SCHOOL HYGIENE

AND

THE LAWS OF HEALTH

CHARLES PORTER

J. Mitchell Wilson

a

SCHOOL HYGIENE AND THE LAWS OF HEALTH

SCHOOL HYGIENE
AND
THE LAWS OF HEALTH

A TEXT-BOOK FOR TEACHERS AND STUDENTS IN TRAINING

BY
CHARLES PORTER, M.D., B.Sc., M.R.C.P. (Edin.)

OF THE MIDDLE TEMPLE, BARRISTER-AT-LAW
ASSISTANT MEDICAL OFFICER OF HEALTH AND CHIEF SANITARY INSPECTOR, LEEDS
FORMERLY LECTURER ON BACTERIOLOGY, SHEFFIELD UNIVERSITY; LECTURER ON SCHOOL HYGIENE AT THE TRAINING COLLEGE, SHEFFIELD; VISITING MEDICAL OFFICER TO THE EDUCATION COMMITTEE, AND DEPUTY MEDICAL OFFICER OF HEALTH, SHEFFIELD

WITH 119 *ILLUSTRATIONS*

LONGMANS, GREEN, AND CO.
39 PATERNOSTER ROW, LONDON
NEW YORK AND BOMBAY
1906

PREFACE

THE matter upon which this book is founded, formed the basis of a course of lectures delivered to the teachers acting under the Education Committee of Sheffield and the students of the Sheffield Training College. Some of those who attended the lectures being kind enough to consider them of value in connection with their school work, it was determined to arrange them in book form, in the hope that the information they contained might be of assistance to teachers elsewhere. The idea of the Education Committee in arranging for the course of lectures, was to afford the teachers an opportunity of acquiring such information as might assist them in protecting the health of the school children. It was desired that the course might include instruction, not only in what have been called the "laws of health," which the teachers might in turn impart to the children, but also hints on the manner of detecting diseases likely to be met with in school.

The lectures themselves were largely modelled on the plan set out in the syllabus for the Sanitary Institute examination in School Hygiene: each system in the body was taken up in turn, the structure and functions of the organs composing it were considered, and the modes in which they might be affected by school conditions and disease, and how they were to be protected were described. The arrangement adopted for the lectures has been continued in the following pages, and each system has been treated of in a separate chapter in the first part of the book. The second part deals with the school building and is largely an extension of the regulations of the Board of Education, 1905, in connection with school construction. In this part school furnishing, sanitation, ventilation, and such other subjects as could not well be discussed in the first part have been considered.

For most of the illustrations introduced I am indebted to the publishers. Certain firms, however, viz. Messrs. Boyle, Chaddock, Curry and Paxton, Defries, Farrer, Lumley and Illingworth and Ingham, have been good enough to lend me blocks and photographs, and I have to thank them for doing so. My best thanks are also due to Dr. Margaret Duncan, formerly house surgeon at the Sick Children's Hospital, Sheffield, for several photographs which she very kindly placed at my disposal.

In the construction of the chapter on "Eyesight" I had the advantage of the advice of Mr. Simeon Snell, ophthalmic surgeon to the Royal Infirmary, Sheffield, and professor of ophthalmology in the University, whose work in connection with the eyesight of school children is so well known, and I have to thank him for many useful hints and much valuable information.

CHARLES PORTER.

LEEDS,
1906.

CONTENTS

PART I

THE SCHOOL CHILD

CHAPTER I

INTRODUCTORY

CHAPTER II

THE SKELETON

CHAPTER III

THE JOINTS

CHAPTER IV

THE MUSCULAR SYSTEM

CHAPTER V

THE CIRCULATORY SYSTEM

CHAPTER VI

THE LYMPHATIC SYSTEM

CHAPTER VII

THE RESPIRATORY SYSTEM

CHAPTER VIII

THE DIGESTIVE SYSTEM

CHAPTER IX

THE EXCRETORY SYSTEM

CHAPTER X

THE NERVOUS SYSTEM

CHAPTER XI

THE SPECIAL SENSES—SIGHT AND THE EYE

CHAPTER XII

HEARING

CHAPTER XIII

THE INFECTIOUS DISEASES

PART II

THE SCHOOL BUILDING

CHAPTER XIV

CHAPTER XV

THE SCHOOL SITE

CHAPTER XVI

THE SCHOOL BUILDINGS

CHAPTER XVII

SCHOOL VENTILATION

CHAPTER XVIII

SCHOOL WARMING

CHAPTER XIX

SCHOOL LIGHTING

CHAPTER XX

SANITATION AND CLEANSING

CHAPTER XXI

SCHOOL FURNITURE

SCHOOL HYGIENE AND THE LAWS OF HEALTH

PART I

THE SCHOOL CHILD

CHAPTER I

INTRODUCTORY

The human body—The cell—Mucous and serous membranes.

HYGIENE is the science which treats of the preservation of health. School hygiene is that branch of hygiene that treats of the preservation of health in the school. For the teacher a knowledge of the science and its branch is essential, first, because it is necessary for him to preserve the health of his pupils, and second, because he should be able to instruct them how to preserve their own health.

In health every organ and every part of the body is carrying out its functions normally and quietly, and in most cases without any very obvious sign of activity. In all organs and at all periods of life the tendency is to this quiet, orderly activity, and any condition that interferes with or interrupts it affects the health of the organ and of the body. Interference may come from within or from without the body, and the health of the organ may be threatened by internal or external conditions. Some of the internal conditions likely to interfere can be controlled, some cannot. Some of the external conditions—the vast majority, indeed—can be controlled.

The study of hygiene is, to a great extent, the study of the external conditions likely to interfere with health, and of how to prevent interference by such conditions, by their removal if possible, or, if not, at least by their modification.

In childhood some of the external interfering conditions are found in the schools which the child is compelled to attend. One external condition threatens the health of the child because it interferes with the functions of one organ. Another external condition threatens health because it interferes with another organ. The aim of the student of school hygiene, therefore, is to obtain a knowledge of the external school conditions likely to injure the health of the school-child, and of the methods of dealing with such conditions so that they shall be rendered harmless. As a preliminary to such study, however, and to ensure that the best use shall be made of the information gained, it is obviously essential that something must be known regarding the function of the organs to be protected. To obtain the information necessary the student must turn to physiology, the science which treats of the functions of the body and its organs, and must make himself acquainted with at least the elements of that science. In order to understand how the functions are carried out by the organs, it is necessary to be acquainted with the structure of the organs—to know their composition, and how they are built up. To obtain information on these points the student must turn to the science of anatomy, the science which deals with the structure of the body and its organs.

The study of hygiene, therefore, involves the study of anatomy and of physiology, and a fairly considerable amount of knowledge of these subjects is required. It involves also a certain amount of study of other sciences, *e.g.* chemistry, physics, etc., since a knowledge of these subjects is likely to be of value in connection with the study of the interfering conditions. The groundwork of the whole of hygiene, however, is a knowledge of anatomy and physiology, and a clear understanding and a proper appreciation of the building up of the body and its organs and the functions to be performed by these. Without such a groundwork and without such appreciation the study of the external conditions is useless, and likely to be productive of little good. With the groundwork, the need for the study of the external conditions becomes obvious, and their proper modification possible.

In the following pages it is proposed to treat of the subject of school hygiene more or less in the manner suggested. First the groundwork will be laid down, and an outline of the chief facts regarding the structure and functions of the various organs and parts of the human body will be stated. Following this, there will be described the conditions, internal and external, which chiefly tend to interfere with the functions of the organs, and the methods of dealing with such conditions will be detailed.

The Human Body

The human body consists of various parts and organs, mainly arranged to form what are usually described as *systems*. The systems and the organs forming them, and the chief functions performed by them, are as follows :—

(1) The **skeleton,** consisting chiefly of the bones and acting as the framework of the body.

(2) The **muscular system,** consisting of the various muscles of the body which bring about the movements of the limbs, etc.

(3) The **respiratory system,** formed by the air-passages and lungs, and concerned chiefly with the taking in of air for the purification of the blood and the nourishment of the tissues.

(4) The **circulatory system,** made up of the heart and blood vessels, and concerned with the sending and carrying of nourishment to the tissues.

(5) The **lymphatic system,** consisting of vessels and glands, and playing a part in the nourishment of the tissues.

(6) The **alimentary or digestive system,** which includes the mouth and teeth, the gullet, stomach, intestines, and certain glands, *e.g.* the liver, and is concerned with the digestion of food and its preparation for use by the tissues.

(7) The **excretory system,** by which waste substances are excreted from the body. The kidneys and the skin, and to a certain extent the lungs, perform this function.

(8) The **nervous system,** which is made up of the brain, the spinal-cord, and the nerves, and has for its function the government of all the organs and functions of the body.

(9) The **organs of special sense,** *e.g.* the eye and the ear.

The Cellular Structure of the Body.—In all the organs in the various systems the essential elements are microscopical bodies known as *cells*. As a result of their activity, the function which the organ is entrusted to carry out is produced. The cells are held together by a tissue known as *connective tissue*, the product of a set of cells called *connective tissue cells*.

In each organ the cells have special features, and the cells in one organ differ from the cells in every other organ in shape and size and function. In certain respects, however, they resemble one another, since all were originally developed from one single parent cell, viz. the *ovum* or egg. This ovum, which may be regarded as a typical cell, has certain essential features and certain elementary functions, and these all the cells derived from it have retained while undergoing certain modifications in form, etc., rendered necessary by the special functions which they have to carry out. In dealing with each organ, reference will be made to the special characters of the cells composing it, and at present only those features common to all cells need be mentioned.

The Cell.—Each cell, like the ovum, is microscopic in size, and consists essentially of a soft, granular, jelly-like substance known as *protoplasm*. In the centre of the mass of protoplasm forming the cell, some of the jelly-like material is concentrated to form a dark-coloured body to which the name of *nucleus* is given.

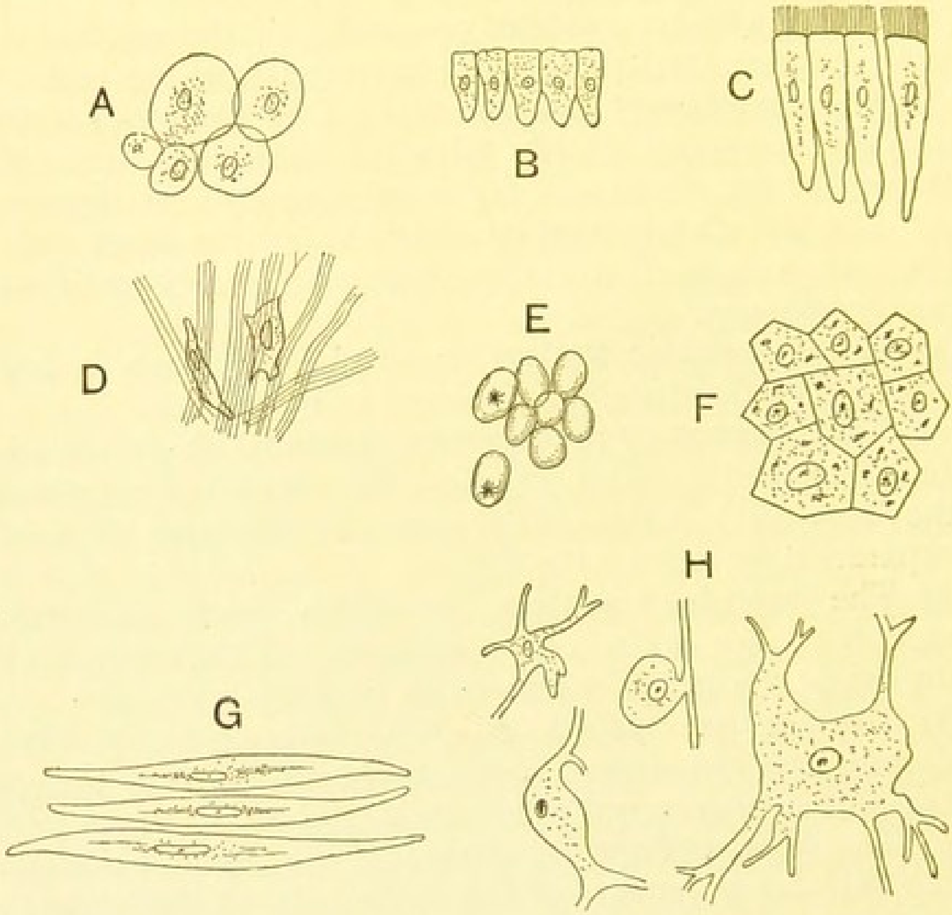


Fig. 1.—Various kinds of cells found in the body. (Magnified.)

A, squamous epithelial cells; B, columnar cells; C, ciliated epithelial cells; D, connective tissue cells and fibres; E, fat cells; F, liver cells; G, involuntary muscle cells; H, nerve cells.

(*From Thornton's "Elementary Practical Physiology."*)

At the outer margin of the cell the protoplasm is again slightly modified to form a *wall* or bag which surrounds the remainder of the protoplasm.

Primarily the cell is only concerned with its own *nutrition* and with *reproduction*, or the forming of cells similar to itself. These two attributes the cells of every organ possess, in addition to any other powers they may have developed in connection with the function of the organ which they form. The nutrition of the cell is brought about by the taking into the body of the cell of various substances which are broken up by the protoplasm and replace any waste that may have occurred as the result, for example, of energy production in connection with other functions. In the organs of the body nutriment is carried to the cells by the blood and from this the cells absorb it.

Reproduction is brought about by the division of the cell into two, another cell similar to the original cell being produced. Division begins first in the nucleus, which is regarded as the most important element of the cell in connection with cell division or reproduction. The reproduction of cells is going on continually in the organs of the body. In the adult the new cells are formed merely to replace cells that have been exhausted and have died and been cast off as waste. In childhood and the early years of life cell division goes on more actively, since growth of the body has to take place. The fact of this increased activity of the cells in this direction must not be lost sight of, especially by those who, like teachers, have charge of children. To permit of growth taking place properly, the cells must not be strained by calling upon them to perform other functions to any very great extent.

In certain cases, and in certain situations, the cells have the power of *motion* in addition to their other powers. This movement is brought about by a contraction and expansion of the protoplasm, and may be induced artificially by the application of stimulants or irritants, *e.g.* heat, to the cell. In the organs of the body the majority of the cells are fixed. A certain number, however—for example, those forming the white cells of the blood, which is cellular like the other tissues—are capable of moving, creeping, usually away from the irritant.

Connective Tissues.—In addition to being found holding together the cells in the organs, connective tissue is found fixing various organs in position, and uniting the bones and soft tissues to one another. Arranged in layers, also, it is found forming a covering or capsule for various organs, *e.g.* the kidneys, the muscles, bones, and so on. To the connective tissue covering the bones, the name *periosteum* is given, and to the bands holding the organs in position and the bones together, the name *ligament* is applied. Structurally, connective tissue consists of fine, wavy, thread-like fibres formed by the connective tissue cells. These fibres are arranged either in bundles side by side, or to form a network, the spaces in the network and amongst the bundles being known as *connective tissue spaces*. These spaces contain a clear fluid, from which the tissue obtains nourishment, and a certain number of connective tissue cells. Cells are commonly found, also, adhering to the fibres here and there, and some of them, like the white blood cells, are capable of movement. On account of the presence of the fibres, this tissue is sometimes named *fibrous tissue.*

Connective tissue varies considerably in texture. In certain situations, *e.g.* amongst the cells of an organ, it is very fine and delicate, while in other places it is exceedingly thick and tough. Where special strength is required, there are usually to be found, mixed with the ordinary connective tissue fibres, others which are coarser, thicker, and of a yellow colour, and rather more elastic. These, also, unlike the ordinary connective tissue fibres, give off branches and have a tendency to curl up. They are known as *yellow elastic fibres.* In some situations, *e.g.* under the skin, the cells amongst the connective tissue are found to contain globules of oil, which may be so large as to occupy the whole cell. These cells are known as *fat cells*, and the tissue containing them is known as *adipose* or *fatty tissue.*

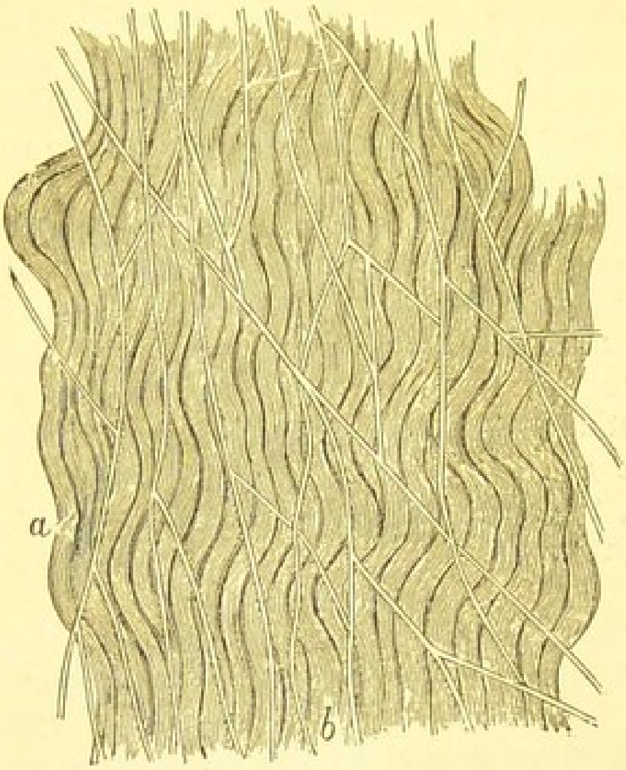


FIG. 2.—Connective tissue.
a, bundles of ordinary connective (fibrous) tissue; *b*, yellow elastic fibres.
(*From Gray's "Anatomy."*)

Epithelium.—All parts of the body, external as well as internal, are covered by simple cells, to which the name *epithelium* or *epithelial cells* is given. These are arranged, usually, in several layers, and may exist merely for the protection of some more delicate tissue underneath, *e.g.* in the skin, or may have some more definite function to perform, and be either secretory or excretory. If *secretory*, they manufacture a substance or secretion which is to be used for some special purpose in the body, *e.g.* the digestive juices secreted by the epithelium found in the glands in the stomach. If *excretory*, they withdraw waste substances from the blood and discharge them from the body, as is the case in the kidneys. In some cases the cells have both the protective and secretory functions to perform.

Mucous and Serous Membranes.—In certain situations the epithelial cells form what is called a *mucous membrane.* Such mucous membranes are found lining internal cavities which open on the external surface of the body, *e.g.* the mouth, the respiratory and alimentary tracts. The surface of the membrane is kept moist by the presence of a fluid secreted by the cells forming the outer layer of the membrane.

