cold or hot when applied to the legs, but it will be able to move the legs. Hence it is seen that the posterior roots carry sensory impulses from the periphery to the spinal cord, while the anterior roots carry motor impulses from the cord to the periphery.

Structure of the Nerves.—Take a small piece of nerve from a frog or rabbit and place it on a glass slide, and by means of a couple of needles tease it out into a number of fine filaments. Place a drop of saline solution on the threads, and examine with the high power of a microscope. These filaments are the nerve fibres, and are bound up in bundles, and the bundles are wrapped together by connective tissue to form the nerves. Each fibre will be seen to be made up of a central core, which is called the "axon"; a layer of white fatty material, which forms a sheath around the axon; and, outside this again, a very thin grey sheath of connective tissue. The axon is the essentially conducting

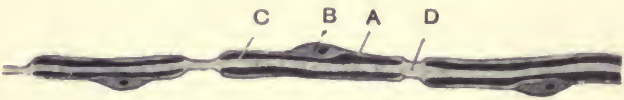


FIG. 82.—STRUCTURE OF NERVE FIBRE.
A, Neurilemma ; *B*, nucleus ; *C*, medullary sheath ; *D*, axon.

part of a nerve fibre, and is derived from a nerve cell. The white or medullary sheath protects and nourishes the axon, and separates it from the axons of neighbouring nerve fibres. The grey sheath, or neurilemma, encloses the fatty sheath and supports it. At regular intervals along the course of a nerve fibre little intermissions will be seen in the medullary sheath, and here the neurilemma comes in contact with the axon; these are called the "nodes of Ranvier." About midway between any two nodes a nucleus will be seen just underneath the neurilemma.

In the sympathetic system the majority of the fibres, after leaving the chain of ganglia, lose their medullary sheath, and hence are called "non-medullated fibres."

If an exposed nerve is pinched, irritated by a hot wire or an electric shock, the muscles to which the nerve is distributed contract. This indicates the passage of a nervous impulse along the nerve. We do not know the exact nature of this nerve impulse.

The Spinal Cord.—The spinal cord is the portion of the central nervous system which lies within the vertebral canal. It extends from the brain above to the upper part of the lumbar region. In order to understand the structure of the spinal cord, it would be advisable for you to have the spinal cord of an ox, and then cut it across at various levels with a sharp knife. (Ask your butcher for the marrow out of the spine.)

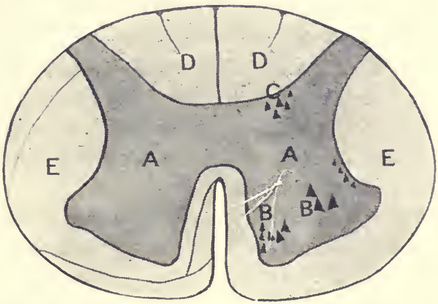


Fig. 83.—Cross-Section of Spinal Cord.

A, Grey matter ; *B*, anterior horn cells ; *C*, Clark's column ; *D*, posterior columns ; *E*, antero-lateral columns.

The cord is intimately covered by a thin vascular membrane called the **pia mater,** and the spinal canal is lined by a strong fibrous membrane called the **dura mater.** Between these two is a very delicate membrane called the **arachnoid.** The space between the membranes is filled with a watery liquid called **cerebro-spinal fluid,** because it is found in the cranial and spinal cavities. The cord is held in its place by the spinal nerves, and also by bands of ligament, and these, with the support of the fluid, protect it from shock or jar. When the cord is cut across with a sharp knife, it will be found to be composed of a white substance lying on the outside, and partly of a pinkish-grey substance lying within.

The cord is almost divided into halves by an anterior and posterior fissure, each of which runs inwards from the outside towards the centre of the cord. In cross-section the grey matter is shaped like the letter H. There are two crescent-like masses of grey substance lying in each half of the cord, and joined by a narrow bridge of the same material which crosses the middle of the cord.

The two ends of each crescent are called its "horns" or "cornua," the one directed forwards being the anterior horn, the one turned backwards the posterior horn.

The **grey matter** is made up of nerve cells; this can be readily proved if a piece of cord is cut into very thin sections and stained with certain dyes.

The **white matter** consists almost entirely of nerve fibres, supported in a delicate framework of connective tissue.

The anterior roots of the nerves arise from the anterior horns of the grey matter, while the posterior roots enter the cord near the posterior horns.

Functions of the Spinal Cord.—The white matter is made up of nerve fibres which are running either towards or away from the brain. It has been said above that the spinal cord is nearly divided into two halves by the posterior and anterior median fissures. The white matter of each half of the cord is divided by the posterior roots of the spinal nerves into an antero-lateral and posterior portions; the former is called the "antero-lateral column" and the latter the "posterior column."

The nerve fibres which carry the same kind of impulses or have the same destination are aggregated together to form what are called "nervous tracts," and these tracts are divided into two great groups—the ascending and the descending tracts; the former carry impulses from the periphery of the body to various parts of the brain, while the latter carry impulses away from the brain and form connections with the cells of the grey matter of the spinal cord. The exact course and destination of these tracts have been worked out by making a large series of transverse sections and staining them in a particular way. The tracts of the posterior columns are all ascending, and carry impulses of muscular sensation, sense of position, touch, and

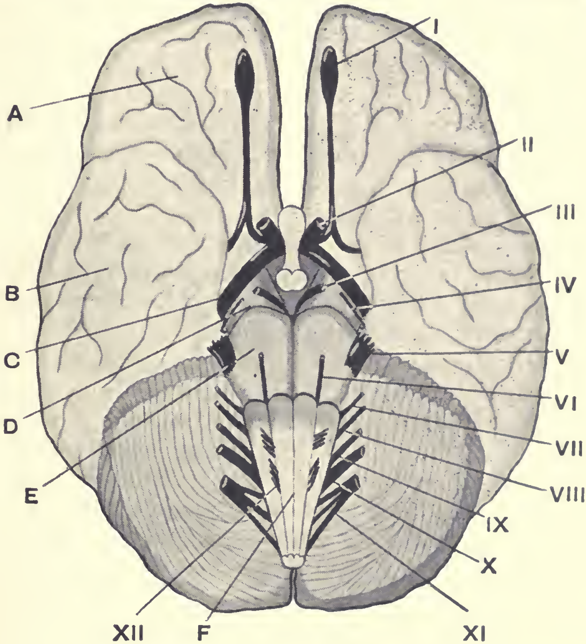


FIG. 84.—BASE OF THE BRAIN.

I., Olfactory nerve, or first cranial; *II.*, second cranial or optic nerve; *III.*, third cranial nerve; *IV.*, fourth cranial nerve; *V.*, fifth cranial nerve, or trigeminal; *VI.*, sixth cranial; *VII.*, seventh cranial or facial nerve; *VIII.*, eighth or auditory nerve; *IX.*, ninth or glosso-pharyngeal; *X.*, tenth or vagus nerve; *XI.*, eleventh or spinal accessory; *XII.*, twelfth or hypoglossal nerve; *A*, frontal lobe; *B*, temporal lobe; *C*, optic tract; *D*, crura cerebri; *E*, pons; *F*, medulla.

pain. All these fibres come into the cord through the posterior root of the spinal nerve, and ascend on the same side of the cord.

The tracts of the antero-lateral columns are partly ascending and partly descending. The ascending tracts carry impulses of sensation of touch, heat, cold, and pain; these also come to the cord through the posterior root of the spinal nerve, but they then cross to the antero-lateral column of the opposite side, and hence these tracts carry sensations from the opposite side of the body. There are two other ascending tracts in the antero-lateral columns, and these have to do with the equilibration of the body; they ascend up to the cerebellum, which is situated behind the lower part of the great brain, and which modifies the contraction of the muscles.

The descending tracts of the antero-lateral columns carry impulses from the brain to form connections with the cells of the grey matter of the spinal cord. The pyramidal tract carries impulses from the brain, and governs all the muscular contractions of the body; these mainly come from the opposite side of the brain, but partly also from the same side. Other descending tracts come from the cerebellum, and serve to co-ordinate the contractions of the muscles.

A tract also comes down in the spinal cord from certain nerve cells in the brain which are connected with a special part of the internal ear, and these also aid in the co-ordinate contraction of the muscles, and thus are important factors in keeping the body in equilibrium in various postures.

The Brain.—The term "brain" is applied to that portion of the central nervous system that lies within the skull cavity. It is made up of several parts—namely, the spinal bulb or medulla, the pons, the cerebellum, and the cerebrum.

The **medulla** is the continuation upwards of the spinal cord. At first it is about equal in size to the spinal cord, but as it approaches the pons it expands, and hence it has a more or less conical shape. From the lateral surfaces some of the cranial nerves (VII. to XII.) arise. When a section is made of the medulla, it is found to be made up of white and grey matter. The white matter is continuous with that of the spinal cord, and is made up of the same tracts, but their relative positions are somewhat changed. The central canal of the spinal cord, as it ascends to the medulla, gradually becomes more and more posterior until it opens out on the posterior surface to form the fourth ventricle. The grey matter is collected around the floor of the fourth ventricle.

The **pons** is a marked white prominence on the basal aspect of the brain, and is interposed between the medulla and the peduncles of the great brain.

When a section is made of the pons, it will also be found to be made up of white and grey matter. A large number of the nerve fibres will be found to run to the cerebellum.

The **cerebellum** is a large mass of nervous tissue attached to the posterior aspect of the medulla. It is divided into two hemispheres by a deep fissure, and these are joined together by an extraordinary bridge of nerve fibres.

Above the pons we find the **mid-brain,** and this is a short, narrow part of the brain stem, consisting anteriorly of the crura cerebri, and posteriorly of four little lumps, two upper and two lower, called the "corpora quadrigemina." Each hemisphere of the cerebellum sends fibres to the mid-brain, and these constitute the superior peduncles of the cerebellum.

In front of the mid-brain and beneath the cerebrum, or fore-brain, we find the basal ganglia. These are made up of large masses of grey matter, and subdividing them we find tracts of white matter, made up of nerve fibres running to and from the brain. These masses of grey matter are called the **optic thalamus,** the **lenticular** and **caudate nuclei.**

The **cerebrum** forms the greater part of the brain. It is divided into right and left hemispheres by a deep cleft, at the bottom of which runs a band of nerve fibres, called the "corpus callosum." This serves to join the two hemispheres together. The outer surface of the cerebrum is thrown into folds called "convolutions," between which are grooves or fissures. The convolutions increase the area of the cortex enormously, and the greater the brain-power of a man the more convoluted will his brain be found to be.

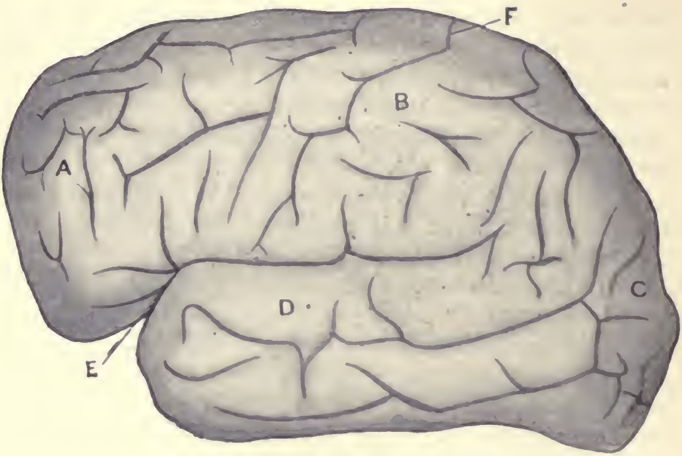


Fig. 85.—The Cerebral Cortex.

A, Frontal lobe; *B*, parietal lobe; *C*, occipital lobe; *D*, temporo-sphenoidal lobe; *E*, fissure of Sylvius; *F*, fissure of Rolando.

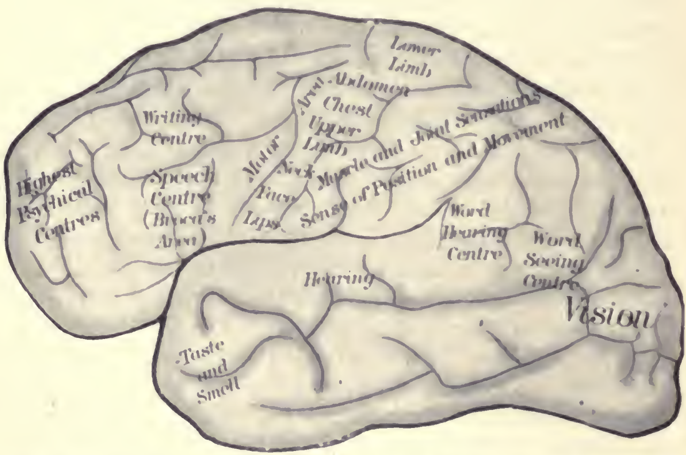


Fig. 86.—Diagram illustrating the Functions of the Various Parts of the Cerebral Cortex.

If a section be made through a cerebral hemisphere, the wall will be found to be made up of an outer layer of grey matter and inner layer of white matter, and enclosed within is a cavity called the "lateral ventricle."

Each cerebral hemisphere is divided up by deep fissures into lobes, and the surface of each lobe is thrown into convolutions by smaller fissures. Hence in the front part of the brain we find the frontal lobe ; the middle and upper part is formed by the parietal lobe ; behind is the occipital lobe ; while below and externally is placed the temporo-sphenoidal lobe.

The Cranial Nerves.—Twelve pairs of nerves arise from the brain and pass out of the skull through holes in its walls.

1. The first pair of cranial nerves are the olfactory, or nerves of smell. They arise from the front part of the base of the brain, and give off a large number of fine twigs which pierce the roof of the nose and supply the mucous membrane of its upper part.

2. The second pair are the optic nerves. These arise from the mid-brain, and pass forward around the base of the brain and intertwine there; they then enter the orbits and supply the eyeball. The optic nerves are connected with various parts of the brain, the corpora quadrigemina, optic thalamus, and the hinder part of the cerebral cortex.

3. The third pair of cranial nerves arise from the mid-brain. They pass to the orbits, and supply the muscles which move the eyeball. They also supply the ciliary muscle, by the contraction of which accommodation is effected. They innervate the constrictor of the pupil.

4. The fourth pair of cranial nerves arise from the dorsal surface of the mid-brain, and each enters the orbit and supplies a muscle which causes a certain movement of the eyeball.

5. The fifth pair of cranial nerves arise from the lateral aspect of the pons. They contain both afferent and efferent fibres. The efferent fibres supply the muscles of mastication, while the afferent fibres carry sensations from the face, anterior two-thirds of the tongue, the mouth, lower part of the nose, and the teeth.

6. The sixth pair of cranial nerves arise just at the junction of the medulla and pons. They enter the orbit and supply the muscles which turn the eyeball outwards.

7. The seventh pair of cranial nerves arise from the medulla. They supply the muscles of the face.

8. The eighth nerve is the nerve of hearing and of equilibration ; this enters the upper part of the medulla, and this spreads out to form connections with the cerebrum, mid-brain, and cerebellum.

9. The ninth pair of cranial nerves are called the "glosso-pharyngeal nerves." They are the chief nerves of taste, and also supply a few muscles of the pharynx.

. 10. The tenth pair of cranial nerves are the vagus nerves. They arise from the medulla, and pass down through the neck and thorax to the abdomen. They supply the pharynx, windpipe, gullet, lungs, stomach, heart, pancreas, and liver. They contain both afferent and efferent fibres.

The afferent fibres carry impulses to the medulla from the larynx and lungs, heart and abdominal organs.

The efferent fibres control the muscles of the larynx, pharynx, and gullet. The movements and the secretion of the stomach are governed by these fibres. They also control the rate of the heart-beat, and the state of contraction of the muscles of the bronchi and bronchioles.

11. The eleventh pair of cranial nerves are the spinal accessory nerves; they arise partly from the upper part of the spinal cord and partly from the medulla. They control some of the muscles of the neck.

12. The twelfth pair supply the muscles of the tongue, and the movements of this organ are controlled by these nerves.

The Functions of the Brain.—The white matter of the **medulla** is made up of various nerve tracts; some are passing through to or from the great brain; others start in certain groups of cells in the medulla, and are passing to the cerebrum or cerebellum. The grey matter of the medulla gives rise to six of the cranial nerves.

There are also groups of nerve cells which are concerned in regulating the movements of respiration and of the heart, and life depends upon the integrity of these centres.

The **pons** contains both white and grey matter. The white matter is made up of fibres which are passing to or from the cerebrum or to the cerebellum. It is through the pons that one side of the cerebrum is connected with the other side of the cerebellum. The grey matter forms cell-stations to a number of the fibres passing through the pons, and also gives rise to the sixth nerve and the efferent fibres of the fifth cranial nerve.

The **crura cerebri** are made up of fibres carrying impulses from the cerebrum to other parts of the nervous system. In the mid-brain there are large tracts of nerve fibres carrying impulses to the cerebrum. The grey matter gives rise to the third cranial nerve. The superior corpora quadrigemina are important centres for sight, while the inferior corpora quadrigemina have to do with hearing.

Several theories have been held regarding the function of the **cerebellum,** but now it may be definitely said to have some important regulatory effect upon muscular contraction, and thus aid in the equilibration of the body. The right half of the cerebellum influences the same side of the body. The cerebellum is largest in birds, and they of all animals have the greatest power of balancing the body in various postures. When the whole of the cerebellum is removed in animals, all the muscles of the body, especially those of the limbs, are deficient in tone, and contract with a peculiar want of steadiness. The signs of disease in the cerebellum are giddiness, a staggering gait, twitching movements of the eyes, and a tremor accompanying voluntary movement.

It has long been established that the **cerebrum** is the organ of the higher psychical activities, and all the higher nervous functions—namely, consciousness, will, reason, ideation, etc.—depend upon the integrity of the cerebrum. All these functions reside in the grey matter of the cerebral cortex, and it is within this that the ceaseless changes take place which result in the above activities. Naturally the question arose whether the cerebrum is functionally equivalent throughout, or whether different parts of the cortex have different functions. It has long been proved, by experimentation on animals and studying the effects of disease in man, that certain parts of the cortex are connected with particular functions, and the modern view is that the cerebrum is composed of a plurality of parts that are intimately associated, and to a great extent dependent one on the other for their full functional importance.

Certain parts of the brain, called the **motor area,** govern all the voluntary muscles of the body. One of these areas is situated on each side of the brain, in the posterior part of the frontal lobe ; the area on one side of the brain governs

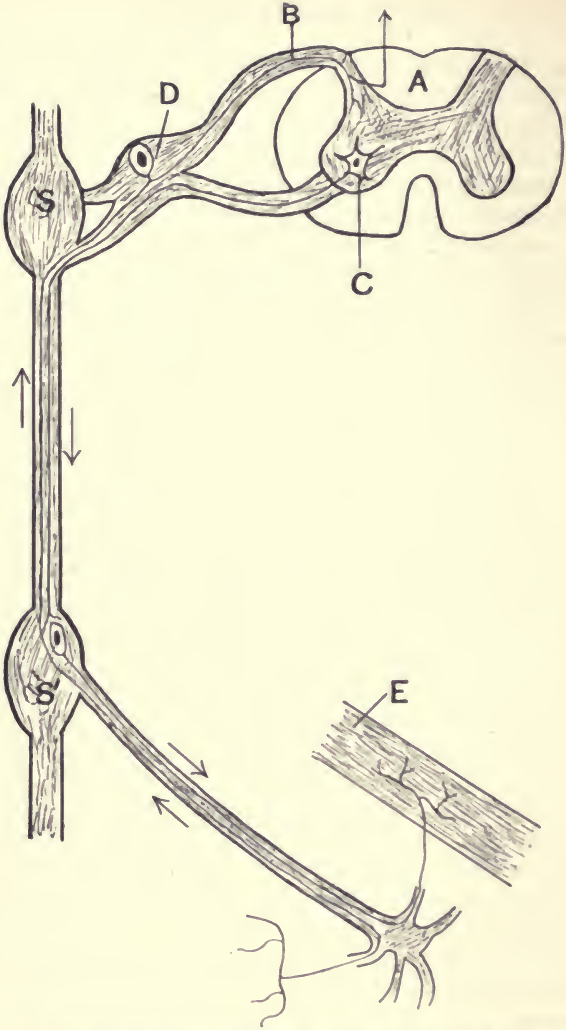


FIG. 87.—SYMPATHETIC SYSTEM AND ITS CONNECTIONS WITH THE CENTRAL NERVOUS SYSTEM.

A, Spinal cord; *B*, posterior root of spinal nerve; *C*, anterior horn cell; *D*, posterior root ganglion; *SS'*, sympathetic cord and ganglia; *E*, tissue or organ supplied by the sympathetic fibres. Note the course of afferent and efferent connections of sympathetic.

the muscles on the opposite side of the body. Even within the motor area there is a further division of labour, so that certain groups of cells govern the muscles of the leg, while others govern the muscles of the abdomen, etc. (see diagram showing various centres).

The anterior part of the frontal lobe is a part where some of the processes involved in the highest mental activities take place, and it is this in particular that is undeveloped or degenerated in idiocy.

Between the motor area and the areas of higher psychical processes are situated two special centres, which are concerned in speaking and writing, and called respectively the "speech" and "writing" centres. These are only present on one side of the brain—on the left side in right-handed persons, and on the right side in left-handed individuals.

The delimitation of the sensory areas in the cerebral cortex is a matter of great difficulty, because the determination of the presence or absence of certain states of consciousness in the animal or person under observation cannot be made except by indirect means. The only method that is of any value is to study the sensory changes produced by disease of the cerebral cortex in man, and determine the site of the lesion by an examination after death.

It has been stated above that certain tracts in the spinal cord carry sensations from various parts of the body. These fibres finally end in the cerebral cortex, and we become conscious of these sensations by changes which take place in the anterior part of the parietal lobe, and this part of the brain is called the **body sense area.**

Centre for Hearing.—The site in the brain where we become conscious of what we hear is situated on the outer surface of the temporo-sphenoidal lobe (see Fig. 86). Destruction of this area on both sides is followed by complete loss of hearing.

Centre for Vision.—When light is reflected from various objects on to the eye, an image is formed of these objects on the retina, but the changes which result in our recognizing and understanding what we see take place in the cortex of the posterior part of the cerebrum (occipital lobe); this is called the **visual centre.**

Centre for Taste and Smell.—We become conscious of sensations of taste and smell by changes which take place at the apex of the temporo-sphenoidal lobes (see diagram).

Co-ordination.—Man inherits certain powers of performing co-ordinate muscular movements. This is present to a greater extent in the lower animals. Some of the lower animals possess power of locomotion very soon after birth, while in the case of the human subject this power is attained after much training. The new-born child is endowed with a certain amount of ability to perform co-ordinate muscular contraction. Thus, it is able to perform those movements of the cheeks, lips, and tongue, on which sucking depends.

Many movements, such as walking, running, or cycling, have to be learnt by the greatest efforts, though when once acquired they appear natural and spontaneous.

In the special trades and professions we find the highest stage of special and elaborate movement. The skilled mechanic by certain movements is able to work certain things which the untrained person cannot do. The difference between a trained and untrained singer is due, to a better co-ordination in the former, of the contraction of muscles involved in the production of the voice.

The process of co-ordination has been studied experimentally in animals, and they seem to depend upon the changes that take place in the cerebral cortex, because it has been shown that in monkeys the co-ordinated movements involved in opening and closing the hand can be produced by stimulation of certain parts of the cerebral cortex, but not by stimulation of the anterior roots of the spinal nerves supplying the hand.

Association.—Above we have described the motor and sense centres of the brain, but these only occupy a portion of the cerebral cortex. The areas which surround the above centres have been called by Flechsig **association areas.** He says that the association areas may be regarded as the regions in which the different sense impressions are synthesized into complex thoughts and ideas. The foundations of all knowledge are to be found in the sensations aroused through the various sense organs ; through these paths alone can our consciousness come into relation with the external world. The *association areas* build up all the impressions received by the sense organs into organized knowledge. The changes that result in the retainment of such knowledge take place within the nerve cells of these special areas. These areas are connected together and with the sense centres by nerve fibres, called **association fibres,** and it is by such means that the various sensations are grouped together and organized into complex knowledge.

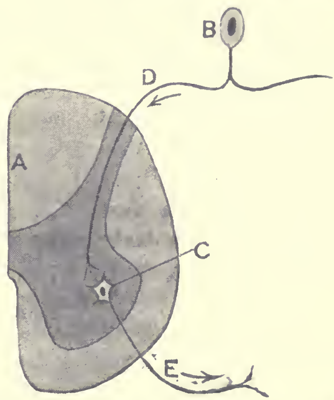


FIG. 88.—DIAGRAM SHOWING THE PATHS INVOLVED IN A REFLEX ACTION.

A, Spinal cord ; *B*, posterior root nerve cell ; *C*, anterior horn cell ; *D*, afferent fibre ; *E*, efferent fibre.

Sympathetic Nervous System.—A chain of ganglia connected by a nervous cord will be found lying on each side of the front of the vertebral column. It will be found that each spinal nerve, except those of the neck, gives off a branch which joins these chains of ganglia. This system of nerve cells and fibres is called the **sympathetic nervous system.** Nerve fibres leave the sympathetic ganglia and supply the viscera, such as the heart, lungs, stomach, intestines, etc., and also the walls of the bloodvessels.

Other fibres pass from the viscera to the sympathetic system, and thence to the central nervous system. When the viscera are in a healthy condition we are unconscious of impulses travelling along these fibres, but under diseased conditions of the viscera we indirectly become conscious of such impulses.

Reflex Action.—Reflex action is a means by which a peripheral tissue or organ is excited to activity by the passage along efferent fibres of impulses generated by stimulation of afferent fibres.

Reflex actions can be studied very well in a frog. Obtain a frog and cut its head off with a pair of scissors. When the tip of one of its toes is pinched, the leg will be pulled away; similarly, if a small piece of blotting-paper soaked in acetic acid be placed on the back of the frog, the lower limbs perform co-ordinate movements which tend to remove the irritant from the back.

If the spinal cord of a man is badly injured, all the muscles of the body below the site of the lesion will be paralyzed, and the man will be unable voluntarily to contract any of these muscles; he will also lose all forms of sensations from this region, and will be unable to control the sphincters of the bladder and anus. If the feet of such a person be tickled, his legs may suddenly jerk up; but he will remain entirely unconscious of the tickling and movement as long as he does not see his legs move. A large number of reflex actions take place in the normal human body, such as the sudden closure of the eye when anything threatens to touch it, contraction of the pupil when light falls upon it, formation of secretion in many glands, and so on.

In all reflex actions an impulse is passed to the spinal cord along a sensory nerve; the fibres of this nerve make connections with cells in the grey matter (*e.g.*, anterior horn cell): this generates an impulse, which travels out of the cord by the efferent fibres (see Fig. 88).

Some reflex movements can be carried out at birth, others are attained later on in life, and, by sufficient practice, movements which at first required great attention will be performed practically unconsciously. For example, walking is learnt with great difficulty, but later on it is performed without any thinking at all. Several other examples may be noted, such as cycling, skating, knitting, etc.

Nervous System of the Child and its Development.—The brain of the child, relative to the body, is much larger than in the adult. The brain also grows very rapidly during childhood, both in size and complexity.

The growth in complexity is indicated by changes in the nerve cells and the nerve fibres. It is most probably correct to say that the number of nerve cells in the body does not increase after birth. As growth takcs place we find the cells become larger, and the processes (dendrites) increase in number and size, and form a large number of new connections with other nerve cells and fibres.

In describing the structure and function of the nervous system, it was said that there were a large number of nerve fibres aggregated into various tracts, which pass to and from the brain, and others, called "association tracts," which connect different parts of the brain together. Each fibre is made up of an axon surrounded by a fatty or medullary sheath. At birth we find that the fibres of a large number of these tracts have no fatty sheath, and some fibres become medullated before the others. It is owing to this fact that we can trace out the tracts by cutting serial sections of the central nervous system, for the fatty sheath stains differently. It is said that the fibres do not attain their full functional activity until they acquire their medullary sheath.

The fibres which carry impulses to and from the spinal cord are medullated at birth, and thus we find that a large number of the movements of the child just after birth are reflex in character.

Very soon after birth myelination takes place in the fibres of the nerves which connect the sense organs and their centres in the cortex. Also we find the tracts which connect the motor area and the spinal cord attaining their fatty sheaths, and concurrently with these we find development of the senses and motor power. The education of the child consists partly in the development of the association fibres which connect different parts of the cortex, and concurrently with this they attain their myelin sheath.

But before the myelination of the association fibres we have the education of the receptive centres. It is most likely that very early in life light and sound have no effect upon the child at all. Soon the child will take notice of a bright light or a sharp sound, but it would be at this stage unaffected by lesser degrees of light or sound. Later he will be able to appreciate differences of light and shade, and these become associated with various planes and shapes. The impressions from objects that are often seen are stored up and remembered ; this results in the child being able to recognize such objects. The centre for hearing is developed in a similar manner, until it can distinguish and appreciate different sounds. It must not be thought that these centres are developed independently, because, as each centre is developed, its connection with other centres becomes functional ; then the child sees certain objects producing certain sounds, and he learns to associate these sounds with the objects, and *vice versa*.