In certain other situations the cells form the chief part of what is known as a *serous membrane.* Serous membranes are found covering the exposed surface of all organs, *e.g.* the heart, the lungs, the stomach, bowels, etc., which in the discharge of their functions have to move to any extent and have to come in contact with the wall of the cavity in which they lie. In order to lessen still further the possibility of friction, the walls of the cavity are also covered with serous membrane, and the cells secrete a clear lubricating fluid with which the membrane is kept continually moistened. These serous membranes will be specially described later, when the organs in connection with which they are found are considered.

CHAPTER II

THE SKELETON

Its composition—The skeleton in the child—Deformities and conditions affecting the bones.

In the skeleton there are some two hundred bones, and these are of four kinds :—

(1) Flat bones, *e.g.* the bones of the skull.
(2) Long bones, *e.g.* the bones of the extremities.
(3) Short bones, *e.g.* the wrist and ankle bones.
(4) Irregular bones, *e.g.* the bones of the spinal column.

According as these bones are arranged the skeleton can be divided into various parts or regions :—

(1) The skull.
(2) The vertebral or spinal column.
(3) The thorax or chest.
(4) The extremities, upper and lower.

The Skull.—The skull rests upon the top of the spinal column and is divided into two parts, viz. the *cranium*, the principal function of which is to hold the brain, and the *face.*

The **Cranium** consists of eight bones, which are united together, at what are called *sutures*, to form an almost completely closed box for the brain. The bone forming the front of the cranium or

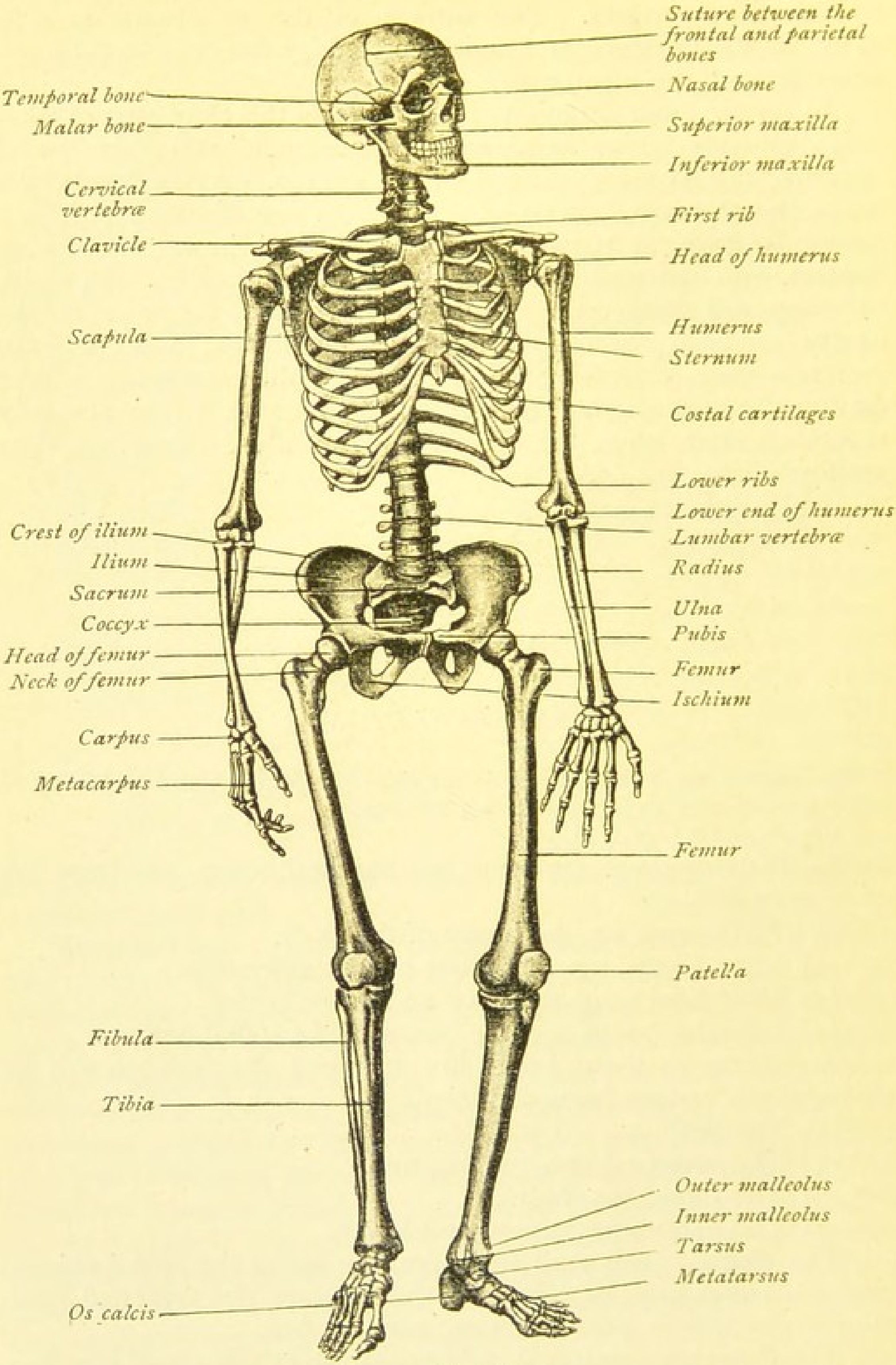


FIG. 3.—The skeleton.

forehead is named the *frontal* bone. Below, it forms the roof of the eye-socket or *orbit* on each side, and also sends a prolongation downwards to help in the formation of the nose. In the interior of the frontal bone two cavities are to be found, situated one on each side, immediately above the orbit. These are known as the *frontal sinuses*. Upon the size of these cavities depends, to a large extent, the configuration of the forehead.

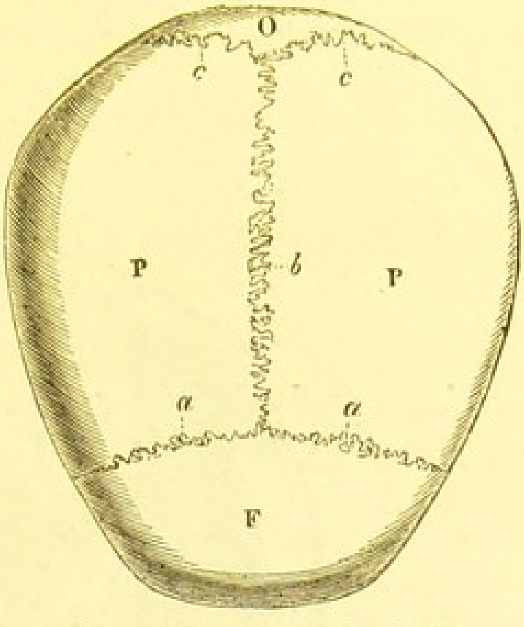


FIG. 4.—Top view of the skull.
F, frontal bone; P, parietal bones; O, occipital bone; *a*, *b*, and *c*, sutures.

United with the frontal bone, by what is called the *coronal suture*, are the right and left *parietal* bones. These two bones meet in the middle line at what is called the *saggital suture*.

At the back of the skull, forming it indeed, is the *occipital* bone. At its upper part this bone joins the two parietal bones, and at its lower it passes forwards towards the base or under surface of the skull. At this lower part the occipital bone is perforated by a large hole called the *foramen magnum*, through which the spinal cord, which springs from the brain, passes into the spinal canal. On each side of this opening there is a projection or *condyle*. These projections rest upon similar condyles on the first bone of the spinal column, the so-called *atlas vertebra*. In life the opposed condyles are perfectly smooth and can glide readily one over the other, and so permit of the various movements of the head taking place.

The bones forming the temples and completing the side walls of the skull are called the *temporal* bones. The temporal bone of each side is perforated by a canal for the ear, the external opening of which is known as the *external auditory meatus*. Inside this opening there lie three small bones concerned with hearing, and called, on account of their shape, the *malleus* or hammer, the *incus* or anvil, and the *stapes* or stirrup. Behind the external auditory meatus there is a distinct projection named the *mastoid process*. The outer surface of this process is exceedingly hard, but internally it is somewhat spongy in appearance and presents many tiny cavities. These cavities communicate with the canal containing the three small bones mentioned, and are named the *mastoid cells*. This communication between the auditory canal and the mastoid cells is of great importance, as will be shown later. In front of the external auditory meatus there is a depression into which a projection upwards of the lower jaw fits. Here the movements of the jaw occur. The temporal bone is provided also with a process which passes forwards to help in the formation of the cheek bone.

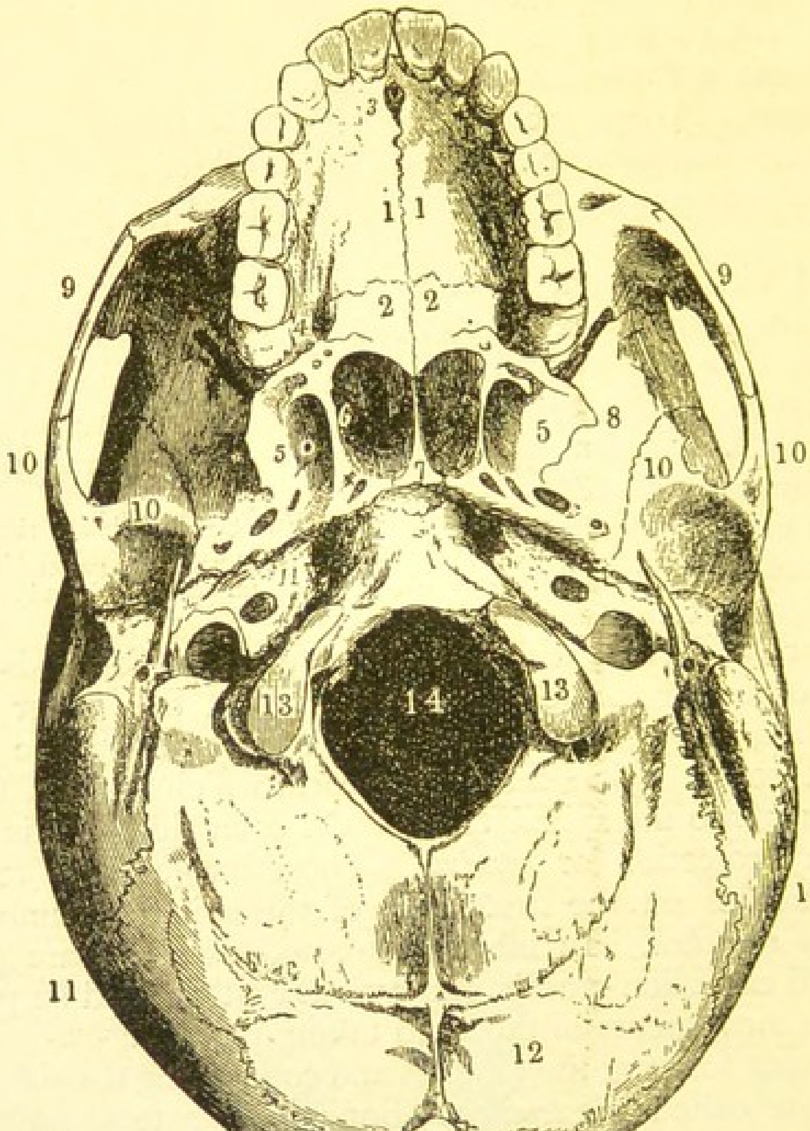


Fig. 5.—Base of the skull.

1, superior maxillæ; 2, palate bones; 5 and 8, parts of sphenoid; 6, inner opening of right nostril; 9, malar bones; 10, temporal bones; 11, parietal bones; 12, occipital bone; 13, condyles of occipital bone; 14, foramen magnum.

(*From Ferneaux's "Elementary Physiology."*)

The two remaining bones of the cranium are the *sphenoid* and *ethmoid* bones. These occupy the base of the skull and complete the under surface of the box. The *sphenoid* is the larger of the two, and resembles a bat in shape, hence the name. It unites with the occipital bone and many of the other bones of the skull. The *ethmoid* lies in front of the *sphenoid* and forms the roof of the nose and part of the side wall of the orbit. The bone is perforated by many openings for the passage of the fibres of the nerve of smell. The name *ethmoid* has been applied to it on account of a fancied resemblance to a sieve.

The **Face.** Of the 14 bones of the face, only the following need be specially mentioned, viz.:—

The two nose bones, or nasal bones.

The two bones forming the upper jaw—the superior maxillæ.

The two cheek bones, or malar bones.

The lower jaw bone, or inferior maxilla.

The *nasal bones* lie below the frontal bone, between the orbits. They form the upper part of the bridge of the nose, the remainder consisting of cartilage. The cavity of the nose, or *nasal fossa*, is divided into two by a partition consisting, at the upper part, of bone, at the lower, of cartilage. In the interior of each half on the outer wall there lie the so-called *turbinated bones*, consisting of three sponge-like masses. In life these contain numerous blood-vessels, and the air drawn in through the nostrils is heated in passing over them.

The *superior maxillæ* form part of the cheeks, part of the floor of the orbit, the side of the nasal fossa, and part of the roof of the mouth.

The *malar* bone on each side, along with the process extending forward from the temporal bone, forms the prominence of the cheek.

The *inferior maxilla* forms the lower jaw, and articulates with the hollow below the ear opening in the temporal bone. The superior and inferior maxillæ are provided with sockets, into which the teeth fit.

The Skull in the Infant.—In infancy, the bones of the skull are much thinner than in later years, and are less firmly united at the sutures. In this way allowance is made for the growth of the brain, which goes on fairly rapidly in the earlier years. The frontal bone, which in the adult forms one complete bone, before birth consists of two equal halves—right and left. These begin to unite early in life, but the union is not complete until about the end of the second year. As the result of the failure of union between these two halves, and between them and the parietal bones, there is left, about the middle of the crown of the skull, a distinct opening covered only by skin and membrane. This is known as the *anterior fontanelle*, and at first it is fairly large, resembling somewhat a heraldic lozenge in shape. In the normal infant, as time advances the opening gets gradually smaller, and closes completely about the end of the second year, when the bones unite. Where the occipital and parietal bones meet at the back of the skull, there is another, though smaller, opening known as the *posterior fontanelle.* This closes at a somewhat later date than the anterior opening.

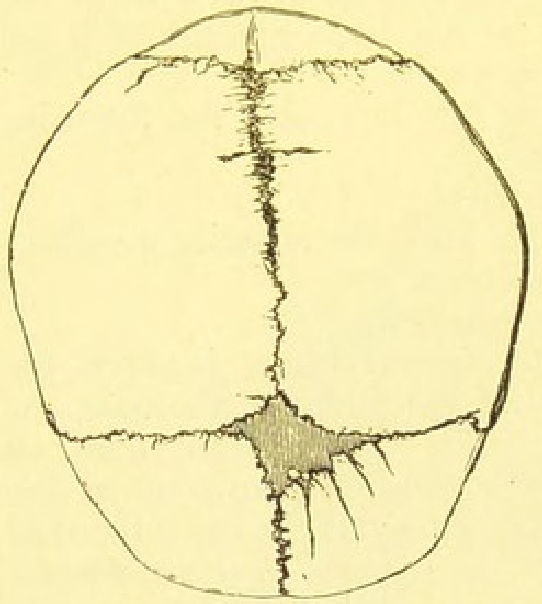


Fig. 6.—Skull of an infant, showing two frontal bones and the anterior fontanelle.
(*From Gray's "Anatomy."*)

In the normal infant, the circumference of the skull should be about 19 inches at the end of the first year. In a child of eight or nine, it should be from 20 to 21 inches in circumference.

The face bones in the young child are small and badly developed, and the face appears distinctly small in comparison with the remainder of the cranium. This is due partly to the height of the crown or vault of the skull. The nasal bones, in the child, are more on a level with the other bones of the face than is the case in the later years. The bridge of the nose is, therefore, rather flat till the nasal bones get forced out, as a result of the child using the nasal passages.

The Vertebral Column

For the sake of mobility the vertebral column consists of separate bones—called *vertebræ*—united by means of a strong, more or less elastic, band of fibrous tissue running the whole length of the column. The vertebræ are placed one upon another, but not directly, for between each pair there lies a pad of cartilage. To this piece of cartilage the name *intervertebral disc* is given. The chief function of these discs is to absorb vibrations set up in walking and so on, and so to prevent jarring of the brain and nervous system.

The vertebral column is divided into several portions—

(1) The *cervical* or neck portion. This consists of 7 vertebræ.

(2) The *dorsal* portion forming the upper part of the back, and consisting of 12 vertebræ.

(3) The *lumbar* portion forming the lower part of the back, and consisting of 5 vertebræ.

(4) The *sacrum* and *coccyx*.

In the adult these last form one large wedge-shaped mass, but in infancy they consist of separate vertebræ—in the sacrum 5, and in the coccyx 4. In the infant, therefore, there are 33 vertebræ. In the adult, by the union of the sacrum and coccyx, the number of bones in the column is reduced to 26.

The typical vertebra consists of the following parts:—

(1) The *body*, which is a solid piece of bone, forming the anterior portion of the bone.

(2) A *transverse process* on each side, which is provided with a flat surface to articulate with the vertebræ immediately above and below.

(3) A *spine* pointing backwards, and which can be felt under the skin.

(4) The *vertebral opening*, which is surrounded by the other parts named, and which, in conjunction with similar openings in other vertebræ, forms the *vertebral canal*, in which the spinal cord runs.

The vertebræ of the dorsal and lumbar portions are more or less typical, the latter being somewhat heavier than the former. The cervical vertebræ present some peculiar features, especially the first and the second, though all are lighter than the dorsal and lumbar vertebræ.

The first cervical vertebra is called the *atlas*, since it supports the globe of the head. It differs from the typical vertebra in having no body, its place being taken by a tooth-like process, hence called *odontoid*, from the second cervical vertebra. This second cervical vertebra is called the *axis*, because around it the movements of the head and atlas occur. The *atlas* has two smooth surfaces on its upper surface which articulate with two similar surfaces, the condyles, at the sides of the foramen magnum.