Speech Centres.—The power of communication by language is attained by the development of certain special centres in the brain, and these are very important from an educational point of view.

About 1860 a French physician of the name of Broca taught that destruction of a small area on the left side of the brain resulted in the loss of speech, but since then several other centres have been shown to be associated with speech. These are situated in the left cerebral hemisphere of right-handed persons, while in left-handed people they are situated in the right cerebral hemisphere.

The following are centres of speech :

1. The word-hearing centre.
2. The motor-speech centre.
3. The word-seeing centre.
4. The writing centre

The word-hearing centre is part of the hearing centre on the left side of the brain, and is developed when the child learns to distinguish special words and to appreciate their meaning. The word-seeing centre is part of the visual centre on the left side, and is developed when the child commences to read.

The left centre, which controls the movements of the lips and tongue, becomes a special centre for governing speech, and the centre which governs the movements of the right arm becomes a new centre to control the special movements concerned in writing.

The child learns to associate certain words with certain objects or ideas. This is done by the development of the word-hearing centre; thus he hears the word *mother*, and this sound he learns to associate with a certain person. One day he attempts and succeeds to say the word *mother*, or any other word that he has heard, and then we have the developments of the motor-speech centre. The connections of the centre of sight with the auditory word and the speech centre are developed, and then, when an object is placed in front of the child, he remembers it, and also the sound that is associated with it, and the speech centre will reproduce this sound, and then the child is able to name the object.

When a number of objects are placed in front of the child, he is asked to pick one of them up; he hears the sound, and the visual centre reproduces the mental picture associated with that sound, and then the child picks up the object that conforms to that mental picture. These processes go on gradually in the brain of the child, and the impressions from external stimuli are increased; such impressions are remembered and associated with different persons and objects.

The child generally goes to school at this stage of its mental development. These centres should continue to grow in school, and their connections to increase and strengthen. When the child goes to school he is taught to read and write, and this is brought about by the development of two other centres—namely, the word-seeing centre and the writing centre. The connections between these centres and with the other centres are also developed, and these are the phenomena involved in the education of the child.

Mentally Defective Children.*—The attendance of children at school was made compulsory by the Elementary Education Act of 1876. Previous to this a large number of children, who subsequently were proved to be mentally defective, had not received any form of attention from the State.

A Royal Commission was appointed to inquire into the matter, and their report was issued in 1889. This was chiefly concerned with the blind, deaf and dumb, but they drew attention to the mentally defective, and advised that they should be separated from the ordinary pupils in the schools and should receive special attention.

"Mental deficiency" is a term that has a very wide application, and is used to cover a number of various abnormal mental conditions.

If the various centres used in education show very great lack of development, the condition is called "idiocy" or "imbecility." Such children seldom reach the schools, and if they did, they would not be able to profit at all from the ordinary school methods of teaching. According to the Defective and Epileptic Children Act of 1899, mentally defective children are defined as those who, "not being imbecile and not being merely dull and backward, are defective, and are incapable of receiving proper benefit from the instruction in the ordinary public elementary schools, but are not incapable, by reason of such defect, of receiving benefit from instruction in such special classes or schools as are mentioned in the Act."

* For a more detailed discussion of this subject, see article by A. F. Tredgold, M.R.C.S., L.R.C.P., on Mentally Defective Children in "Medical Inspection of Schools and Scholars," edited by T. N. Kelynack, M.D. (publishers: King and Son).

Conditions associated with Mental Deficiency in Children.

1. *Heredity*.—There is often a history of mental deficiency, insanity, epilepsy, or some other nervous derangement, in the family.

Many of the inmates of the London asylums belong to a few families. A wise State would prevent the mentally deficient having children.

2. *Alcoholism*.—It has been asserted that alcoholism in the parent plays an important part in the production of mental deficiency in the offspring. It is said to act by either injuring the germ cells of either parent or by deteriorating the brain of the fœtus after being absorbed by the placental circulation. There is no trustworthy evidence that intemperance of the parent is a factor in the causation of mental deficiency in children. Those who are mentally defective by heredity may drink, and have children defective, not owing to drink, but to heredity.

3. *Tuberculosis*.—Opinions differ as to the importance of a family history of tuberculosis in the production of mental deficiency.

4. *Cretinism*.—This is due to congenital absence of the thyroid gland, and is always associated with mental deficiency. This condition is rarely noticed before the child is six or seven months old, and the signs become marked during the second year. The face is large; hair is dry and scanty; eyelids are puffy and swollen; the skin is dry and rough. The abdomen is swollen, the legs are thick and short, the hands are short and broad, and the finger-tips square.

5. *Microcephalus*.—Congenital smallness of the head. The head may be very small in size. One observer quotes a case of a child, aged three years, in whom the circumference of the head was only 13¾ inches. The body and face of the child are usually well developed.

6. *Hydrocephalus*.—Abnormally large head. It is not a common cause of mental deficiency, and it is surprising how large a head may be, and still the mental power be well retained.

7. *Injury*.—The brain may be injured during intra-uterine life or at birth, and result in paralysis and mental deficiency.

8. *Fits*.—In some cases it is found that a child during the first two or three years is quite normal; then he has a severe convulsion, which seems to damage the brain, and from that time the mental development suffers, though the fits do not recur.

In other cases the child has a series of fits, and the mental state suffers in consequence.

Cause of Mental Deficiency.—It has been said above that the higher intellectual functions reside in the frontal region of the cerebral cortex; and though the exact relationship between the mind and matter is not known, still, we should expect a defective mind to be accompanied by diseased condition of the brain cells. In the severe forms of mental deficiency gross changes are seen in the brain, but in the milder forms the changes can only be discovered by the microscope. The cortical cells are diminished in number, incompletely developed, and irregularly arranged, and it is this condition which gives rise to the ill-developed mind.

Detection of Mental Deficiency.—It is very important that all mentally defective children should be detected early. Hence, if the teacher has any suspicion regarding the mental development of any of the pupils, they should at once be sent to the medical officer. It is only medical men with good experience of diseases of children that are able to properly detect and classify such conditions.

The diagnosis of mental deficiency is made on the (1) family history, (2) personal history, (3) physical and mental conditions of the child.

A specially trained teacher may greatly help in the preliminary detection of abnormal mental conditions. He should ask the parent or guardian about the family and personal history of the child, and then note its physical and mental characteristics.

The Family History.—It has been said above that family history of chronic alcoholism, tuberculosis, and insanity, are important conditions associated with mentally defective children, and thus it is important to make inquiries to ascertain whether a child who is suspected to be mentally defective has such a family history.

Personal History.—Ascertain whether (1) there is a history of injury at birth or subsequently; (2) history of previous disease—*e.g.*, meningitis, convulsions, or paralysis; (3) age at which the child walked and talked; (4) educational facilities.

Physical Condition.—Note (1) the facies, or facial expression, which is a valuable index of the mental state; (2) general nutrition; (3) presence or absence of certain physical stigmata—*e.g.*, harelip, cleft palate, development of jaws and teeth, adherent lobes of the ears, opacities in the media of the eye ; (4) measurements of the head and its shape ; (5) the movements of the eyeballs by moving a bright object in front of the eyes when the head is held fixed ; (6) the balance of the hands and arms, by asking the child to hold out his hands in front.

Tests of Mental Deficiency.—" In principle the method of M. Binet and M. Simon is very simple. By extensive observations on French school-childıen at different ages, they were able to arrange a great number of mental tests in a series of groups graduated according to their increasing difficulty after such a fashion that each group corresponds to what the average child of a given age can do. The tests in each group are of several kinds, and, though theoretical considerations are deliberately eschewed by the authors, it is evident that the choice of the tests has had in view the different aspects of intellectual activity. This can be seen from a glance at the list of tests :"

Three Years.—(1) Point out nose, eye, mouth ; (2) repeat a number with two figures ; (3) enumerate the objects in an engraving ; (4) tell surname ; (5) repeat a sentence with six syllables.

Four Years.—(1) Tell whether a little boy or a little girl ; (2) name key, knife, penny ; (3) repeat three numerals ; (4) point out the longer of two lines.

Five Years.—(1) Find which is the heavier of two boxes ; (2) copy a square ; (3) repeat a phrase with ten syllables ; (4) count four pennies ; (5) reconstruct a card cut diagonally into two pieces.

Six Years.—(1) Distinguish morning and evening ; (2) define common objects—fork, chair, table, horse, mother—by use ; (3) copy a rhomb ; (4) count thirteen pennies ; (5) compare a number of drawings of faces from an æsthetic point of view.

Seven Years.—(1) Point out right hand and left ear ; (2) describe an engraving ; (3) do three simple errands ; (4) count three pennies and three halfpennies ; (5) name four colours—red, blue, green, yellow.

Eight Years.—(1) Make mental comparison between fly and butterfly, wood and glass, paper and cardboard ; (2) count from 20 to 0 ; (3) point out features missing in incomplete figures ; (4) give the date ; (5) repeat five numerals.

Nine Years.—(1) Take twopence out of a shilling and give the change ; (2) define common objects (see above) otherwise than by use ; (3) recognize all the current coins; (4) name the months; (5) answer simple questions involving problems of ordinary life—*e.g.*, "When you have missed the train, what should you do ?"

Ten Years.—(1) Arrange five boxes (3, 6, 9, 12, 15, and 18 grammes) according to weight; (2) copy two simple geometrical designs—a prism and a Greek moulding—from memory after having seen them for ten seconds; (3) criticize a number of absurd statements—*e.g.*, "The body of an unfortunate young girl, cut into eighteen pieces, was found yesterday in Hyde Park; it is thought that she killed herself"; (4) answer questions of similar nature but more difficult than in test for nine years; (5) bring three given words into two phrases.

Twelve Years.—(1) Resist a visual suggestion made by a series of pairs of unequal lines followed by a series of pairs of equal lines, the subject being asked which line is the longer, and passing the test if he recognizes the equality in the later pairs; (2) bring three given words into one sentence; (3) say more than sixty words in three minutes; (4) define abstract words—charity, justice, and kindness; (5) rearrange a simple sentence, the words of which have been put out of their order.

Fifteen Years.—(1) Repeat seven numerals; (2) find three rhymes for a given word; (3) repeat a sentence of twenty-six syllables; (4) interpret an engraving; (5) explain an unfinished account of a common episode.

Treatment of Feeble-minded Children.—Very little can be done for the feeble-minded children. If there are any physical defects, it may be well to remove them—such as removal of adenoids, division of tendons if there is paralysis, treatment of rickets if present, etc. If the mental deficiency is slight, the removal of the above difficulties will result in a great improvement. Regarding the treatment of the mental defect, it must be realized that it is incurable, and that no special training will convert these children to normal persons able to hold their own in the world and to look after their own interests without supervision.

The Elementary Education (Defective and Epileptic Children) Act, 1899, empowers local authorities to provide special schools for these children. This provides for their education up to the age of sixteen, and then they are sent out to do what they can for their living, and the results have not been very encouraging.

The only cases that derive any benefit from such education are those children with one or more defective centres, and these by careful training and individual attention may make great improvement.

Backward Children.—There are a group of children in our schools who, though they appear intelligent, are not up to the "average" in their educational progress. It is difficult to draw a hard-and-fast line between this group and the slightly mentally deficient children, but in attempting to make a practical distinction between these two groups it would be well to remember the dictum of Charles West, quoted by Dr. R. Hutchison, *that a mentally deficient child would be abnormal for any age, whereas a backward child is merely abnormal for its own age.*

Some authorities divide this group into two subclasses—namely, those who are backward but intelligent, and those backward and dull. The backwardness in the first group may be physiological, merely retarded development, or it may be due to some physical cause—*e.g.*, late entrance at school, slight deafness, or illness preventing school attendance.

The dulness of the second group may be due to physical or mental causes, or a combination of both. Some of the physical causes are lowered vitality due to bad nourishment or unhealthy home surroundings, and adenoids with associated deafness. In other cases of this group there is no associated physical cause, and the condition seems entirely mental.

Treatment of Backward Children.—Ascertain whether there are any physical defects present, and remedy them. The general health must be attended to, and adenoids or any other removable cause must be treated.

Good results have been obtained by sending these children to open-air recovery schools.

It has been pointed out by many medical authorities that it is impossible for all children in the elementary schools to follow the same course of instruction and reach the same goal, and thus the curriculum of the school must be altered, so that there is more individual attention given to each child.

The Congenitally Word-Blind and Word-Deaf.—These are conditions of mental deficiency arising from lack of development of certain special areas in the cerebral cortex. It will be remembered in describing the function of the cerebral cortex that certain areas were said to be concerned with special forms of consciousness.

Word-blindness will result from affection of the word-seeing centre, and the child will be unable to remember or recognize letters or words. It is useless to try and teach a word-blind child to read or write, though they will be able to draw and recognize pictures, and even do arithmetic.

Word-deafness will result from lesions of the auditory word centre, and the child will be unable to understand or remember what is said to him, though he will be able to understand and remember what he reads. They are often supposed to be deaf or imbecile, but they are not. In such a condition excellent results are obtained by special training in articulation and writing.

CHAPTER VII

RELATION OF SENSES TO THE NERVOUS SYSTEM—THEIR TRAINING AND DEVELOPMENT

The **sense organs** are the means by which we become conscious of the changes in the world around us, and they convert the external stimuli which reach the body into nerve impulses, which travel along the nerves to the cerebral cortex, where the changes that result in consciousness take place.

Sound is caused by the vibrations of air, and when these vibrations fall on the ear they are converted into nerve impulses, which are carried to the brain and give rise to a sensation of sound.

Light is due to vibrations of the ether, a substance which permeates all things; these vibrations are converted by the eye into impulses, which are carried along the optic nerve to the brain and give us a sensation of sight.

Thus the sense organs are means by which these physical stimuli are changed to nerve impulses.

The Sense of Sight.

Structure of the Eye.—The eyeball lies in the cavity of the orbit, the walls of which protect it, except in front, where it is guarded by the eyelids. The eyelid is a fold of skin strengthened by a thin layer of muscle and fibrous tissue, while on the inner side there is a thin mucous membrane called the "conjunctiva." Along the edge of the eyelids are the eyelashes, and just behind these open the ducts of small glands. A stye is due to blocking and inflammation of one of these glands. The eyelashes protect the eye from too much light, and also from dust, and give warning of the approach of insects, etc.

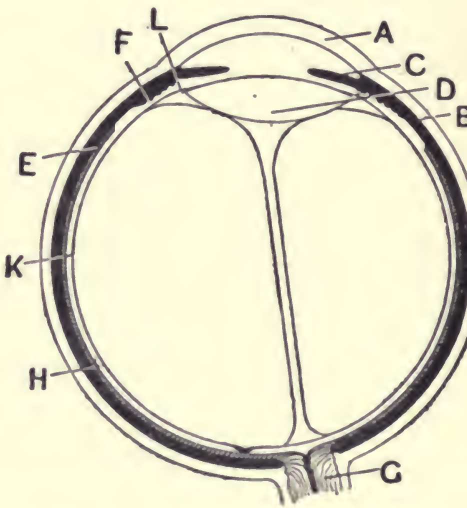


Fig. 89.—Diagram showing the Structures seen in a Cross-section of the Eyeball.

A, Cornea; *B*, sclerotic; *C*, iris; *D*, crystalline lens; *E*, choroid; *F*, ciliary processes; *G*, entrance of optic nerve; *H*, retina; *K*, hyaloid membrane; *L*, suspensory ligament of the lens.

The eyeball has three coats, or layers, and from without inwards they are—

1. The sclerotic and cornea.
2. The choroid and iris.
3. The retina.

The sclerotic, or white of the eye, is a tough, white, opaque membrane forming the greater part of the wall of the eyeball. In front this fibrous capsule of the eye, though it does not change its essential character, becomes transparent, and thus allows light to pass through it; it is

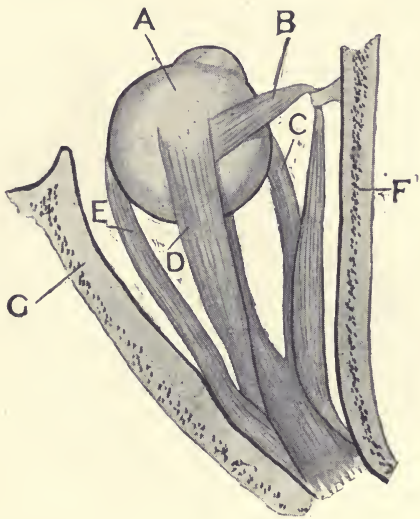


FIG. 90.—EXTRINSIC MUSCLES OF THE EYE VIEWED FROM ABOVE.

A, Eyeball; *B*, superior oblique; *C*, internal rectus; *D*, superior rectus *E*, external rectus; *F*, bony wall of orbit.

called the **cornea**. The **sclerotic** is the only part of the eye that is capable of resisting any strain, and if it gives way all the other structures of the eye will certainly do the same.

The front of the cornea is lined by epithelium continuous with that which forms the conjun ctiva on the inner surface of the eyelids. The cornea is more convex than the sclerotic.

The middle coat of the eyeball is formed by the choroid and iris. The choroid lies internal to the sclerotic, and consists of a network of bloodvessels arranged in a complex manner, bound together by connective tissue, and towards its inner side there are a number of branched, connective-

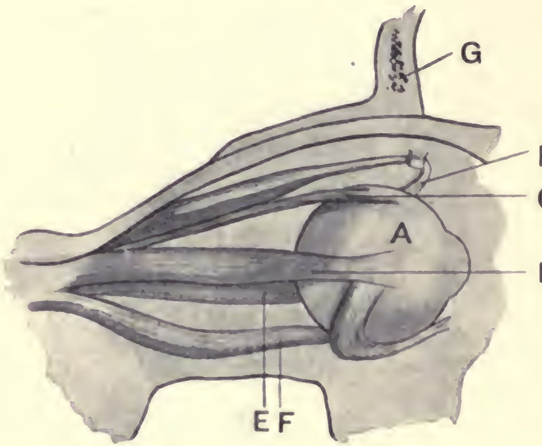


Fig. 91.—Extrinsic Muscle of the Eye: Lateral View.

A, Eyeball; *B*, superior oblique; *C*, superior rectus; *D*, external rectus; *E*, internal rectus; *F*, inferior rectus; *G*, bony wall of the orbit.

tissue corpuscles containing a large amount of black pigment. The choroid lines every part of the sclerotic; anteriorly, just at the junction of the sclerotic with the cornea, the choroid is thrown into numerous ridges called the *ciliary processes*. The choroid is continuous anteriorly with the iris, which forms a perforated diaphragm in front of the lens.

The iris is a circular contractile diaphragm, situated behind the cornea and in front of the lens. The round hole in the middle is called the **pupil.** The *iris* is made up of a supporting structure of fibrous tissue, involuntary muscular tissue disposed in circular and radial layers, and the whole is covered by a layer of epithelium, which on the posterior surface contains pigment and gives the characteristic colour to the eye. The contraction of the circular layer of muscle of the iris causes constriction of the pupil, while contraction of the radial layer causes dilatation of the pupil.

The innermost coat of the eye is formed by the **retina.** It is a very delicate and thin membrane, and has a very complicated structure. The optic nerve enters the eyeball behind and on the nasal side; the fibres of this nerve, after it has passed through the coats of the eye, spread out as fine non-medullary fibres, and form the inner layer of the retina. External to this there are various layers formed by nerve cells and their intertwining dendrites; the layer that is most external but one is called the "layer of rods and cones." These are probably the structures that are changed by the influence of light, and this acts as a stimulus to the nerve cells. Outside the rods and cones is a layer of pigment cells; these are concerned in the formation of "visual purple," which is present in the rods.

Internal to the retina is a thin membrane called the **hyaloid membrane**; anteriorly this becomes thickened, and then divides to surround the lens; the part which goes anterior to the lens is called the **suspensory ligament of the lens.**

The **crystalline lens** is situated just behind the iris; it is a thick biconvex lens contained within a capsule, and this capsule is adherent all round to the ciliary processes. It is composed of long ribbon-shaped fibres disposed in a complicated manner.

The lens divides the cavity of the eyeball into two. The small anterior chamber lies between the lens, iris, and the cornea, and contains a watery fluid called the **aqueous humour.** The large chamber situated behind the lens contains a clear, jelly-like substance called the **vitreous humour.** This is not called the "posterior chamber," for that name is reserved for a small space behind the iris, between it and the circumference of the lens.

In order to understand the structure of the eye, you should procure half a dozen bullock's eyes from your butcher. They will be found to be covered externally by a layer of fat; remove this, and carefully dissect out the muscles on the outer side of the sclerotic; also clean up the optic nerve, which will be found to pierce the sclerotic behind and to the inner side.

After the eyes have been cleaned, place them under water, and with a sharp razor cut one of them from front to back, and another transversely just behind the cornea. Then the various parts of the eye should be identified and studied.

Muscles of the Eye.—The muscles of the eyeball are divided into extrinsic and intrinsic; the former are situated outside the eyeball, while the latter are placed inside.

The **intrinsic muscles** are the ciliary muscle, the dilator and constrictor of the pupil.

The **ciliary muscle** arises at the junctions of the cornea and sclerotic, and passes to the ciliary processes; it is therefore circular in shape. This is the muscle which, when it contracts, brings about accommodation. It is supplied by the third cranial nerve.

The **dilator of the pupil** is made up of the radial fibres of the muscle of the iris; its contraction causes dilatation of the pupil. It is supplied by the sympathetic system.

The **constrictor of the pupil** is made up of the circular muscle of the iris; its contraction causes constriction of the pupil. It is supplied by the third cranial nerve.

The **extrinsic muscles** will be found on the outer side of the eyeball, and attached just behind the cornea to the sclerotic, and also, when the eye is in its place, to the bony wall of the orbit. There are six extrinsic muscles of the eyeball—the superior, inferior, external, and internal recti, the superior and inferior oblique muscles. The recti muscles pass straight from the back of the orbit to be inserted in front of the eyeball. The external rectus is on the outer side, and its contraction causes movement of the eye outwards ; the internal rectus is on the inner side, and moves the eye inwards ; the superior and inferior recti are placed, respectively, above and below the eyeball, and their contractions cause, respectively, movements of the eye upwards and downwards.

The two oblique muscles are inserted, slantwise, one

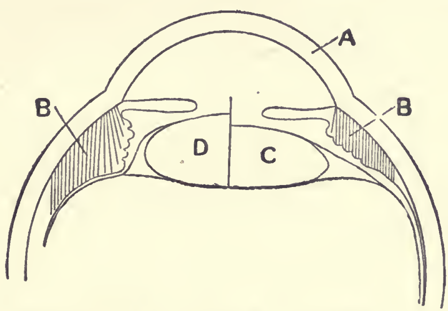


FIG. 92.—DIAGRAM ILLUSTRATING THE MECHANISM OF ACCOMMODATION.

A, Cornea ; *B*, ciliary muscle ; *C*, lens when viewing a distant object ; *D*, lens when viewing a near object (accommodated).

above (superior), and one below (inferior), the eye. Their contraction causes rotatory movement of the eye round its axis.

Accommodation.—The eye is practically a photographic camera. Images of external objects are formed on the retina, and the impressions of such images are carried to the brain. The retina is the sensitive plate upon which the image is formed and is focussed in position. To have a definite image of an object upon the retina, the rays of light from that object must be brought to a focus on the retina, and there must be some mechanism by which images of objects at various distances are brought to such a focus; and this mechanism, by which we adapt our sight to near and distant objects, is called **accommodation.** To understand this process, it would be well for us to take a physical example of a similar change. If you take an ordinary magnifying-glass (convex lens), and hold it at a certain distance from a screen or a wall in a dark room, and place a lighted candle on the side of the glass farthest from the screen, it will be easy to adapt the distances of the lens and candle in such a manner that an inverted image of the candle flame shall be thrown upon the screen. If the candle be brought nearer to the lens, the image on the

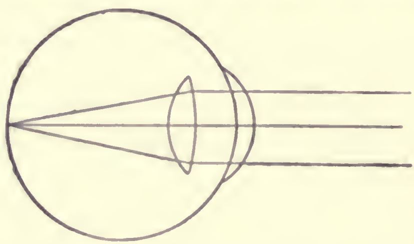


FIG. 93.—DIAGRAM SHOWING THE PATH OF PARALLEL RAYS OF LIGHT IN A NORMAL EYE.

Note how they are brought to a focus on the retina.

screen becomes blurred, and can be made clear again either by moving the lens towards the candle or by replacing the lens by one of greater curvature. The distance between the lens and the retina in the human eye cannot be altered as in a photographic camera, therefore the first of the above-mentioned methods cannot be adopted; but the convexity of the lens can be altered, and this is what happens in accommodation. The essential point in accommodation is, therefore, an increase in the convexity of the lens, and this increase, as has been proved by experiment, takes place in the anterior surface of the lens. The ciliary muscle, described above, arises from the corneo-sclerotic junction, and is inserted to the ciliary processes, to which is also attached the suspensory ligament of the lens. Contraction of the ciliary muscle causes a forward movement of the ciliary processes and the relaxation of the suspensory ligament of the lens; and this results in the lens bulging forward by its own elasticity, because the suspensory ligament is rather tight, and normally compresses the lens. The convexity of the cornea and the lens, and the distance between the lens and the retina, are so arranged in the human eye that parallel rays of light are brought to a focus on the retina. If the rays are convergent—that is, coming from a near object—they will not be brought to a focus on the retina unless there is an increase in the convexity of the lens, and this increase is brought about by accommodation.

Convergence.—When we look on a near object the eyes converge, and this is of great importance, because the image of the object is thus formed on the corresponding parts of the two retinæ; and if this were not so we should see double. This can be proved by experiment. Look at any object, and lightly press the globe of the eye; the consequent displacement of the eye will make the object appear double. The muscular sensation associated with convergence helps us to judge the distance of objects.

Cause of Defective Vision — Eyestrain. — The factors concerned in the causation of defective eyesight are numerous and complex, and have not by any means been finally ascertained. Defective vision is generally acquired, but high degree of myopia tends to run in families. The main causes are the faulty methods of education, especially in the infants' department. Work involving excessive accommodation and convergence causes an increased tension within the eyeball, and the contraction of the extrinsic muscles tends to distort the eyeball, especially in young children. The chief causes of defective vision may be grouped as follows;

1. Bad general health, inadequate nutrition, and constitutional disease.
2. Methods of education involving near and strained vision.
3. Too little or too much light, or when the light falls from the wrong direction.
4. Faulty position of the pupils relative to the blackboard, resulting in excessive contraction of some of the extrinsic muscles of the eye.
5. Faulty desks and seats; this leads to bad posture.

Hence bad light, small print, long hours at work, all tend to produce eyestrain which results in defective vision.

Defects of Vision.—A normal eye is able to focus on the retina, without accommodation, all parallel rays of light that reach the cornea, and distant objects are therefore

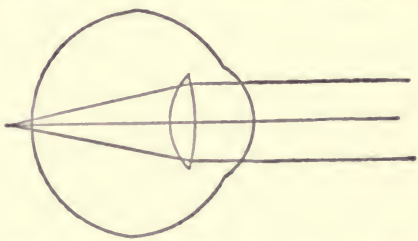


FIG. 94.—COURSE OF PARALLEL RAYS OF LIGHT IN A HYPERMETROPIC EYE (LONG-SIGHTED).

Note how the rays of light are brought to a focus behind the retina.

clearly seen even when the eye is at rest. The rays of light falling on the cornea from a point 20 feet away are practically parallel.

Long-sighted Eye, or Hypermetropia. — Hypermetropia is a congenital defect, common amongst the younger children. The antero-posterior axis of the eyeball is too short, and parallel rays of light, when the eye is at rest, are brought to a focus behind the retina. In order to have a clear image on the retina, the hypermetropic eye has to perform for distant vision what the normal eye does for near vision—that is to say, it has to accommodate. If the long-sighted eye turns its attention to near objects, it will either not see them clearly or it will accommodate excessively. This excessive accommodation is associated with excessive convergence, and should be treated by appropriate spectacles (convex lens) and avoidance of near work.

Signs of Hypermetropia.—The child complains of headache. He blinks and waters at the eyes. He can distinguish distant objects with ease; but, when reading, he does so accurately for a few lines, and then makes mistakes or stops, and will often complain that the words "seem to move about."

Short-sighted Eye, or Myopia.—In this condition the antero-posterior axis is too long, and therefore parallel rays reaching the cornea are brought to a focus in front of

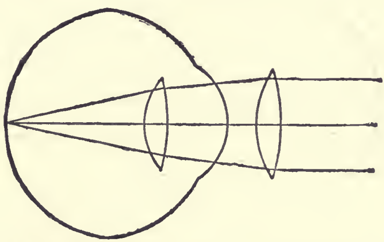


FIG. 95.—DIAGRAM SHOWING THE PATH OF PARALLEL RAYS OF LIGHT IN A HYPERMETROPIC EYE AFTER CORRECTION BY MEANS OF A CONVEX LENS.

the retina. It is not a congenital, but an acquired, condition, though the predisposition is often hereditary. There are several factors at work in producing myopia: congenital or acquired weakness of the coats of the eye; excessive accommodation, convergence, and congestion. The child may have a congenitally weak sclerotic, and when this is exposed to excessive accommodation and convergence it gives way, and causes the lengthening of the antero-posterior diameter of the eyeball. It generally begins to become troublesome at the age of nine or ten. In nutritional disorders and constitutional diseases, the sclerotic shares the general weakness of the body, and is less capable of withstanding the strain than the normal sclerotic. Hence myopia is often seen amongst weakly and underfed children, and it frequently happens that a child whose vision was normal acquires myopia as a result of an acute illness followed by the strain of school work. Some authorities doubt whether convergence and accommodation produce myopia unless there is either a congenital or acquired weakness of the sclerotic. But when the latter conditions are present, they certainly are important determining factors in its causation. Convergence acts by the extrinsic muscles pulling on the sclerotic, and also by the increased intra-ocular tension

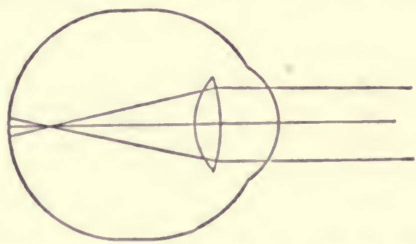


FIG. 96.—DIAGRAM SHOWING THE PATH OF PARALLEL RAYS OF LIGHT IN A MYOPIC EYE.

Note how the rays of light are brought to a focus in front of the retina.

associated with near work. Accommodation has long been indicted as a cause of myopia.

Congestion or overfilling of the small vessels of the eye is an important cause of the stretching of the sclerotic, which results in short-sightedness. This is brought about by mental fatigue or unnatural posture due to improper light and bad desks.

Signs of Myopia.—In its early stages careful eye-testing is required to detect it. When the condition is pronounced, the child, when reading, holds his book close to his eyes. He is able to read when the book is in this position, but frequently makes mistakes when reading from the board

Headaches and pains in the eyes are often associated with this trouble.

Treatment of Myopia.—The strain of near work should be avoided, and suitable glasses with biconcave lenses should be worn.

Testing of Eyesight.—The acuity of vision is generally tested by Snellen's test types. A person with average acuity of vision ought to be able to read the top letter of the type at a distance of 60 metres, the second line at 36 metres, the third at 24 metres, the fourth at 18 metres. and so on. In some test-cards the distances are recorded in feet, and generally the smallest letters are such that can

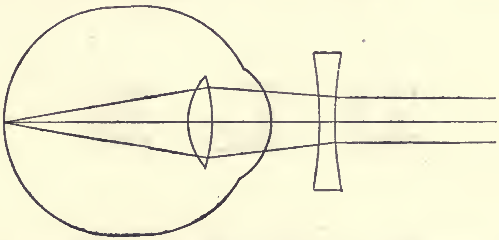


Fig. 97.—Diagram showing the Path of Parallel Rays of Light in a Myopic Eye after Correction by Means of a Biconcave Lens.

be read by a normal eye at a distance of 20 feet. The child is made to stand at a distance from the test-card equal to that at which he should be able to read the smallest type on the card, and this distance is generally 6 metres or 20 feet. He is then asked to read the letters row by row, and if his vision is normal he will be able to read all the types at this distance. If distances are recorded in metres, and the child can only read the 24 metre line at a distance of 6 metres from the types, his vision is defective. The numerical convention used to record this defect is a fraction in which the numerator is the distance in metres the child is from the types, and the denominator is the distance at which he ought to be able to read the last line which he

E

T B

D L N

P T E R

F Z B D E

O E L Z T G

L P O R F D Z

Fig. 98.—Snellen's Test Types reduced in Size.

has succeeded in reading. The normal child's vision would be $V=\frac{6}{6}$. If, however, at a distance of 6 metres he would only be able to read the 24 metre line, his vision would be recorded $V=\frac{6}{24}$.

Astigmatism.—This is one of the optical defects of the eye, and is due to an irregularity in the convexity of the cornea, so that the curvature is greater from above downwards than from side to side, or *vice versa*. Most eyes are slightly astigmatic, but when the condition is marked it prevents distinct vision, because the rays of light passing through the different planes of the cornea will not be brought to a focus at the same point. A child whose cornea has a greater convexity in the vertical than in the horizontal plane, looking at the face of the clock, will see the figures XII and VI (vertical) quite clearly, while the figures III and IX (horizontal) will be blurred. Severe forms of astigmatism cause "eyestrain" and headaches, and should be corrected by the use of proper cylindrical glasses.

Squint, or Strabismus.—"Squint" is the term applied to the condition in which the two eyes are not directed to the same point, and one eye may turn more inward or more outward than the other. It often arises very early in infancy. Long sight, or hypermetropia, is frequently associated with squint, and both these conditions are aggravated by the excessive accommodation required for near work in school. Squint sometimes follows an illness—*e.g.*, diphtheria causes paralysis of some of the eye muscles, which results in squint—but this form is generally only transitory. It is imperative that squint should be recognized and treated early, because the eye that habitually squints tends to deteriorate, and may eventually become blind.

External Eye Diseases.—The following are a few of the most common diseases of the eyelids and conjunctiva :

Blepharitis ("Sore Eyes" or "Red Eyes").—This is the term applied to the inflammatory condition of the margin of the eyelids, of the follicles of the eyelashes and their glands, and of the portion of the skin and conjunctiva bordering the margin. It is one of the most common forms of eye disease occurring in children, and is seen more especially amongst the poorer classes. It is frequently caused by measles and scarlet fever, and its course is prolonged and intensified by the bad general conditions of the child and his unhealthy environment. Pediculosis of the eyelids is sometimes responsible for this form of disease. Certain defects of vision or continuous overstrain tend to intensify it, and may be directly responsible for it. The child suffering from this condition requires medical treatment, and the parents should be instructed that great care and cleanliness are necessary.

Stye.—A stye is a small abscess at the margin of the eyelid, usually arising round one of the sebaceous or other glands. It is most frequently found amongst poorly-fed, weakly and neglected children. It gives rise to a great deal of pain, and children suffering from this complaint should be medically treated and their vision carefully tested.

Conjunctivitis.—Inflammatory condition of the conjunctiva may be mild or severe ; it may vary from slight redness to very acute disease, resulting in the destruction of the conjunctiva and underlying cornea. This disease may be due to several different conditions—irritation from dirty, ill-ventilated rooms, exposure to strong light, or acute infection by various microbes. The last variety is usually very infectious, and will spread throughout the school, and any child suffering from this condition should be sent to a medical officer for treatment.

Children whose **Eye Conditions** require treatment by medical officers—

1. All children with congested or sore eyes.
2. All those who have difficulty in reading from the blackboard.
3. All those who blink to enable them to see anything distinctly.
4. Those who, when reading, hold the book close to the eyes.
5. Those who, when reading, hold the book at an arm's length.
6. Those who complain of headaches, more especially after reading.
7. Those who squint.

CHAPTER VIII

RELATION OF SENSES TO THE NERVOUS SYSTEM—THE SENSES OF HEARING, ETC.

The Sense of Hearing.

The ear is the means by which sound waves are converted into nerve impulses, which are carried to the brain by the eighth cranial or auditory nerve, and by changes in the cerebral cortex we become conscious of sound.

Sound is produced by rapidly vibrating bodies. The vibrations are transmitted by the air, and stimulate the sensitive cells in the internal ear, where they are converted into nerve impulses.

The pitch of a sound depends upon the rate of vibration, the timbre upon the character of the vibration; the loudness depends upon the amplitude of vibration.

Physiological Anatomy of the Ear.—The ear consists of three portions: outer, middle, and inner.

The External Ear.—The auricle, or flap, is made up of skin supported by a plate of elastic cartilage of peculiar shape. In its deepest part is an opening leading into a bony passage lined by skin, called the "external auditory meatus." At the inner end of the passage lies a circular membrane set like a drum-skin in a ring of bone; this is called the "drum of the ear," or the "membrana tympani." This membrane separates the external from the middle ear. The skin lining the external auditory meatus contains glands, which secrete wax. This wax sometimes accumulates to such an extent as to block the passage and cause deafness.

The Middle Ear.—This is a small cavity lined by a mucous membrane, and situated inside the temporal bone. Its outer wall is formed by the membrana tympani. Its inner wall is formed of a plate of bo ne perforated by two openings —the oval window (fenestra ovalis), and the round window (fenestra rotunda). Both these are covered by membranes and lead to the internal ear. F rom the floor of the middle ear there runs downwards into the pharynx a tube, called the "Eustachian tube." The function of this tube is to

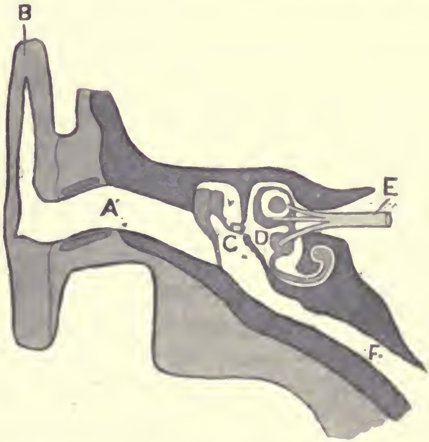


Fig. 99.—Diagram showing the Structure seen in a Section through the Auditory Apparatus.

A, External auditory canal; *B*, external ear; *C*, middle ear containing the auditory ossicles; *D*, the internal ear; *E*, auditory nerve; *F*, Eustachian tube.

keep the pressure of air on each side of the membrana tympani equal to the atmospheric pressure. When a person has a cold or adenoids, the mucous membrane of the tube is swollen; its lumen is blocked, and the oxygen of the air inside the middle ear is absorbed. This results in unequal pressure on the two sides of the drum of the ear, which causes it to be drawn inwards, and the result is deafness.

Three small bones stretch across the middle ear. The outermost is called the **malleus,** and is attached to the tympanic membrane. On the inner side of the malleus, and attached to it, is the **incus.** Attached to the incus is the **stapes.** The stapes is shaped like a stirrup, and the foot-piece of the stirrup fits into the fenestra ovalis, where it is attached to the membrane that spreads over it. This chain of bones forms a kind of bent lever by which the oscillations of the membrana tympani are transferred to the membrane covering the fenestra ovalis. They conduct the slight vibration of the tympanic membrane produced

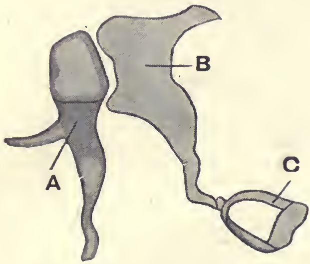


Fig. 100.—The Three Ear Ossicles.
A, Malleus ; *B*, incus ; *C*, stapes.

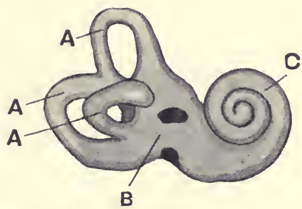


Fig. 101.—Bony Labyrinth.
A, *A*, *A*, Three semicircular canals ; *B*, vestibule ; *C*, cochlea.

by a low sound without change, but they damp down the vibrations produced by a loud sound, and thus they protect the inner ear from injury.

There are two slender muscles, the tensor tympani and stapedius, contained in the tympanic cavity, and they are connected with, and may act upon, the ossicles. The former is attached to the handle of the malleus, and is able to influence the tension of membrana tympani. The stapedius is attached to the neck of stapes.

The Internal Ear.—The internal ear consists of the bony and membranous labyrinth.

The **bony labyrinth** is made up of a series of cavities hollowed out in the temporal bone, called the " vestibule," the " cochlea," and three " semicircular canals."

The **vestibule** forms the central portion of the osseous labyrinth into which the cochlea and semicircular canals open.

The **cochlea** is a tube coiled two and a half times round a central column called the "columella." A shelf of bone protrudes from the columella, and partially divides the cavity of the cochlea; the division of the cavity is completed by the basilar membrane.

The **semicircular canals** are three in number, and are situated above and behind the vestibule. They are distinguished from each other by their position, and are called the "superior," "posterior," and "external." Each canal has a small swelling at the end where it opens to the vestibule called the *ampulla*.

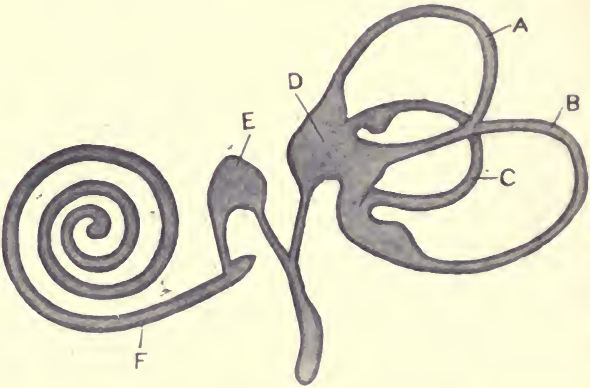


FIG. 102.—MEMBRANOUS LABYRINTH.

A Superior semicircular canal; *B*, posterior semicircular canal; *C*, external semicircular canal; *D*, utricle; *E*, saccule; *F*, membranous cochlea.

The **membranous labyrinth** assumes more or less closely the shape of the bony labyrinth in which it is situated. It contains a fluid called the *endolymph*, while the interval between it and the bony labyrinth is called the *perilymphatic space*, and is occupied by a fluid called *perilymph*.

The position of the membranous labyrinth in the vestibule is divided by a deep groove into two portions called the *utricle* and *saccule*. The membranous cochlea arises from the saccule, and passes into the bony cochlea. The floor of the membranous cochlea is formed by the basilar membrane. The roof is formed by the membrane of Reissner, which is a delicate membrane covered on both surfaces by a layer of epithelium. The outer wall is formed by the periosteal lining of the bony cochlea. In the membranous cochlea lies the organ of Corti.

The **organ of Corti** consists of a series of modified epithelial cells planted upon the basilar membrane. The pillars

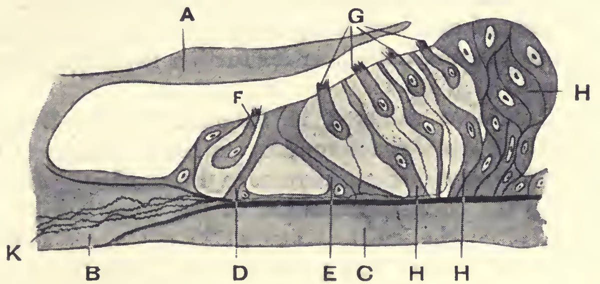


FIG. 103.—ORGAN OF CORTI.

A, Membrana tectoria; *B*, lamina spiralis; *C*, basilar membrane; *D*, inner rod of Corti; *E*, outer rod of Corti; *F*, inner hair cells; *G*, outer hair cells; *H*, *H*, *H*, supporting cells of Deiters; *K*, auditory nerve.

or rods of Corti, in two series (inner and outer), slope against each other like the rafters of a roof, and with the basilar membrane form a tunnel which runs from the base to the apex of the cochlea. On each side of the rods of Corti lie the hair cells, around which are the fibres of the auditory nerve, and supporting these there are large epithelial cells.

Causes of Defective Hearing.—The causes of deafness in children may be enumerated as follows: 1. Adenoids blocking up the Eustachian tube; the oxygen in the middle ear is absorbed, and results in inequality of the pressure on the two sides of the membrana tympani. 2. Accumulation of wax in the external auditory canal. 3. Middle ear disease, arising as an infection from the throat along the Eustachian tube. 4. Disease of the internal ear. 5. Damage to the auditory nerve. 6. Defective development or injury to the hearing centre situated in the brain.

Many children seem deaf owing to mental deficiency; they are unable to distinguish different sounds, although able to hear them quite well. On the other hand, some children appear mentally defective who are in reality only backward because they are not able to hear properly.

All cases of deafness recognized by the teacher should be sent to the medical officer for further investigation and treatment.

Ear Conditions common in School-Children.—Diseased conditions of the ears are common in school-children; this is shown by the very great increase in the number of children attending the aural departments of the large hospitals in London, since the medical inspection of school-children was begun. It is of the greatest importance that symptoms associated with the ear should receive immediate attention: for example, earache may be simply due to a cold in the head; on the other hand, it may be a sign of serious condition of the auditory apparatus.

Another common condition is discharging ears. Parents do not realize the danger that arises from ear discharge. It is generally due to a chronic inflammatory condition of the middle ear, which might at any time spread through the thin bony roof of the middle ear to the brain. Diphtheria and scarlet fever are generally accompanied by inflamed condition of the mucous membrane of the throat. This may spread to the middle ear along the Eustachian tube, and set up inflammation in that cavity, which may result in an ear discharge. Sometimes this discharge is infectious, and may cause an epidemic in the schools. All children with discharging ears and earache should be sent to the medical officer for investigation and treatment.

Tests for Hearing.—All children whose hearing is defective should be sent to the medical officer for investigation and treatment. There are one or two simple tests of hearing that can be performed by the teacher, either by means of the voice or by a watch. The pitch and loudness can be regulated more effectively in a whisper than in the usual speaking voice ; hence the voice test should always be performed by means of a whisper. Each ear should be tested separately, and it is advisable that all the children should be examined by the same teacher. The examiner should first of all ascertain the distance at which his forced whisper can just be heard by children possessing good hearing, and if the maximum distance be, say, 30 feet, a straight line of this length, divided into feet, should be drawn on the floor of the classroom. The child stands sideways at one end of this line, with the ear to be tested turned towards the examiner, and the other ear carefully stopped by the finger of an assistant. The examiner then whispers single words, and should the child be unable to hear him distinctly, or make a mistake, the examiner should move a foot at a time nearer the child, until the latter clearly understands the word whispered. The distance between the examiner and the child is measured and recorded.

The alternative test is performed by means of a watch ; and since the ticks of various watches differ in pitch and loudness, the same watch should be used for all experiments. As in the voice test, the maximum distance at which the ticking is heard by children of good hearing is recorded. In this test the child should have his eyes covered, and the watch should be held at a distance from the ear and gradually brought nearer. The child is asked to make a sign the moment he hears the ticking, and the distance between the child and the watch should be ascertained. The hearing of a child is represented by the ratio of this distance in feet to the length of the line drawn on the floor prior to the commencement of the experiment.

THE SENSE OF SPEECH.

Structure of Vocal Organs.—The larynx, or voice-box, lies at the top of the trachea, or windpipe. It opens into the pharynx above and the trachea below. The gullet lies at the back of the larynx.

Obtain from your butcher a sheep's tongue with the larynx, windpipe and gullet attached. The gullet will be

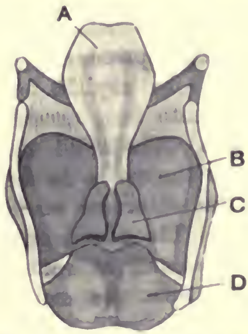


FIG. 104.—POSTERIOR VIEW OF THE CARTILAGES OF THE LARYNX.

A, Epiglottis; *B*, thyroid cartilage; *C*, arytenoid cartilages; *D*, cricoid.

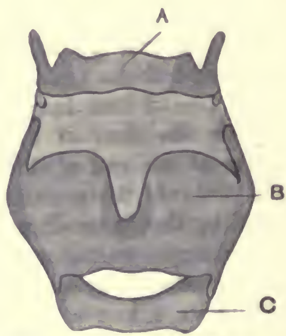


FIG. 105.—ANTERIOR VIEW OF THE CARTILAGES OF THE LARYNX.

A, Hyoid bone; *B*, thyroid cartilage; *C*, cricoid cartilage.

attached behind, and the larynx will be covered by thin bands of muscle. These muscles pass from the prominence of the larynx either upwards to the *hyoid* or downwards to the *sternum*, or breast-bone. The hyoid is a small bone embedded in the muscle below the tongue; it is slung to the skull by muscle and ligaments, and forms a means of attachment for muscles which pass upwards to the tongue and downwards to the cartilage or larynx and sternum.

Dissect the muscles and fat off the front and sides of the larynx, and expose its cartilaginous framework. Just above the trachea lies the cricoid cartilage; it is shaped like a signet ring, the narrow part of the ring being in front, and the broad part behind. It is this broad part which forms the posterior wall of the larynx, and on the top of it lie the two *arytenoid* cartilages. These are two pyramidal-shaped cartilages, and are each attached to the cricoid cartilage by a final joint. The *thyroid* cartilage is a broad V-shaped cartilage with the angle anteriorly. The sides of the thyroid cartilage are prolonged above and below into horns. The upper pair of horns is bound to the arch of the hyoid bone; the lower part is articulated by a pivot joint to the outside of the cricoid cartilage. The epiglottis will be seen as a thin leaf-like lumina of yellow fibro-cartilage covered by a mucous membrane; it is placed behind the tongue and the body of the hyoid bone, and in front of the upper aperture of the larynx.

A number of very important muscles are attached to the cartilages of the larynx. On each side the crico-thyroid muscle will be seen; this runs from the thyroid to the cricoid cartilage, and when it contracts it causes a tilting of the cricoid, and thus tightens the vocal cords.

Muscles will be seen passing from the cricoid to the arytenoid cartilages. These cause the arytenoids to swivel round upon their pivot joints, and by this means the vocal cords are brought nearer together or farther apart, and thus lessen or increase the aperture between them, which is called the "glottis." The two arytenoids are connected together by muscle, and this, when it contracts, causes approximation of the vocal cords. Another muscle on each side runs from the thyroid to the arytenoid cartilage, and some of its fibres are directly attached to the vocal cords, and by this means the cords can be slackened either in part or in the whole of their length. With a sharp knife bisect the larynx and study its interior. It will be found to be lined by a mucous membrane, and divided into three portions by two elevated folds of mucous membrane, which extend from before backwards, and project inwards from each side of the cavity. The upper pair of folds are called the *false vocal cords;* the lower pair receive the name of *true vocal cords.* The latter are the chief agents in the production of the voice, and the muscles mentioned are so arranged as to cause changes in their relative position and degree of tension.

Interior of the Larynx in Man.—The glottis is examined in a living person by means of a small mirror placed on a long handle, and passed to the back of the throat. The observer by means of a tape fixes a concave mirror over his forehead. This mirror is pierced by openings, so that the observer can see the image of the glottis formed by the small mirror inside the throat, which is illuminated by a light from a strong lamp, having been reflected from the mirror on the forehead.

The Production of the Voice.—Sound is produced in the larynx by the vibrations of the vocal cords. It was said at the beginning of the chapter that the pitch of a sound depends upon the rate of vibration, the loudness upon the amplitude, and the timbre, or character, upon the form of vibration.

By means of physical instruments it can be proved that short strings vibrate at a quicker rate than long strings, and thus the pitch of a note evolved by a string is inversely proportional to the length of the string. Similarly, the loudness will depend upon the amplitude of vibration, while the character depends upon the form of vibrations. The same holds true for the vocal cords of human subjects.

Man has longer vocal cords than a woman, and hence his voice is deeper.

The loudness of the voice depends upon the strength of the current of air setting the cords in vibration, because the greater the force, the greater the amplitude.

The quality of the voice depends upon the character of the vibration, and hence the thickness, elasticity, and smoothness, of the cords, and the shape of the cavities of mouth, pharynx, and larynx, will influence it.

Song is produced by very complicated muscular movements, which can only be carried out with accuracy after continual practice and years of training. The exact degree of tension must be given to the vocal cord to produce the required pitch, and the quality at the same time must be determined by the muscles of the mouth and throat. The singer must learn to execute these movements with great rapidity and precision. The range of the voice seldom exceeds two and a half octaves.

Production of Speech.—Speech is voice modulated by the throat, tongue, and lips. Voice may exist without speech, but this is only true, however, if the term "voice" be restricted to sound produced by vibration of the vocal cords. In whispering, the slight sound produced by the air passing through the air-passages is modified into speech by movements of the tongue and lips.

Differences in the shape of the cavity of the mouth and the form of its opening are the factors which cause the variety of vowel sounds. Pronounce the pure vowel sounds *e* as in "he," *a* as in "ay," *a* as in "ah," *o* as in "oh," *oo* as in "coo," and notice that they are produced by varying the form of the cavity and the shape of the opening of the mouth.

The consonants are produced by closing, more or less, certain exits on the outgoing blast. If the exit be partly closed, and the air rushes through with a hiss, the result is an "aspirate"; thus, *f*, *v*, and *w*, are produced by partial closure with the lips; *s*, *z*, *l*, *sch*, and *th*, by the tongue and hard palate, and *ch* by the tongue and soft palate. The consonant *h* is produced by increasing the expiratory force with which the vowel is spoken.

M and *n* are produced by sending the current of air through the nose; in the case of *m* the lips are closed, while to pronounce *n* the tongue is applied to the palate. The consonants *b*, *p*, *t*, *d*, *k*, *g* (hard), are called "explosives," because the mouth is first closed, and then suddenly burst open. In the case of *b* and *p* the lips close the mouth; in *t* and *d* the tongue is applied to the teeth or front part of the palate; while in *k* and *g* hard the middle or back of the tongue is forced against the back of the palate.

Speech Defects—Stammering.—This is a spasmodic affection of the organ concerned in speech, in virtue of which the enunciation of words becomes suddenly checked. It is much more common among boys than girls.

Stuttering.—Where there is spasmodic repetition of initial syllables of words, it is due almost entirely to imperfect breathing, and is more amenable to treatment by respiratory exercises than stammering.

Motor Aphasia.—This arises from imperfect development of the speech centre of the brain, and the child is unable to control and co-ordinate the various muscles which take part in the mechanism of speech.

Habitual Speech Defects.—Defects of this kind are very common, and are due only to habit. The child may imitate the language of its parents and associates, or he may have an habitual lisp or the affected speech of spoiled children. These are only correctly identified by knowing the type of child and its surroundings, and by compelling him to imitate correct speech.

Speech Defects due to Adenoids.—There is a marked nasal intonation, and in the younger children the speech is thick and indistinct, and pronunciation is defective.

The Sense of Smell.

The olfactory sense organ lies in the upper parts of the nose, and consists of elongated cells, each of which bears on its free end a tuft of hair-like processes, while at its nasal end it is continued into a nerve fibre that passes through the upper wall of the nasal cavity to reach the cranial cavity.

It has been held that smell is due to vibratory movement of some medium, because it can be transmitted through space like light and sound, but this view is erroneous. Sensation of smell is elicited by small particles being carried up the nose, which, after solution in the moisture of the mucous membrane, act chemically upon the sensitive hairs described above.

The Sense of Taste.

At the back of the tongue a few large papillæ surrounded by a groove will be seen. These are called "circumvallate papillæ." The entire dorsal surface of the tongue will be

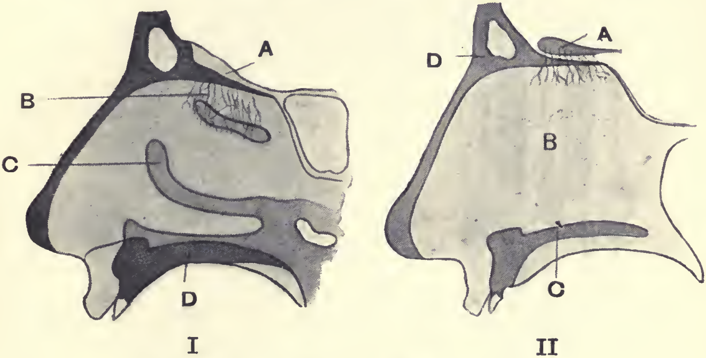


Fig. 106.—Anatomy of the Nasal Cavity.

I. Outer wall: *A*, base of skull; *B*, branches of olfactory nerve; *C*, inferior turbinate bone; *D*, palate-bone. II. Inner wall: *A*, olfactory bulb and olfactory nerves arising from it; *B*, nasal septum; *C*, palate-bone; *D*, frontal bone.

found covered by papillæ, some of which are long and slender (filiform), and others are shaped like a puff-bull fungus (fungiform). At the side of some of the fungiform papillæ, and of all the circumvallate papillæ, the cells are modified to form taste-buds. These consist of small cavities containing a cluster of cells, which are of two kinds—the gustatory and supporting cells. The gustatory cells have small hairy processes which project above the opening of the taste-bud, and are exposed to the juices in the mouth.

Four qualities are detected by the sense of taste—

namely, sweet, bitter, acid, and salt. We detect the flavours of food and drink by the sense of smell. The sensations are carried to the brain from the anterior two-thirds of the tongue by the lingual nerve, a branch of the fifth cranial nerve, and from the posterior third by the glosso-pharyngeal or ninth cranial nerve.

Peripheral Sensations.—These are made up of cutaneous

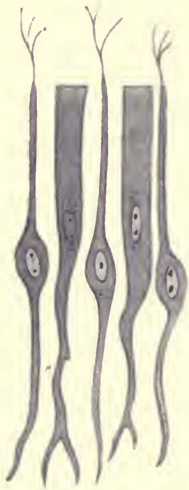


FIG. 107.—CELLS OF THE OLFACTORY MUCOUS MEMBRANE.