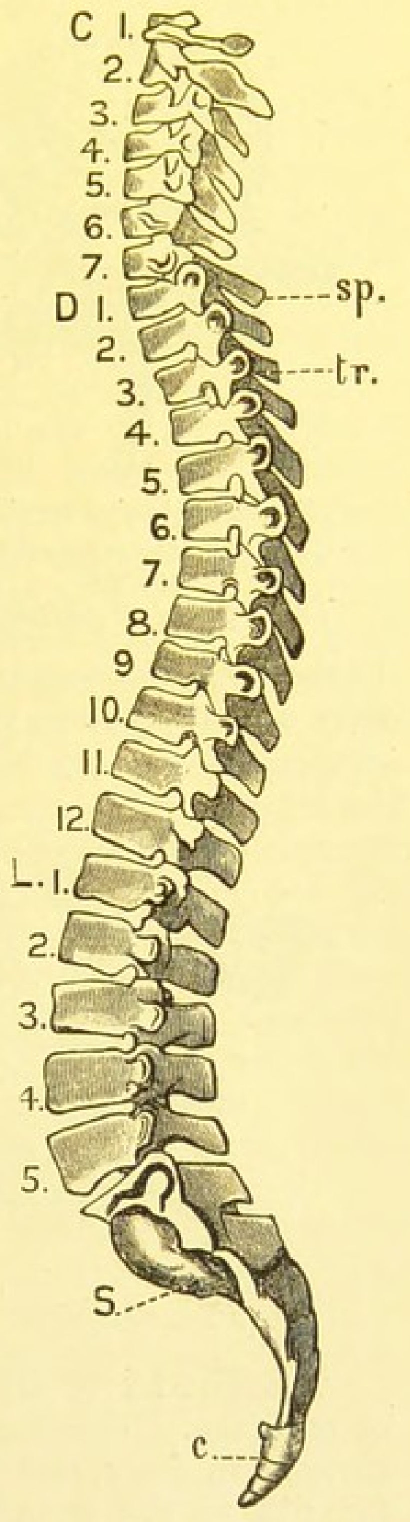


FIG. 7.—The vertebral column from the left.

C 1, first cervical; D 1, first dorsal; L 1, first lumbar vertebra; S, sacrum; *c*, coccyx; *sp*, spine or spinous process; *tr*, transverse process.

The odontoid process of the axis is held in position by a transverse band of fibrous tissue behind. If this slips and the process escapes, the cord is pressed on and death results. This is what occurs in hanging and in "broken neck."

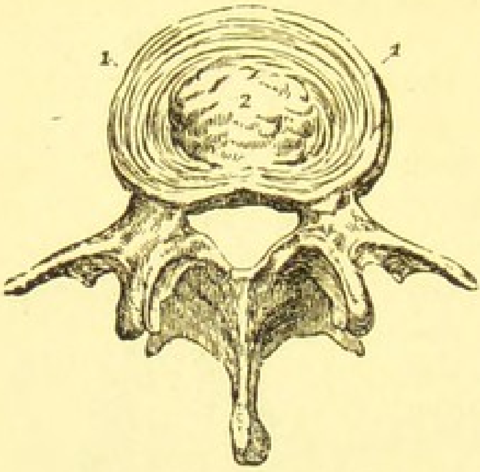


FIG. 8.—A lumbar vertebra.
1, body; 2, intervertebral disc or cartilage.
(*From Quain's "Anatomy."*)

The *sacrum* is a thick strong mass fitting between the hip bones. The *coccyx* is continuous with the sacrum, and curves forwards in man. In tailed animals it is straight and points backwards. Very occasionally, in the human subject, it is straight and forms a kind of tail.

The vertebral column, as a whole, presents several curves. In the *cervical portion* there is one short curve, the convexity being forwards. In the *dorsal* there is a longer curve, the concavity being forward. In the *lumbar* the convexity is forward, and the *sacrum* and *coccyx* have a marked concavity in front.

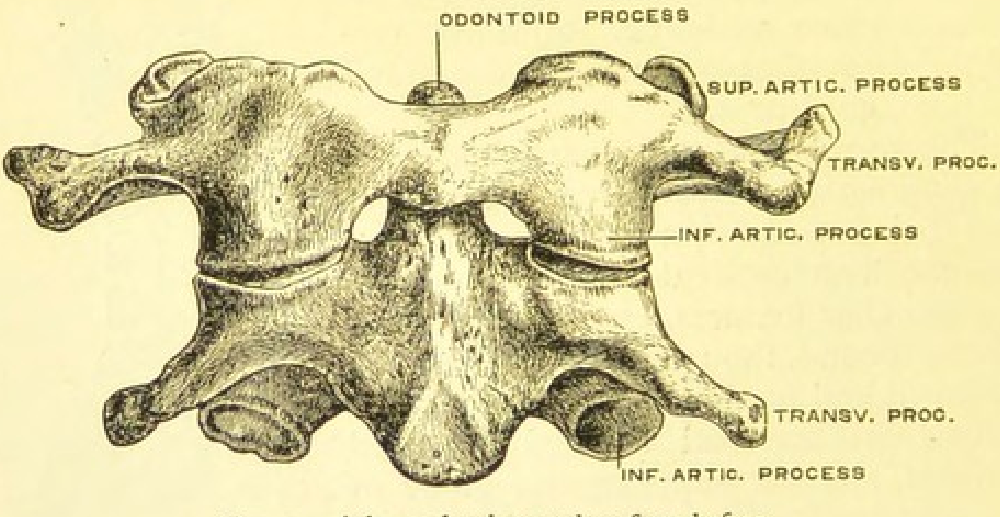


FIG. 9.—Atlas and axis vertebræ from before.

The Thorax or Chest.—This consists partly of bone, partly of cartilage. The bones are the 12 dorsal vertebræ behind, the *sternum* in front, and the *ribs* at the side. The cartilage joins the ribs to the sternum, and on account of its elasticity gives mobility to the chest walls.

The *sternum* is a flat bone, broad at the upper end and narrowing as it reaches the lower end. It more or less resembles a sword in shape. It consists of three parts, the lowest of which, except in very old people, is made of cartilage. This is called the *xiphoid* or *ensiform cartilage*. Normally it points downwards or inwards, but in shoemakers and others who, in the course of their trade, press on the lower part of the chest, it may be forced more or less backwards, a marked hollow at the lower end of the sternum being formed.

The *ribs* are 24 in number, 12 on each side, and in shape each resembles a bow. Behind they are attached to the transverse processes of the vertebræ, and in front terminate in cartilages called the *costal* or *rib cartilages*. The first 7 ribs on each side are known as *true ribs*, because they are attached through their cartilages to the sternum. The remaining 5 on each side are *false ribs*. The 8th, 9th, and 10th are attached to the 7th rib. The 11th and 12th are free in front, and are called *floating ribs*.

The spaces between the pairs of ribs are called *intercostal spaces* and are occupied by muscles called *intercostal muscles*. These are attached to the edges of the ribs that form the space in which they lie. Their function is to pull the lower rib of the pair up to the rib above when a breath is taken in. This pulling up, on account of the shape of the rib, and the fact that each slopes downwards, both from its attachment behind and from that in front, results in a widening of the cavity of the thorax. This increase in size is absolutely necessary for the accommodation of the lungs inflated with air after inspiration. The upper end of the thorax is called the *inlet*, the lower the *outlet*. Through the inlet certain structures like the windpipe, the gullet, and the veins, pass to their destination in the lungs, the stomach, or the heart. Through it also pass the great arteries carrying blood to the head and brain. Its lower end or outlet is separated from the cavity of the abdomen by a large flat muscle, the *diaphragm* or midriff, one of the muscles of respiration. In this there are several openings through which certain structures, blood-vessels, etc., pass to or from the abdomen.

The function of the thorax is chiefly to protect the lungs and heart, and it is because the lungs are continually varying in size, now big, now small, that it consists partly of bone and partly of cartilage, and is made up of a number of strips of bone—the ribs—instead of one sheet of bone.

The Extremities

1. **The Upper Extremity.**—The upper extremity consists of, on each side, the *clavicle*, the *scapula*, the *humerus*, the *radius* and *ulna*, the *carpus*, the *metacarpus* and *phalanges*.

The *clavicle* or collar bone of each side is a long curved bone, which articulates at its inner end with the sternum and first rib, and at its outer end with processes of the scapula.

The *scapula* or shoulder blade is a flat bone, resembling a spade in shape, which with the clavicle forms the shoulder. Its anterior surface is hollowed, and rests against the back wall of the thorax. Its posterior surface is divided into two unequal portions by a ridge near the upper margin. At the upper and outer angle there is a smooth oval depression called the *glenoid cavity*, into which the head of the humerus fits.

The *humerus*, the bone of the upper arm, is one of the long bones, and like all these has a shaft and two ends. Its upper end, or head, is smooth and rounded, and fits into the glenoid cavity of the scapula to form the shoulder joint. Its lower end is expanded and moulded. It articulates with the two bones of the forearm to form the elbow joint.

The forearm bones are called the *radius* and *ulna*. The radius lies to the outer side of the forearm. Its upper end is small and rounded; its lower end large and broad. The ulna lies to the inner side, and has a large upper end and a small lower end. The upper end has a large process, named the *olecranon process*, on it. This lies at the back of the elbow, and fits into a pit in the back of the humerus when the arm is straight. In life, in order to prevent injury from pressure, this process is protected by a bag containing an oily fluid and named a *bursa*. Similar bursæ are found at the knee and elsewhere.

The lower end of the ulna, like that of the radius, articulates with the wrist bones. Movements of the forearm from side to side, as in changing the arm from the supine position, with the palm upwards, to the prone position, with the palm downwards, are brought about by rotation of the radius round the ulna, hence the name of the bone. The movement of bringing the palm so that it looks upwards is supination; of bringing it so that it looks downwards pronation.

The wrist, or *carpus*, is made up of eight small bones arranged in two rows and called the *carpal* bones. Being made up of these small bones, greater mobility of the wrist is permitted. Beyond the carpal bones there is a row of five long bones, called the *metacarpal* bones. These articulate with the wrist bones above and the bones of the fingers, or phalanges below. The *phalanges* are fourteen in number, three for each finger and two for the thumb.

2. **The Lower Extremity.**—The lower extremity consists of—

(1) The *pelvic girdle* or hip bone.

(2) The thigh bone or *femur*.

(3) The leg bones, viz. the *tibia* or shin bone, and the *fibula*.

(4) The ankle bones or *tarsal* bones

(5) The *metatarsal* bones—corresponding to the metacarpals in the hand.

(6) The *phalanges*.

The hip bones on each side, with the sacrum wedged between them behind, form the *pelvis*, so called because it resembles a basin. The hip bone is irregular in shape, and, though it looks like one bone, and is, indeed, called the *innominate* bone, really consists of three bones. In infancy the three are quite distinct, being joined together by cartilage. As age advances the cartilage disappears, and they become completely united.

The three bones are named respectively:—The *ilium*, which is uppermost and forms the prominent part of the hip. The *ischium*, which is lowermost and which terminates in a thick mass of bone, upon which the body rests in the sitting posture, and which is protected by a bursa. The third bone is the *pubic* bone, or *pubis*. The two pubic bones meet in front to form the anterior part of the pelvis. On the outer side of each hip bone there is a deep depression, named the *acetabulum*, which receives the head of the thigh bone.

The *femur* is the longest bone in the body. Its upper end is smooth and rounded, and fitting into the acetabulum forms the hip joint. Its lower end is expanded into two large prominences, which articulate with the tibia to form the knee joint. In front of the knee joint, and forming a protection for it, we have a biscuit-shaped bone called the *patella*. This bone is covered by a bursa similar to that found at the back of the elbow. Inflammation of this occasionally results in persons who have to kneel a great deal, and the condition known as "housemaid's knee" is produced.

The *tibia* is the inner and larger bone of the leg, the sharp anterior edge of which can be felt under the skin of the front of the leg. Its upper end is large, and articulates or forms a joint with the lower end of the femur. Its lower end has a projection which looks downwards, and forms the inner prominence of the ankle. The *fibula* is the outer bone of the leg. It is very thin and long. Its upper end articulates with the tibia. Its lower end forms the outer prominence of the ankle.

The ankle or *tarsal bones* are seven in number. One large one lies between the tibia and fibula, and forms a joint with them. It is called the *astragalus*, and round it most of the movements of the ankle take place. Another bone projects backwards to form the heel, and is called the *os calcis* or *calcaneum*. Into this is attached the *tendo achilles*, the tendon of the muscle forming the calf of the leg. Four of the seven tarsal bones help to form part of the arch of the instep. Beyond these are the five *metatarsal* bones, and beyond these again the *phalanges*, three for each toe, except the great toe, which has only two. In walking the foot rests upon the calcaneum and astragalus, or heel, and the tarsal bones and heads of the metatarsals. These form the pillars of the arch of the instep. When the arch gives way more of the foot touches the ground, and *flat foot* results.

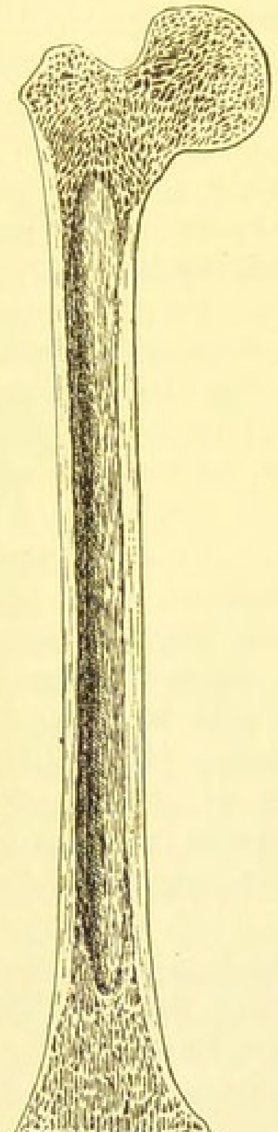


FIG. 10. — Longitudinal section of the femur, showing the compact and cancellous tissues, and the medullary cavity.

(*From Furneaux's "Elementary Physiology."*)

STRUCTURE OF BONE

On section of such a bone as the femur or humerus, when fully developed, certain things become visible.

Medullary Cavity.—The middle of the whole shaft of the bone is occupied by a cavity which in life is filled with a yellowish material named the marrow or *medulla*. This cavity is called the *medullary cavity*. The marrow is rich in blood-vessels, and is itself one of what are called the *blood-forming tissues of the body*, being occupied in making and sending into the blood-stream the cells which form the blood, and which are continually breaking down and continually being replaced. The blood-vessels nourishing the marrow and the bone itself come from the outside of the bone, entering it through an opening on its shaft. This opening is known as the *nutrient foramen*, and nutrient foramina can be found on the shaft of any long bone, and in other bones as well. The openings in the inferior maxilla are particularly easily seen.

Surrounding the medullary cavity there is very dense or *compact bone* save at the ends where it looks more spongy, and is given the name of *cancellous bone*. In the spaces of this spongy bone there is again marrow, but it is red in colour, and is called therefore *red bone marrow*.

The cancellous bone is bounded by a shell of compact bone. Outside this again, at the end of the bone, there is a thin layer of cartilage named the *articular cartilage*. Covering the compact bone, except at the ends where the cartilage is, there is a layer of tough membranous material to which the name of *periosteum* is given. This is rich in blood-vessels which pass into the substance of the bone to nourish it. Growth in thickness of the bone takes place from this periosteum. Most of the bones of the skull develop entirely from the periosteum, and are said therefore to develop in membrane.

Development of Bone

In early life most of the bones are represented by *cartilage*, the skeleton being more or less outlined or sketched in in this material. Cartilage is much less brittle and much more elastic than bone. It is made up of rounded cells embedded in a

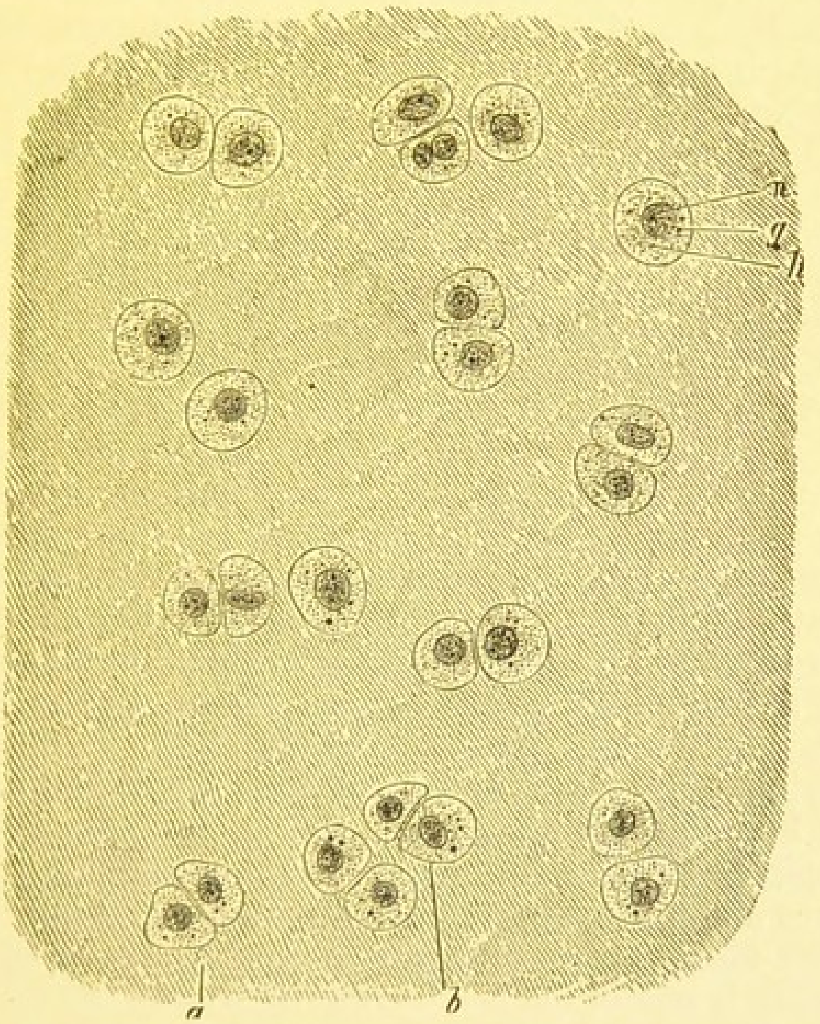


Fig. 11.—Section of cartilage (magnified) showing, *a*, matrix; *b*, cells; *n*, nucleus; *g* and *h*, protoplasm of a cell.

smooth, firm, more or less glass-like substance, produced by the cells and called the *matrix*. It can be readily cut with a knife, differing in this respect, of course, from bone. It also differs from bone in containing no blood-vessels.

In the course of time the cartilage throughout the greater part of the body is replaced by bone, and, in the adult, cartilage is only found in such situations as the windpipe, the ends of the long bones, and forming the costal cartilages. In advanced age the cartilage, even in these situations, shows a tendency to become ossified or transformed into bone. The change from cartilage into bone is termed *ossification*, and begins just before birth, and continues thereafter at first rapidly, later more slowly. The change is brought about by the shooting into the cartilage of numerous blood-vessels. The cartilage cells begin to disappear, and in their place bone cells make their appearance. These cells are not smooth and rounded like cartilage cells, but have many branches, and they arrange themselves in circles around the blood-vessels, forming minute canals called *haversian canals.* They produce a hard, bony substance, rich in mineral and animal matter, which becomes deposited around them in the matrix or bed in which the cartilage cells formerly lay. In this way the elastic character of the cartilage is lost, and the more brittle and compact bone formed. In the long bones the change from cartilage into bone takes place first at what is called a *centre of ossification* in the shaft, but soon the work of this centre is supplemented by the appearance of two other centres placed one at each end. From these centres growth in length of the bone takes place, and from them also ossification of the ends is brought about.