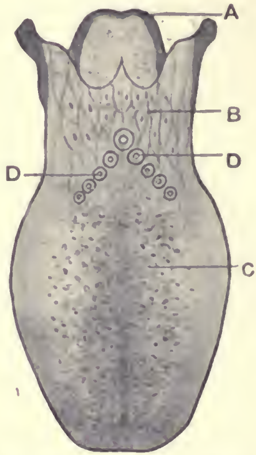


FIG. 108.—ANATOMY OF THE TONGUE.

A, Epiglottis; *B*, pharyngeal portion of tongue; *C*, oral or buccal portion of tongue covered by papillæ; *D*, *D*, circumvallate papillæ.

sensations—namely, touch, heat, cold, and pain, and also the deep sensations arising from muscles and joints.

Touch is a skin sensation, and is elicited by stimulation of nerve plexuses around hair follicles or some special form of tactile corpuscle.

Heat sensation is experienced by stimulation of certain specific end organs in the skin.

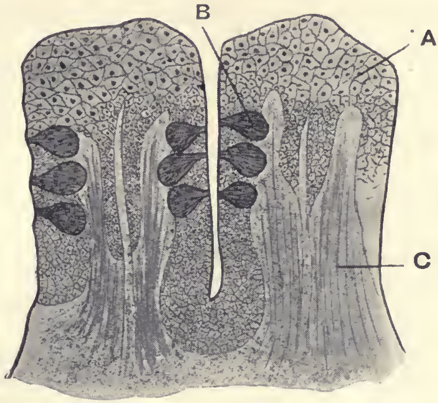


FIG. 109.—MICROSCOPIC STRUCTURE OF THE MUCOUS MEMBRANE OF THE TONGUE.

A, Stratified epithelium ; *B*, taste-buds ; *C*, corium.

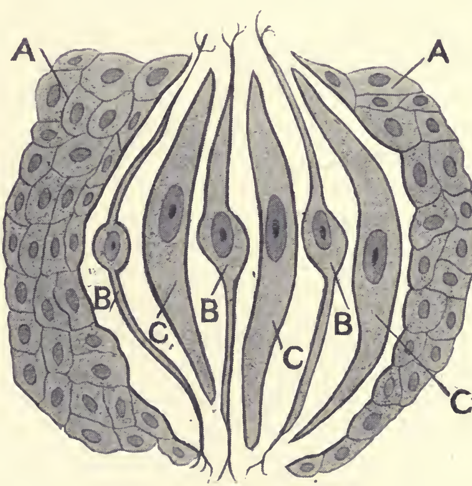


FIG. 110.—DIAGRAMMATIC REPRESENTATION OF TASTE-BUDS.

A, Stratified epithelium forming its wall ; *B*, gustatory or taste cells ; *C*, supporting or sustentacular cells.

Cold is also elicited by stimulation of other special end organs in the skin.

Temperature is a compound sensation, a combination of touch and either heat or cold.

Pain is due to stimulation of the free nerve endings of the skin.

Muscular and Joint Sense.—Afferent nerve fibres from the muscles, tendons, and joints, convey nerve impulses which give rise to the sense of position and of the movements of various parts of the body.

By muscular sensation combined with touch we determine the size and shape of objects.

The powers to localize touch in various parts of the body, and to determine the size, consistence, and weight, of an object, are acquired by practice in childhood—hence the naturally eager desire of all young children to touch and handle whatever they see.

CHAPTER IX

SANITATION OF THE SCHOOL

Relationship of Soil and Health.—Sanitary authorities have for a long time held that the health of the inhabitants of a locality bears a close relationship to the nature of the soil of that locality, and this is still more marked in the case of a single house or building.

It is seen, therefore, that it is of the greatest importance, before building any house or school, to know the exact nature of the soil of the site where it is to be erected. Let us further consider the relationship of the character of the soil to disease. Bowditch in America and Buchanan in this country have brought certain facts to prove that there is an intimate connection between the moisture in the soil and consumption of the lungs. Pettenkofer in Germany has shown that there is a relation between the height of the water in the soil and epidemic outbreaks of typhoid fever. Malaria is most prevalent in the moist, hot climate of the tropics; it is very probable that with better drainage the prevalence of this disease in such districts will be greatly diminished. Some writers in this country state that too much moisture in the soil and air of a building is closely associated with conditions of catarrh, rheumatism, neuralgia, etc., in its inhabitants.

It is wonderful what bacteriology and sanitary science have done towards the extinction of yellow fever in America.

The two factors in the soil that influence the health of the people living upon it are the composition of the air that lies in the interstices between the particles of soil, and also the amount of moisture that it contains.

Surface and Subsoil. — The soil is subdivided into the superficial surface soil and the deeper subsoil. The **surface soil** is made up of organic and inorganic constituents; it contains a large number of bacteria, some of which are able to cause certain diseases in man, such as the tetanus bacillus, causing lockjaw, or typhoid bacillus, causing enteric fever. Others are of the greatest utility to all forms of animal life, because they bring about the putrefaction of organic materials containing nitrogen and convert them to nitrates, which can be absorbed by plants, and built up again to complex nitrogenous compounds, which are eaten by man or animals. Since most plants are not able to absorb nitrogen directly from the air, these bacteria play a most important part in the "circulation of nitrogen" in the animal and vegetable kingdoms. The deeper **subsoil** is made of particles which are derived from the rocks below, and it is thus made up of only inorganic material. It will vary in composition in different localities according to the nature of the rock that lies beneath such localities.

The interstices between the particles of the upper layers of the soil are occupied by air, and this is called the **ground air,** and its composition is of great importance in its influence upon the health of the inhabitants living on the soil. It may contain some organic constituents from the decay of animal and vegetable substances; further, it contains more moisture, more carbon dioxide, and less oxygen, than the atmospheric air.

The interstices between the particles of the deeper layer of the soil are occupied by water, and this is called the **ground water.** This is formed by rain water percolating through the upper layers of the soil until it reaches an impervious stratum on the surface of which it flows towards the nearest river or sea. The rate at which the ground water flows away depends upon the condition of natural drainage, and if this be inefficient it can be greatly accelerated by artificial drainage.

The line of separation between the ground air and water does not always remain at the same level. Thus, after a heavy rainfall the level of ground water is raised, while after a drought the level will be lowered. These will cause corresponding movements in the ground air. Other factors which cause movement of the ground air are the difference in temperature between it and the atmospheric air, changes in barometric pressure, and the action of the wind.

Some soils readily allow water to percolate through, and are said to be *porous—e.g.*, sand, gravel, sandstone, and chalk. Other soils do not allow the passage of water through them, and are said to be *impervious—e.g.*, clay.

Site of the School.—From the above facts it is seen that the two important conditions that must be determined regarding the soil as to its value as a building site are the composition of the ground air and the amount of moisture present.

The constituents of the ground air that must be avoided are the volatile organic compounds which are formed by decomposition of animal and vegetable matter. The amount of such compounds in the ground air will naturally be proportional to the amount of animal and vegetable matter in the surface soil; thus, it is found that excavations made for various purposes are often filled up by all kinds of rubbish. This results in what is called a **made soil**; it will contain large quantities of organic substances in varying stages of decomposition, causing great pollution of the ground air. Great care should be taken to avoid such sites, or, if that is impossible, they should not be built upon for at least eight or ten years after the excavation has been completely levelled. The amount of moisture in the soil will depend on its permeability and power of absorption of water, level of ground water, and the condition of natural drainage.

A healthy site is one in which the soil is porous, or impervious and non-absorptive, contains little organic matter, where the ground water is 10 feet or more below the surface, and where there is a good slope to allow for natural drainage. Judged from these standpoints, we find that rock, chalk and sandstone of considerable depth are dry and healthy, while clay and made soils are very unhealthy.

Environment of the School.—In this country, north and north-eastern aspects are cold, whilst southern are warm; north-western and south-western are exposed to boisterous winds, and the latter generally to driving rains. The southerly aspect is generally dry and mild, and should, if possible, be always selected.

The school should be some distance from all other buildings, and especially from any offensive works, such as tanneries, chemical works, etc. It should also stand at a good distance from the street, to avoid noise and dust.

Trees should not be planted too near the school, because they tend to prevent the evaporation of water, and also impede the free circulation of air. At the proper distance they are of great value to protect the building from cold winds.

General Plan of School Buildings.—The considerations requisite for proper hygienic conditions are so simple that they are frequently overlooked even in elaborately-constructed modern schools. It is essential that a constant supply of fresh air and daylight be obtainable, and in addition some hours of direct sunlight. The exact requirements of a school will depend, of course, upon the number of scholars. The plan of a school required to accommodate only fifty children will differ greatly from that required to accommodate four hundred. It is desirable, however, that all schools should be planned to meet the above-mentioned general requirements, and such buildings can be classified into two groups: (1) The central hall type, where the classrooms open into the assembly hall;

(2) pavilion type, where the classrooms open into a corridor or veranda, and are independent of the assembly hall.

The **central hall type** of school appears at first sight eminently satisfactory. It is convenient and compact, and tends to render supervision easy. It has, however, its disadvantages from a hygienic point of view. In this type of school the assembly hall is surrounded by classrooms, and the ventilation of the classrooms and this room are therefore far from satisfactory. This is especially the case during the hot summer weather, because the assembly hall derives its ventilation from the surrounding classrooms, and does not receive a constant supply of fresh air from outside. The second hygienic essential, an abundant amount of daylight, can easily be arranged for in this type of school by the provision of a sufficiently large number of windows. A serious difficulty is, however, experienced when a direct supply of sunlight to each classroom has to be arranged for. The importance of direct sunlight in all classrooms cannot be over-estimated, because, as it will be pointed out later, sunlight is one of the best germicides, and schools should be so constructed as to allow of the presence of sunlight for some time during school hours. The inconvenience caused by excessive heat in summer can be avoided by the use of blinds and curtains.

The **pavilion type** of school satisfies all the essential hygienic conditions mentioned above. Each classroom has an abundant supply of fresh air from the corridor or veranda, the lighting of the rooms is satisfactory, and the excessive heat of summer and the severe cold of the winter can be moderated by a judicious use of the windows. The chief objection to this type of school is that it covers a large area of ground, which is a great drawback in large towns, where the price of land is high.

The pavilion type has been most ably advocated in this country by Dr. Reid, the Medical Officer of Health for Staffordshire. (See his Report to the Staffordshire County Council Education Committee, 1908.)

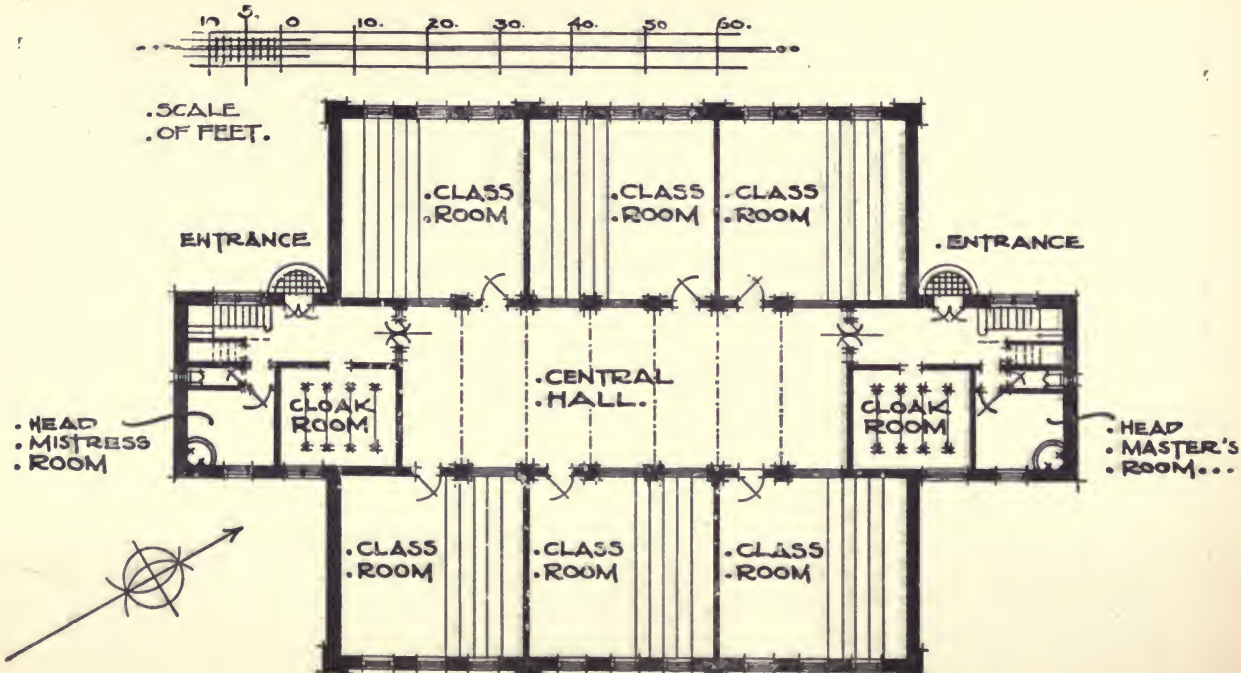


FIG. 111.—PLAN OF CENTRAL HALL TYPE OF SCHOOL.

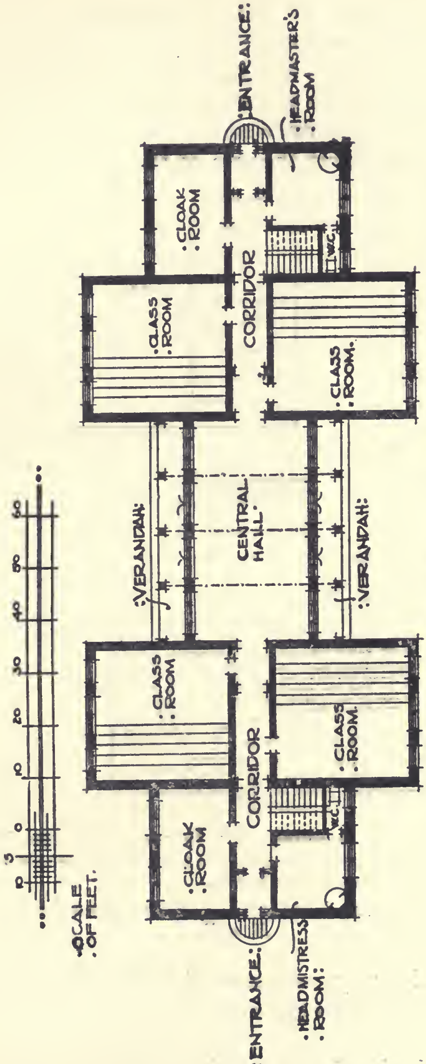


FIG. 112.—PLAN OF PAVILION TYPE OF SCHOOL.

The Construction of School Buildings. — First of all adequate foundations must be secured. It is advisible to have concrete foundations, grouted over by cement; this prevents the entrance of ground air and moisture. After the removal of the surface soil, until a layer of hard earth is exposed throughout the site of the school, it is covered

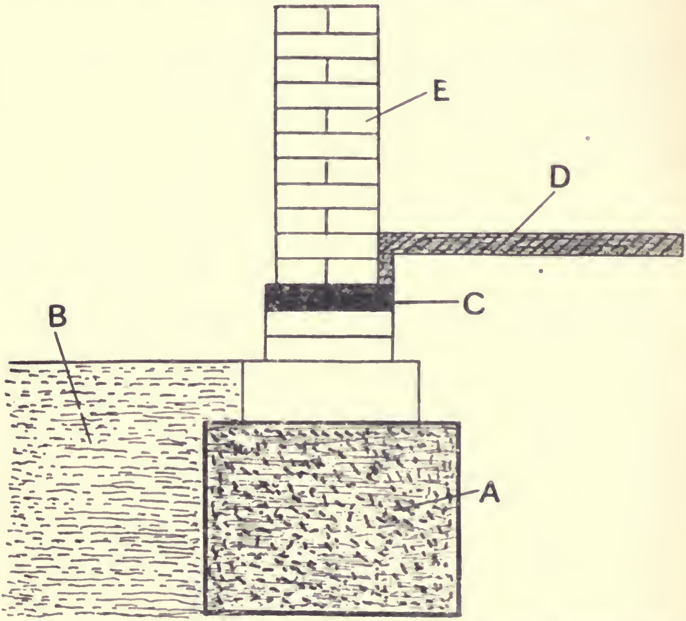


Fig. 113.—Diagram showing the Foundation and Wall of a Building, and the Means provided to prevent the Ascent of Dampness within the Wall.

A, Concrete foundation; *B*, outside soil; *C*, damp-proof course; *D*, floor; *E*, wall.

by a layer of cement concrete, 6 inches in thickness, and under the walls the concrete must be at least 20 inches deep.

The walls built of ordinary bricks and mortar are very porous and capable of absorbing large quantities of water.

In the construction of the walls of a building, some precautions are taken to prevent the moisture ascending within the walls. Where there is no basement, and the floors are above the ground level, this result can be attained by placing a damp-proof course of slates embedded in cement, a half inch layer of asphalt, or slabs of perforated glazed stoneware, in the walls. This should be placed at least 6 inches above the ground outside and below the level of the lowest timbers. The stoneware slabs serve a second function, in that the perforations allow the passage of air through the walls, and thus ventilate the space under the floor.

In buildings where a basement is necessary or in which the floors lie at a lower level than the soil outside, some other means must be taken to prevent the ascent of moisture in the walls. One method is called the "dry area," in which a second wall is built at a short distance outside the main wall; it serves to keep the damp soil away from the main wall of the building.

The external walls should be made of stone or good bricks, bonded and solidly put together by means of mortar or cement. The width will be proportional to the height. The Board of Education demands that for walls of one story high the thickness must be one and a half bricks, and if of stone 20 inches thick. Hollow walls must be built in very exposed situations.

Glazed bricks or enamelled tiles are very impervious and readily cleaned, and therefore are very satisfactory as internal wall surfaces.

If the walls are plastered, it should be a durable, smooth, and non-porous variety, and it should be painted and varnished. The surface will then be almost non-absorbent, and can be readily cleaned.

Great precautions should be taken so as to make the roofs water-tight, and protective against heat and cold. Slates and tiles are the best materials. Adequate means must be attained to carry off the water from the roof as quickly as possible, and the spouting must be such as to be able to cope with the maximum rainfall on any day in the year.

Floors should be made of wood blocks, and these laid on cement and concrete (see Fig. 115). If boarded floors and joists are used, the joists should be placed side by side, and the floor boarding nailed to the upper surface of the joists.

In order to abolish crevices, and thus facilitate sweeping

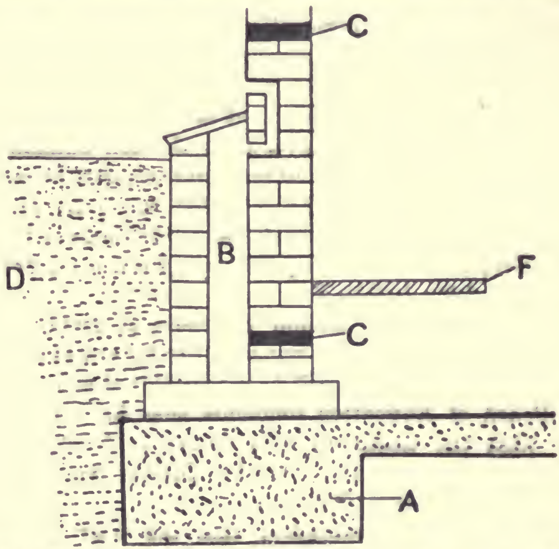


FIG. 114.—DIAGRAM SHOWING FOUNDATIONS AND WALL OF A BUILDING WITH A DRY AREA INSTALLED TO PREVENT THE ACCESS OF WATER FROM THE OUTSIDE SOIL.

A, Concrete foundation ; *B*, dry area ; *C*, *C*, damp-proof courses ; *D*, soil ; *F*, floor.

and cleaning, the wainscot and floor must be joined by a rounded insertion.

A basement should be present under the whole building. Under certain conditions it may be used for cloakrooms. Rooms situated in the basement should never be used for teaching purposes. It may be taken up by the heating apparatus and storerooms. The floor should be cemented concrete.

The staircases should be made of some fire-resisting material, such as iron and slate or steel and lead. It is safer to have no balustrade, and to have the stairs walled on both sides, because children often fall over the banisters. There should be at least two staircases in every school, and in mixed schools one should be used by the boys, and another by the girls. The staircases should be about 6 feet wide, and must not have more than fifteen steps to each flight.

No school should have less than two entrances, and in mixed schools there should be separate entrances for boys

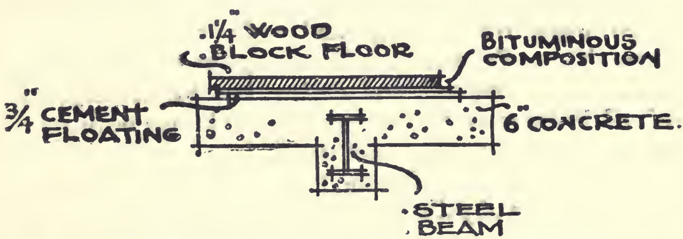


FIG. 115.—PLAN OF CONSTRUCTION OF FLOORS THAT SHOULD BE ADOPTED FOR SCHOOLS.

and girls. In all schools the number of external doors should be such as to allow the school to be completely emptied in two or three minutes, if any emergency should arise.

Cloakrooms and lavatories are essential for all school buildings, and special rooms must be set apart for such purposes.

Cloakrooms should be very well lighted and ventilated. The pegs for hats and coats should be numbered, and placed about 18 inches from each other. It is very important to have free circulation of air around the clothing, and therefore insuring rapid drying.

Water-Supply.—Water is an absolute necessity to maintain life, and the supply should be pure and liberal. A scanty and insufficient water-supply or scanty use of available water results in every form of sickness associated with filth, whilst an impure supply will result in various forms of diseases.

To no class of the community is a plentiful water-supply so essential as to the children in the schools, and therefore it is the duty of the authorities to see that there is an efficient water-supply to all the schools of the land. The schools in all urban districts should obtain the water from the general supply, but in rural districts is it generally necessary to arrange for their own water-supply either by sinking a well or obtaining some means of collection and storage of rain water.

The water from springs and wells varies greatly in composition. Superficial wells are apt to contain organic matter from cesspools and drains, but by an improved subsoil drainage the water from these wells may be rendered pure and wholesome ; therefore, if the water-supply of a school comes from a shallow well or spring, there should be no suspicion of pollution with drains or cesspools. These wells should be examined after the holidays, and all the water should be pumped out of them just before the opening of the school. Since shallow wells are so liable to pollution, it is better for country schools to have a private deep or " Artesian " well. Deep wells contain much lime, but they are the best source of drinking water. An " Artesian "—from Artois in France—is a deep well bored through impervious strata to a water stratum in which the water is under such a pressure as to cause it to rise to the surface. It is often better to filter the water before it is drunk ; this should be done by a Pasteur-Chamberland filter.

In the majority of towns the supply of water is maintained at a pressure which enables it to be drawn off in houses at all times ; yet it is necessary to store some in cisterns to feed boilers or for other emergencies. In some places, however, water is only supplied at stated intervals, and then a storage becomes a necessity. Thus there are two systems of water-supply—the constant and intermittent.

In their report on the storage of water in houses the Rivers Pollution Commissioners say: "All storage of drinking water in houses is attended with the risk of pollution. Good water is spoiled and bad water rendered worse by the intermittent system of supply. All drinking water ought to be drawn direct from the main. Under proper supervision the waste of water is less on the constant than it is on the intermittent system of supply. These and other advantages have led to the adoption of the constant system in a great majority of British towns." From above it is seen how important it is to have a constant supply of water whenever possible.

If the supply is intermittent, some form of storage is absolutely necessary, and this is generally done by means of cisterns; they should be made of galvanized iron or slate with cemented joints. All cisterns should be kept covered to prevent contamination, but free ventilation should be provided. They should be so placed as not to damage the school or render it damp in case of leakage, and also be easy of access for inspection, cleaning, etc. The waste should open into the open air, and should on no account communicate with the drains or closet tap. All the cisterns should be inspected and cleaned periodically.

Where there is a public water-supply, the best means of distribution is to have a drinking-fountain in the playground. The best authorities advocate the instalment of a fountain so constructed that a small stream of water issues from an upright pipe for about 3 or 4 inches, and the scholar drinks by receiving the stream into his mouth. Drinking-cups should not be used, because they are often potent factors in the spreading of contagious disease.

Various Forms of Water Pollution.—Shallow wells receive their pollution from the surface soil, and from the leaking of drains and cesspools. In order to prevent these, the well must be sunk in such a position as regards possible sources of pollution that the underground water flows from the well to the sources of pollution. The mouth of the well should be protected by a coping carried up to about a foot above the surface of the ground ; it should be closed over, and the water raised by an iron pump. The water supplied by deep wells is generally remarkably free from organic impurities, even when sunk in the midst of large cities ; but every means should be taken to prevent contamination from surface drainage and from soakage from sewers or cesspools.

School Drainage.—" The general aim in connection with the drainage of a building is to insure a prompt and complete removal of all waste, deleterious matter, the retention of which may prove injurious to health. This is effected by means of suitably-arranged pipes or drains, which shall convey the waste water from baths, lavatories, etc., and the removal of this and the construction of the pipes must be such that, whilst they permit water to flow away into the sewers, they shall not allow the access back again of any gases produced by decomposition, from the drains or sewers themselves into the building " (Hope and Buchanan).

The principles that guide the constructions of drains for schools does not differ from those applied in the case of other residential or public buildings.

The exact course of the drains should be carefully planned.

The trenches should be dug as straight as possible, and covered with concrete 6 inches in thickness, and should be so graduated as to give a gradient of 1 in 40 for 4 inch drains or 1 in 60 in 6 inch drains. Stoneware pipes should be used, and laid with the socket end pointing towards the commencement of the drain. Stoneware pipes are better than those of earthenware because they are less porous and more durable. Iron pipes may also be used. It is important

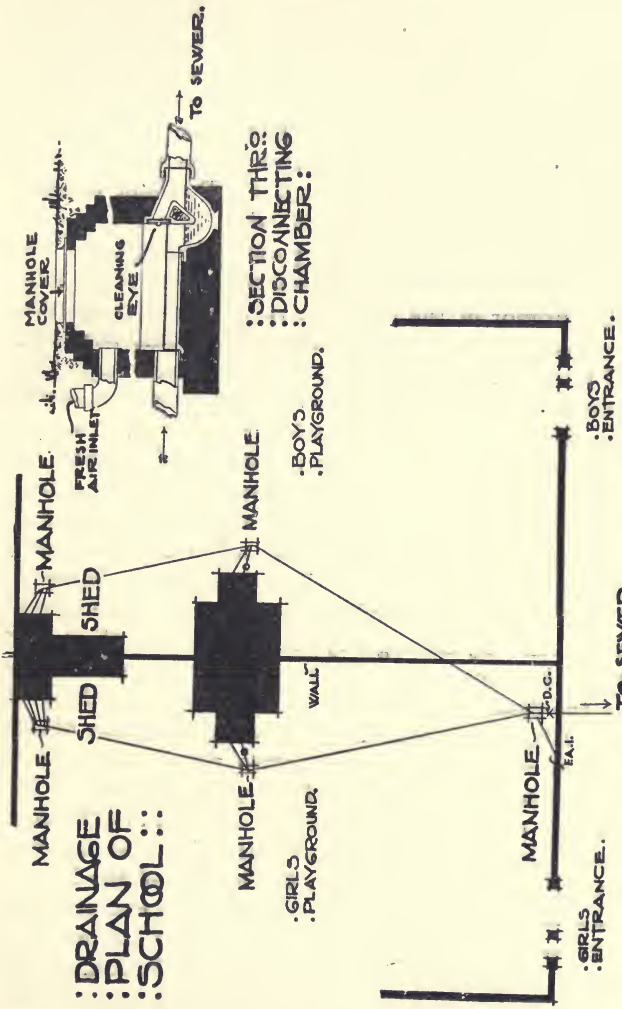


FIG. 116.—PLAN OF SCHOOL DRAINAGE AND CONSTRUCTION OF DISCONNECTING OR INSPECTION CHAMBER.

to avoid the passage of a drain under the basement of a house or school; and if this is impossible, greater care should be taken with the joints, and the whole pipe should be covered with concrete, and the wall supported by a relieving arch to prevent settlement and fracture of the pipes at the point where the drain leaves the premises.

The drains should be laid as straight as possible, and stoneware pipes should be jointed by Portland cement, and cast-iron pipes well caulked with blue lead. Care should be taken to prevent any possible leakage, and also the projection of any of the cement at the site of the joint into the interior of the drain, so as to obstruct the flow of its contents. If a bend is necessary, it should be accomplished by a special pipe curved to the required degree.

Whenever a branch drain joins the main drain, it should be done by means of a V junction pipe; in such a case there will be very little obstruction at the site of junction, because both currents are flowing very nearly in the same direction. All the branch drains should join the main drain as near together as possible, and around such junctions a small inspection chamber be built. In addition, any change in direction of the drain should take place inside the inspection chamber. By having a system of such chambers, and the drains between them running in straight lines, inspection of the drain is simplified and obstruction or deposits can be readily removed. The inspection chambers should be so constructed as to allow ample room for workmen to manipulate rods and other cleaning apparatus. In the case of iron drainage, it is usual to fix at the bottom of these chambers a cast-iron box with the cover screwed down; with earthenware drains the bottom of the inspection chamber is laid with half-round glazed channel, and the concrete benched, so as to prevent any lodgment of excretory or foul matter remaining at the bottom of the chamber after a flood or partial stoppage. A person entering this chamber can say whether there is any obstruction at the junctions, and, further, the chamber itself can be easily cleaned and rods can be passed up the different branches.

After the drains have been jointed they should then be tested, and this can be done in several ways. One method is to plug all the openings of the inspection chamber, and then separately fill each branch of the drain with water. If the water remains at the same level for an hour and a half or two hours, the drains may be considered as satisfactory. Another test is the smoke test, where a smoke rocket is placed inside the drain, and inspection made for any leakage of the smoke through the drain. Another test is to break small capsules of phosphorus and asafœtida inside the drain, and then look for any leakage of white fumes formed by the reaction of these two chemicals. If a leakage is present it should be remedied at once. Precautions must also be taken to prevent the entry of gases from the common sewer, soil pipes, drains, or waste pipes, to the house or school. The most effectual means of prevention is to have good ventilation of all the drains. Certain forms of traps are of some use in this direction, but they are never so effectual as good ventilation. Good ventilation can only be effected when there is an outlet for foul air at one end of the system, and an inlet for fresh air at the other end. The grating over the inspection chamber acts as the inlet, while the soil pipe or a separate ventilating pipe acts as the outlet.

Traps are simply means to prevent the passage of sewer gas into the building. Siphon traps are the best, because they can be readily flushed, and they have no corners where any deposit can accumulate.

Cesspools.—These are, fortunately, not very commonly used at present as means of collection for excreta ; but if they are necessary, they should be removed as far as possible from the school buildings, be made of brick, and rendered water-tight by a good lining of cement.

Closet Accommodation.—It is of the greatest importance that efficient sanitary conveniences should be installed in all the elementary schools. There are two systems used to dispose of human excreta—conservancy and water-carriage systems.

Conservancy System.—This should only be installed in rural districts where there is no water-supply. All towns which have an efficient water-supply should install a water-carriage system. It is very undesirable to have any form of conservancy system, because excremental matter is kept near the school, and does not conduce to good hygienic conditions.

Closets under this system may be of three kinds—privy or midden, pail, and earth closets.

Privy or Midden Closets.—In this form of closet, a hole is dug in the earth and a seat erected above it; the hole acts as a receptacle for the fæces. In the older forms of midden closets, no provision was made to prevent their contents mixing with the soil around, polluting the water of the neighbouring wells and the air around the building. The Local Government Board have formulated certain laws which define requirements in the construction of a privy. It must be at least 6 feet away from any dwelling, and 40 or 50 feet from any well, spring, or stream. Ventilating openings must be provided near the roof, which must be rainproof. This method is very inefficient, and should not be used in any form for schools.

Pail System.—The excreta in this system are received into pails or tubs, which are removed very frequently and their contents thrown away. The pails or tubs are then replaced by clean ones. The contents should be kept as dry as possible, because in this way certain decompositions resulting in noxious gases are prevented. The contents of the pail should be mixed with sawdust, soot, or other absorbent material, or the pails may contain crude aluminium chloride or cupric sulphate. In agricultural districts the contents, after mixture with ashes, can be used as manure. In the larger towns where this system is used, the pail contents are converted into dry manure by the action of vitriol and ashes.

Earth Closets.—These are modifications of the pail system where there is an automatic arrangement for covering each stool with about 1 or 2 pounds of dry earth. The bacteria of the earth convert the nitrogenous substances in the fæces to nitrates, and thus render them inoffensive. Dried garden soils, peaty soils, or clay soils, should be used for this purpose. The pail contents may be used as manure, or they may be exposed to the air, dried, and used again. This may be repeated five or six times.

None of the above forms of closets should be placed in the school buildings; they should be placed at the farther end of the playground. A servant should be employed to see that they are kept in good and sanitary condition.

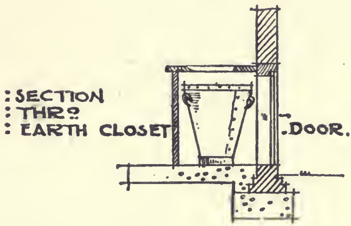


FIG. 117.—DIAGRAM SHOWING THE CONSTRUCTION OF AN EARTH CLOSET.

Water-Carriage System.—This method should be employed for disposing of refuse in all cases where there is an efficient water-supply.

Water Closets.—These are contrivances for the reception of excreta and for their carriage away by a stream of water. In one set of water closets the contrivance for retaining the water in the basin is not movable, while in the other set there is a movable contrivance for the retention of the water in the basin—*e.g.*, movable pan, plug, or valve.

Since all forms of pan, valve or plug water closets are unsatisfactory, they should never be installed in the schools. Some form of water closet with an immovable arrangement for the retention of the water in the basin should be used, such as the hopper closet.

The pedestal form of wash-down water closet with a flushing rim is the best form for schools and dwellings.

Short Hopper or Wash-Down Closet.—This consists of an inverted stoneware cone, with a ∽-shaped pipe attached to it below. This acts as a trap by retaining enough water to prevent the access of air from the sewer to the rooms. The cone is about 8 or 9 inches in length. In order to prevent the excrement dropping on the sides of the basin, it is important to have the posterior wall of the cone nearly vertical. It should also be provided with a "flushing rim," and thus the sides of the basin will be well cleaned.

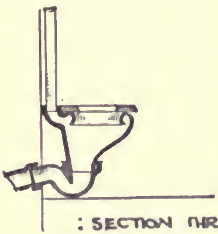


Fig. 118.—Diagram showing Construction of a Short Hopper Closet.

Trough Closet.—This is a common form of water closet used in schools. It is an open trough made of stoneware, and inclined towards the outlet. Its length will vary according to the number of compartments required. At the lower end or outlet there is a high siphon trap, which causes the retention of enough water to cover the bottom

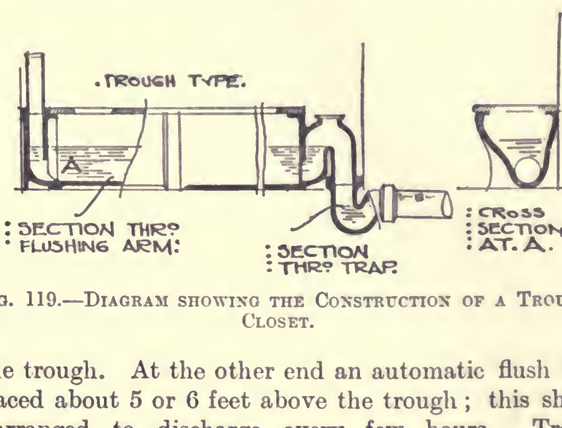


Fig. 119.—Diagram showing the Construction of a Trough Closet.

of the trough. At the other end an automatic flush tank is placed about 5 or 6 feet above the trough; this should be arranged to discharge every few hours. Trough closets do not work very satisfactorily, and have therefore been replaced in the more modern schools by separate wash-down closets.

The walls of the closets should be made throughout of glazed bricks, and all corners should be rounded off. The floors should be made of brick set in cement, and should have a good slope towards the door. This will insure rapid drying after being flushed with water, a procedure that should take place daily. Each closet apartment should have a fixed open grating near the ceiling, and a fresh-air inlet near the floor level. Each water closet pan should, wherever possible, be fixed to an outside wall.

Urinals.—Urinals in a large number of schools are, unfortunately, kept in an insanitary and offensive condition. There is no excuse for it at all, especially in places where there is an abundant water-supply. All the surfaces with which the urine comes in contact should be smooth and non-absorbent, and should therefore be made of slate or glazed earthenware. There should also be an arrangement for a flushing with water of all the surfaces with which the urine comes in contact; this is generally done by having a trough full of water, which fills and empties automatically. In districts where there is no water-supply, an attendant should wash the urinals twice or three times daily by pouring bucketfuls of water over them.

Lavatories.—A large number of authorities have not yet realized that good lavatory accommodation is absolutely necessary for all schools. One lavatory basin should be provided for every ten scholars. The basin should be made of hard and durable material, and possibly the best outlet is an opening fitted with a movable plug.

There should be no direct connection between the waste pipe of the lavatories and any sewer or drain. If the lavatory is on the ground-floor, the waste pipe should pass through the outside wall and discharge upon a surface sloping down to a gully trap; but if the lavatory is on one of the upper floors, the waste pipe should communicate with a vertical pipe which discharges on a sloping surface above a gully trap.

Baths.—It is very essential to provide swimming baths and shower baths in the schools. In the past very little has been done in this direction by most educational authorities, but it is hoped that more will be done in the future.

Effects of Sewer Gas.—Drain or sewer air often has a bad effect upon the general health of persons who inhale it. This is most marked when there is a leakage from cesspools or drains into houses, and the occupants are exposed to it for a long time. The long-continued inhalation of diluted sewer air results in a chronic condition of ill-health, and children are very susceptible to this condition; "it is characterized by the presence of anæmia, loss of appetite, prostration, diarrhœa, fever, headache, vomiting, or sore throat. It may be only present as a condition of lowered vitality, and such persons would have a very low resistance to any form of acute infection.

"There is a severe form of sore throat which attacks the occupants of badly drained houses. It is marked by swelling of the tonsils, very foul tongue, derangement of the stomach, severe headache, and great depression."

In some persons sewer air poisoning is shown by the presence of boils and carbuncles, enlarged glands, and special form of skin rashes.

CHAPTER X

SANITATION OF THE SCHOOL—*Continued*

Ventilation.—Ventilation is of very great importance, and very worthy of the attention that is paid to it by all sanitary authorities. Of late too much stress has been laid upon certain aspects of this question, while other very important points have been entirely neglected. The increased amount of carbonic acid and the exhalation of hypothetical volatile poisonous compounds from the lungs have received great attention, while the effects of the stagnation of the air, its increased temperature, and the rise in the percentage of water vapour, have not had the amount of study which their importance demands.

The atmosphere is a gaseous envelope which surrounds this earth. It is a mechanical mixture of various gases, but the one that is essential for the maintenance of life is called "oxygen."

The chemical composition of ordinary air can be determined by analysis, and is found to contain oxygen, nitrogen, and carbon dioxide, and traces of other rare gases.

The percentage composition is as follows :

	Per Cent.
Oxygen	20·96
Nitrogen	79·00
Carbon dioxide	0·04
Water vapour	variable

Expired air contains the same gases, but differs in its percentage composition from the ordinary atmospheric air. Expired air has the following composition :

	Per Cent.
Oxygen	16·40
Nitrogen	79·19
Carbon dioxide	4·41
Water vapour	saturated

It is seen that the difference between inspired and expired air is that expired air contains less oxygen, more carbon dioxide, and is saturated with water vapour.

When a person enters a crowded room, he will generally remark it feels stuffy and the atmosphere is impure. Now let us inquire into the conditions which bring this about, because it is only by a correct idea of their causation that we shall be able to apply rational means of prevention. The volume of air space for each person is too small, and therefore the volume of air that is available for each person in a room is a very important factor to determine. We have seen about the difference between inspired and expired air; the process of breathing by the occupants of a room results in a gradual decrease in the amount of oxygen and an increase in the amount of carbon dioxide. This can go on to a certain point without having any bad effects; if it is allowed to go on until the percentage of carbon dioxide rises up to about 2 to 3 per cent., then breathing would become rather deeper, but the symptoms presented would not be anything like so serious as those that are described by a large number of writers on this question. The air of the room would practically be at a standstill, its temperature would be raised, and the percentage of water vapour would be greatly increased. More modern research on ventilation tends to prove that these last-mentioned factors are the most potent in bringing about the condition of discomfort in crowded rooms. They have their deleterious effects by preventing the loss of body heat. The resultant product of the chemical changes that are going on in the body is heat, and this is lost from the body by the various physical methods by which anything that is heated will lose its heat. Any condition that will unduly inhibit the loss of body heat will decrease the rate of the chemical changes going on in the body and the amount of available energy; hence mental and physical vigour will be diminished, and result in lassitude, which is the commonest condition of persons in ill-ventilated rooms.

Personal emanations are very largely responsible for the unpleasant odours which are perceptible on passing from the outer air into a crowded unventilated room, and this is particularly the case if the persons are of uncleanly habits. These can to a great extent be obviated by personal cleanliness; great care should be taken to keep the skin of the whole body clean, and this can only be done by frequent bathing, and it is also of great importance to have clean clothes, and underclothing.

To summarize, we have found that the air in a crowded ill-ventilated room differs from ordinary air in the following points:

1. Diminished amount of oxygen.
2. Increase in the amount of carbon dioxide.
3. A great increase in the amount of water vapour.
4. Temperature is higher.
5. Decomposition of organic matter on the skin and clothes, if the persons are unclean, giving rise to offensive odours.
6. Certain other gaseous impurities may be present due to the combustion of coal and coal gas, carbon monoxide, and the oxides of sulphur.

Having learnt the nature of the changes undergone by air in a crowded room, it is easy to lay down principles on which methods of prevention would depend. In order to keep the percentage of oxygen and carbon dioxide at the right level, there should be a sufficient cubic capacity for each occupant, and the air should be continually renewed, so that each person gets a sufficient volume of fresh air in a certain interval of time.

Dr. Newsholme, of the Local Government Board, says that for each scholar there should be 150 cubic feet of space, 15 square feet of floor space, and 1,500 to 1,800 cubic feet of fresh air per hour.

The continual renewal of the air, which is attained by some form of ventilation, will not only tend to keep the percentage of oxygen and carbon dioxide at the right level, but will also obviate all the other changes enumerated above; stagnation of the air, rise in temperature, and increase in the amount of water vapour, will be prevented.

Methods of Ventilation.—The problem of ventilation of many school classrooms is rendered a very difficult one from the circumstance that a series of rooms considerably overcrowded may be occupied almost continuously for as long as three hours. In some of the older schools the question of ventilation was not studied at all, while, unfortunately, in more modern schools conditions are often not much better, though large sums of money are spent on elaborate installation.

There are two methods of ventilation—namely, the natural and artificial. By **natural ventilation** is meant any method that depends on the natural forces that cause movement of the air, and does not necessitate the application of any mechanical appliance for its renewal. In **artificial ventilation,** on the other hand, the air is renewed by means of fans, pumps, or bellows.

Natural Ventilation.—In this method of ventilation there are three causes at work—diffusion of gases, the change in density of the air caused by heat, and the force of the wind.

1. **Diffusion** is a property of both liquids and gases, by which their molecules are able to mix thoroughly even against gravity.

This phenomenon can readily be shown by taking a jar containing air and a drop or two of bromine placed in it. The coloured bromine vapour will be seen to rise up, even against gravity, until the colour of the contents of the cylinder is everywhere of the same depth.

It can also be seen when two jars are used, one containing air and the other carbon dioxide. If the carbon dioxide be placed in the lower jar, it will pass up to the upper until the contents of both jars will have a uniform composition. The presence of carbon dioxide can be proved by the addition of lime-water, when a white precipitate of calcium carbonate will be formed. The rate of diffusion of a gas is inversely proportional to its density, so that the lighter a gas is the faster it diffuses ; if a light gas is on one side of a porous partition, and a heavier gas on the other, then the light gas will diffuse through into the heavy one faster than the heavy gas will diffuse into the lighter one. In a room the air inside has a higher temperature and is lighter than the cold air outside, and therefore diffusion outwards of the lighter air will take place at a greater rate than diffusion inwards. This will result in a difference of pressure between that exerted by the air inside and outside the room, and thus fresh air will enter the room not only by diffusion, but also to equalize this difference of pressure.

Some authorities state that the air of a room of 3,000 cubic feet will be completely changed in one hour provided there is a difference of 35° F. between the temperature of the air inside and outside.

2. **Changes in Density of the Air.**—When air is heated it expands and becomes lighter in weight ; it will therefore rise up, and cold air will take its place. *Winds* are produced in this way, by the unequal heating of the air over different parts of the earth's surface.

3. **Force of the Wind.**—Winds are powerful ventilating agents, and act in two ways : (*a*) *by perflation—i.e.*, setting masses of air in motion and driving them onward by propulsion ; (*b*) *by aspiration*. When wind passes over chimneys or a tube placed at right angles to its course, it causes a diminution in pressure within them, and thus creates a current of air up the chimney, and fresh air must be drawn into the room below to take its place.

The aspirating action of the wind is constantly being used to ventilate rooms by means of the chimney; this is increased when there is a fire burning. If the chimney is lower than the surrounding structures, the wind striking these, and then descending, will often cause a back draught and smoky chimney.

Different Forms of Openings used in a Natural System of Ventilation. — In a natural system of ventilation the openings are so arranged as to admit the air from outside just above the level of the heads of the occupants of the room. To avoid a draught, various contrivances are used to direct the current of air upwards; it then mixes well with the air of the room, and is warmed thereby, before it falls down and reaches the occupants of the room. The impure air is warm, and therefore its density is lowered; it will rise up towards the ceiling, where means of exit should be provided.

A large number of different contrivances are used in a natural system of ventilation, and they may be broadly divided into inlets and outlets. The inlets, as said above, are placed rather low down, while the outlets are placed at the top of the building.

Inlets—1. *Windows and their Modifications.* — The simplest method of natural ventilation is by means of open windows. The efficiency of such methods will depend upon the type of school building. Dr. Reid of Stafford has proved that in the pavilion type of school building excellent results can be obtained by cross window ventilation.

A common modification of window ventilation is that of **Hincke-Bird,** where a solid block of wood is placed under the whole length of the lower sash frame of a window, and hence the upper rail of the lower sash is raised above the lower rail of the upper sash. Air can enter from outside between the two sashes, and is directed upwards by the upper part of the lower sash.

2. *Chaddock's Windows* are often installed in schools and colleges, and give very good results. The upper smaller

portion of the window can be opened by a hopper arrangement. The lower portion may be in one piece, and open by rotation round a pivot, or, better, it is divided by a central mullion, and each half opens on hinges.

3. *Tobin's Tubes.*—These are very common forms of inlets used in schools and public buildings. An opening

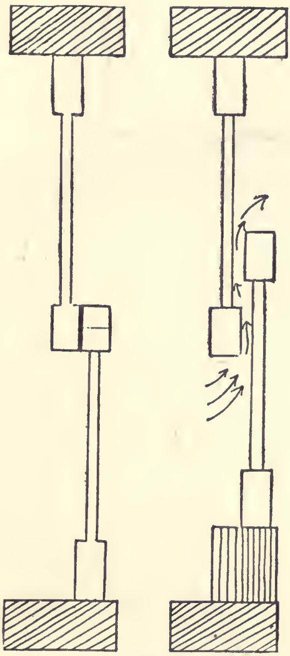


Fig. 120.—Diagram showing Hincke-Bird's Modification of Window Ventilation.

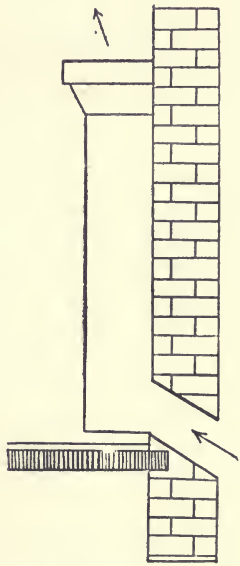


Fig. 121.—Tobin's Tube.

is made in the outer wall just above the floor level, and is guarded by a perforated plate; this is connected with a vertical tube, which ascends up 6 feet above the floor level. The upper opening of the tube is guarded by a valve by means of which the air entry can be regulated.

4. *Sherringham Valve.*—This is another common inlet ventilator. A special form of perforated plate is placed

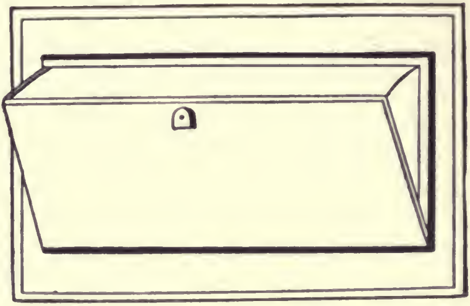


FIG. 122.—SHERRINGHAM VALVE.

in the wall about 7 feet above the floor, and on the inner side of this plate there is a hopper valve and side-checks. Air enters through the perforations, and is directed upwards by the inclination of the valve.

5. *Ellison's Bricks.*—These are special forms of bricks pro-

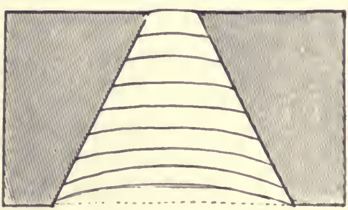


FIG. 123.—DIAGRAM SHOWING A SECTION THROUGH ELLISON'S BRICK.

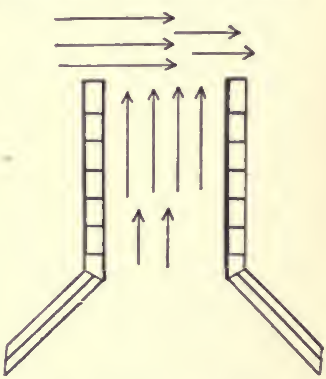


FIG. 124.—DIAGRAM SHOWING PERFLATING ACTION OF THE WIND.

vided with a conical perforation; the apex is directed outwards, and the base inwards. As the air enters, the cross-section of its path is increased; hence its velocity is diminished, and thus draughts are prevented.

Outlets—1. *Chimney*.—This is the most important outlet for foul air. The ascent of such air in the chimney is brought about by the decrease in its density, because it is warmed and the aspirating action of the wind produces a partial vacuum.

2. *Arnott's and Boyle's Valves*.—These are metallic frameworks supporting small talc or mica plates, which

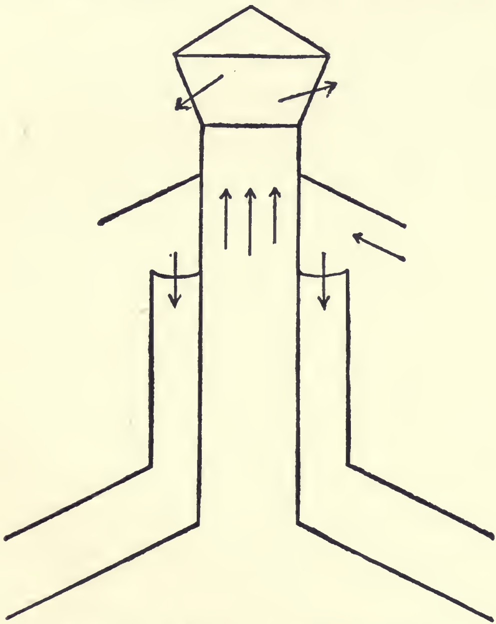


FIG. 125.—MACKINNELL'S VENTILATOR.

guard small openings that communicate with the chimney flue near the ceiling.

3. *MacKinnell's Ventilator*.—This can only be applied to a room which has no other apartment over it. It consists of two concentric tubes; the inner tube forms an outlet, and the space between the two tubes forms an inlet.

Artificial Ventilation.—There are two methods of artificial ventilation :

1. **Extraction or Vacuum Method.**—Mechanical appliances are installed to withdraw the impure air from the room. In order to keep the pressure inside constant, fresh air from outside is drawn in through certain special openings.

2. **Propulsion or Plenum Method.**—Here the appliances mechanically force fresh air into the room, and the impure air is thereby forced out through special openings that are installed.

Extraction or Vacuum Method.—It consists in connecting the apartment to be ventilated, by means of tubes, with a ventilating shaft.

A strong updraught is obtained in the ventilation shaft by having some means of heating the air within it. It may be heated by a fire in a small furnace below, hot-water pipes or steam, or lighted gas-jets at the bottom of the shaft.

Another method to obtain a strong updraught is to have a fan fixed near the top of the vertical shaft ; this generally works very satisfactorily.

Buchanan and Hope mention the following objections to this method of ventilation : (1) "The inequality of the draught, due to difficulty of always maintaining the fire at the proper height ; (2) the inequality of the movement of the air in the several rooms of a building, those nearest the shafts being more rapidly exhausted than those at a greater distance ; (3) regurgitation of smoke from the shaft into the room ; (4) difficulty in controlling the supply of fresh air at a proper temperature."

Propulsion or Plenum Method.—This method consists in forcing air into the room by means of fans, and further arrangements are made to regulate the volume and physical condition of the air.

The volume of air propelled into the classroom will depend on the rate of rotation of the fan ; the greater the rate, the greater the volume, and *vice versa*.

The air is generally heated by passing it over steam coils placed at the bottom of each shaft. The temperature of the air will therefore depend upon the time that it has been in contact with the steam coils; if the rate of propulsion is increased, the time during which the air remains in contact with the coils is diminished, and therefore it is not so well heated, and the reverse is the case when the rate of propulsion is diminished; therefore by varying the rate at which the air is forced into the room the temperature of the room can be regulated.

It is of the greatest importance to have the air at the right degree of humidity, and this is well proved by the more modern work on ventilation. In the American schools the air that is propelled into the classrooms is often too dry, and has very deleterious results on the respiratory system; on the other hand, too much moisture has an equally bad effect, and thus it is very desirable to have some means of regulating the amount of moisture in the air. This is generally arranged for by having a stream of water passing over the screen, through which the air is filtered, or steam jets are placed in connection with the steam coils used to heat the air.

The air can be filtered from dust particles and soot by passing it over screens made of coke or jute.

Combination of Propulsion and Extraction.—This method of artificial ventilation is called the **balance** system, and is specially applicable for the ventilation of large halls.

Dr. Ralph Crawley has pointed out the following advantages and disadvantages of an artificial system of ventilation in elementary schools.

The system has the following advantages:

1. The amount of air supplied can be carefully regulated.

2. The source of the air can be effectively controlled either near the ground or, by means of a shaft or small tower, from a good height above the ground.

3. The mechanical impurities can be filtered off.

4. The temperature and moisture of the air can be regulated with great accuracy.

It has the following disadvantages :

1. It is expensive, not only to fit it up, but for its continual working.

2. Uneven distribution of the current of air in the room ; also there is often an accumulation of foul air near the outlet.

3. The presence of closed windows is a bad training for the children.

4. The physical condition of the air is so altered as to result in a lack of freshness.

During the past, natural ventilation has been condemned as inefficient by most authorities ; this is most likely due to the fact that little trouble has been taken to plan the school and fit appliances suitable for natural ventilation ; on the other hand, when a school is to be ventilated by artificial means, very careful calculations are taken, and the whole system is carefully planned. Dr. Reid has proved that excellent results may be obtained by natural ventilation in the Staffordshire or pavilion type of school building.

Warming.—There is great variation in the susceptibility of different individuals to grades of heat and cold, and this depends upon the age, constitution, and usual mode of life. The temperature of a sitting-room or schoolroom should be about 60° F. to 65° F. Since the heat regulatory mechanisms in the child are not so well developed as in the adult, it is very important that great care should be taken to apply adequate heating apparatus in the school. The heating of the school is closely associated with its ventilation, and has been discussed indirectly in the section on ventilation.

It has been previously stated (p. 176) that heat tends to pass from warm bodies to the colder surrounding structures by three processes—namely, conduction, convection, and radiation.

The following methods are used for heating school buildings :

1. *Open Fires.*—Houses are generally heated in this country by means of open fires, but such a method can only be applicable to small schools.

The back and sides of the grate should be made of fire-clay, and the back should slope forwards, so that the flames play upon it; by such means the loss of heat through the chimney is diminished, because some of it will be reflected to the room by the sloping surface with which it comes in contact. In order to have better distribution of the heat, it is advisable to have the grates as low as possible, and brought forward into the room.

Open fires are very cheerful, and, as has been said above, they are important factors in aiding ventilation, but a large amount of heat is lost by being carried up the chimney; further, they require frequent stoking and cleaning, and create a large amount of dust and ashes.

Ventilating grates may be combined with the fireplaces. These are made by building small chambers around the back and sides of the fireplaces, and should extend up to and surround the lower portion of the chimney flue. Fresh air enters this chamber by openings provided in its posterior wall; it is heated inside the chamber, expands, and enters the room through openings provided just above or below the mantelpiece. The Galton grate is built on this principle.

2. *Stoves.*—There is a great variety of heating stoves, and they are classified as either closed or ventilating stoves. In the former class no provision is made to take advantage of the stove as a ventilating agent; whilst in the latter fresh air from outside the room circulates through the stove, and thus the stove acts as a good ventilating mechanism.

They have certain advantages over open fires: the amount of heat that is lost is smaller; they are cleaner, and provide a more uniform supply of heat; and if of good quality they require very little attention. On the other hand, they do not aid ventilation as well as open fires, and if made of cast iron they may give off carbon monoxide, which is a highly poisonous gas.