In a section of a child's bone these centres at the ends are usually very clearly marked as lines of cartilage. In a skiagram of a long bone in a child, what is usually seen is a long piece of bone representing the shaft, and a piece at each end apparently unconnected with it, the cartilage permitting the passage of the X rays, and casting therefore no shadow on the plate. To the cartilage the name of *epiphyseal cartilage* is given, the end of the bone being named the *epiphysis* (Fig. 12). A separation of the end piece or epiphysis is no uncommon accident in children, and may lead to great deformity if not properly treated. Union of the epiphysis and shaft occurs as youth advances. In some long bones union is completed earlier: in others later. By about the twenty-fifth year all epiphyseal cartilages are usually gone. The clavicle is one of the last to show complete union.

In the bones of the skull the process of development differs from that in other bones. With the exception of the sphenoid and ethmoid none of the skull bones are preceded by cartilage, bone formation taking place from one or more centres of ossification in the membrane or periosteum, which afterwards covers them. The *frontal* bone develops as two portions, each with a separate centre of ossification. Union of the two portions takes place after birth. The *parietals* have each one centre of ossification. At this point bone formation takes place very rapidly, resulting in the production of a protuberance varying in size

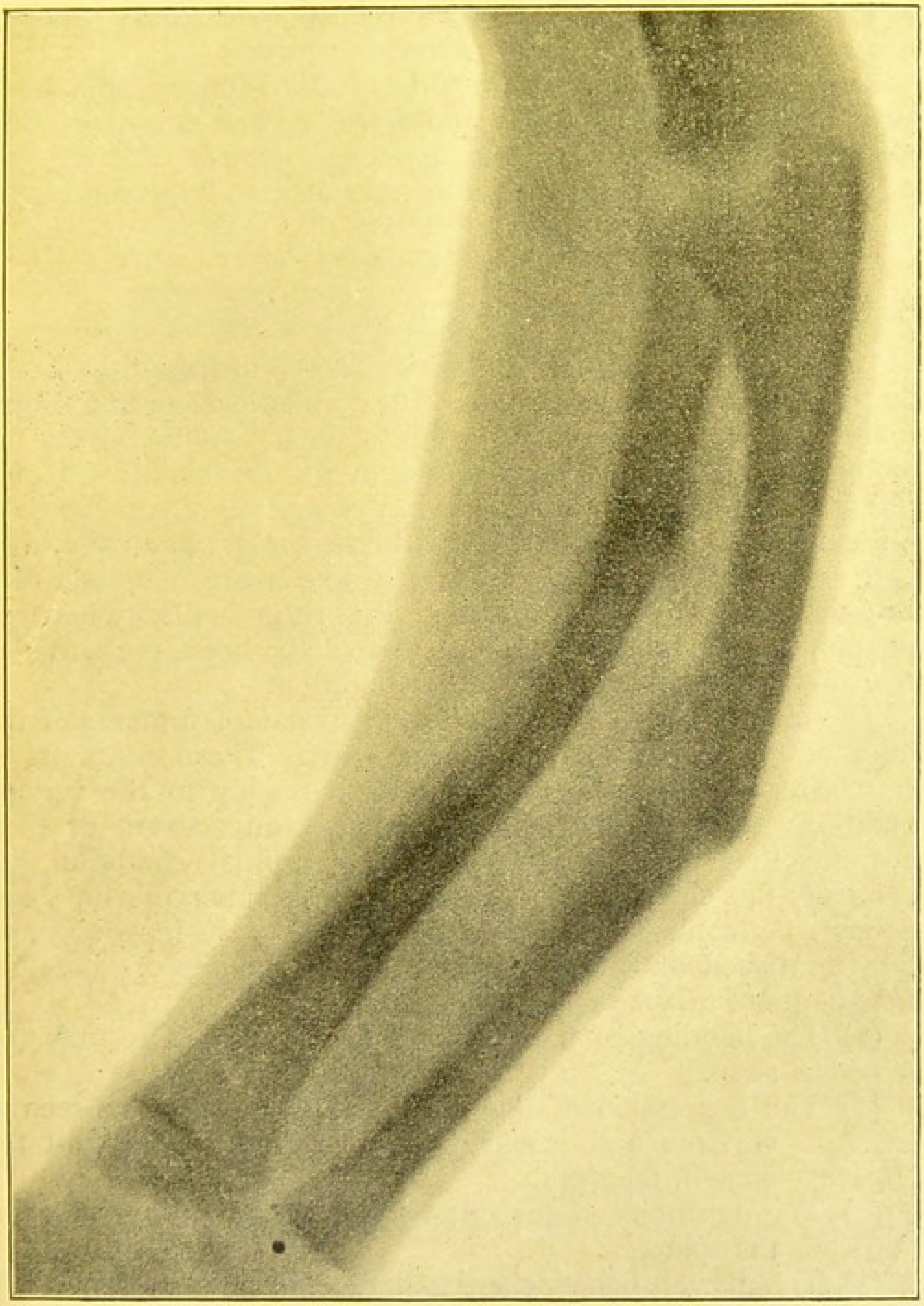


FIG. 12.—Skiagram of the forearm of a child, showing a green stick fracture at the middle of the ulna. At the lower end of the radius the epiphysis and epiphyseal cartilage are shown.

in different individuals. The *temporal* bone develops as three portions united by cartilage which after a time disappears, the three portions uniting to form one bone. The *occipital* develops in four parts united, till the fourth or fifth year, by cartilage.

The *sphenoid* and *ethmoid* are preceded by cartilage which is replaced by bone in five or six years after birth.

The principal factor in growth and development of bone is *proper nutrition*. Good food and fresh air are essential. The influence of physical exercises upon the growth of bone can undoubtedly be traced to the improved nutrition following proper and regular muscular action.

The Skeleton in the Child

In the child the skeleton contains more cartilage than in the adult and is therefore much less brittle. This is seen in the type of accident which occurs in a child's bone. In the adult, the commonest accident likely to occur in the neighbourhood of a joint is a dislocation; in a child, it is a separation of the epiphysis. In the adult, the bones being brittle break across; in a child, they bend and crack longitudinally, exactly like a green branch of a tree; they bend but do not break. From the similarity between the splintering of the branch and that of the bone, the name of *green stick fracture* is applied to the condition.

The importance of remembering this want of firmness of the bones of the child's skeleton is very great. These soft, more or less elastic bones can adapt themselves readily to the varying conditions they may encounter. At first, on account of their elasticity, they tend to return to their normal condition, but eventually the elasticity is overcome and the alteration in shape becomes permanent. This is especially the case in young and badly nourished or ricketty children. As examples of alteration in shape there may be mentioned :—

(1) The bending of the legs seen in children set to walk too soon.

(2) The depression of the lower end of the sternum seen in children and resulting from pressure, *e.g.* against the edge of the desk.

(3) The deformity of the chest following lateral curvature of the spine.

(4) The barrel-shaped chest and the pigeon-breast met with in weakly children suffering from frequent attacks of bronchitis.

(5) The flat chest and rounded shoulders resulting from stooping postures taken up at school and at home.

Teachers working in infant departments should, especially, remember the softness and elasticity of the bones in young children, in order to prevent deformities produced by permitting them to work with rounded shoulders or in other improper attitudes.

Important Points in connection with the Skeleton

These are—

(1) The height of the skeleton, from which information regarding the physical growth and development of the child may be obtained.

(2) The condition of the skull, from which information regarding the mental as well as the physical condition may be obtained.

(3) Certain deformities and diseased conditions likely to be met with.

TABLE I

Bowditch's Table

Age last birthday.	Boys.		Girls.	
	Inches.	Pounds.	Inches.	Pounds.
5	41·74	41·20	41·47	39·82
6	44·10	45·14	43·66	43·81
7	46·21	49·47	45·94	48·02
8	48·16	54·43	48·07	52·93
9	50·09	59·97	49·61	57·92
10	52·21	66·62	51·78	64·09
11	54·01	72·39	53·79	70·26
12	55·78	79·82	57·16	81·35
13	58·17	88·26	58·75	91·18
14	61·08	99·28	60·32	100·32
15	62·96	110·84	61·39	108·42
16	65·58	123·67	61·72	112·97
17	66·29	128·72	61·99	115·84
18	66·76	132·71	62·01	115·80

(1) **The Height of the Skeleton.**—In the accompanying table are shown the average height and weight of children of both sexes at different ages. The information contained in these tables was collected by an American physician named Dr. Bowditch, who examined many hundreds of school-children in America some years ago. Although the average height and weight of American

children are above those of English children, the table forms a very excellent guide, even in this country. One point of interest to which attention might be called, is the rapid increase in height and weight in girls at twelve and thirteen. Before this time the boys are, on the average, taller and heavier, but at twelve and thirteen the girls shoot ahead. At fourteen the boys make up the lost ground, and afterwards keep the lead. These years are a very critical period both for boys and girls; in the latter especially, profound changes taking place in the system.

In the normal child the rate of increase in height and weight is usually very regular, and is readily affected by conditions affecting the general health. There can be no doubt as to the value of the information to be gained by watching the progress of the child as regards height and weight. In many schools it is now customary to provide a weighing and measuring machine, and the teachers are expected to take, regularly, the height and weight of the children under their charge. This is an excellent plan, and one well worthy of imitation as likely to be to the advantage not only of the individual child, who could be thoroughly medically examined if found to be losing instead of gaining in height and weight, but also of the race.

(2) **The Condition of the Skull.**—With regard to the skull there are certain points which the teacher should get into the habit of observing. One or two points of difference between the skull of the child and that of the adult have already been mentioned (see p. 11). These were the thinness of the bones, the incompleteness of the union between them, the small size, comparatively, of the face, and the circumference of the skull. In examining the head, it should be looked at, first from the front and then from the side. Looking at it from the front, the eye should pass from one ear to the other, first over the top of the head, and then horizontally across the forehead. In this way an idea as to the capacity of the skull can be obtained. In the profile view the bridge of the nose should be examined. In the child the bridge of the nose is usually less prominent than in the adult, the nasal bones being forced upwards and forwards as the years advance. The slope and width of the forehead should be noted, and then, further to gauge the capacity, the eye should be carried over the top of the head from the bridge of the nose to the nape of the neck. Further information as to capacity and development may be obtained by placing the hand on the top of the head, noting in doing so the volume of the skull, and any depressions or irregularities in the bone. A depression in the front of the cranium may indicate *rickets*, as may also marked prominences on the forehead. Measurements may next be made

and compared with those already mentioned as being those of the normal child's head. In estimating the mental development, the shape and size and level of the hard palate are of importance. These points will be considered later, when dealing with the mouth.

(3) **Deformities and Diseased Conditions of Bones.**—The chief disease condition with which the teacher should be acquainted is *rickets.* The accidents which may be met with affecting children's bones are *green stick fracture* and *separation of the epiphysis.*

Rickets.—Rickets is a disease of bones most frequent and most severe among the children of the poor. Teachers working in the schools in the poorer districts of any town are most likely to find signs of it amongst their pupils. By the time the ricketty child is sent to school the acute stage of the disease, it may be the disease itself, is past, and the indications most likely to be seen are really the after effects. These may be summarized as follows:—

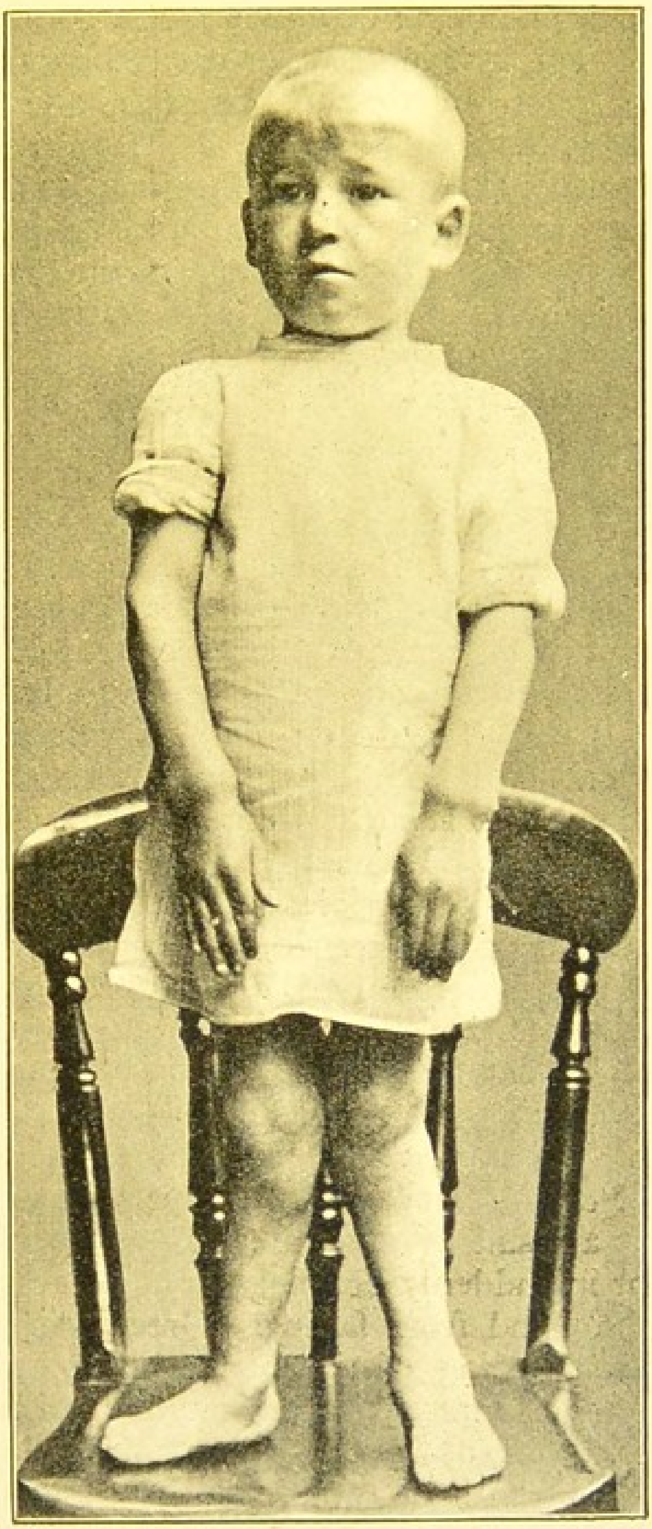


FIG. 13.—Rickets. Note the deformity of the legs and the thickening of the wrists and ankles.

(1) The ricketty child is usually a flabby child. The face is pale and pasty looking, and the muscles are soft.

(2) He is usually undersized, the neck is short and the chest small.

(3) The shape of the skull is altered, being more square than normal. The anterior fortanelle may be found unclosed even in

the third or fourth year, and prominences or *bosses*, as they are called, on the frontal bones are not uncommon.

(4) Thickening of the ends of the long bones is a very common sign, and is well seen at the wrists, the lower ends of the radius and ulna being distinctly larger than normal.

(5) The bones are easily broken, green stick fractures being common in ricketty children, and resulting from very trivial injuries.

(6) Deformities of the long bones, of the spine and the ribs are frequently seen. Bending of the legs is perhaps the commonest; but bending of the ribs, to produce pigeon-breast, and curvatures of the spine also frequently occur. The spinal curvatures usually met with are the backward curvature, in which the normal backward curving of the dorsal region is increased, or lateral curvature either to the left or right, the former being the commoner.

(7) Ricketty children are very liable to catch cold and suffer frequently from attacks of bronchitis.

The cause of rickets is improper feeding. A diet deficient in animal fat, such as diluted cows' milk, or the so-called condensed milks, is the one most likely to lead to the production of the disease. The ricketty child is generally found in the infant department of the school, and requires special care. He should not be allowed to stand too much. Improper attitudes must be at once corrected. Regular physical exercises should be given, but they should not be violent, and should not last too long. The child should be encouraged to go as much as possible into the fresh air. For the deformities, *e.g.* of the legs, surgical treatment may be required, and this might be suggested to the parents of the child.

Accidents.—With regard to accidents likely to occur in children, green stick fracture and separation of the epiphysis are the only two which need be mentioned. The mode of production of the former has already been described. The latter may occur as a result of a sudden jerk, as in lifting a child up by the arm, or in suddenly bending one's own arm to prevent a child held by the hand from falling. Green stick fracture is easily detected, the bending of the bones being quite easily seen. Separation of the epiphysis is indicated by pain and swelling at the end of the bone, and loss of power in the limb affected.

In both of these accidents the best thing to do is to put the limb at rest, either by means of a sling or an improvised splint, and to send the child to a doctor. Unskilful interference is bad, as likely to increase the tendency to deformity.

Deformities.—The deformities to be met with may be divided into (*a*) those occurring at school, and perhaps induced by school conditions; and (*b*) those already existing, and likely to be aggravated by school conditions.

As instances of the former the following may be mentioned :—

(1) The *rounded shoulders* and *flat chests* and *spinal curvatures* induced by badly constructed desks, or defective eyesight or careless attitudes adopted as being restful, and persisted in. These are to be prevented by watchfulness.

(2) *Flat foot* is a deformity which has already been mentioned. It results from the breaking down of the arch of the instep following the weakening of the small muscles of the foot and the ligaments which support the bones forming the arch. It is sometimes seen in poorly nourished and rapidly growing girls of about thirteen or fourteen. The *heels raising* exercise is directed to the prevention and cure of this condition, but is likely to do little good unless properly carried out, and with proper heel-less shoes on the feet.

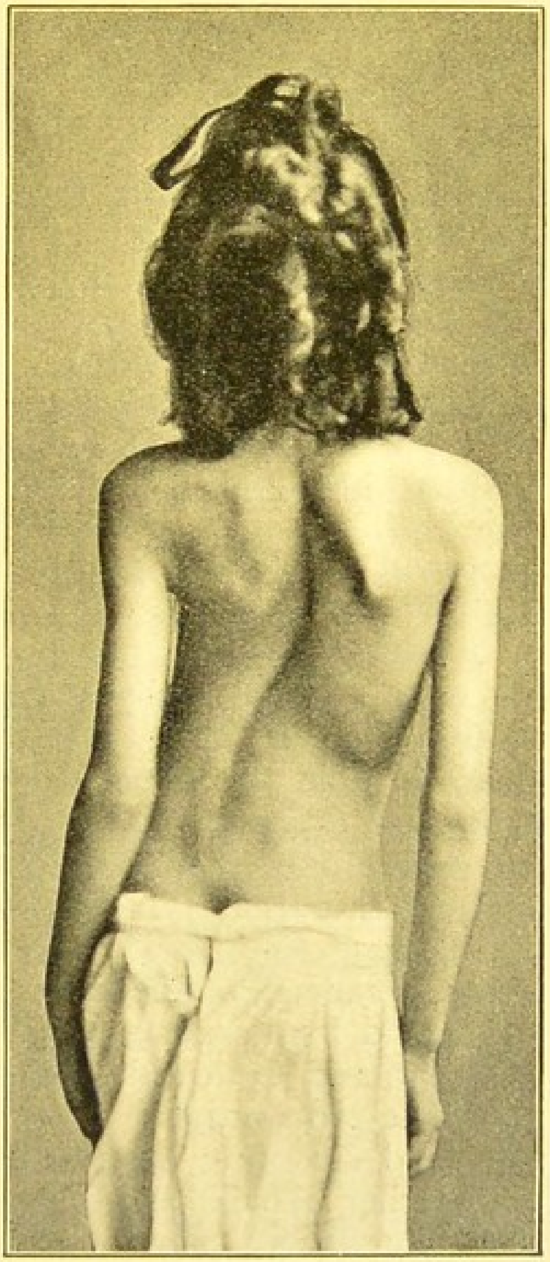


FIG. 14.—Lateral curvature of the spine, the result of rickets.