3. *Hot-Water Pipes.*—This is a method that has been applied to heat large rooms, halls, etc., where open fires and stoves have been inadequate. It is a well-known

physical fact that the boiling-point of water and all liquids depends upon the pressure under which they are heated. Under normal atmospheric pressure water boils at 100° C. or 212° F.; if the pressure to which it is exposed is increased, the boiling-point will be raised; thus, under a pressure of four or five atmospheres the boiling-point of water would be 300° F. On the other hand, if the pressure is diminished the boiling-point will be lowered; thus, at the top of high mountains the boiling-point of water is so lowered that it will be useless for cooking purposes, unless special contrivances are taken to increase the pressure under which the water boils. In the heating of rooms by hot-water pipes two methods have been applied —one, where the water is heated at atmospheric pressure, and certain arrangements are made to allow for its expansion. This is called the **low pressure system;** the other, where the water is heated under an increased pressure, is called the **high pressure system.**

In the low pressure system 3 or 4 inch cast-iron pipes are connected with a boiler placed in the basement, in such a manner as to allow for a complete circulation of the water inside. The exit pipes are attached to the top of the boiler, while the return pipes reach it at the bottom. The water on being heated expands, its density is diminished, it circulates through the pipes, parting with some of its heat to the air in contact with them, and on cooling returns to the boiler; the circulation depends on the difference in specific gravities of the water in the flow and return pipes. At the highest part of the system an expansion tank is placed, so as to allow for increased volume of the water on being heated, and to make good any leakage or waste from evaporation the tank is supplied with water from the water-supply by means of a ball-valve.

There are some modifications of this system used, such as circulating pipes of smaller diameter, and radiators are placed at convenient points. In Barker's "cable" system there is a mechanism placed to assist the circulation.

Wrought-iron pipes of small diameter are used in the high pressure system. The water is heated by about a sixth of the piping being coiled and placed inside a brick furnace at the basement. The pipe is completely filled with water, and from the top of the coil in the furnace it passes vertically, and goes round each room in turn, and then returns to the bottom of the coil. The water is heated to about 300° F., and, to prevent overheating and too great a pressure, an expansion tank is connected to the highest point of the system.

With this system there is a great tendency for the air to become overheated and too dry, and thus become "stuffy" in character.

Ventilating heat radiators give very good results where there is a mechanism by which air can be drawn from the outside and pass over the heating surface, and through a grating placed at the top of the radiator into the room.

The Temperature and Humidity of the Air of Schools.— All schoolrooms should be supplied with two or three reliable thermometers, placed at different points in the room. The temperature should not be allowed to rise above 60° F. or to fall below 48° F. at any time.

When discussing the question of regulation of body heat, it was said that the evaporation of sweat was one of the most important ways in which the body lost its superfluous heat. Naturally, the rate of evaporation from the skin will depend upon the degree of saturation with water vapour of the air surrounding it. If the air is moist and nearly saturated, the body cannot lose its body heat at a proper rate, the skin becomes hot and moist and its bloodvessels dilated, and therefore not so much blood is carried to the brain; this results in mental and bodily langour. On the other hand, when the air is too dry it is likely to have a bad effect on the respiratory system of the children, because they will be exposed to such differences in degree of moisture in the school air, the outside air, and the air of their homes.

The amount of moisture contained in the air depends on the temperature. The warmer the air, the greater is the amount of water vapour that it can hold, and *vice versa;* so that if you raise the temperature of a certain volume of air saturated with moisture, it will no longer remain saturated, because it will be able to take up more water vapour. On the other hand, if the temperature is lowered it becomes incapable of holding so much water, and some of it is deposited as dew.

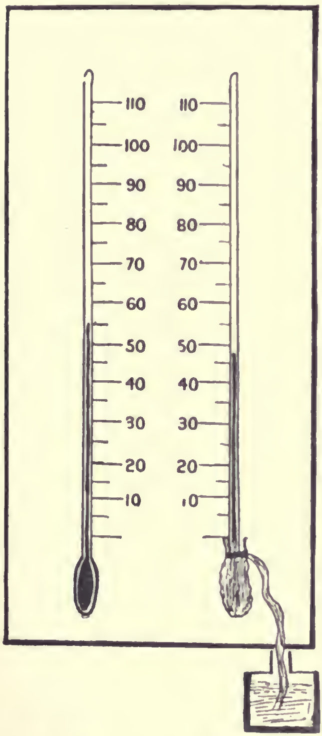


Fig. 126.—Dry and Wet Bulb Thermometer.

Dry and Wet Hygrometer.—This is an instrument to determine the relative amount of moisture present in the atmosphere. It consists simply of two ordinary thermometers placed side by side on a frame. The bulb of one of the thermometers is covered by muslin, which is kept moist by a piece of lamp wick which dips into a small vessel containing water. The wet bulb thermometer registers a lower temperature than the dry one ; this is due to the cooling resulting from the evaporation of the water. If the air is dry, evaporation takes place more rapidly, and therefore the temperature of the wet bulb will be lowered, and there will be a good difference between the readings of the two thermometers ; on the other hand, if the air is moist evaporation would be slight, and result in a small difference in the temperature of the two thermometers. The dry bulb temperature should be between 56° and 60° F., and the wet bulb temperature between 53° and 56° F.

Lighting.—An adequate and proper supply of light is of the greatest importance in our schools. A large number of authorities maintain that some eye conditions found amongst the children of our elementary schools are directly due to deficient and improper illumination of the schoolrooms.

It must also be remembered that sunlight is one of the best germicides, and some of the bacteria that cause disease in man are killed when exposed to sunlight for a short time. The areas of the windows must not be calculated by that necessary on a sunny day or when the sky is clear, but by that necessary on dull days during the winter months; and, secondly, it is the illumination of the portion of the room that is farthest away from such windows that must be considered.

The windows should be arranged so as to admit light from the left side of the scholars, and provided the light comes from this direction it is impossible to make too much allowance for its entry; but as a minimum the window glass must not be less than one-fifth the area of the floor. The windows should be made of white glass, extend up as far as possible and as close into the corners as possible, and wide partitions between the panes of glass must be avoided, because they cast troublesome shadows. Light should not come from the front of the scholar; and if it comes from the back, a shadow is cast over the work of the scholars and it is troublesome for the teacher.

A large number of our school buildings are so built that they are surrounded by neighbouring walls and houses. Under such conditions it is necessary to deflect the light into the room by ribbed glass or prisms.

The best form of artificial light is the incandescent electric lamp. If gas illumination is used, suitable incandescent burners and shades must be applied.

Desks.—In the past, not enough attention has been given to the desk accommodation in our elementary schools, but it is hoped that in the future, with the advent of the medical officer to the schools, this question will be more satisfactorily solved. It is obvious that desks ought to be graduated according to the *size* of the scholars, but this has not been appreciated even by the Board of Education, whose rules state that the desks should be graduated according to the *ages* of the children.

The best position in which a child can be seated is such that the body be equally balanced and symmetrical; such a posture will require the least effort to keep the body in stable equilibrium. Such a posture is attained when the child sits with the two ischial tuberosities on the same

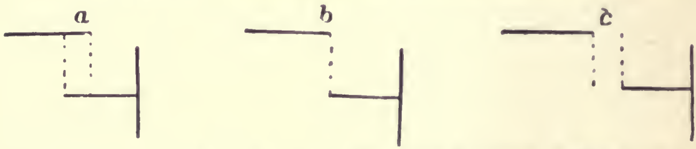


FIG. 127.—DIAGRAM SHOWING THE RELATIVE POSITION OF DESK AND SEAT IN VARIOUS FORMS OF DESKS.
A, Minus desk ; *B*, zero desk ; *C*, plus desk.

horizontal plane, the thighs horizontal, the feet resting flat on the floor, back well supported, and the body erect, with vertical line from the centre of gravity bisecting the line joining the two ischial tuberosities.

In order to attain such an ideal, it is obvious that there must be some adjustment of the desks and seats to the size of the scholars who work at them. This can more or less be easily done in schools where each class has its own classroom. On the other hand, in schools where a special room is allotted to each subject, and not to each class, this question becomes very difficult, and the only thing that can be done is to arrange the seats and desks in rows, those for the smaller pupils being in front, and those for the tallest behind, the other rows being arranged for the intermediate heights; and each class, when using the classroom, should sort itself according to the size of the individual pupil.

Let us consider the adjustment of seat and desk for each individual pupil. The height of the seat is obtained by bending the knee at right angles, placing the foot flat on

FIG. 128.—PUPIL SEATED IN A "PLUS" DESK.

the ground, and measuring the distance from the floor to the under-surface of the thigh; the back must be curved forwards and high enough to support the lower parts of the shoulder-blades; the seat should be hollowed out to a depth of ½ inch, and the concavity should extend to within 2 inches of the front edge.

In the adjustment of the desk, the "difference"—*i.e.*, the vertical distance from the edge of the desk to the level of the seat—must be such that the edge of the desk be brought opposite the navel of the child.

Desks are classed into three groups, according to the relation of a vertical line drawn from the posterior edge of the desk to the anterior edge of the seat.

FIG. 129.—PUPIL SEATED IN A "MINUS" DESK.

A "plus" desk is one in which the vertical line from the posterior edge of the desk falls in front of the anterior edge of the seat.

A "zero" desk is one in which the vertical line from the posterior border of the desk touches the anterior edge of the seat.

A "minus" desk is where the vertical line from the posterior edge of the desk passes through the seat.

All desks in schools should be either the "zero" or "minus" forms, although the commonest desk in our schools at present is the "plus" form. The "plus" desk should never be used, because it results in the body being bent forwards, and causes the lungs, heart, and abdominal viscera, to be unduly pressed upon; and the vertical line from the centre of gravity does not fall through the line joining the ischial tuberosities, therefore the body is not in stable equilibrium unless muscular effort is brought to balance it.

It is seen that the entirely separate desks are the best, and each desk and seat should be adjusted for each pupil The teacher must also realize that in the past children have been made to sit at the desks for too long a period; it is criminal to allow a child to sit in any form of a desk for three hours at a time. Sitting-down periods should be limited to three-quarters of an hour, relieved by intervals of lessons in the standing posture or an interval of play.

Blackboards.—The best form for schools is the slate blackboard, and it should be placed around all the available walls of the classroom. Children can be sent in groups to the blackboard to do some of their lessons; this will obviate too much fatigue arising from sitting at the desks. Damp dusters should always be used to clean the boards; this lessens the amount of chalk dust floating in the air.

Hygiene of Infants' Department.—The first question that arises with regard to the infants' department is—At what age should children be first admitted to the schools? Unless some other provision is made for the education of the child, the Board of Education demands its attendance at school at the age of five, provided its physical condition will permit it. On the other hand, there are many children under the age of five attending our elementary schools. The propriety of such rule and custom will depend upon the relative sanitary and moral condition of the home and schools.

If the home is such as to provide adequately for the proper physical and moral training of the infant, it is better for the child not to attend school until the age of seven ; but it must be remembered that such ideal homes are not, unfortunately, possessed by the majority of the children attending the elementary schools of this country ; hence, under the present conditions, some provision must be made for children of five, or even three, years of age.

It will be advisable for us to consider the most obvious dangers to the physical and mental conditions of such children by their attendance at schools. Firstly, all the cells of the body are young and delicate ; hence every precaution must be taken to allow for the proper development and prevention of overfatigue of the body, because any damage done during this stage is very difficult to remedy. Suitable and adequate nourishment, abundant supply of fresh air, and ample opportunity for rest and exercise, must be provided. Secondly, the fatality from infectious diseases—*e.g.*, measles, whooping-cough, diphtheria, etc.—is greatest at this period of life. This danger may be overcome by preventing overcrowding, allowing ample space for each child, adequate facilities for good ventilation combined with efficient medical inspection ; under such conditions the risk of infection will, in the majority of cases, be less at school than at home.

If the children are not provided at home with sufficient nourishment, it is the duty of the local authorities to supply them with adequate and suitable food.

The floor space per child must be greater than in the higher schools, and the greatest care should be taken to provide for an adequate supply of fresh air and sunlight.

Heavy desks and galleries should never be used, but small tables and chairs should be used instead, as they can be easily put on one side to make more room for games and play.

An adequate playground should be provided, and be partly covered, so that the infants can be taken out often to play, even on rainy days. The curriculum must be based on knowledge of the physiological development of the child.

Lessons involving fine muscular co-ordination or mental concentration—*e.g.*, writing, needlework, and reading—must be banished, and instead large objects and course movements must be the instruments of education. Correct physical habits must be taught. When discussing the growth of the child's nervous system, we mentioned how co-ordinated contraction of muscles is developed by the opening up of new nervous tracts, and hence the importance of walking, running and marching exercises in the infants' curriculum.

Open-Air Schools.*—Modern educational legislation and administration are characterized by their efforts to adapt the curriculum and surroundings of a child to its physical and mental capacities. It is illustrated in the many Acts that have passed making special provisions for different groups of school-children. One such group is that comprising children who suffer from various physical defects, resulting in their not being able to profit to a satisfactory extent by the ordinary school methods. Some of these children have no definite illness, but they are debilitated, and not up to the standard of efficiency; others suffer from definite physical conditions, such as enlarged glands, adenoids, anæmia, malnutrition, tuberculosis, in various forms of bones, joints, and glands, nervous disorders, or ear discharge. Mental backwardness is closely associated with the physical defect, and is caused by it in the majority of cases. Such children require good feeding, the best hygienic surroundings, and open-air life; the problem has been satisfactorily solved in the establishment of open-air schools.

The first open-air school was established in 1904, at

* For a fuller discussion of this question, see chapter xiv. in "Hygiene of School Life," by Ralph Crawley, M.D. (publishers, Methuen and Co)., and chapter xvi. in "Medical Examination of Schools and Scholars," edited by T. N. Kelynack, M.D. (publishers, King and Son).

Charlottenburg in Germany. Rough sheds and school barracks were erected in a pine-wood at the outskirts of the town. In three months' time the physical defects were either cured or improved, and there was also great improvement in the mental and moral condition of the children.

In 1906 the first English open-air school was opened by the London County Council in Bostall Wood, Woolwich. The great success of this school led to the establishment in 1908 of three other similar schools in London, and subsequently schools of this type for debilitated children have been established in Sheffield, Bradford, Halifax, and Norwich.

The site of such schools should be well in the country, and still within easy walking distance of the tramway terminus or other means of conveyance.

The soil should be pervious, and the water-supply should be ample and good.

An excellent type of building is that of the Bradford open-air school, which has six classrooms, each with a teaching veranda, together with dining and resting sheds. A corridor connects the various buildings, behind which are placed the baths, kitchen, lavatories, etc.

The children come to the school about 8 a.m., and depart for home about 7 p.m. They are given three meals —breakfast, dinner, and tea.

It must be remembered that the children are at the school because of their physical condition, and therefore much elasticity must be allowed with regard to the school curriculum, which should be as practical as possible ; thus, geography may be taught by the construction of relief maps in sand or earth, arithmetic by measuring actual distances or the circumference of trees by tape measure. Nature study should form a very prominent part in the curriculum. Arrangements should be made for singing and breathing exercises, and all work should be done in the open air, except in stormy weather, when the sheds should be used. Very adequate periods of rest and play must be provided for.

The results have been most encouraging. Dr. Ralph Crawley in the Bradford schools found great improvement in the physical appearance and carriage of the children, increased weight, increase in the amount of hæmoglobin, and great improvement in the physical condition of the chest.

CHAPTER XI

DISABILITIES AND DISEASES OF CHILDREN

The Relation of Micro-Organisms to Disease.—Bacteria is the name given to a group of organisms which lie lowest in the scale of vegetable and animal life. The bacteria consist of minute unicellular masses of protoplasm devoid of chlorophyll, which multiply by simple fission. Some are motile and others non-motile. They measure in certain diameters only $\frac{1}{25000}$ of an inch.

The great characteristic of most vegetable organisms is that they are able, by means of the green pigment called "chlorophyll," to obtain their food from the water and salts of the earth, and the carbon dioxide present in the air. They are able to absorb carbon dioxide from the air through their leaves, break it up, liberate oxgyen, and combine the carbon with hydrogen and oxygen of the water, which they absorb by their roots, together with various salts dissolved in the water. This building up of complex organic compounds—sugar, starch, fat, protein—practically from their elements, only takes place in the presence of this green pigment (chlorophyll). The resultant compound is used as foodstuff by the plant itself. When the plant utilizes these foodstuffs to maintain its life, the process is similar to what takes place in animals: there is absorption of oxygen and the elimination of carbon dioxide.

It is seen, therefore, that in plant life there may be two forms of gaseous exhanges. The first one is similar to what takes place in animals. In order to utilize its foodstuffs to maintain its life, the plant absorbs oxygen, and as a resultant product of various chemical reactions carbon dioxide is evolved and eliminated. The second form of gaseous exchange is peculiar to plants, which have chlorophyll, and can only take place in the presence of sunlight. Here there is absorption of carbon dioxide and the elimination of oxygen.

The great difference between animal and vegetable life is that animals are not capable of forming their foodstuffs

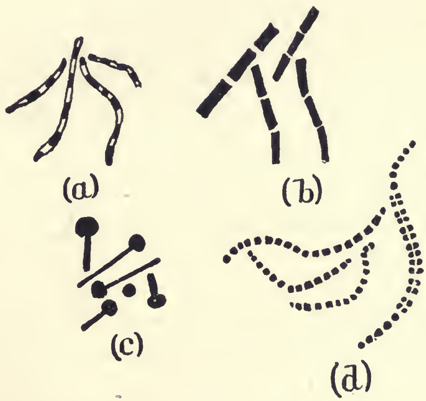


FIG. 130.—DIAGRAM SHOWING THE FORM OF SOME BACTERIA.
(*a*), Tubercle bacillus; (*b*), anthrax bacillus; (*c*), tetanus bacillus; (*d*), streptococci, or pus-forming bacilli.

from their elements, while plants are, in the majority of cases, able to build up their foodstuffs from their elements. Animal life is maintained by making use of food that has been already prepared by plants.

Some plants do not contain chlorophyll, and are therefore unable to form their foodstuffs; these plants must live like animals—that is, by obtaining their nourishment from either dead or living organic substances. Such plants are called "fungi," and the lowest group of fungi are called "bacteria."

Those bacteria which live on dead organic matter are called "saprophytes," while those which are able to attack living tissues, and obtain their nourishment in that way, are called "parasites." The great majority of bacteria which produce disease in man are parasites.

The realization of the existence and growth of these organisms within the human body has brought about the greatest revolution in medicine and surgery that these sciences have experienced. How do these organisms produce disease in man? The bacteria, being unable to form their foodstuffs as most other plants, must obtain it from either dead or living organic material, and in the production of disease in man these organisms gain entrance to the tissues of the human body, and obtain their nourishment from them.

These organisms may produce a disease simply by their presence in the body. Their metabolic products are toxic, and cause a reaction in the tissues around them—an "inflammation" as it is called. The bloodvessels are dilated, more blood is carried to the part, it becomes red, swollen, hot to touch, and painful.

The toxins secreted by the bacteria are very similar in nature to ferments, cause great injury to the tissues around, and give rise to very active inflammation. This is exemplified in the case of the bacteria which give rise to diphtheria. These organisms generally attack the throat, and they secrete a poisonous substance, diphtheria toxin, which is absorbed by the blood-stream and carried to all the tissues of the body, giving rise to the signs and symptoms of diphtheria. Other forms of bacteria may enter the blood-stream and cause a general microbic infection—that is, the organisms are not confined to the site of invasion, but are carried to all the tissues, and exercise their deleterious influence throughout the whole body; such is the case with typhoid bacilli or the organisms which give rise to general blood-poisoning, or septicæmia. These produce the diseased condition by their presence throughout the body; they abstract their nourishment from the tissues, and pour out the products of their metabolism, which are poisonous, to the body.

Conditions of their Life.—There are five factors which must be considered in the maintenance and growth of bacteria—namely, food-supply, moisture, relation to gaseous environment, temperature, and light.

Food-Supply.—Bacteria, like animals, must have as their food already synthesized organic compounds. They live on either dead or living organic material.

Moisture.—The presence of water is necessary for the continued growth of all bacteria. The amount of drying which bacteria will resist varies very much in different species. Thus, the organism which causes cholera is killed by two or three hours' drying, while the diphtheria bacilli will resist drying for several days.

Relation to Gaseous Environment.—The effect of the oxygen of the air on bacteria is of great importance. Some bacteria prefer to live in an atmosphere containing oxygen, and are called aerobes; others thrive better in the absence of oxygen, and are called "anaerobes." For example, the germ which causes lockjaw will thrive better in the absence of oxygen, while most germs which cause disease in man live better in the presence of oxygen.

Temperature.—For every form of bacterium there is a temperature at which it grows best. This is called the "optimum temperature." The optimum temperature of the organisms which thrive in the human body is the temperature of the body. The growth of organisms is inhibited by cold, but they are killed by excessive heat. Boiling in water will kill practically all bacteria.

Effect of Light.—Direct sunlight is one of the most powerful factors in killing bacteria; it is therefore of great importance to have plenty of sunlight to all the schoolrooms, for in this way the germs are destroyed.

Means of Resistance.—Every part of the human body that communicates with the outside air is in contact with a large number of micro-organisms, which, if they gained entrance in sufficient numbers to the tissues, would set up a diseased condition of those tissues. It is only by certain means that the body is able to hold this invading army in check. How does the body protect itself from being overpowered by these micro-organisms? The structure of the surface layer hinders their entrance; when a section of the skin is studied microscopically, it is seen to be made up of a thick layer of cells, which are very closely aggregated together, so that in the normal state it is impossible for bacteria to gain entrance through the skin in sufficient numbers to cause any damage to the tissues. If there is an abrasion or cut in the skin, and it be left unprotected, organisms readily gain entrance, and may set up variable degrees of inflammation. The discharges from the surfaces of the body have protective functions. Thus, if saliva were to be absent from the mouth, the growth of bacteria in it would be far more luxuriant. It is well known that the gastric juice and bile retard the growth, or even destroy, various forms of bacteria. Some authorities maintain that mucus has bactericidal properties, and this substance is formed by the cells which line the surface of the respiratory and alimentary tracts. The ciliated cells which line the respiratory tract drive the dust and germs entangled in the mucus into the pharynx, where the mucus is swallowed. Hence the expired air contains no germs. In coughing, speaking, and sneezing, droplets of saliva are sprayed out by the explosive force of the air-blast. By these droplets, colds, measles, etc, are spread.

Passing out, in between the cells which line the surfaces of the respiratory and alimentary tracts, there will be found some phagocytic cells. These have the power of sending out processes of their protoplasm, which surround the bacteria and destroy them.

Another means of defence is the lymphatic system. Within the tissue spaces there is lymph, and this contains white blood-corpuscles, and very close to various possible sites of entrance of bacteria we find groups of lymphatic glands, and these, as is well known, act as scavengers of the body. For instance, at the entrance of the pharynx we find the tonsils; deep to the mucous membrane of the stomach and intestines there are nodules of lymphatic tissue; in close relationship with the trachea and bronchi are a number of lymphatic glands.

Some authorities maintain that the endothelial cells of bloodvessels (see structure of bloodvessels) have bactericidal properties.

The circulatory fluids of the body have very important protective functions. When studying the composition of blood, it was said to have red and white corpuscles; the great function of the white corpuscles was to get rid of any noxious substances which gained entrance to the body, and hence these are the most effectual means of killing the bacteria after they have entered the body.

In the plasma of the blood there are substances which act on these micro-organisms and make them palatable to the leucocytes; these substances are called "opsonins."

It has been said above that bacteria during their growth in the body generate certain poisonous substances called "toxins"; the tissue fluids are able to generate substances called "antitoxins," which combine with the toxins and render them innocuous. It is obvious that there are a large number of factors concerned in the protective mechanisms of the body, and the only way to have these in the optimum condition is to have the general health at its best. This is only possible when a person has a sufficient quantity of nourishing food and sleep, exercise in the fresh air, and a reasonable amount of work and amusement to keep him happy.

Relation of Seed (Bacteria) and Soil (Body Tissues).—The susceptibility to the different microbic diseases varies greatly in different children, and this difference in the resisting power of individuals is very difficult to explain in many cases.

Some persons are immuned to certain diseases, while they are very susceptible to other infections. Further, two different persons may be exposed to the same degree of infection, and acquire the disease; but the course taken by the malady may differ greatly in the two individuals: in one it may be severe and prolonged; in the other it may be mild and of short duration.

An attack of infectious disease renders the subject nonsusceptible to that specific organism for a longer or shorter period of time; this is called "acquired immunity." In the case of smallpox the period of non-susceptibility after the attack is very long, and it is rarely that a person ever becomes infected twice with that disease. With measles and scarlet fever the immunity is not so permanent. It is clear, therefore, that, in the causation and severity of disease, not only has the virulence of the organisms to be taken into account, but also the susceptibility of the person that is exposed to infection.

The susceptibility of children to infectious diseases will vary inversely as their general health condition and hygienic surroundings.

Conditions disposing to Disease.—All conditions which lower the vitality of a child predispose it to disease. Some of the conditions may be enumerated as follows:

1. *Congenital Abnormalities—e.g.*, children with congenital heart lesions are very susceptible to any form of infection.

2. *Injudicious or Deficient Food.*—During infancy, those children which are artificially fed are more liable to die than those which are fed on the breast.

Older children, when improperly and insufficiently fed, are very liable to any form of infection—*e.g.*, consumption. The body, not having proper nourishment, is not able to generate a sufficient power of resistance. Overfeeding leads to digestive troubles, and results, not in greater strength, but in ill-nourishment and weakness.

3. *Bad Ventilation and Overcrowding.*—Fresh, cool, moving air is as essential to proper maintenance of life as good food. When children are forced to live in badly-ventilated and crowded rooms, their vitality will certainly suffer, and make them very disposed to any form of infection.

4. *Insufficient and Improper Clothing.*—It is the experience of everyone that a sudden change of cold, raw, moist weather is the immediate predisposing cause of a large number of respiratory diseases, caused by the entrance of micro-organisms to the body. For example, the bacteria which cause pneumonia are present always in our mouths; a sudden change in the temperature will diminish the resistance to these organisms. This explains how persons after a severe chill are so liable to contract pneumonia.

If children are insufficiently or improperly clothed, the activities of their bodies will certainly be deranged, and result in diminished resistance to disease.

Overclothing weakens all the defensive mechanisms, and is to be avoided just as much as underclothing.

5. A great many infective diseases are spread by the bites of insects. The insects carry the organisms of disease from the blood of one person to another. This is the case in plague (flea), yellow fever and malaria (mosquito), sleeping sickness (fly), etc. All parasitic biting insects should be kept out of our houses and away from our persons, and all manure-heaps, etc., which breed flies and mosquitoes, should be cleaned up and done away with. Flies bring dirt and germs into our food.

Early Signs and Symptoms of Common Ailments in Children.

Chorea, or St. Vitus's Dance.—This is a disease which generally affects children, and is characterized by irregular, non-repetitive, and involuntary contraction of the muscles, a variable amount of psychical disturbance, and liability to inflammation of the lining membrane of the heart. It is most common between the ages of five and fifteen, and the type of child who suffers from this disease is generally very intelligent at his work, and is often overstrained by the work that is given to him in schools.

There is no doubt that there is a close association between chorea and rheumatism. The child will have suffered from joint pains and sore throat in a large number of cases, and there will be a history of rheumatism in his family.

In the mild form of chorea the affection of the muscles is slight, the speech is not seriously disturbed, and the general health not impaired ; the child will simply appear clumsy and awkward, and there will be restlessness and inability to sit still, conditions often termed "fidgets." There are emotional disturbances, such as crying spells or night terrors. A change in temperament may also be noticed ; a docile, quiet child may become cross and irritable. In the more severe forms there will be very obvious signs. The characteristic involuntary movements may be limited to the face, or one limb, or one side of the body, or they may be general. If the face is affected, there will be curious jerkings and twitchings of the muscles of the lips, cheeks, nose, and eyes. When asked to put out his tongue, such a child usually jerks it out and in again and snaps together the teeth. Speech is very often affected.

When the limbs are affected they perform jerky, irregular, purposeless movements. When the child is asked to pick up a pin, a large number of irregular movements will be made around the object before it is finally picked up.

All the movements of the disease are intensified by excitement or by knowledge that anyone is watching.

During the whole course of this disease the child is entirely unfit for school, and the disease lasts three or four months. If a child shows any of the above symptoms and signs, it should be sent to the school medical officer to be examined, and he will advise appropriate treatment.

Nervous Disorders of Childhood.—All the nervous disorders of childhood may be divided into two great groups—functional and organic.

In the first group there are no anatomical changes in the nervous system to account for the disorder; it is a question of deranged function. Such is very prevalent in childhood, because the nervous system at this age is unstable, the higher parts of the brain are yet imperfectly developed, and therefore the lower ones are incompletely controlled. There is also lack of co-ordination between the different nerve centres, and this often results in inco-ordination of function.