(3) *Lateral curvature of the spine* and a lop-sided attitude may be found in girls or boys of thirteen or fourteen. It is due not to disease of the bones but to weakness of the muscles, the result of impaired nutrition.

The curvature may be produced at school, improper attitudes in standing or sitting being the chief factors. It may, however, be produced at home, and girls set to nurse the baby, and carrying it on one or the other arm frequently develop a curvature with the convexity on the side opposite the carrying arm. Children who lie habitually on one side, with the head and shoulder resting at a higher level than the trunk, may develop a lateral curvature. The clothing worn by girls and the custom of leaving the lower part of the spine and hips, instead of the shoulders, to support the greater part of the weight of the garments are blamed also as producers of spinal curvature. Some cases of spinal curvature can be prevented by watchfulness on the part of the teacher and physical exercises, by improving the muscular tone, may, to a certain extent, help in remedying the defect. In addition, in these cases, fresh air and good food are of great importance and value.

The *existing deformities* likely to be aggravated by school conditions are: the spinal curvatures, already mentioned as occurring in children the subjects of rickets, and the spinal curvatures due to tuberculous disease (consumption) of the bones. In the former good may be done by exercises, by watchfulness, and by hints to the parents. As it is often difficult, however, to be absolutely certain that the cause of spinal curvature is rickets and not tuberculous disease, in cases of doubt the opinion of a medical man should be obtained. Broadly speaking, it may be said that the ricketty curvatures are generally lateral or merely exaggerations of the normal gentle curves of the spinal column, while those due to tuberculous disease are more acute. In the early stages of tuberculous disease of the bones it is often difficult to know what is wrong, and the things likely to do good—absolute rest, fresh air, and, especially, nourishing food—are withheld in favour of home remedies for rheumatism, the disease usually suspected of producing the symptoms.

Rheumatism is often vague in its manifestations in children, but does not commonly attack the joints of the vertebræ. A child in the early stages of spinal tuberculous disease has a tendency to hold the spinal column very stiff and straight, and to walk painfully erect. If the cervical region is affected a stiff neck may be the only sign, and though this may be due to rheumatism of the neck muscles, it is well for the teacher to be on his guard, and his suggestion to the parents to seek skilled advice may be to the advantage of the child. Pain may not be complained of by a child in the acute stage, but it may be induced by a very slight jar, and the child may begin to cry on what appears to be very little provocation. When the disease has got past the acute stage and curvature has resulted, if the child is attending school the teacher should avoid overstraining or overexercising him, since the disease may be merely quiescent and ready to break out anew. In all probability, however, the child will be under medical supervision, and directions will be given as to what he should and should not do.

CHAPTER III

THE JOINTS

Fixed and movable joints—Structure of a joint—Conditions affecting joints—"Growing pains"—Tuberculous disease (consumption).

WHEREVER bones meet a joint results, and joints may be roughly classified as fixed and movable joints. *Fixed joints* are much less numerous than movable joints, and those found between the bones of the skull and the bones of the face may be taken as examples. In the *movable joints* the amount of movement varies to a great extent. In such a joint as the shoulder, practically universal movement is obtained, while in that between the two pubic bones, between the sacrum and hip bones, or between pairs of vertebræ, which are also movable joints, the amount of movement permitted is very slight. In both of the latter the bones are separated by a layer of cartilage, the *interarticular cartilage*, more or less of a double joint resulting.

Formation of a Joint.—In movable joints, to permit of movement taking place smoothly between the bones forming the joint, some provision must be made for the gliding of the one over the other. If the bones forming the shoulder-joint in a prepared skeleton be examined it will be found that the head of the humerus is smooth and round, and moves fairly easily in the glenoid cavity, which is also smooth. In the living subject, to make movement still more easy and to prevent rubbing of the bones, they are protected by a layer of cartilage, and are lubricated by an oily fluid called *synovial fluid*, which is secreted by a layer of cells covering what is known as the *synovial membrane*, and which lines the joint. To prevent the escape of the synovial fluid or *synovia* from the joint, and to keep the bones together, the whole joint is surrounded by a *capsule*. At points where the strain is likely to be greatest the capsule is increased in thickness to form what are known as *ligaments*.

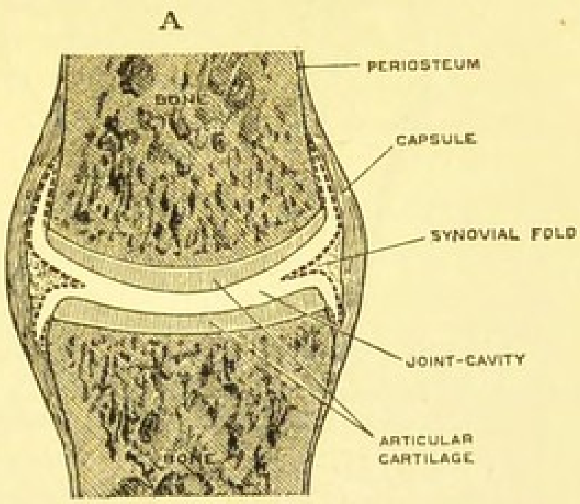


FIG. 15.—Section showing structure of a joint. The dotted line represents the synovial membrane.

(*From Quain's "Anatomy."*)

The Typical Joint.—The shoulder joint may be taken to represent the typical joint, so far as construction is concerned. It is what is called a *ball and socket joint*, the other kinds of movable joints being *hinge joints* and *pivot joints*. It possesses all the structures named; cartilage, a capsule, synovial membrane, and synovia. The only other ball and socket joint is the hip joint, and it is similar in construction to the shoulder joint, except that the head of the femur is more or less fixed to the acetabulum by means of a strong ligament running from the middle of the

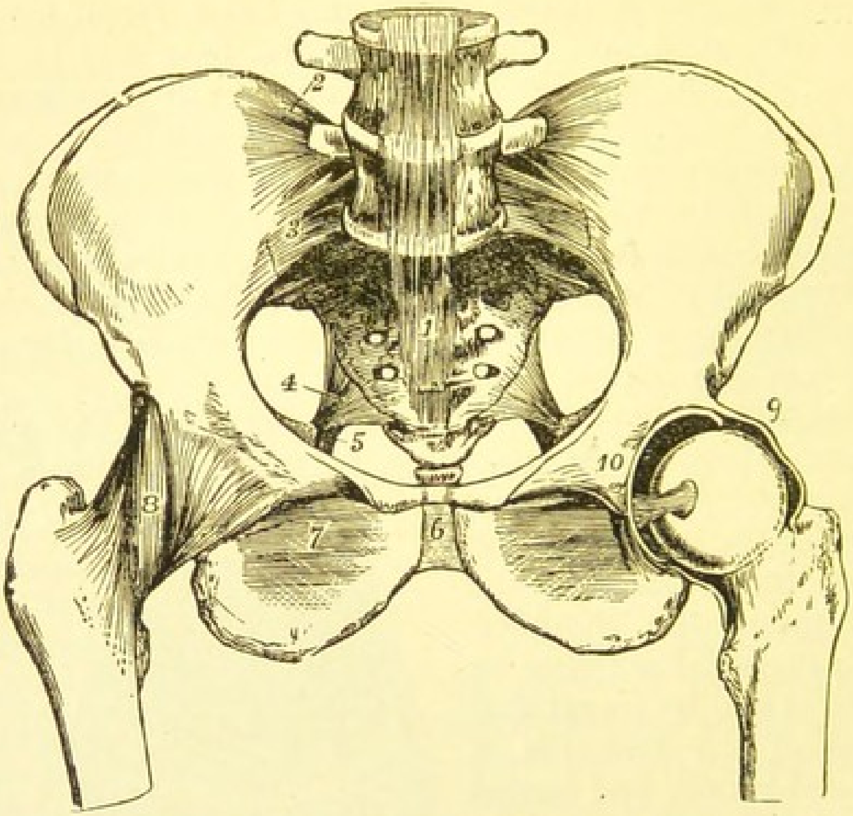


FIG. 16.—Articulations of pelvis and ball and socket joint of the hip.
1–6, various ligaments; 8, capsule of right hip joint; 9, 10, cut edge of left capsule. Note the ligament fixing head of femur to acetabulum.
(*From Quain's "Anatomy."*)

head of the bone to the bottom of the depression. The ball and socket is the only arrangement that would permit of the free movements necessary at the hip and shoulder.

Hinge Joints.—Of hinge joints the elbow joint is the type. Here again the structures forming the joint are bone covered with cartilage lubricated by synovia, the whole surrounded by a capsule and ligaments. In a hinge joint movement occurs only in one plane. Other hinge joints which may be mentioned are: the joints between the upper and lower jaw bones; the wrist joint; the finger joints; the knee joint; the ankle joint; the toe joints.

The *jaw joints* are more or less typical hinge joints. In the interior of the joint, however, there is an *interarticular cartilage* between the bones. The function of this cartilage is to absorb vibrations likely to be set up in chewing.

The *wrist joints* are double hinges, and movement can take place in two planes, up and down, and from side to side.

The *knee joint* is a typical hinge joint. The patella, however, takes part in its formation. It is provided with interarticular cartilages, one on each side of the top of the tibia. Their function is again absorption of vibrations. These cartilages are semi-lunar in shape, and are called *semi-lunar cartilages*. Displacement of one or other sometimes results from twisting or sudden bending inwards of the knee, *e.g.* at football, and painful symptoms result.

The *finger*, *toe*, *and ankle joints* are fairly typical hinge joints. The ankle joint has a certain amount of lateral movement in addition to the up and down movement.

Pivot Joints.—The pivot joints are: (1) that between the radius and ulna at the upper end, where rotation of the head of the former round the latter takes place; and (2) that between the atlas and axis vertebræ, at which the rotation of the head occurs.

Conditions affecting Joints.—The conditions affecting joints, to which the teacher's attention should be directed, are: (1) the so-called growing pains; and (2) tuberculous disease of the joints. Instances of both of these are likely to be met with amongst the scholars.

Growing Pains, it should be remembered, have nothing to do with growth, which is a natural and painless process. Such pains are usually a manifestation of tuberculosis or rheumatism. As rheumatism is frequently followed by serious affections of the heart, the occurrence of growing pains should be noted, and the parents advised to protect the children from damp, and to seek skilled advice if necessary.

Tuberculous Affections of the Joints.—These are unfortunately very common in children. The hip joint is very commonly affected, but the knee and other joints are frequently attacked also. In the earliest stages the condition may be overlooked even by a skilled observer. When the symptoms become more marked, however, parents recognizing from the pain, from the stiffness of the joint, and the presence of a limp that something is wrong usually seek medical advice, and the child is kept at home. It may, however, be the teacher who first suspects the existence of disease, and it is well to remember that a persistent limp in a child is a sign calling for attention as are also a tendency to stand on one leg with one foot resting on the top of the other, and a complaint of pain at the hip or knee.

The usual treatment recommended is absolute rest, by means of splints, good food, and fresh air. While this treatment is going on the child should not attend school; but, occasionally, children are sent to school with the limb in splints. Sometimes, also, parents refuse or neglect to carry out the treatment advised or refuse to consent to an operation, and, the disease becoming less acute, the child is sent to school. In cases such as these the teacher is often at a loss to know whether to send the child home or to admit him and make him as comfortable as possible. The generally accepted opinion is that the confinement in school is bad for the child, even though the affected joint has been put at rest, since the schoolroom air is not always of the purest and the splints may get displaced and exert no beneficial effect whatever. It seems hardly likely that the child's education will suffer to any great extent if he is kept from school for six months or so while the treatment is going on. Teachers are, of course, unwilling to exclude children altogether, and the weakly ones are tenderly cared for, a great amount of trouble being taken to obtain special seats and so on for them. No one knowing these things can fail to be struck by them; but, on the whole, a child with tuberculous disease of one or other of its joints is better not to be confined too much, and the teacher will be well advised to share the responsibility of keeping him at school with the medical officer for the school or the child's medical attendant.

CHAPTER IV

THE MUSCULAR SYSTEM

Chief functions of the muscles—Origin and insertion of a muscle—Structure of tendons—Structure of muscle—Muscular action—Growth of muscle—Voluntary and involuntary muscles—Classification of voluntary muscles—Postures and mal-postures—Physical exercises—Fatigue—Muscles of expression.

THE chief function of the muscles is to produce movements at the joints. Before it can do so each muscle must have an attachment to a more or less fixed point, from which to act, on one side of the joint, and on the other side an attachment close to the joint. The fixed point of attachment is called the *origin* of the muscle, and may be close to or some distance from the joint upon which the muscle acts. The other attachment is called the *insertion*, and usually the muscle, or that part of it forming this attachment, passes over the joint to be inserted on its further side. These attachments or *tendons*, or leaders as they are sometimes called, are made up of a very tough fibrous tissue. Into the fibrous tissue the true muscular tissue is inserted.

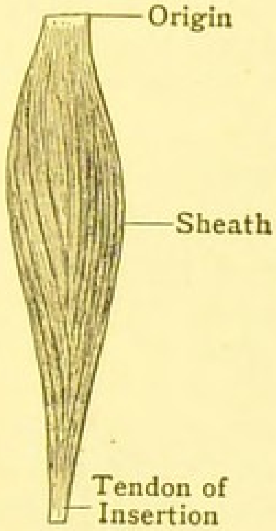


FIG. 17.—A typical muscle. (*From Thornton's "Elementary Physiology."*)

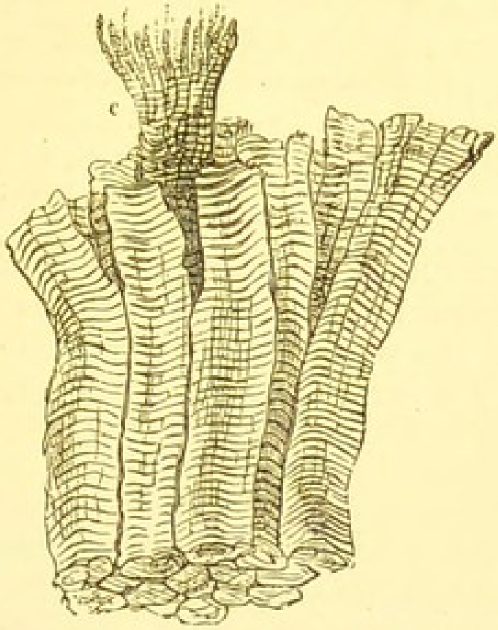


FIG. 18.—Bundles of striped muscle fibres. *c*, fibres separated by teasing. (*From Quain's "Anatomy."*)

Structure of Muscle.—True muscular tissue, which brings about the movements of joints, consists of innumerable microscopic fibres, running side by side, and arranged to form separate bundles. Each bundle is contained within a capsule composed of delicate tissue, and the whole muscle consists of a vast number of these bundles more or less bound together. Each fibre consists of a bundle of very fine fibres or fibrils, surrounded by a sheath and united to its fellows in the bundle by a fine cement-like substance. Examined microscopically, the fibres are seen to be made up of a substance more or less yellowish in colour, and to be marked by bands running across the fibre, bands light in colour alternating with others of a darker colour. Muscles whose fibres present such bands are known as *striped* or *striated* muscles. All the muscles of the limbs and trunk generally, consist of bundles of striped fibres. Each fibre is well supplied with blood, the blood-vessels lying between the fibres outside the sheaths. Each also has a nerve-supply, a fine nerve fibril penetrating the sheath of each fibre and spreading out in contact with the contained substance.