Two diseases — namely, rheumatism and rickets — are very common in childhood, and these predispose children to all forms of functional nervous disorders.

The signs of functional disorders of the nervous system in children are so numerous and varied that it is impossible to give an adequate description of them here. Such are convulsions, habit spasms—*e.g.*, blinking or sniffing—night terrors, incontinence of urine, and various pseudo-paralyses.

The symptoms and signs of organic nervous disease will vary according to the site of the lesion.

If the higher parts of the brain are affected there will be mental deficiency.

If the motor paths of the nervous system are affected there will be paralysis.

If the sensory paths are affected there will be loss of various sensations.

Overpressure.—This results from the evil methods of our educational system, and also from the bad hygienic conditions found in the homes of the children attending our elementary schools.

Symptoms.—The child may become restless, excitable, and even hysterical, or the conditions may be characterized by lapses of memory, mental dulness, incapacity for concentration, and headaches.

Treatment.—1. Better nutrition and more hygienic surroundings at home.

2. More time must be spent in the open air, and the periods of rest must be greater.

3. Less mental work, avoidance of all excitement.

Hysteria.—This is a term applied to a variety of well-recognized symptoms, which appear to depend upon abnormalities of the irritability and conductivity of nervous tissues. It is not commonly met during school life.

Symptoms.—It is very difficult to give a satisfactory classification of the symptoms, because they are so varied and numerous. There may be mental irritability, depression, or exaltation. Paralysis of muscles and loss of sensation are commonly present. It may result in physical and mental inefficiency or chronic invalidism. Patients suffering from this condition often have hysterical attacks, or fits. These are attended by laughing or crying, but sometimes they are distinguished with difficulty from ordinary epilepsy.

Epilepsy. — This is a disorder of the nervous system characterized by loss of consciousness to a varying degree, with or without convulsions.

Causes.—Little is known definitely about the causation of epilepsy. It is frequently met with amongst the children of insane, hysterical, or alcoholic parents.

Symptoms.—These vary according to the degree of severity of the disease, but there are two main forms—namely, "petit mal" and "grand mal."

Petit Mal resembles a fainting attack, and is accompanied by pallor, dazed appearance, and momentary loss of consciousness; the child drops any object that he happens to be holding.

Grand Mal.—Previous to an attack the patient has a warning of its onset. This may take the form of peculiar sensations of sight and hearing, or tingling of the limbs. The child then gives a cry, and falls down. All the muscles of the body become tense, the jaws are clenched, the whole body is rigid, and the face becomes blue. The muscles then become relaxed, and convulsive movements are set up. The saliva pours out from the mouth—so-called "foaming at the mouth." A fit will last from one to five minutes, when the child falls asleep.

Treatment.—The only treatment necessary during the attacks is to prevent the child injuring himself. He should be laid on the floor in a clear space, and prevented from biting his tongue by placing something between the teeth, such as a handle of a toothbrush or pencil wrapped round with a piece of cloth, such as a towel or handkerchief. Such a patient should be sent to the medical officer for investigation and treatment.

Headaches.—Headache is a very common complaint amongst school-children. It is a symptom that arises from various causes. Bad ventilation and overheating is a frequent cause of this condition, and this origin should be suspected by the teachers if several members of the class complain, especially late in the day's work. Eyestrain is also a common cause of headache. It will often be associated with certain eye defects, and such children should be sent to the medical officer to have their vision tested and treated.

Another common cause of headache in children is disturbance of the digestive tract, such as bad teeth, dis ordered stomach, or constipation.

Children suffering from adenoids and enlarged tonsils are very liable to catch a cold, and such catarrhal condition of the mucous membrane of the throat and nose are frequently associated with headache.

Some of the acute specific fevers, such as scarlet fever, measles, etc., commence with a headache.

Children who are rickety or anæmic will often suffer from headache, especially after mental or physical exertion.

Infectious Diseases.

The term **infectious disease** is applied to any disease caused by the growth of a living virus, known or unknown, within the tissues of the body. Before giving an account of the symptoms and signs of the infectious diseases commonly met with in schools, let us discuss in general how the factors are produced, and the way in which the diseases and their dissemination can be prevented. Each disease is produced by a specific micro-organism. This has been decidedly proved in the case of diphtheria, typhoid, influenza, etc., because a germ with certain definite characteristics can be isolated from persons suffering from such disease. Further, the germ can be cultivated apart from the body, and on injection into animals the germs produce the same specific disease. On the other hand, the organisms causing some of these diseases, such as smallpox, scarlet fever, mumps, etc., have not yet been isolated; but, by analogy with the diseases mentioned above, we may certainly conclude that these latter diseases are also caused by certain specific germs, but the means of observation and technique at present at our disposal are not such as to enable us to isolate and identify such germs.

The first factor in the causation of any of these diseases is the carriage of the germs to a susceptible person. When the virus can only be transferred by contact, the disease is said to be **contagious**; but when the germ is conveyed by air, the disease caused is said to be **infectious.** Having reached the surface of the body, the germ cannot produce disease unless it has a favourable channel of entrance to the body; *e.g.*, typhoid bacilli can only be admitted to the system by the alimentary canal, and tetanus bacilli require an open wound to produce infection. It has been pointed out previously that these germs thrive in the body. They cause their deleterious effects by the production, by their own metabolism, of poisonous substances which injure or may even cause death of the tissues. The symptoms and signs of these diseases are produced partly by the reaction of the tissues of the body against such invasion, and also by the direct poisonous effect of the germs upon the tissues. When the bacteria first enter the body, they are not numerous enough to produce instantly the symptoms and signs of the disease; but if the conditions are favourable they grow and thrive, and when their number and poisonous products have increased to a certain extent the characteristics of the disease are displayed. The period that elapses between the entrance of the virus and the first sign of the disease is called the "incubation period." This varies with different diseases, but for the same disease it is more or less constant. The disease will end either in death or recovery. Death will result because the amount of poison produced in the body is such as to directly or indirectly kill the nerve cells upon whose integrity the vital functions of respiration and circulation depend. Recovery takes place when the reaction of the body is such as to destroy the germs and neutralize and eliminate their poisonous products. Physiologists and bacteriologists have within recent years carried out important researches upon the factors which defend tissues against invasion by bacteria, and the means by which the body destroys such bacteria and neutralizes their products. The factors depend to a large extent upon the corpuscles and plasma of the blood, and it is marvellous what power of response to such invasions the blood possesses; and the response is specific for each species of germs. It has been previously pointed out that the white blood-corpuscles are able to surround and destroy the bacteria, and that there are present in the blood substances called "opsonins," which prepare the bacteria for ingestion by the white corpuscles. By the reaction of the tissues a substance called "antitoxin" is produced, which neutralizes all the poisonous effects caused by the germs. There are also present in the blood-plasma substances called "complements," which are able to destroy any foreign cells introduced into the body; but this action is only possible when a connecting material called "amboceptor" is produced. The amboceptor connects the foreign cell to the complement, thereby causing the cell to be destroyed or rendered innocuous. Recovery takes place when the above processes are able to cope with the infection and its results. The germs are killed and their toxins neutralized, and the cells of the damaged tissues then grow and attain their normal structure and function.

When recovery has taken place, there is left an overproduction of the means of such recovery; consequently there follows a period of non-susceptibility to that particular disease. In some cases, such as smallpox, it is permanent; in others, unfortunately, it is not so. A person therefore is liable to only one attack of smallpox, and it is not often that a person has more than one attack of any of the specific infectious diseases. This condition of non-susceptibility to a disease is called **immunity,** and it may be natural or acquired. The degree of susceptibility of a person to infection varies with his constitution, age, and hygienic surroundings. Children are far more liable than grown-up persons to contract measles, scarlet fever, mumps, etc. Unhygienic conditions are most important factors in the production and spread of these diseases. Acquired immunity may be active or passive. The immunity after recovery from an infectious disease is an active acquired form, because the antitoxins have been produced in the tissues themselves. Active acquired immunity can also be produced by repeated injections into a person of dosages of the virus not sufficient to produce disease. His tissues will react and produce antitoxins, and his resistance to a particular disease will be greatly increased. This is done in the case of tubercle and typhoid fever. Passive immunity is attained when a serum containing antitoxin is injected into the body. This principle is applied in the treatment of diphtheria, and has been accompanied with great success. Diphtheria bacilli are injected into a horse. Its tissues form antitoxin, and from its blood a substance is obtained which is injected into human beings suffering from this disease. The results have been excellent.

There are three conditions essential for the production of an infectious disease : (1) Source of infection ; (2) susceptible person ; (3) means of carriage of the virus from the source to a susceptible person.

1. **Source of Infection.**—The source of a great majority of infectious diseases is another human being who has recently suffered from such a disease, or who harbours the germs without showing any signs of the disease.

2. **Susceptible Person.**—It has been shown above how susceptibility depends upon constitution, age, etc.

3. **Means of Carriage of the Virus**—(*a*) *Air.*—The bacteria causing smallpox, measles, and scarlet fever, are undoubtedly carried by air.

(*b*) *Human Beings.*—They are often not only the source of infection, but the means of its carriage to a susceptible person.

(*c*) *Animals.*—Flies carry the germs of typhoid, sleeping sickness, and yellow fever. Mosquitoes spread malaria.

(*d*) *Clothing, Books, etc.*—Some germs cling for a considerable time to these articles, which would therefore be potent factors in the causation of an epidemic in schools.

(*e*) *Water.*—Typhoid, cholera, and other diseases, are carried by water.

Means for the Prevention of the Occurrence and Spread of Infectious Diseases in Schools.

This question will be discussed from three standpoints: (1) The duties of the teacher; (2) the duties of the medical officer; (3) the duties of the local authorities.

1. **Duties of the Teacher.**—He should learn the elementary principles of physiology and hygiene, and should instil such knowledge into the children, and at every opportunity into their parents. If the children and parents acted according to these principles, their general physique would be improved, and their resistance to all forms of infectious diseases increased. These principles should guide the teacher in the classroom as regards adequate light, proper ventilation, alternate periods of work and play, etc. He should exercise his power of observation, and ought then to be able to notice early signs of disease in the children, who should be sent for treatment to the medical officer. It is of the utmost importance that the teacher should be able to identify the early symptoms and signs of the common infectious diseases; consequently, when a child presents any of these signs, his condition is diagnosed early and the spread of the infection curtailed.

2. **Duties of the Medical Officer.**—He should diagnose these diseases early, take effectual means to isolate the suffering, and hold in quarantine the persons who have been closely associated with the child. The means of isolation will depend upon the social condition of the patient, nature of the disease, and means provided by the sanitary authorities.

3. **Duties of the Local Authorities.**—Great care should be taken in securing a proper site, plan and construction of the schools. There should be an adequate supply of sunlight, fresh air, and floor space per child. Every case of infectious disease should be notified to the sanitary

authorities, and the medical officer of health should trace, as far as possible, the infection to its origin, and take adequate means to abolish it.

If an epidemic breaks out in a school, they should provide means of giving the children acquired immunity. This is, up to the present, only of value in a few of these diseases—*e.g.*, vaccination for smallpox, antitoxin for diphtheria, etc.

Isolation hospitals should be provided in every locality for the treatment of infectious diseases.

Disinfection should be carried out in the rooms occupied by the infected child; it should also be done in the school whenever a large number of children have been infected. This is generally provided for by the local sanitary authorities.

A short account will be given of the symptoms and signs of the more common forms of infectious disease that attack children at school age.

Measles.—This is a very common disease amongst children; and though the general public does not attach much importance to it, it is responsible for about 10,000 deaths annually in England and Wales. This heavy death-rate is not due to measles in itself, but to pulmonary complications, which occur when the patients do not have appropriate care and attention, and live in bad hygienic surroundings.

The incubation period of measles is about fourteen days. The period of invasion—that is, the time the child is ill before the appearance of the rash—lasts three to four days. The child generally presents the signs of a feverish cold. There will be sneezing and running at the nose, redness of the eyes and lids, and cough. The skin will be dry and hot, and the child will complain of headache. If during an epidemic of measles a child should show any of the above signs and symptoms, he should at once be sent home. "*Whether measles is prevalent or not, a child in the infants' department who shows suspicious symptoms should be sent* *home at once. If the teachers would adopt this course, most epidemics of measles would be avoided.*"

In about four days after onset the rash characteristic of measles comes out, and then the diagnosis will be certain. Small red spots just like fleabites will appear first on the forehead, and then on the rest of the face; they then become raised and form dark red patches. The rash then spreads to the other parts of the body.

The child is infectious during the whole course of the illness, which usually lasts about four weeks.

German Measles.—This is rather a mild infectious disorder, having symptoms and signs similar to those of measles. The incubation period is about a fortnight. The period of invasion is very short, generally about twenty-four hours, and during this time there may be chilliness, headache, pains in the back and legs, and coryza. There may be very slight fever. All these symptoms are generally very mild. The rash usually appears on the first day, and is often the first symptom noticed. It comes out first on the face, and then on the chest, and in twenty-four hours it will have spread all over the body. The eruption consists of a number of round or oval, slightly raised spots, pinkish-red in colour, usually discrete, but sometimes confluent.

The lymphatic glands of the neck are frequently swollen, and when the eruption is very intense and diffuse, the lymph glands in other parts of the body will be enlarged.

The mildness of the initial symptoms, the more diffuse character of the rash, its rose-red colour, and the early enlargement of the cervical glands, are the chief points of distinction between German measles and ordinary measles.

Scarlet Fever.—This is a widespread affection, occurring in nearly all parts of the globe, and attacking all races. It varies greatly in the intensity of the outbreaks. In some years it is mild; in others, with equally widespread epidemics, it is very malignant. The specific germ of it is not known. The incubation period is two to four days, and the disease is highly infectious from the commencement. The infection is spread in the early stages by the breath and the secretion of the nose, mouth, and throat; later on the desquamated scales from the skin are probably the cause of infection. These are very liable to cling to clothes, and the germs lie latent for a long period. The discharges from the nose and ears, which are common in this disease, are very infectious, and will rapidly spread the disease.

The onset is as a rule sudden. There may be shivering. Vomiting is one of the most common initial symptoms. Sore throat and headache are generally present. The skin is dry and hot, the face flushed, the tongue furred. The rash appears in about twenty-four hours. It first makes its appearance on the side of the neck and on the chest, and then spreads to the abdomen and limbs, but, curiously, it does not appear on the face, the palms of the hands, or the soles of the feet. The rash appears as scattered red points on a deep red skin. It disappears about the seventh day.

The tongue is red at the tip and edges, and furred in the centre. The papillæ of the tongue are red and swollen, so that after a few days, when the fur comes off, the surface of the tongue appears red and rough—hence the name "strawberry" or "raspberry" tongue.

Inflammatory condition of the throat is very common in this disease, and the glands around the lower jaw are often enlarged and painful. Another very constant sign is pallor of the skin around the mouth, compared with the flush on the cheeks.

With the disappearance of the rash and fever the skin looks somewhat stained, dry, and a little rough. Gradually the upper layer of the skin begins to separate. The peeling generally starts on the sides of the neck and chest, spreads next to the trunk and arms, and finally to the palms of the hands and soles of the feet.

Mild cases of this disease may escape notice, and not be discovered until the desquamation stage. It is important, therefore, during an epidemic to have constant routine examination of the children's hands and fingers.

A child is generally considered infective until the peeling is complete. This occurs about six to eight weeks after onset. Special care should be taken of cases with discharge from the nose and ears, or with throat trouble, because these are highly infectious, and no child should be allowed to return to school with any of these signs.

Diphtheria.—Diphtheria is very fatal in young children. The diphtheria bacillus may be present in healthy throats without causing any sign of the disease, but such a person is able to infect other individuals. Special local predisposing causes are sore throats, nasal catarrh, laryngitis, unhealthy conditions of the mouth and teeth. When the bacilli gain entrance to an unhealthy throat, they are able to set up the disease called "diphtheria."

From the above it is evident that, in order to prevent the occurrence and spread of diphtheria, the children who have the bacilli of diphtheria in their throat should be excluded from school; and all conditions which tend to produce a diseased condition of the throat should be removed, such as bad drainage, insanitary conveniences, access of sewer gas and ground air into school, bad ventilation, and overheating.

The period of incubation of diphtheria is two to seven days. The initial symptoms are those of an ordinary febrile attack—slight chilliness, fever, and aching pains in the back and limbs.

Then the child complains of sore throat. The glands round the jaw and throat next become enlarged and tender.

On examination of the throat, the mucous membrane of the pharynx is reddened, and the tonsils are swollen. There will also be one or more patches of a greyish-white membrane seen over the tonsils, the palate, or the back of the pharynx.

The membrane may form in the nose or in the larynx. In the latter situation it gives rise to difficulty in breathing.

The germs are localized to the throat, nose, or larynx, and these produce a poisonous substance called the "diphtheria toxin," which is absorbed into the blood-stream and causes the general signs of the disease. It is very important that the disease should be diagnosed early, so that the antitoxic serum may be injected. The use of this serum has greatly lessened the mortality.

In schools the infection spreads by the saliva and mucus from the throats of those suffering from the disease, and by infected pencils, pens, papers, books, drinking-cups, etc.

During an epidemic of diphtheria the school medical officer should examine the throats of the children bacteriologically, and all the scholars which have the germs of this disease in their throats should be excluded from school until a further examination proves them to be free from diphtheria bacilli.

Whooping-Cough.—"This is a specific affection characterized by catarrh of the respiratory passages, with a series of convulsive coughs which end in a long-drawn inspiration, or 'whoop.'" It is an extremely infectious disease among young children. and a dangerous disease where unhygienic conditions prevail. It is not in itself a dangerous disease, but, like measles, it has as a frequent complication, bronchitis and broncho-pneumonia, and it is this which is so fatal amongst young children.

The specific micro-organism has not yet been isolated. There is a variable period of incubation from seven to ten days. There are two stages to this disease—catarrhal and paroxysmal.

In the *catarrhal stage* the child has the symptoms of ordinary cold, there will be slight fever, running at the nose, redness of the eyes, and a cough. After lasting for a week or ten days the cough becomes worse and more convulsive in character, and then the disease starts on its paroxysmal or whooping stage, where associated with the cough is the long-drawn inspiration or whoop. Vomiting often takes place at the end of a paroxysm of cough.

Infected children should be excluded from school for at least two months, or for a longer period if the paroxysms of cough accompanied with vomiting have not disappeared.

Children with whooping-cough want plenty of open air and good feeding.

Mumps.—The period of incubation is from two to three weeks, and there are rarely any symptoms during this stage.

The onset is marked by slight fever, the child complains of feeling ill, and soon after the characteristic swelling appears on one side of the face and adjacent parts of the neck; later the swelling appears on the other side of the face and neck. There is seldom great pain, but an unpleasant feeling of tension and tightness. Great inconvenience is experienced in taking food, for the patient is unable to open the mouth. Even speech and swallowing may be difficult.

After persisting for seven to ten days, the swelling gradually subsides, the child rapidly regains his strength and health, and is none the worse for the attack.

Cases should not be regarded as free from infection until the lapse of four weeks after the onset of the disease.

Chicken-pox.—"This is an acute contagious disease characterized by an eruption of vesicles on the skin."

The disease is common amongst children, and spreads rapidly through schools. It is a disease of childhood, and the majority of cases occur between the second and sixth year.

After a period of incubation of ten or fifteen days, the child becomes feverish, and there may be a slight chill. The eruption usually occurs within twenty-four hours. It is first seen on the trunk, the back, or the chest; afterwards on the face and scalp, and then on the limbs. The rash appears first as raised red papules; these in a few hours become transformed into hemispherical vesicles containing a clear or turbid fluid. After two or three days the latter burst, dry up, and form scabs.

Children are not free from infection until the disappearance of all scabs.

Smallpox.—At the present day smallpox is not commonly met with in our schools, and this undoubtedly is due to the good results of vaccination. The incubation period is nine to twelve days, and during this time no symptoms are complained of. The onset commences commonly with a convulsion in a child, and repeated chills in an adult. Then severe headache, marked pain in the back, and sickness, set in. On the third or fourth day a rash appears first on the forehead and anterior surface of the wrists. It first appears as hard red spots, which become vesicles or small blisters, and then pustules, which dry up and form scabs.

More than a hundred years ago smallpox was frightfully prevalent, and took toll of the best and noblest as well as the poorest in the land. It scarred the faces and destroyed the sight of many who escaped with their lives. Jenner's great discovery has relieved the world from the terror of this pest.

Heart Affections.—All forms of heart disorders may be classified as functional, congenital, or acquired.

1. The *Functional Disorders* of the heart are quite common in childhood. The pulse may be irregular or too quick, or the heart's action may be very rapid after slight exertions.

2. *Congenital Affections* are due to imperfect development of the heart. Children with such often have a poor physique, and are very liable to all forms of infection.

3. *Organic or Acquired Heart Disease.*—This is generally due to rheumatic fever. When you ask for the history of the child, you will be told that he has had rheumatic fever, tonsillitis, St. Vitus's dance, or growing pains. It may also arise after scarlet fever, diphtheria, or other infectious diseases.

Symptoms.—The child generally complains of shortness of breath, palpitation, or cough, and shows very little vitality. Fainting attacks are common. There are signs of bad circulation—cold feet and hands clubbed fingers. The existence of murmurs in place of the normal sounds of the heart is of little importance so long as the child has signs of vigour and health.

Treatment.—The child should be sent to the medical officer, who will advise the teacher regarding the amount of work the child should do, etc.

Bronchitis.—This is due to inflammatory conditions of the bronchial tubes, and arises very frequently from the unhygienic conditions under which children are often brought up. It may follow measles or whooping-cough and other infectious diseases. It varies greatly in its severity, from a slight catarrhal condition of the larger tubes to a severe form of capillary bronchitis, which may end fatally in a short time.

Tuberculosis.—This is a disease caused by the entrance and growth of the tubercle bacillus in the body. It may affect any organ in the body, but in school-children it is found more frequently attacking the lymphatic glands, bones, joints, and the lungs.

Tuberculous Disease of Bones and Joints.—The disease usually commences in a most insidious manner. It may be dated back to a slight injury, or there may be no such history. Slight impairment of movement, together with some pain, especially after use, are the first signs. Thus, a child with a tuberculous hip-joint will first complain of slight pain after walking, and he will be noticed to limp. Angular curvature of the spine is due to tuberculous disease of the vertebræ. All children with such symptoms must at once be sent to the medical officer.

Tuberculous Glands.—The glands most commonly attacked by the tubercle bacillus are the glands of the neck. Any chronic inflammatory condition of these glands predisposes to their infection by tubercle. Thus, glands enlarged secondarily to sore throats or carious teeth are very liable to become tuberculous. The inflammation caused by the tubercle bacilli may result in the formation of an abscess, or the germs may be carried along the lymphatics or bloodvessels, and be deposited in other parts of the body, or result in a general dissemination.

Another set of glands commonly affected by tubercle are the bronchial glands or mesenteric glands.

It has been held by many writers that the mesenteric glands are infected by the germs being swallowed with the food, and absorbed by the lymphatics of the intestine.

Pulmonary Tuberculosis, or Consumption. — In comparison with other forms of tuberculosis; this is comparatively uncommon in school-children; but its early recognition is not only necessary for the effectual treatment of the individual sufferer, but also to prevent the infection of other members of the school. This is the most infectious form of tuberculosis, because by coughing and spitting the bacilli are readily scattered about, and thus infect other people.

It is very difficult to recognize it in the early stages, but children suffering from a persistent cough or wasting should be sent to the medical officer for examination.

Anæmia.—This is a term applied to a diminished amount of hæmoglobin in the blood. It will be remembered that in Chapter IV. we gave an account of the properties and function of the hæmoglobin. The general symptoms and signs of anæmia and the factors in their causation are varied. The anæmia found amongst the children of our large towns is directly due to their environment. Overcrowding, lack of proper food, and unhygienic surroundings, are the commonest cause of the disease. Anæmia is associated with rickets, rheumatism, enlarged tonsils, and adenoids.

The child becomes pale, languid, drowsy, disinclined for exertion, readily fatigued, and the appetite becomes poor. All children with the above symptoms should be sent to the medical officer for examination and treatment.

Vomiting.—This may arise from very trivial or serious conditions. It may be a sign of slight indigestion, or it may be the commencement of a more serious affection of the digestive tract. It also may be the first sign of the onset of one of the specific fevers.

Diarrhœa.—This commonly arises from intestinal indigestion due to the taking of too much or tainted food. In towns, during hot weather, it may be due to infection with certain germs, and will occur as an epidemic.

All children suffering from diarrhœa should be sent home or to the medical officer for treatment.

Sore Throat.—All children suffering from a sore throat should be sent home or to the medical officer for examination and treatment. The importance of attention being paid to this condition lies in the fact that it may be infectious in character, though the symptoms complained of may be slight.

It may arise simply from catarrhal conditions of the throat commonly associated with adenoids and enlarged tonsils. On the other hand, it may be the first sign of diphtheria, scarlet fever, and other infectious conditions. Recurrent sore throat is generally associated with rheumatism.

Skin Affections.—A large number of skin diseases affecting children in our elementary schools are infectious, and therefore it is advisable to exclude them from school when they suffer from such conditions.

Verminous Conditions. — It is said that half of the elementary school children have been affected to a certain extent with verminous conditions. Head lice are the commonest, and their eggs, called "nits," are attached to the hair, and removed with difficulty. These "nits" develop into lice in five or six days under favourable conditions. The irritation and scratching result in infection of the scalp, so that sores and crusts will appear on it. The crust should be removed by poulticing or bathing, and a weak antiseptic ointment applied. The parents should be informed of the condition of the child's head, and should be advised to give the child a hot bath, using plenty of soap, and thoroughly cleansing the scalp and hair. After careful drying, paraffin-oil should be thoroughly rubbed over the hair and scalp. Great care must be taken not to bring a flame near the child's head when this is done. The paraffin is washed out with soap and water. This treatment should be repeated two or three times, and it will result generally in a complete cure.

Body lice lay their eggs in the clothes. Children affected with these should be given a hot bath, and their clothing be disinfected.

The Children Act, 1908, gives new powers and responsibilities to local authorities to treat verminous children.

Itch, or Scabies.—This is a contagious disease caused by the entrance of a small parasite into the skin, where it lays its eggs. Infection is carried by personal contact, clothing, towels, or bedclothes. The insect generally first attacks the skin between the fingers and the back of wrist and forearm. The intense itching causes the child to scratch vigorously, and this results in a secondary infection with other septic organisms. The itching, presence of burrows, and signs of scratching between the fingers, are the signs by which the condition is recognized.

Infected children should be sent away from school. The parents should be advised to give them a hot bath, using plenty of soap, followed by the application of sulphur ointment. This should be repeated for three or four consecutive days. The clothing should be thoroughly disinfected before being worn again.

Impetigo.—This is an infectious condition attacking dirty and neglected children. It often attacks the skin around the mouth and the chin. Impetigo of the scalp is generally associated with verminous conditions. It first appears as small blisters surrounded by red patches; they dry up and form yellow crusts. It is spread by scratching.

All children suffering from this condition should be excluded from schools. The parents should be told to wash away all the crusts, and an antiseptic ointment should be applied.

Eczema.—This is a term applied to a large number of inflammatory conditions of the skin. It may be produced by any form of irritant. It is not often infectious in character. Children suffering from it should be sent home. The treatment consists of removing the irritation and applying soothing ointments or lotions.

Ringworm.—This is due to infection by a form of fungus. It is very contagious and resistant to treatment. It appears on the skin as a round, reddish, scaly patch, causing itching and irritation. When affecting the scalp, the hairs of the affected area become brittle and break off. This results in bald, scurfy patches, on which may be seen broken stumps of hair, very characteristic of the disease.

All cases should be excluded from school, and sent to the medical officer for treatment. A good form of treatment is exposure to X rays.

Favus.—This is another disease due to the infection of the skin by a fungus. It is rather rare, and mostly confined to the alien population of the East End of London. It is very chronic and resistant to treatment.

Intestinal Worms.—**Tapeworms** are found at all ages, but not uncommonly in children. They may give rise to no symptoms, and even if they do so they are rarely dangerous. If a person is aware that he has tapeworms, it sometimes worries him, though he may have no symptoms at all. There may be abdominal pain, feeling of sickness, diarrhœa, and anæmia. In some cases the appetite is ravenous.

The diagnosis is confirmed by finding segments of the worm in the stools.

There are three prophylactic measures that should be noted—namely, all tapeworm segments should be burnt, and should never be thrown outside or into the water closet; all meat should be carefully examined and sufficiently cooked.

Every child suspected of having **tapeworms** should be sent to the medical officer for treatment.

Round worms rarely give rise to any symptoms unless they are very numerous, and then they may present the following symptoms and signs : Diarrhœa, colic, sickness, and convulsions. In the majority of cases the passage of a worm by the anus or mouth is the first and only indication of its presence.