Muscular Action.—When a muscle is called upon to act, the fibres become shorter and thicker. As a result, the whole muscle becomes shorter and thicker, the tendon is pulled upon, and movement at the joint takes place. When the work is done, each

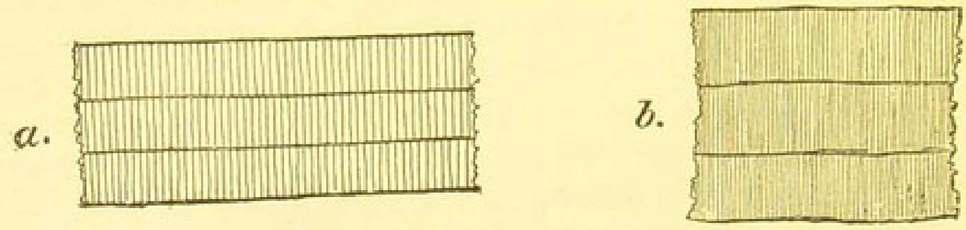


FIG. 19.—Three striped fibres.
a, relaxed; *b*, contracted.

fibre relaxes, returning, on account of its perfect elasticity, to its former length; the pull upon the tendon and the bone ceases, and the position occupied previously is resumed. As an example of a muscle, the simplest is that which occupies the front of the

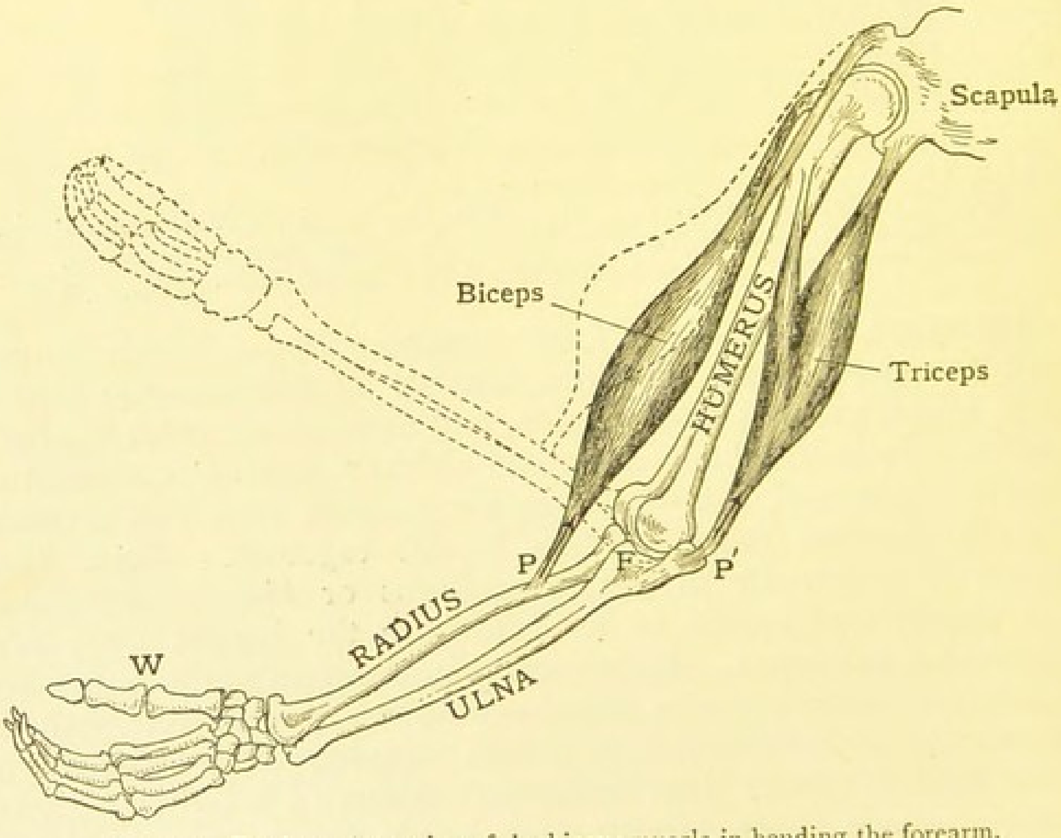


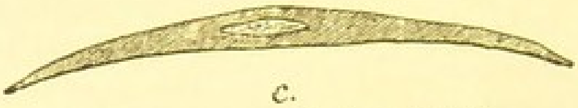
FIG. 20.—To show the action of the biceps muscle in bending the forearm.
(*From Thornton's "Elementary Physiology."*)

upper arm and produces bending of the elbow joint. The tendon of *origin* of this muscle is attached to the scapula, and as it has two points of origin on this bone it is named the *biceps* or two-headed muscle. Its *insertion* is into the radius, and at the bend of the elbow in front the firm, tough tendon of insertion is readily felt. The body of the muscle is made up of ordinary muscle fibres, and occupies practically the whole of the front of the upper arm, giving form to that region. When there is a call for bending of the elbow joint, the fibres contract, and the body of the muscle becomes hard and firm like a ball; the tendon of insertion is pulled upon, and the forearm is approximated to the upper arm, the head of the radius and ulna rotating round the lower end of the humerus. When bending or flexion is ended and the arm is to be again straightened, the fibres relax and gradually resume their former length; the pull on the tendon ceases, and the radius and ulna rotate back over the humerus to take up their old position. The return to the straight position is assisted by the contraction of a muscle on the back of the upper arm, which has three attachments of origin, and is therefore called the *triceps* muscle. It has one tendon of insertion into the ulna.

Growth of Muscle.—Growth of muscle is brought about by the production of new fibres, the result of division of the already existing fibres. This production of fibres is encouraged by increasing the blood-supply to the muscle, and the way to bring this about is by exercising the muscle. Every time the muscle is exercised, as a result of its contraction and diminution in bulk, a great part of the blood contained in it is expressed. When the fibres relax, the blood rushes back in larger quantities, the muscle gets more food, and the fibres are encouraged to divide and add to the number of fibres already present. The whole muscle becomes thicker and therefore stronger. With the ordinary supply of blood sent to an unexercised muscle production of new fibres takes place, but the quality is poor. A certain number of the fibres also become incapable of reproduction and eventually disappear. In this way the muscle becomes smaller, and because the quality of the fibres is poor, it becomes also flabby.

Tone.—In connection with the nutrition of muscle, one important quality must be mentioned. That quality is *tone.* The term tone practically means health. A muscle good in tone is a healthy muscle. All its fibres are healthy, they are firm, well formed, and elastic, ready to act instantly when called upon and to act well. Tone depends upon the quantity and quality of the blood supplied to the muscle, and is, as is natural, improved by exercising the muscle.

Kinds of Muscles.—Broadly speaking, all muscles are divided into two groups, namely, *voluntary* and *involuntary muscles.* Voluntary muscles are those under the influence of the will, and only perform their function when called upon to do so. They form the bulk of the muscles of the body and are all striated muscles. Involuntary muscles perform their functions apart from the will. The muscle forming the heart and that in the wall of the stomach may be taken as examples. Both act apart from the will and continue to act for some time even after death. Structurally, there are several points of difference between voluntary and



c.

Fig. 21.—A non-striped muscle cell.
c, nucleus.

involuntary muscles. The latter are unprovided with tendons of origin and insertion, and are made up of cells distinctly tapering and with a distinct nucleus. The muscular substance is unstriped. The appearances and striping of voluntary muscle fibres have already been described.

Classification of Voluntary Muscles

Voluntary muscles are classified according to their function and are divided into—

(1) **Flexors** or **Benders,** *e.g.* the muscles on the front of the neck; the biceps; the muscles on the front of the forearm, which bend the wrist and fingers; the muscles on the back of the thigh, which bend the knee; the calf muscles, which bend the foot and toes.

(2) **Extensors** or **Straighteners,** *e.g.* those at the back of the neck; those on the back of the upper arm and forearm; those on the front of the thigh and leg; those on the front or top of the foot.

(3) **Rotators** or **Twisters,** *e.g.* those concerned with twisting the radius round the ulna.

(4) **Adductors,** those pulling the limbs towards the middle line of the body, *e.g.* the chest muscles inserted into the inner side of the upper arm; the muscles inserted into the inner side of the thigh; the muscles forming the ball of the thumb; the small muscles in the palm of the hand and the sole of the foot, pulling the fingers or toes towards the middle finger or toe.

(5) **Abductors,** those pulling the limbs away from the middle line of the body, *e.g.* those muscles inserted into the outer side of the arm, of which the muscle known as the *deltoid* is the chief; those inserted into the outer side of the thigh.

Movements produced by Muscles.—The fundamental movements produced by the muscles are *flexion*, *extension*, *rotation*, *abduction* and *adduction*. All other, more complex, movements are merely combinations of these. When they take place at any joint the muscles carrying out the fundamental movements all take part. For example, in *circumduction*, the name given to a twisting-round movement, and one possible only at ball and socket joints, practically every muscle attached to the moving bone is called into play.

It must be borne in mind that no movement of a joint is really a simple thing, since the stimulus producing the contractions of any one muscle calls into play at the same time the opposing muscle. In this way over-action of the muscle is prevented. In bending up of the forearm, for example, the muscles on the front of the upper arm contract, but at the same time the muscles on the back of the upper arm also contract. In straightening of the arm, the triceps, as the muscle chiefly concerned, contracts, but the biceps also contracts slightly and holds the triceps more or less in check. The existence of opponents to muscles must be remembered. The opponents of any muscle or set of muscles are those having exactly the opposite action. Extensors are the opponents of flexors, abductors the opponents of adductors.

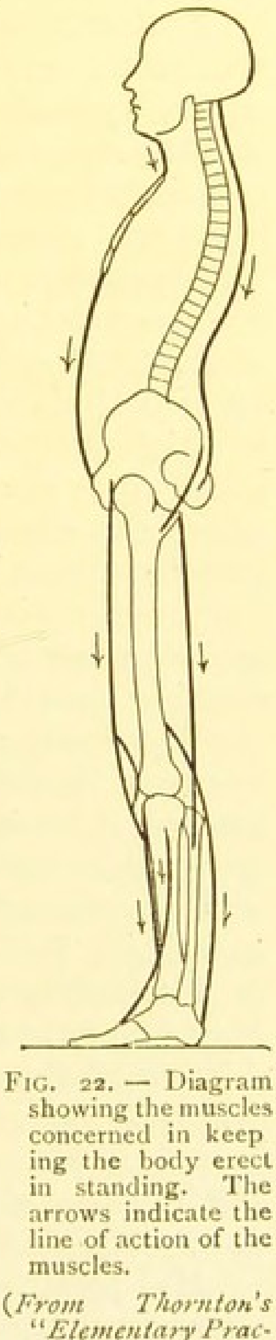


FIG. 22. — Diagram showing the muscles concerned in keeping the body erect in standing. The arrows indicate the line of action of the muscles.

(*From Thornton's "Elementary Practical Physiology."*)

The Part played by Muscles in Certain Ordinary Acts.—In such acts as standing and walking a tremendous number of muscles take part. In sitting and lying fewer muscles are concerned. In the act of *standing*, practically all muscles are stimulated—

The leg muscles to keep the tibia and fibula straight.

The thigh muscles to keep the femur upright.

The hip muscles to keep the pelvis steady.

The trunk muscles to keep the spine erect.

The shoulder muscles to keep the shoulders back.

The neck muscles to keep the head upright.

In *sitting*, muscular action is less. The muscles of the trunk and head are most in use. The work of these, even, is considerably diminished, if the seat be properly constructed and the back supported by a convexity below and a concavity above. The thigh muscles are supported by the seat, which should be sufficiently deep to accommodate at least two-thirds of the length of the thigh. The muscles of the back of the neck are engaged in holding the head upright, and in this they are to be encouraged. In infancy the head tends to fall forward. With advancing years the muscles become stronger, and the nerve centres controlling them learn their duty and how to stimulate them to act. The habit of keeping the head up must be learned in childhood. No child in school should be allowed to drop his head too much over his work, nor be kept so long at any task that the head tends to droop. The neck muscles in the growing child are soft and elastic, but the elasticity may be overcome, and, the muscles becoming elongated, the head droops forward over the chest.

Postures and Mal-postures.—Because sitting and standing require the expenditure of muscular energy, children, as well as adults, try to diminish the amount of energy expended, by taking up attitudes that rest some at least of the muscles. Children especially have to be watched, and any tendency to depart from the proper attitude corrected. The positions in which relief for the muscles in sitting is sought are: (1) that in which the body is slid forward on the seat, the back of the neck and the upper part of the trunk resting on the top of the back of the seat, while the lower part of the back rests on the front edge of the seat; (2) that in which one or both arms are thrown over the desk and the head rested upon them. In both of these attitudes, but especially the latter, the chest is constricted and breathing impeded. In the first, also, there is a tendency to a curvature backwards of the lower part of the spine, especially in badly nourished children. In the second, there is a tendency to a weakening of the neck muscles, to rounded shoulders, and to injury to eyesight.

The position to be taken up by the arms in sitting at attention seems to be difficult to decide, especially when the hands are not holding a book or engaged in some work. Folding the arms across the chest is universally regarded as bad, since it interferes with the movements of the chest, and tends rather to encourage stooping. Folding them behind is unnatural, and moreover leads to a stretching of the muscles of the chest, shoulders, and back. It is infinitely better to tell the children to keep the arms by the sides, the hands resting on the upper surface of the thigh, or to bid them place the arms in the position taken up in breathing exercises, viz. with the hands resting upon the hips. Young children should be allowed full control of their arms, and should not be made to take up artificial attitudes.

Mal-postures in Standing.—In standing, strain is avoided by advancing, usually, the left foot, bending the left knee, and resting the whole weight of the trunk upon the right foot. In this position the left hip and shoulder are lowered, the right being pushed up. The spine is twisted to the left, and the head droops to the right. Curvature of the spine and displacement of internal organs may result. The proper posture is the perfectly erect one, and rest may be obtained by advancing one foot straight in front of the other, the knee remaining unbent.

The Prevention of Mal-postures in School.—Mal-postures are to be prevented by (1) change of position, (2) change of occupation, (3) correction. The necessity for *change of position* arises from the fact that the child is a growing animal, and therefore incapable of remaining long in any one attitude. To force him to do so can only be productive of harm. The changes are to be rung on all possible positions throughout the session of a class. Each lesson, so far as practicable, should be given partly sitting, partly standing. No lesson should last long enough to cause fatigue. *Change of occupation* is necessary for the prevention of fatigue and of mal-postures. Lessons should be interspersed with breathing and other exercises, calling into play muscles that have been inactive. The *correction of mal-postures*, whenever noted, is a part of physical training, and must not be omitted.

Physical Exercises

Physical exercises are divided according to their effect into *nutritive*, *corrective*, or *control* exercises. Lessons may be either *formal*, when they are given as school lessons, or *recreative* when they are given merely to serve as a relief for certain muscles in the course of other lessons.

Educational and Developmental Effects.—Broadly speaking, the effects of physical exercises are educational and developmental, but it is difficult to separate the two effects. In the earlier stages all exercises have an educational effect, being secondarily and only later developmental. *Nutritive exercises* are those which stimulate circulation and respiration. By exercising the larger joints and groups of muscles, as children do in play, circulation and respiration are both stimulated, and the nutrition of all parts of the body is improved. Respiration itself may be stimulated by special breathing exercises, which are therefore nutritive exercises. They are, in addition, largely educational in their effects. They teach the child that the nose is the proper channel through which to inspire; they teach him how air is to be inspired, how it is to be expired, and how the special muscles of expiration are to be used. While these things are being learned, but especially afterwards when the educated muscles are working properly, and the educated nerve centres are stimulating and controlling the muscles, the exercises produce developmental and corrective effects.

Corrective exercises are so called because their objects are the prevention and remedying of defects induced by school conditions. But such corrective exercises as "backward bending," "heels raising," and so on, performed as part of formal lessons, are not to be trusted to entirely to prevent and remedy defects. During the ordinary class work, correct postures should be insisted upon, and the correction of mal-postures must be regarded as part of the physical training.

The so-called *control exercises* are mainly educational in their effect. The will centres are taught how to control the muscles and to regularize their action. The chief examples of such exercises are balancing on a bicycle, on skates, and on stilts. Learning to slide and learning to walk are good examples also of control exercises. In all exercises the muscles are being controlled by the will. The oftener the centres are called upon to exercise their controlling influence the better they can do it, and the more perfect becomes the control.

Of the educational and developmental effects of exercises, the most important for the teacher to aim at obtaining are the educational. They are the less obvious, and therefore are apt to be overlooked. It must always be borne in mind that though the child is born with all its muscles, it has to learn how to use them. The muscles have to learn their function; the nerve centres have to learn how and when to stimulate and to control and regularize the action of the muscles. In the young child the larger muscles and those commanding the larger joints are mostly required. These it first has to be taught how to use. The nerve centres concerned with them have also to be educated. The smaller muscles and those commanding the smaller joints and producing delicate movements are not required in early childhood, and their education and that of their centres need not and should not be hurried.

The education of his muscles the child can really see to himself, and the games he plays are all for the purpose of educating his muscles and their centres. Physical exercises, especially the formal ones, have the same object, but differ in being more direct. The lesson is stripped of all those accessories which, perhaps, in the case of the game, make the lesson interesting. The lesson, however, in physical exercises is, or should be, more accurately taught and learned. The person teaching the muscles how to act should teach them accurately. The movements should be accurately carried out by the teacher, and the child must be watched in order to see that the muscles do exactly what the teacher's muscles are doing. The imitative faculty in children is strongly developed, and the muscles and centres soon learn, but they learn incorrect movements no less readily than correct ones. For the smallest children physical exercises for the large muscles are sufficient. Exercises for the smaller muscles, like those of the hand, should be only gradually given, and only for a few minutes at a time, when the children are fresh. They are likely to be fatiguing, as the brain centres are immature.

The small muscles of the eye-ball, viz. those moving the eyes to the sides and up and down, may be taught fairly early. Quite a large number of young children tend to move the head instead of the eye-balls when looking at a moving object. Such children often appear to be, and are classed as, stupid. For the exercise of these muscles the teacher may use a moving object, *e.g.* something held between the fingers, the hand being moved up and down and from side to side. A swinging ball suspended by means of a string is good, and the eyes of the children should always be watched. In some children the eye muscles have a tendency to act irregularly and jerkily. Such children frequently suffer from headache, and it may be necessary to call the attention of the parents to the eyes, and to recommend that medical advice be taken. The name applied to this condition is *nystagmus.*

For the teaching of physical exercises an accurate knowledge of the anatomy of all the 240 muscles in the body is not essential. It is sufficient for the teacher to know the actions of the various groups of muscles. He should know what muscles are involved in various actions, and should see to it that these are exercised by the pupils in carrying out the actions. All that is necessary the teacher can learn from his own body, by carrying out the movements quietly, and noticing which muscles are active. The physical exercises to be taught, and the effect they are likely to produce, should be thoroughly known by the teacher. The pupils should be instructed what the effect is to be, and must be shown how to produce it. The exercises, both by teacher and pupils, should be performed with the *intention* of producing the effect. The muscles must never be lost sight of. In this way the most satisfactory educational and developmental effects are likely to be produced.

In order to ensure that physical instruction, formal or recreative, shall be a success and beneficial, certain very obvious and elementary details must be attended to.

(1) The instruction is to be given in the purest air possible; in the open air, if it can be so arranged; or, if not, then in a room with the windows open.

(2) The classes for formal instruction should not be too large.

If the classes are too large the teacher cannot be certain that all the children are working with intention and accurately.

(3) Teacher and taught should be on the same level. If the teacher stands on a chair the children have to look up, the eye muscles are fatigued, and a wrong impression of the movements is obtained. If the children are elevated on benches, the freedom of their movements is restricted.

(4) Proper loose garments and proper shoes should be worn.

(5) New exercises should be taken first and should not last too long, since they are likely to be fatiguing.

(6) The children must be told what they are to do and why they are doing it.

(7) The exercises should not be too formal, and should be varied in type as much as possible.

The Recreative Exercises.—The above rules, perhaps, apply more to the formal than to the recreative exercises. The latter are intended merely as a relief from other work and take the place of free play, which would do the children more good. They should, however, be as *free* as possible, and exercises with which the children are already acquainted should be employed. The teacher should insist upon accuracy, and should never permit "slackness" of any description. The windows should, of course, be open.

Fatigue.—In all exercises the teacher must stop short of causing fatigue. The cause of muscular fatigue is the retention in the body of waste poisonous substances, produced by the muscles during their activity. These substances are complex bodies, the simplest being carbon dioxide. They are got rid of by the organs of excretion, the lungs, skin, and kidneys, during rest. If large quantities are produced by excessive muscular activity, elimination is delayed, and a kind of blood-poisoning is produced. The chief signs of this are weakness and flaccidity of the muscles leading to a failure of co-ordination of the muscles, and inaccuracy in carrying out various movements. The muscular tone is lowered, the poisonous materials acting mainly upon the nerve centres controlling the muscles. Unless the quantity of poison is excessive, other brain centres, those concerned with purely intellectual functions, are little affected, and good work from these is possible and may even prove restful. It has been shown, however, that after a lesson in gymnastics the intellectual functions are not so well carried out as before. The stupidity of certain girls in the forenoon is possibly due to muscular fatigue produced by doing part of the housework before coming to school. The backwardness of many "half-timers" is probably due to muscular fatigue also, to a certain extent. Children who are readily fatigued by physical exercises, or who easily get breathless, should be specially looked for, and the amount required of them reduced, if necessary. An attempt should be made to discover why these children can stand less, by obtaining the advice of an expert. The cause may be a want of, or insufficient, food, or organic disease of the heart or lungs, etc., conditions to which attention will be directed later.

The Muscles of Expression.—Though not of importance in connection with physical exercises a word or two may be said here

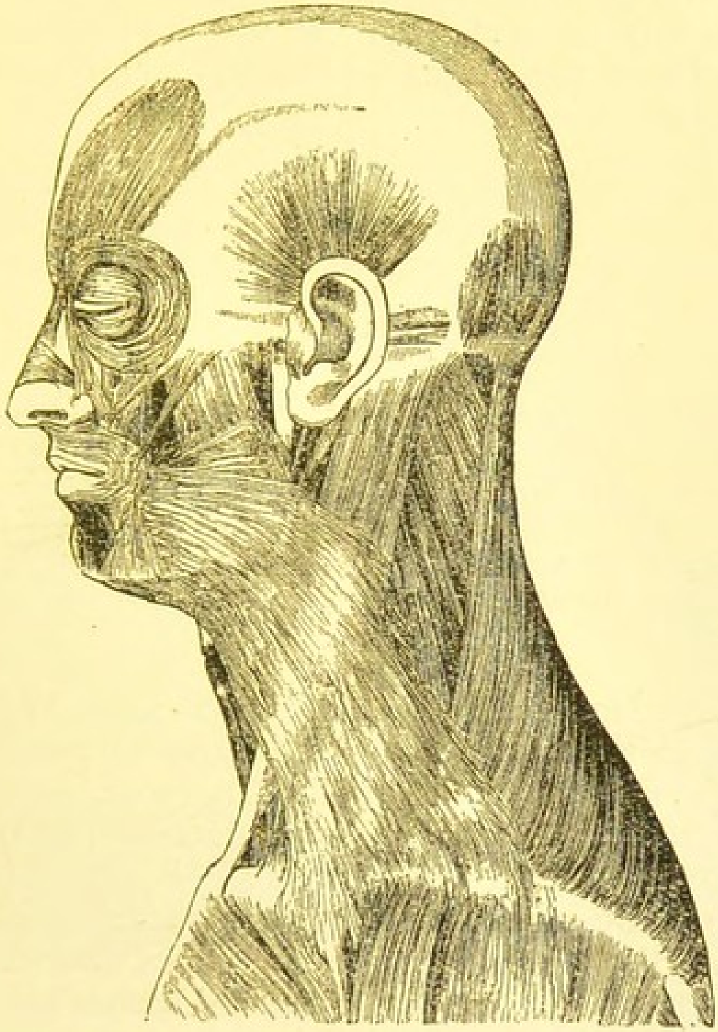


FIG. 23.—Side view of the muscles of the face and neck. The orbicular muscle of the mouth and of the left eye and the left frontalis muscle are shown.

(*From Furneaux's "Elementary Physiology."*)

with regard to some of the muscles of expression. Those of the forehead and round the eyes and mouth are most important. The muscles on the forehead are those named the *frontalis* and the *corrugator* muscles. The muscles surrounding the eyes and mouth are known as the *orbicular* muscles. The frontalis muscle raises the eyebrows and wrinkles the brow transversely; the corrugator muscles contract the brows, producing vertical furrows. The orbicular muscles of the eyes close the eyelids; the orbicular muscle of the mouth commands the lips. In nervous, excitable children irregular action of the frontal and corrugator muscles and of the orbicular muscle of the mouth is apt to occur, and over-action of these muscles is an almost certain sign of over-pressure. In fatigue the orbicular muscles of the eyes are the earliest affected and suffer in tone. Consequently they relax, and puffy and baggy eyelids result. The occurrence of either of these phenomena is an indication that a rest is required, or a breakdown may follow. If not marked, change of occupation may be sufficient. If marked, absolute rest may be necessary. In any case the teacher should be acquainted with these signs, and should be prepared to prevent their occurrence.

CHAPTER V

THE CIRCULATORY SYSTEM

Component parts of the system—The heart—The blood-vessels—The blood—The circulation through different parts of the body—Conditions affecting the heart and blood.

THE chief function of the circulatory system is the carrying of nourishment, in the form of blood, to the various parts of the body, though it also serves another purpose, namely, that of taking away from the tissues waste products which are afterwards to be expelled by the excretory organs. For the carrying out of these functions the circulatory system is made up of (1) vessels through which the blood reaches the tissues named *arteries*, and vessels through which it returns from the tissues after these have been nourished, and have added to it their waste products. These latter vessels are the *veins*. (2) The *heart*, the organ which drives the blood into the arteries, receives it from the veins and sends it to be purified before once more sending it back to the tissues. (3) The flourishing fluid itself, viz. the *blood*.

The Heart.—The heart is a hollow muscle situated in the thorax. It is placed obliquely, and the greater portion is to the left of the middle line. It is made up of involuntary muscular tissue, consisting of cells oblong in shape with short stripes running across them, and provided each with a nucleus. The heart is surrounded by a bag of firm fibrous tissue, called the *pericardium*, which is attached below to the *midriff* or *diaphragm*, a sheet of muscle separating the thoracic from the abdominal cavity, and above to the great vessels that enter and leave the heart.

The *pericardium* consists of two layers, one closely investing the heart and adhering to it, the other loosely surrounding it. The pericardium is really a sort of double bag, one, the outer, closely, the inner, which is continuous with the outer, loosely

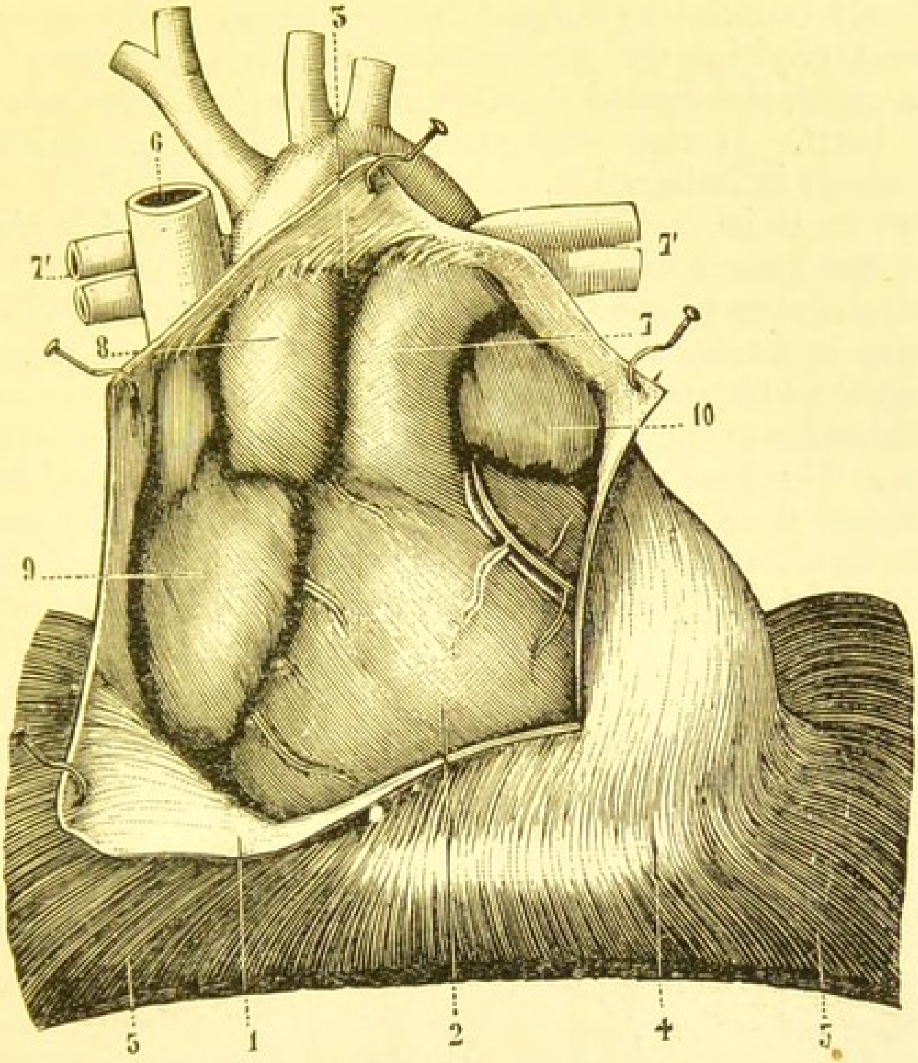


FIG. 24.—Front view of the heart in the pericardium.

1, the outer layer of pericardium cut and hooked back to show—2, front of right ventricle covered by inner layer of pericardium; 3. attachment of pericardium to great vessels at the base; 4, attachment to 5, the diaphragm; 6, superior vena cava; 7, pulmonary artery; 7, its branches; 8, aorta; 9, right, and 10, left auricle.

enfolding the heart. The outer surface of the bag closely adhering to the heart, and the inner surface of that covering it, are smooth and shiny, and between them there is a space which permits of variations in the size of the organ. The smoothness of these two surfaces is due to the presence of a *serous membrane*, the cells of which secrete a fluid called *serous fluid*. This fluid, being poured into the space in which the heart moves, facilitates the movements of the organ, which are, alternately, contraction and dilatation.

The heart, as it lies in the chest cavity, bears certain relations to other organs. On either side it has a lung; below it, but separated from it by the diaphragm, lies the stomach, and behind it runs the gullet and part of one of the large vessels springing from the heart, viz. the *aorta*. The anterior surface is almost completely covered by lung. The proximity of the stomach to the heart explains the unwisdom of taking any severe exercise after a meal, the dilated stomach interfering with the movements of the heart. It also accounts for the palpitation which sometimes occurs in indigestion.

The heart in the adult weighs about 9 ozs., and is about the size of the closed fist of the individual. It is conical or pear-shaped, the apex of the cone pointing downwards and to the left, the base upwards, and to the right. The apex lies normally between the fifth and sixth ribs on the left side about 3 inches from the left border of the breast bone. The under side lies on the diaphragm. The base gives origin to the great vessels, and the front surface and the sides are almost completely covered by the lungs.

The Cavities of the Heart.—The hollow interior of the heart is divided primarily into two halves, right and left, by a muscular

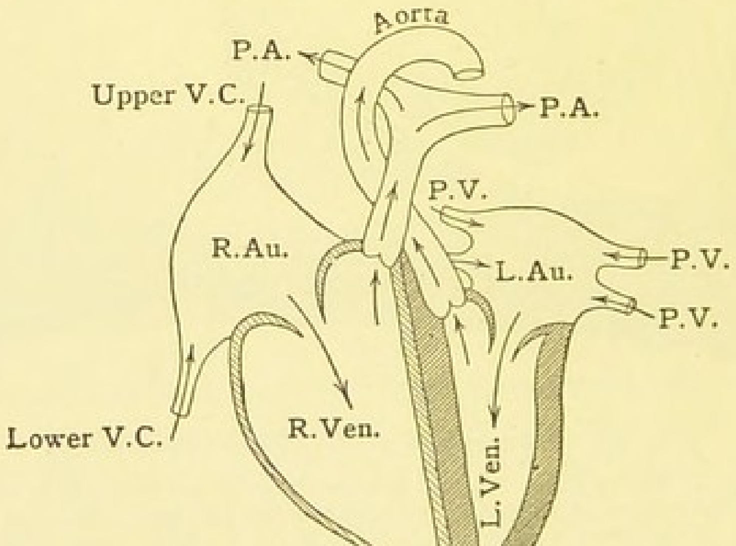


Fig. 25.—Diagrammatic section of the heart, to show its chambers and the direction of blood flow on each side.

V.C., vena cava; P.A., pulmonary arteries; P.V., pulmonary veins.

(*From Thornton's "Elementary Physiology."*)

partition extending from the apex to the base. Each half is further, though less completely, divided into an upper and lower chamber, a distinct way of communication being left between them. The two upper chambers thus formed are called *auricles*, right and left, respectively, the two lower are named *ventricles*, again right and left. The function of the auricles is mainly to receive blood; that of the ventricles to discharge it. The cavities on the right side deal with impure blood which has circulated through the body, those of the left side with pure blood which is to be sent to the tissues and organs. The blood in its course through the heart passes first to the right side, reaching the left side only after having passed through the lungs. In an examination of the heart, it is simpler to follow the same course, beginning first with the right auricle.

The Right Auricle.—This cavity lies immediately above the right ventricle, and forms part of the base of the heart. It is called auricle because it more or less resembles an ear in shape. The walls of the cavity are thin and lined, like the other cavities, with a delicate membrane consisting of cells to which the name *endocardial membrane* or *endocardium* is applied. Attached to its outer surface there is an appendage shaped like a dog's ear, and called the *auricular appendage*. Into this cavity there are two main openings, and out of it one. The openings into it are those of the great veins, the *superior* and *inferior vena cava*. The former collects blood from the head, neck, arms, and thorax, the latter, from the legs and abdomen. The small veins bringing back the blood which has nourished the heart itself also open into this cavity. The opening out of the right auricle is into the right ventricle, and through it these two cavities communicate. This communication between the right auricle and the right ventricle is called the *right auriculo-ventricular opening*, and it is guarded by a valve with three delicate flaps or cusps. It is named the *tricuspid valve*. The flaps do not hang free, but are attached below to small muscular elevations or *papillæ*, on the wall of the ventricle, by fine thin cords called *chordæ tendineæ*. The function of the valve is to prevent blood from passing from the right ventricle to the right auricle while, at the same time, permitting it to pass from the auricle to the ventricle. The function of the chordæ tendineæ is to prevent the flaps from being washed back into the auricle by the eddies set up in the blood. If, by disease or any other means, any part of the valve is thrown out of gear, blood passes back from the ventricle to the auricle, and symptoms of heart disease are produced.

The Right Ventricle.—The right ventricle is larger than the right auricle, and its walls are thicker and more muscular because they have more work to do in driving the blood through the lungs. In the right ventricle there are two openings: the *auriculo-ventricular* into it, already described, and the opening of the *pulmonary artery* out of it. This latter opening lies at the upper left-hand corner of the ventricle, and through it the venous blood passes, to be carried by the pulmonary artery to the lungs for purification. The orifice of the pulmonary artery is guarded by

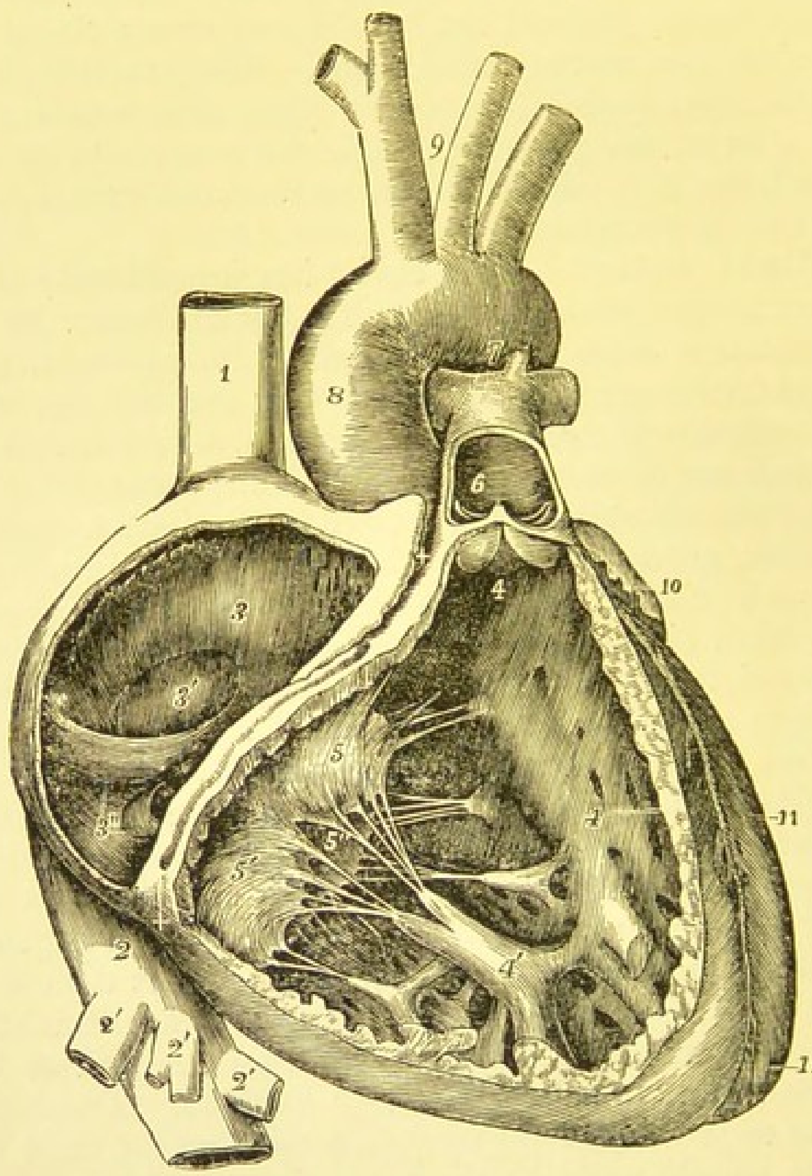


FIG. 26.—Interior of right auricle and ventricle.

1, superior, and 2, inferior, vena cava; 2', hepatic veins; 3, right auricle; 4 and 4, on inter-ventricular septum; 4', a papillary muscle; 5, 5', 5'', segments of tricuspid valve, attached by chordæ tendineæ to papillary muscle; 6, in pulmonary artery above semi-lunar valves; 7, division of pulmonary artery; 8, aorta; 9, placed between innominate and left common carotid artery; 10, left auricular appendage; 11, left ventricle.

(*From Quain's "Anatomy."*)

a valve with three cusps semi-lunar in shape, opening in one direction only, viz. towards the artery. They permit blood to flow from the ventricle into the artery, but prevent its return. This valve, on account of the shape of its cusps, is known as the *semi-lunar valve.*

The Left Auricle.—The left auricle in appearance resembles the right auricle. Into it open the vessels carrying purified blood from the lungs, and which may be either three or four in number.