Threadworms generally live in the large intestine and adjacent portion of the small intestine. They are often present in large numbers, and wander down to the lower part of the large intestine and the anus, in the neighbourhood of which they cause intense irritation, especially during the night. The eggs of the threadworm are expelled with the fæces, and require to be taken into the stomach before they redevelop. Children constantly reinfect themselves by scratching the anus and conveying the eggs by means of the finger-nails to the mouth.

The symptoms are, commonly, heat and irritation around the anus and nose. In children, restlessness, nervous irritation, choreic symptoms, and convulsions, may be seen.

Brisk saline purgatives to expel the worms, and extreme cleanliness to prevent reinfection, are usually all that is required.

All children suspected to suffer from intestinal worms should be sent to the medical officer for treatment.

CHAPTER XII

MEDICAL INSPECTION OF SCHOOLS

The Organization of Medical Inspection of Schools.—Section 13 of the Education (Administrative Provisions) Act, 1907, states that—

The powers and duties of a Local Education Authority under Part III. of the Education Act, 1902, shall include—

1. Power to provide for children attending public elementary schools, vacation schools, vacation classes, play centres, etc.

2. The duty to provide for the medical inspection of children immediately before, or at the time of, or as soon as possible after, their admission to a public elementary school, and on such other occasions as the Board of Education direct, and the power to make such arrangements as may be sanctioned by the Board of Education for attending to the health and physical condition of the children educated in public elementary schools.

The Board of Education issued a Memorandum on Medical Inspection of Children in Public Elementary Schools, explaining the various provisions made by the above sections of the Education Act. The following are briefly the most important points dealt with in the Memorandum :

1. " The aim of this new legislation is not merely to obtain a physical or anthropometric survey or a record of defects disclosed by medical inspection, but to improve the physical conditions, and, as a natural corollary, the moral and mental conditions of coming generations."

2. *Organization.*—The respective functions of the Board of Education and the Local Education Authorities are clearly defined by the Act :

" The duties thrown upon the Board consist in advising Local Education Authorities as to the manner in which they should carry out the provisions of the Act, and in supervising the work they are called upon to undertake ; in giving such directions as may be necessary regarding the frequency and method of inspection in particular areas ; and in considering and sanctioning such arrangements for attending to the health and physical conditions of the children as may be submitted to them by individual authorities. The Board will also collate the records and reports made by the authorities, and will present an annual report to Parliament. The duty of carrying out the medical inspection has been entrusted by Parliament to the Local Education Authorities and not to the Board. Each authority must therefore in due course appoint such medical officers or additional medical assistance as may be required for the purpose. The Board view the entire subject of school hygiene as an integral factor in the health of the nation. The application of this principle requires that the work of medical inspection should be carried out in intimate conjunction with the Public Health Authorities, and under the direct supervision of the Medical Officer of Health."

3. *Teachers.*—The necessity of the cordial sympathy and help of the teachers is specially mentioned.

4. *The Parents.*—"The increased work undertaken by the State for the individual will mean that the parents have not to do less for themselves and their children, but more. Their co-operation is very essential, and will prove effective and economical. Efforts must be made to obtain their presence at the medical inspection of the child."

5. *Character and Degree of Medical Inspection.*—"The fundamental principle of the new Act is the medical inspection and supervision not only of children known or suspected to be weakly or ailing, but of all children in the elementary schools, with a view to adapting and modifying the system of education to the needs and capacities of the child, securing the early detection of unsuspected defects, checking incipient maladies at their onset, and furnishing the facts which will guide Education Authorities in relation to physical and mental development during school life."

The directions given in this circular as to the degree and frequency of inspection refer only to the minimum medical inspection, the effectiveness of which will in future be one of the elements to be considered in determining the efficiency of each school as a grant-aided school.

The statutory medical inspection should, at entrance or at subsequent inspection, take account of the following matters:

1. Previous disease.
2. General conditions and circumstances:
    (1) Height and weight.
    (2) Nutrition (good, medium, bad).
    (3) Cleanliness (including vermin of head and body).
    (4) Clothing (sufficiency, cleanliness, and footgear).

3. Throat, nose, and articulation (mouth-breathing, snoring, stammering, tonsillar and glandular conditions, adenoids).
4. External eye diseases and vision testing.
5. Ear disease and deafness.
6. Teeth and oral sepsis.
7. Mental capacity (normal, backward, defective).
8. Present disease or defect:
    [(1) Deformities, or paralysis.
    (2) Rickets.
    (3) Tuberculosis (glandular, pulmonary, osseous, or other forms).
    (4) Diseases of skin and lymph glands.
    (5) Disease of heart or lungs.
    (6) Anæmia.
    (7) Epilepsy.
    (8) Chorea.
    (9) Ruptures.
    (10) Spinal disease.
    (11) Any weakness or defect unfitting the child for ordinary school life or physical drill, or requiring either exemption from special branches of instruction or particular supervision.

Regulations.—" It is suggested that each child should be inspected four times during its school life. The first inspection should take place on admission to school, the second three years after, the third after another interval of three years, and the fourth on leaving school.

" Provision should therefore be made by each authority, when the Act has been sufficiently long in operation to be in normal working, for the inspection in each year of—(*a*) the children newly admitted; (*b*) the children in the school who in that year had matured for their second inspection; (*c*) those who had matured for their third inspection; (*d*) those about to leave school."

" The following further regulations should be observed:

1. " The inspection should be conducted in school hours and on school premises, and in such a way as to interfere as little as may be with school work. The examination of each child need not, as a rule, occupy more than a few minutes.

2. " The convenience of the teaching staff and the circumstances of each school must receive consideration, and in these matters and in

actual examination the medical officer will no doubt exercise sympathy and tact, giving due thought to the personal susceptibilities of those concerned.

3. "Facts revealed by inspection must be entered in a register kept at the school, the confidential nature of many of the entries being carefully respected.

4. "Every school medical officer should make an annual report to the Local Education Authority on the schools and children under his superintendence.

5. "A number of suggestions are given regarding the facts that should be stated in the report of the medical officer."

Amelioration and Physical Improvement.—"The aim of the Act is practical, and it is important that Local Education Authorities should keep in view the desirability of ultimately formulating and submitting to the Board for their approval schemes for the amelioration of the evils revealed by medical inspection, including, in centres where it appears desirable, the establishment of school surgeries or clinics for further medical examination, or the specialized treatment of ringworm, dental caries, or diseases of the eye, the ear, or the skin.

"Verminous heads and bodies form another illustration of a common condition in which amelioration can be secured by school nurses.

"It is of the utmost importance to remember that baths, with the necessary accompaniments of soap, sponges, towels, etc., should be utilized, not merely for the immediate and obvious purpose of cleansing the bodies of the children, but also as a humanizing influence and as the means of inducing habits and instincts of cleanliness, and of inculcating practical lessons in the value of personal hygiene and in self-respect."

Objects of Medical Inspection.—The objects of medical inspection of schools are—

1. To discover any physical or mental defects which will prejudicially affect the future physical or mental development of a child.

2. To diagnose conditions of an infectious or contagious character which render it inadvisable that children suffering from such conditions should associate with other members of the school.

3. To ascertain whether the educational methods are adapted to the physical and mental condition of the child.

4. To examine the hygienic conditions of the school buildings (ventilation, light, heating, type of, and arrangement of, desks, etc.).

Method of Medical Inspection.—Different opinions prevail regarding the exact method of inspection of schools and school-children, and it is impossible to lay down any hard-and-fast rules that would be acceptable to all local authorities. The following should be regarded as general lines upon which the inspection should be conducted :

The necessary notification is sent to the head-teacher concerned, stating the group of children it is intended to examine, and the day and time upon which such examination is to be made. The head-teacher then sends out notices to the parents or guardians of the children selected for examination, stating the time of the examination, and requesting their presence at the school at the appointed time.

The teacher should see that the health schedules of the selected children are filled up as far as possible in readiness for the inspection.

In the routine of medical examination it would be well that the Board of Education Schedule, or some modification of it, should be followed. The history of any previous disease is taken from the parent or guardian. The child's height and weight are taken, and notes made regarding the nutrition, cleanliness, and clothing of the child. The various points in the Schedule are taken *seriatim.* The presence of skin affections, external eye disease, otorrhœa, enlarged glands, defective teeth, etc., can be recognized at a glance. The heart and lungs should then be examined, and the condition of abdominal viscera ascertained. By such means the normal can be separated from the abnormal. Further detailed examination may be applied to the children who are abnormal, to find out their exact condition.

Since at present it is impossible in a large number of cases for the school medical officer to treat the abnormal conditions that he finds, his chief duty is to separate the abnormal from the normal children, and to classify the abnormal conditions into various groups.

Treatment.—The general lines of treatment for various ailments will be indicated by the school medical officers.

If the parents can afford it, the children may be treated by a private practitioner. In the majority of cases the parents will not be able to pay their doctor's fees, especially when the condition requires prolonged treatment, and thus some arrangement will have to be made with local hospitals and dispensaries for the treatment of school-children.

The ideal thing would be the equipment of a school clinic, where the medical officer could personally supervise the treatment of his cases.

The teacher, by learning some of the common signs of disease mentioned in Chapter XI., will soon be able to apply such knowledge, and thus identify some of the common physical and mental defects of the children in the school. It is most important that the teacher should have a good knowledge of the early symptoms and signs of infectious diseases, and thus early and more effectual means may be taken to prevent an epidemic in the school.

School Closure.—During an epidemic of infectious disease in a neighbourhood, school closure in the past has been practised in an arbitrary manner when the school attendance had fallen a good deal below the average. Such a means, especially in towns, is generally useless in preventing the spread of infection, because already the children have been exposed to infection, and it is practically impossible to prevent them coming in contact with each other whilst playing in the streets.

The only successful way of preventing the spread of infectious disease is to train the teachers in methods that will enable them to recognize the early symptoms and signs of all infectious diseases met with during school life.

A child suspected of having the signs and symptoms of any such disease should be sent home at once. The teacher should inform the medical officer of the fact. The exact course that he will take regarding that particular child will depend whether the child is attended by a private doctor or not.

If the diagnosis has been confirmed, the teacher and medical officer should closely observe the other members of the class, especially the associates of the child first infected The exact methods taken to prevent the infection will be indicated by the medical officer.

Disinfection.—In order to discuss some of the general lines of disinfection of schools, let us define certain terms which are often used and confused in this connection—namely, *disinfectant*, *antiseptic*, and *deodorant*.

A *disinfectant* is a substance in certain strength, which is able to destroy germs which come in contact with it. An *antiseptic* is a substance that can stop the growth of micro-organisms, and prevent decomposition of organic material. A *deodorant* is a substance that is able to oxidize or absorb substances causing evil odours.

All substances which are disinfectants are antiseptics; but, on the other hand, deodorants and antiseptics are not disinfectants.

Disinfectants are intended to destroy micro-organisms, and to ascertain their relative value methods have been applied to determine their relative effects upon culture of certain micro-organisms, and comparing them in each case with a certain standard. Rideal and Walker have suggested that carbolic acid should be the standard disinfectant, and that the *Bacillus typhosus* or *B. coli communis* (the former causes typhoid fever, and the latter is present in the intestine of every person) should be the germ used in all tests. In modifications of the test the germs are placed in certain definite media, because the surroundings of the germ most influence the power of the disinfectant.

Processes of Disinfection—1. *Burning.*—This is the best means of disinfection, but, unfortunately, is only applicable to articles that are of no value.

2. *Boiling.*—This is also a very efficient means of disinfection, but here again its application is limited.

3. *Hot Air.*—This is efficient, but several objections may be raised against it—namely, prolonged exposure, destruction of large numbers of articles—and hence its limited application.

4. *Steam.*—This gives very good results when proper precautions are taken.

5. *Application of Liquid Disinfectants.*—Such disinfectants may be used to wash the walls of a room, or articles which require disinfection may be placed in such solutions. Some of the common liquid disinfectants are solutions of corrosive sublimate, carbolic acid, and other tar preparations, bleaching powder, formaldehyde, etc.

6. *Application of Gaseous Disinfectants.*—This is a method that is often applied to rooms. After all the doors and windows have been carefully sealed, certain gas is produced inside the room, and allowed to remain there for at least twenty-four hours. Examples of such disinfectants are formaldehyde, sulphur dioxide, and chlorine.

Disinfection of the Schoolroom.—Every means must be taken to prevent the accumulation of germs in the schoolroom. This is of much greater importance than devising any plan to destroy such germs after their entrance and accumulation.

The teacher must have greater faith in good ventilation and windows, allowing abundant supply of fresh air and sunlight, and in frequent and efficient use of soap and water, than in any other form of more artificial disinfection. If such precautions are taken, the school will harbour but few noxious germs, and will certainly not be a very potent factor in the spread of infectious disease.

It may be necessary at times to apply more potent methods of disinfection—*e.g.*, when an epidemic of diphtheria or scarlet fever has occurred.

The disinfection should be carried out by the local sanitary authority.

Curtains, rugs, etc., should be sent for steam disinfection.

Books may be burnt, or disinfected by hot air, or exposed to 3 per cent. formalin vapour.

Pencils, pens, and *slates* should be placed in a disinfectant fluid.

The *exposed surfaces of the schoolroom* may be disinfected by one of three methods :

1. By the use of sprays, where the disinfectant is applied directly by means of a spray—corrosive sublimate, or formaldehyde, can be applied by such method.
2. By washing the walls, ceilings, and floors with a disinfectant solution—formaldehyde, lysol, or corrosive sublimate, can be used.
3. By charging the air with certain gases or vapours, and allowing them to remain in contact with the walls for at least twenty-four hours.

After any of the above methods, the walls, ceilings, and floors should be well washed with soap and water, and then thoroughly dried by a good current of air and sunlight.

First Aid in Injuries and Ailments.

Fractures. — The causes of fractures are threefold — namely : (*a*) *direct violence*, when the fracture occurs at the part that is struck ; (*b*) *indirect violence*, when the bone gives way at a distance from the site of application of the force ; (*c*) *muscular action*. This is due to excessive contraction of some of the muscles of the body. Fracture of knee-cap often arises in this way. Fractures may be either simple or compound.

A *simple fracture* is one in which the skin is unbroken, and the external air does not communicate with the site of injury in the bone.

A *compound fracture* is one in which the force producing the injury is so great that one of the broken ends of bone is forced through the flesh and skin or mucous membrane, thus resulting in an open wound as well as a fracture.

A ompound fracture is a very serious injury, because there is great danger in micro-organisms gaining access to the wound, and the bone setting up an inflammation resulting in general blood-poisoning. Before the introduction of antiseptics into surgery the death-roll from compound fractures was very great.

The signs of a fracture are—(*a*) pain, bruising, or swelling at the site of fracture; (*b*) loss of power of movement of the part involved; (*c*) change in shape of the limb, or deformity from displacement. This results from three factors—namely, the direction of the violence, the weight of limb, and contraction of muscles.

The diagnosis of a fracture is sometimes difficult, but every doubtful case should be treated as a fracture until the doctor arrives.

The principle of the first-aid treatment of fractures is to adopt means to prevent any undue movement of the fragments of the fractured bone until medical help arrives. Thus immobility of the parts must be secured before any movement of the body is allowed. Injudicious movement or rough handling, especially by untrained persons, aggravate the condition, and may even convert a simple to a compound fracture.

Fracture of the Skull.—If a fracture of any part of the *skull* is suspected, the patient should be placed on a bed or couch with head well raised, and cotton-wool or lint soaked in cold water should be applied to the site of injury. The doctor should be sent for immediately.

Fracture of the Lower Jaw is generally due to direct violence, and is diagnosed by feeling a depression at some area of the bone. The patient will be unable to speak properly, and will often bleed at the mouth, because the lining of the mouth is usually torn.

If the jaw is displaced, it should be gently raised to its natural position. One handkerchief is fastened under the jaw and round the top of the head, and another is passed round the chin to the back of the neck.

Fracture of Ribs may be due to direct or indirect violence. The patient will complain of having felt something snapping or giving way, and of a sharp localized pain at the site of the injury, increased on deep breathing and coughing. A grating sensation is felt over the spot at each breath. A broad bandage should be fastened tightly round the chest, or the injured side of the chest may be strapped with broad strips of adhesive plaster, each strip being applied when the chest is in a state of forcible expiration.

Fracture of the Collar-Bone, or Clavicle.—This is one of the commonest bones to be broken. It may arise from direct or indirect violence, generally due to the latter. There will be drooping of the corresponding shoulder, an irregularity will be felt on passing the finger along the bone and the patient will be unable to raise the arm any farther than the shoulder.

Place a pad of cotton-wool or rolled-up handkerchief in the armpit ; the arm should then be placed in a sling, and fixed to the side by passing a bandage round the arm and chest.

Fractures of the Upper Limb.—Fractures of the *humerus, or arm-bone*, are caused by direct or indirect violence. Two temporary splints should be obtained and covered with cotton-wool, or wrapped round with handkerchiefs. One of the splints is placed on the outer side of the arm from the shoulder to the outer side of the elbow ; the other should run from the armpit to the inner side of the elbow. These splints should be firmly bandaged to the arm, and the forearm placed in a sling.

If a fracture of the forearm is suspected, two pieces of wood should be obtained and bound at right angles to each other, thus forming an angular splint. The arm should then be bent at a right angle, and fastened to the splint by means of handkerchiefs or pieces of bandage. The forearm should then be placed in a sling.

The best way to apply temporary treatment in a fracture of any of the bones of the hand is to fasten it by a bandage to a broad flat splint, and then the forearm placed in a splint.

Fractures of Lower Limb.—In fracture of the thigh, the first thing that must be done is to take means to prevent shortening of the limb. Therefore the lower portion of the injured limb should be held by both hands, and then pulled gently until both limbs are of the same length. Fasten both feet together by means of a handkerchief applied below the ankles. A long splint may be extemporized from a broomstick, or any other piece of wood or metal which is about the right length. It must run from the armpit to the foot. Both limbs should be further bound together by a handkerchief tied around them at the knee, and another round the thighs.

Great care should be taken when removing a patient with a broken lower limb from the place where the accident happened to his home or hospital. He may be carried in the arms, or a blanket, extemporized stretcher, or in an ambulance.

A fractured leg is treated very similarly to a broken thigh, except that the splint runs from above the knee to below the feet.

In applying bandages to a limb, great care must be taken not to stop the circulation. See that the fingers or toes do not turn blue and cold.

Sprains and Dislocations.—If a sprain is seen immediately after the accident, the injured part should be held under a cold-water tap. The limb should then be raised, wrapped in cotton-wool, and firmly bandaged, a splint being put on to keep the part at rest. These measures will limit the subcutaneous bruising. Hot fomentations is the best form of treatment that can be applied to relieve the great pain which follows a few hours after a sprain, but their application should be limited, because they tend to increase the after-swelling.

Dislocations are generally caused by injury, and have the following signs : Evidence of local trauma—*e.g.*, pain, bruising, and swelling of the soft tissues ; deformity of the limb, due to the abnormal position of the head of the displaced bone ; and restricted mobility of the affected joint, resulting in impairment of function of the limb. It is best to leave all forms of dislocation alone until the doctor arrives.

Bruises.—These are very common accidents in the playground. They are treated on the same lines as sprains—by applying a cold-water compress to the site of the injury, giving rest to the part, and firm bandaging to help absorption of any inflammatory fluid.

Stings and Bites.—Stings of insects, such as bees and wasps, may be very irritating and painful, but they are rarely dangerous except when they are on the tongue, or very numerous, or some secondary infection such as erysipelas supervenes. Great care must be taken that the sting or poison-sac is not left in the body ; then a strong solution of washing-soda should be rubbed on the spot.

Bites of animals cause ragged wounds, which take a very long time to heal. Free bleeding should be allowed for some time, aided by suction. Having previously cleansed the wounds, they should then be touched with caustic, or a piece of lint soaked in strong Condy's fluid applied. In the case of a poisonous snake-bite, the wound should be scarified, and some crystals of permanganate of potash rubbed in. The same treatment should be applied to the sting of the weaver—a fish with a poisonous spine in its dorsal fin.

Wounds.—The great principle underlying treatment of all kinds of wounds is to keep them clean. As long as wounds are kept clean, they will in the great majority of cases heal up quickly.

Small wounds, such as simple abrasion caused by falling on the ground, should be cleaned with water, and then bandaged, the sole object being to protect the part until the formation of a scab, which is Nature's means of protecting wounds.

The treatment of small clean cuts, such as those caused by a penknife, is the same.

The bleeding from slight wounds generally stops very quickly of its own accord. In some cases, however, bleeding will continue, and will require more effectual treatment.

Bleeding may be capillary, venous, or arterial in origin.

Capillary hæmorrhage appears as slow oozing of blood from the raw surface. This is treated by bandaging a cold-water compress tightly on the site of the bleeding.

Venous hæmorrhage is characterized by the dark colour of the blood. This can be stopped by raising the limb, and by bandaging a cold-water compress firmly on the wound.

Arterial hæmorrhage is the most dangerous form of bleeding, and in some cases may be very difficult to stop. The blood is bright red in colour, and comes out in a continuous stream in the case of the smaller arteries, or in jets synchronous with the pulse in the larger arteries. The slight cases of arterial bleeding may be stopped by firmly bandaging a compress over the wound.

Pressure may be applied continuously by some form of tourniquet. This may be applied by tying a knot in the middle of a handkerchief, and pressing this on the spot where compression is needed. A piece of wood or a flat stone may be tied on by means of a handkerchief, and the pressure increased by passing a stick under the handkerchief and twisting it round.

It should be remembered that the pressure of a tourniquet, though sometimes necessary, is always more or less injurious, and in five or six hours is likely to kill the tissues below the point where it is applied.

If bleeding takes place from one of the large arteries of the limbs, compression of the main artery against the bone at a point nearer the heart than the wound is a very effectual method of stopping the hæmorrhage. The exact point where pressure should be applied varies with the course of the particular artery involved.

Bleeding from the face and head will usually be stopped by pressure against the bony surface beneath.

Bleeding from the artery of the armpit may be checked by placing a pad of cotton-wool or lint, or a rolled-up duster, in the armpit, and bandaging the arm to the side.

Bleeding from the artery of the arm is stopped by placing a pad of cotton-wool over the wound and applying a firm bandage.

If the blood comes from the arteries of the forearm, place a pad of lint over the elbow, flex it, and bandage the forearm on to the arm. Bleeding from the palm is checked by making the patient grasp a pad of lint and bandaging the fingers over it.

Bleeding at the back of the knee can be stopped by placing a pad of lint over the wound, flexing the leg, and bandaging it firmly to the thigh. Bleeding from the arteries of the leg is checked by a similar process.

Hæmorrhage from the arteries of the foot is checked by direct pressure, or by the same treatment as applied in a case of bleeding from the arteries of leg.

Bleeding from the Ears after rather severe accidents is generally due to a fracture of the base of the skull. In such cases the doctor should be sent for at once.

Nose-Bleeding.—This arises from various conditions. It is generally unilateral, and can in a large number of cases be stopped by grasping the nostrils firmly, and allowing the blood to collect within and giving it an opportunity to clot.

The child should sit in a chair with the head thrown back, and cold water may be applied to the root of the nose or the nape of the neck. In other cases the nose can be syringed out by any styptic solution—*e.g.*, alum solution.

Burns and Scalds.—Remove the clothing; but any part that is stuck to the skin should not be forcibly removed, but left there after cutting all loose parts around. Some cotton-wool soaked in olive-oil or linseed-oil and lime-water should be placed on the wound. Another layer of cotton-wool should be placed over it, and then a bandage applied.

Shock is a very common feature associated with burns and scalds, and should be treated by placing the patient in bed, keeping him warm, and administering morphia or stimulants when required.

The best treatment when a child's clothes catch fire is to wrap him instantly in some thick woollen material, such as a coat, mat, rug, or blanket. This will put out the fire.

Fainting.—This arises from temporary weakness of the heart, resulting in a lack of blood-supply to the brain. The patient should be given plenty of fresh air, and the body should lie full length on the floor.

Foreign Bodies in the Throat.—If any foreign body sticks in the throat, pass the forefinger into the mouth, and try to remove the body causing the obstruction. Even if not successful in reaching the obstruction, vomiting will have been incited, and this will very frequently be sufficient to result in its expulsion.

Foreign Bodies in the Stomach.—If a small object, such as a pin, nail, plum-stone, or small toy, has been swallowed, aperients should not be given, and the diet during the next few meals should be dry, consisting of plenty of bread and vegetables. The course of a metal object can be followed by means of the X rays.

Eye.—The most common accidents to the eyes that occur in schools are the lodgment of foreign bodies, or bruising. If a foreign body sticks in the eye, evert the upper or lower eyelid ; and if the body is seen, remove it by a fine camel-hair brush or the wetted corner of a clean handkerchief. If it is not easily dislodged, do not make any further attempts, but send the child to see a doctor. If after the removal of the foreign body the eye feels very sore, place a drop or two of castor-oil on the cornea. Teachers should be taught by the medical officer how to evert the eyelid properly. Bruises of the eyelid are treated on the same lines as bruises elsewhere—cold-water compress and bandage.

Ear.—Foreign bodies in the external ear do not give rise to any symptoms unless it is a living creature, such as an insect. It will be well for the teacher never to attempt to remove a foreign body from the ear, because damage is so readily done by persons not medically trained ; therefore, leave all such cases to the doctor.

Skin.—Common accidents to the skin are cuts, bruises, and lodgment of foreign bodies. Wounds of the skin should be treated on the lines previously indicated. Foreign bodies, such as thorns, needles, etc., should be removed; but if the teacher should have any difficulty, he should ask for the help of the medical officer.

Nose.—The treatment of nose-bleeding has been discussed above. If a small object is lodged in the nose, it will excite sneezing, and this is often enough to remove it; if not, send the child to see the doctor, because interference by untrained persons is contra-indicated.

Poisoning.—Poisoning does not often occur in schools; but in case such misfortune might happen, the teacher should know some of the principles that will guide him in the treatment of such cases until the arrival of the doctor. The general condition of the patient must be treated. If there is any prostration, he should be placed on a bed or couch, and kept warm. Stimulants, such as strong tea or coffee, should be administered. Means must also be taken to get rid of the poison that has not been absorbed from the stomach, and the only method that can be applied by the teacher is the administration of emetics—that is, substances which induce vomiting. It must be remembered that the administration of emetics, and even the use of the stomach-pump by the doctor, is contra-indicated in some cases; therefore, before applying such treatment, some knowledge must be attained regarding the nature of the poison that has been taken.

If a corrosive poison has been taken, shown by blisters around the mouth and excoriations of the lining membrane of the mouth, no form of emetic should be given, except in the case of carbolic-acid poisoning.

If any form of acid, such as vitriol or spirits of salt, has been taken, give chalk or magnesia.

If an alkali has been taken—*e.g.*, caustic alkali—give large amounts of water, dilute vinegar, or citric acid. Give also raw eggs, milk, and oils.

If an irritant poison, such as arsenic, lead, or copper salt, has been taken, give an emetic (tablespoonful of mustard in a tumbler of water, or strong salt solution). Give raw eggs, milk, and oils, and treat the general condition by rest and stimulants. If there is any suspicion of phosphorus-poisoning—*e.g.*, taking heads of matches—do not give oils.

If a narcotic poison has been administered—*e.g.*, laudanum—give emetics ; and if the patient is sleepy, keep him awake by walking him about, flapping him with a wet towel, and shouting at him.

Treatment of those apparently Drowned.—A doctor should be sent for at once. The clothing should be loosened about the neck and chest, and the mouth cleared of water and dirt, if present. The tongue should be drawn forwards. Every means should be taken to keep the patient warm. Wrap him in hot blankets, and place hot-water bottles near him. Artificial respiration should at once be resorted to, and there are two methods in use at present—namely, those of Sylvester and Schaefer.

In Sylvester's method the patient is placed on his back, with a pillow or something similar beneath the shoulders. Care should be taken to have the tongue pulled forward and the mouth kept open. The arms are grasped below the elbow, and then pull them gradually over the head. This will draw air into the lungs.

Artificial expiration is produced by bending the arms and forcibly pressing them against the chest-wall. These movements should be done about twenty times a minute. They should be kept up for at least an hour, though there may be no sign of return to life. One great objection to Sylvester's method is that the performer gets very tired, and Schaefer has devised a method which involves less fatigue.

In Schaefer's method the patient lies with his face downwards, and the upper part of the chest is supported by a pillow or a thick folded garment.

The operator stands at the side of the subject, facing his

FIG. 131.—SYLVESTER'S METHOD OF ARTIFICIAL RESPIRATION: MEANS OF PRODUCING INSPIRATION.

FIG. 132.—SYLVESTER'S METHOD OF ARTIFICIAL RESPIRATION: MEANS OF PRODUCING EXPIRATION.

head, and places his hands on each side over the lower part of the back (lowest ribs). "He then slowly throws the weight of his body forward to bear upon his own arms, and thus presses upon the thorax of the subject and forces air out of the lungs. Then he gradually relaxes the pres-

Fig. 133.—Schaefer's Method of Artificial Respiration.

sure by bringing his own body up again to a more erect position, but without moving the hands." This method does not involve so much fatigue to the operator, and hence can be carried out for much longer periods by the same person.

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