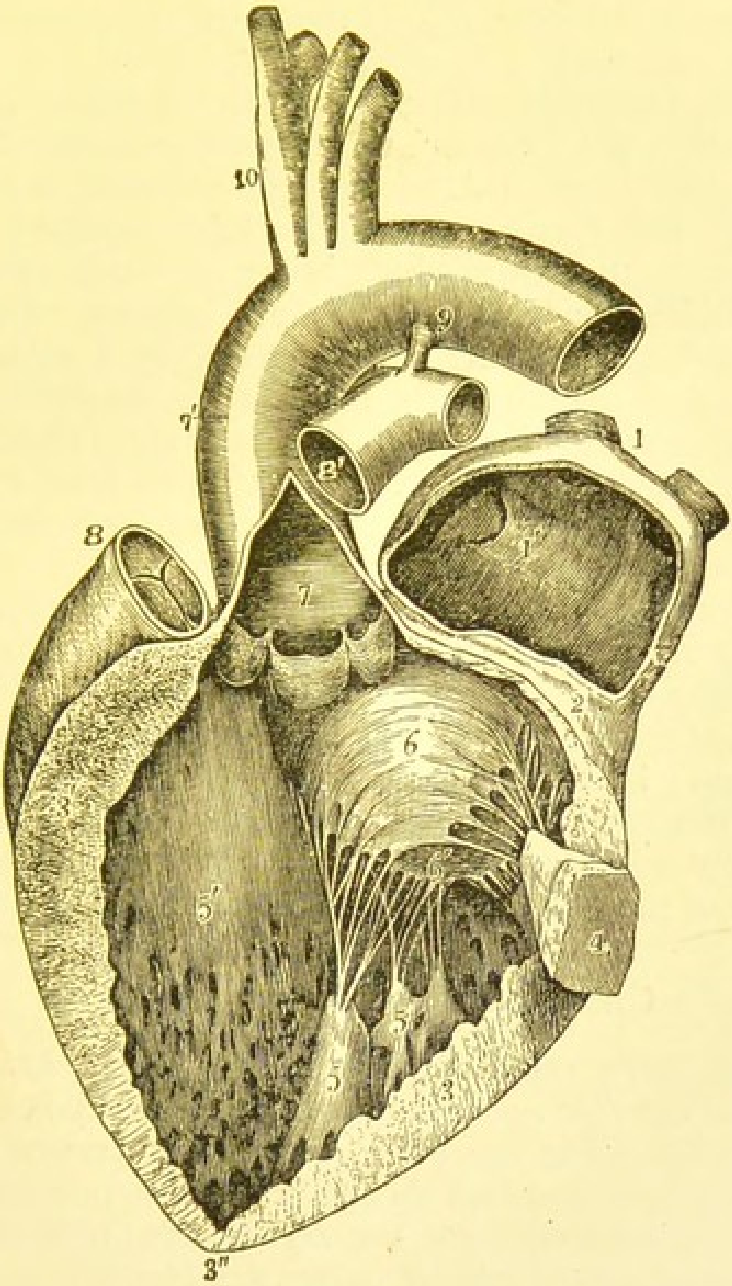


FIG. 27.—Interior of left auricle and ventricle.

1, pulmonary veins; 1', interior of left auricle; 2, part of wall of auricle; 3, 3', wall of left ventricle; 3", apex of left ventricle; 4, part of wall with papillary muscle attached; 5, papillary muscles; 5', left side of inter-ventricular septum; 6, 6', flaps of mitral valve; 7, interior of aorta, above the valve; 7', aorta; 8, 8', pulmonary artery cut across; 10, branches from arch of aorta.

(*From Quain's "Anatomy."*)

These, although they carry pure and therefore arterial blood, are, nevertheless, called the *pulmonary veins*. There is one opening out of the left auricle. This is the *left auriculo-ventricular opening*, which forms the communication between the left auricle and the left ventricle. Like the right auriculo-ventricular opening, it is guarded by a valve, which, however, has only two flaps. These two flaps form something resembling a bishop's mitre, and the valve is called the *mitral valve* or, sometimes, the *bi-cuspid valve*. The flaps, as on the right side of the heart, are attached by chordæ tendineæ to papillæ.

The Left Ventricle.—The left ventricle has a much thicker wall than the right because its work is greater. Its cavity is circular in shape, while that of the right ventricle is crescentic or semi-lunar. The opening out of the left ventricle is that of the largest artery in the body, which bears the name of *aorta*. The opening of this artery is called the *aortic opening*. Like the opening of the pulmonary artery, it is guarded by a valve with three semi-lunar flaps, opening only towards the artery. The wall of the artery immediately beyond these three flaps is slightly expanded to form three dilatations. From two of these there pass the small *coronary arteries* to nourish the substance of the heart, which takes nothing directly from the blood filling its cavities.

The cavities of the heart are separated one from another by partitions or *septa*. The partition between the auricles is named the *inter-auricular septum*, and that between the ventricles the *inter-ventricular septum*. Before birth the inter-auricular septum is incomplete ; later in life the communication disappears. Sometimes children or adults are found with the opening unclosed, and serious symptoms are produced as a result of the mixing of the pure blood of the left side with the impure blood of the right.

Circulation through the Body

The two large veins opening into the right auricle, viz. the *superior* and *inferior vena cava* are built up of smaller veins named *branches*, which bring the blood back from various parts of the body after it has nourished them. The most important branches of the inferior vena cava are the *hepatic veins* from the liver. By these is carried all the impure or venous blood from the stomach and intestines and the glands connected with digestion, which passes through the liver before it reaches the inferior vena cava. This part of the circulation is called the *portal circulation*, and its composition is as follows :—the blood which has nourished the part of the large intestine on the left side of the abdomen and the spleen, is collected by small veins which unite to form a vessel named the *inferior mesenteric vein*. That which has nourished the stomach, the small intestine, and the parts of the large intestine on the right side and upper part of the abdomen, is collected by veins which unite to form the *superior mesenteric* *vein.* The superior and inferior mesenteric veins unite to form the *portal vein,* which passes through the liver. The blood in the portal vein being blood which has nourished the tissues, is *venous* blood, but in addition it contains the fruits of the digestion of food in the alimentary canal. For this reason it passes to the liver where the fruits are deposited, the blood afterwards passing on to fall simply as venous blood into the inferior vena cava. When the portal vein reaches the liver it divides into two. One division or branch passes to the right half of the liver, the other to the left. Each division breaks up into smaller and smaller branches, which spread throughout the substance of the organ. In this way every part of the liver gets some of the blood from the alimentary canal, and from it some of the digested food. When all the digested material has been removed by the liver, the blood has to be passed out of it again. For this purpose another set of small vessels is provided. Into these the blood is poured from the small divisions of the portal vein. These small vessels unite to form larger vessels, which pass out of the liver and open into the inferior vena cava. The large vessels are named the *hepatic veins.*

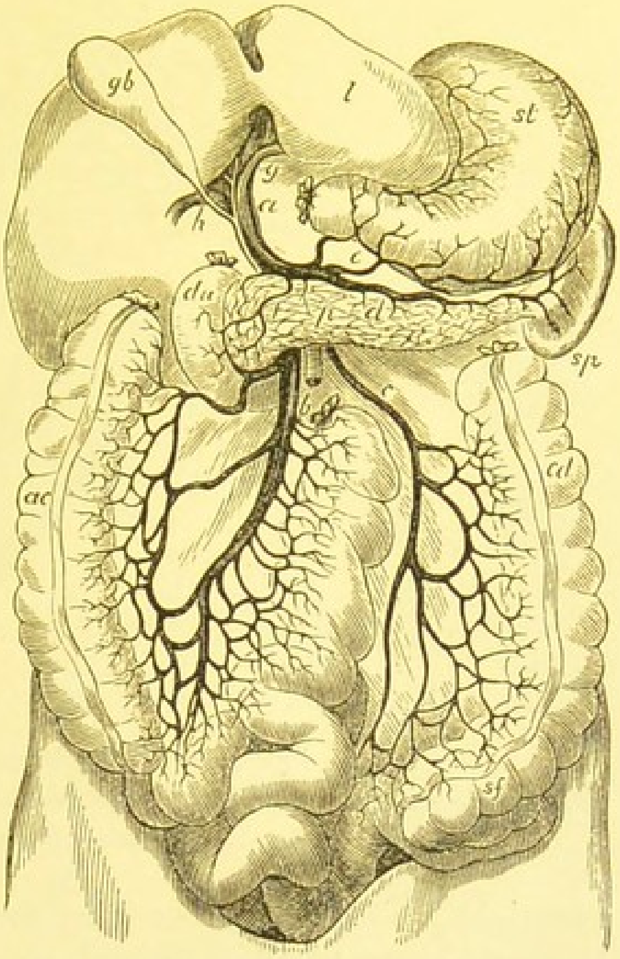


FIG. 28.—The portal vein and its branches.

a, portal vein; *b*, superior, and *c*, inferior, mesenteric vein; *g* and *h*, divisions of the portal vein; *l*, liver; *gb*, gall bladder; *st*, stomach; *sp*, spleen; *cd*, descending colon; *sf*, sigmoid flexure; *ac*, ascending colon; *du*, duodenum; *p*, pancreas.

The Circulation through the Lungs.—When the heart contracts, the auricles contract first, and the blood in them is sent into the ventricles. Almost immediately afterwards the ventricles contract, the contained blood being discharged—that in the right ventricle into the pulmonary artery, that in the left ventricle into the aorta. The blood which passes into the aorta passes through the body generally; that passing into the pulmonary artery is carried by it to the lungs, and its course through these may now be traced. Having contracted, the heart relaxes, and the blood in the pulmonary artery tends to run back again into the right

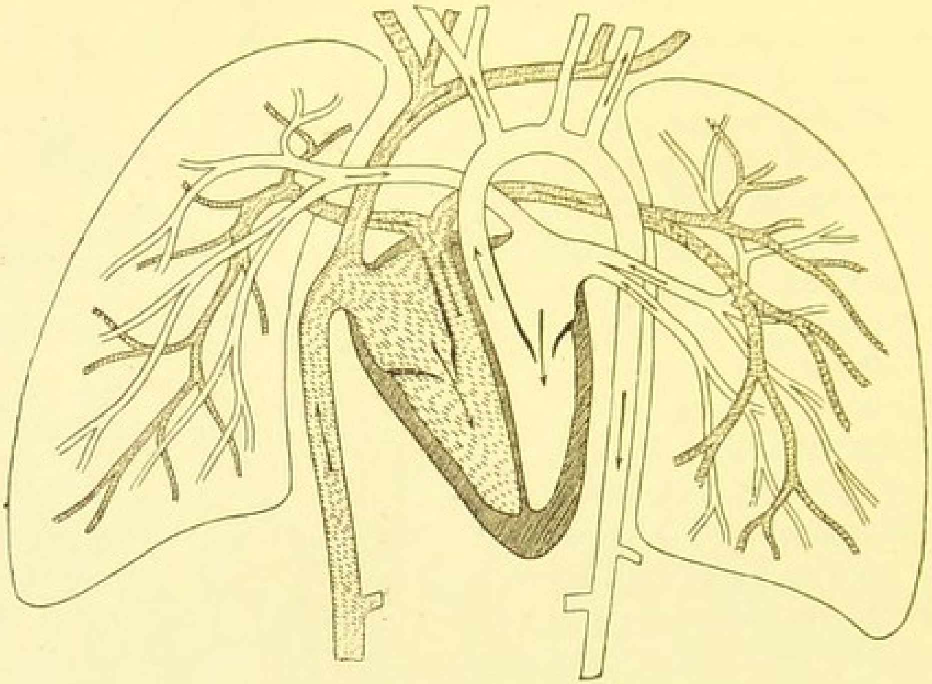


FIG. 29.—The circulation through the lungs.
The shading indicates venous blood. The arrows indicate the direction of the blood-stream.
(*From Furneaux's "Elementary Physiology."*)

ventricle. This is prevented by the valve already mentioned, viz. the semi-lunar valve. Forced, on account of this opposition, to pass in the other direction, it goes onwards till it comes to a point where the artery divides into two, viz. the *right* and *left pulmonary artery*. Here the stream of blood divides also, and part goes along the right pulmonary artery to the right lung, and part along the left pulmonary artery to the left lung. On its way through the lung, each pulmonary artery breaks up into smaller and smaller branches, till finally these merge into the fine branches of the pulmonary vein, by which the blood is carried back out of the lung to the left auricle. The very fine branches which form the junction between the artery and the vein are called *capillaries*.

Changes in the Blood in the Lungs.—In its passage through the lung the blood has undergone a change, for whereas it entered the lung in the pulmonary artery as *dark-coloured venous blood*, it leaves it, in the pulmonary vein, as *bright red arterial blood*. This change is due to oxygenation, or taking up of oxygen by the blood. In the lung the blood is brought into contact with the air drawn in with each breath, and gives up to the air carbonic acid gas, collected from the tissues in its journey through the body, receiving in exchange oxygen, which it carries with it to nourish the tissues. The change in colour is due to a chemical reaction, the oxygen forming with one of the constituents of the blood a definite chemical compound.

Blood

If a drop of blood be examined with the naked eye, it seems to be merely a thickish fluid, more or less dark red in colour. If, however, a drop be examined with a microscope, it is seen to consist of bodies, called *corpuscles*, floating in a clear fluid. The fluid is called the *plasma*, the corpuscles are *red blood corpuscles*, *white blood corpuscles*, and *blood plates*. The blood plates usually occur in clusters, resembling bunches of grapes, and their function is unknown.

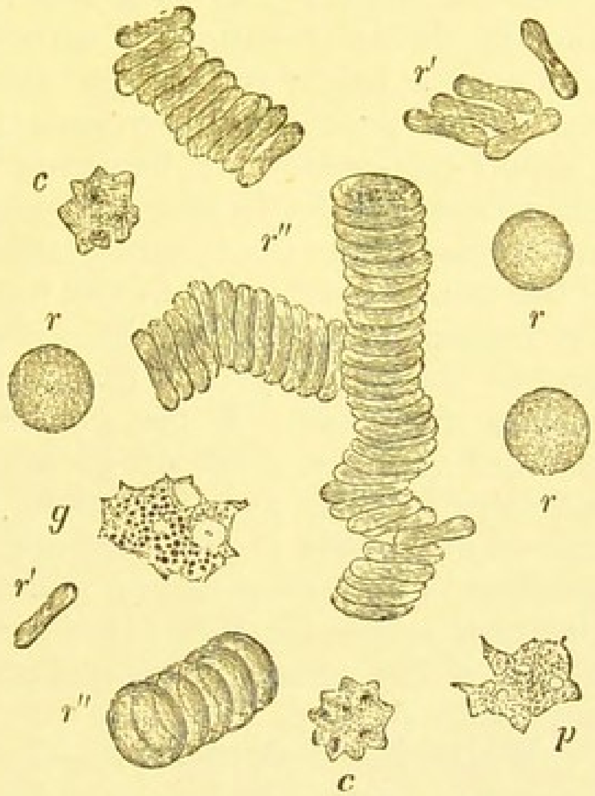


FIG. 30.—Blood as seen under a microscope.
r, red blood corpuscles lying flat, *r'* on edge and viewed in profile; *r''*, rouleaux of red blood corpuscles; *p* and *g*, white blood corpuscles.
(*From Quain's "Anatomy."*)

Red Blood Corpuscles.—The red blood corpuscles under the microscope are seen to be rounded cells, darker at the centre than at the edge, because they are concave on both surfaces, and the central part is out of focus when the outer part is in focus. The greater number of these corpuscles run together into what are called *rouleaux*, on account of their resemblance to piles of coins. Some may be seen lying flat, and others on the edge. The rouleau is, however, characteristic. It is to these corpuscles that the blood owes its colour, and it is in them that the oxygen is carried to the various parts of the body. In the red blood corpuscle is a substance called *hæmoglobin*, which has a great affinity for oxygen, and seizes it readily; fortunately, however, it as readily gives it up to anything which may call for it. In the lungs, the hæmoglobin in the red blood corpuscles takes up oxygen, and forms *oxy-hæmoglobin*. This substance is red in colour, and to it is due the bright red colour of arterial blood. In its journey through the body, the hæmoglobin gives off the oxygen to the tissues, and the blood loses its red colour, taking on the darker colour of venous blood. From the tissues also it takes up carbonic acid gas, which it carries to the lungs to be got rid of.

Another gas for which hæmoglobin has an affinity is *carbon monoxide*. This unites very firmly with hæmoglobin, which it hinders from taking up oxygen. If this gas be present to any great amount in the air breathed, the hæmoglobin seizes upon it instead of oxygen, and as a result death may follow. Curiously enough, the combination of carbon monoxide with hæmoglobin produces a bright red colour also, differing, however, from the red colour produced by oxygen in that it is more permanent. Carbon monoxide may be found in classrooms where cast-iron stoves are used for heating purposes, or coal gas as an illuminant. In the case of the stove, carbon monoxide is likely to be produced if the iron is overheated to any extent. In the case of coal gas, the carbon monoxide will be found if an escape of gas should occur. In ordinary coal gas there is about 6 or 7 per cent. of carbon monoxide. If the gas be mixed with carburetted water gas the quantity is about 30 per cent. A very small leak is sufficient to give rise to trouble, and instances of illness being caused in schools in this way are not wanting. The symptoms produced by inhaling carbon monoxide are headache, a feeling of tightness across the chest, giddiness, fainting, and impairment of health, if the person is compelled to inhale small quantities for any length of time.

White Blood Corpuscles.—The white blood corpuscles are irregular in shape, and do not form rouleaux. They are not so numerous as the red corpuscles, being in the proportion of about one to five hundred of the latter. In the blood vessels, they occupy the part of the blood stream near the walls. They play a part in the prevention of disease by absorbing bacteria. They also probably play some part in the clotting of the blood. It is suggested that they produce a body resembling such a ferment as rennin—the milk-curdling ferment. This substance acts upon a constituent of the blood plasma, which is known as *fibrin*. The substance is itself usually called *fibrin ferment*, and it coagulates or curdles the fibrin which entangles in its meshes the various blood corpuscles and leads to the formation of the blood clot. After a time the blood clot contracts, and the fluid part of the plasma is expressed. To this fluid the name *blood serum* is given. This process of clotting is nature's method of stopping bleeding.

Pulmonary Veins.—After it has been ærated or oxygenated the blood passes into the *pulmonary veins*. These, in some individuals, are three in number, in others four. In such cases as there are three, two come from the right lung and one from the left; if there be four, two veins come from each lung. They open into the left auricle. From the left auricle the blood which has reached it through the pulmonary veins passes through the bi-cuspid or mitral valve into the left ventricle. This passage from the left auricle to the left ventricle takes place when the heart muscle is relaxing and the heart is dilating. When the heart contracts again the mitral valve closes, and the blood is shot from the ventricle through the aortic valve into the aorta to pass thence into all the arteries of the body. The passage back into the ventricle is prevented by the closure of the aortic valve. This part of the circulation is known as the *systemic circulation*.

Systemic Circulation.—The *aorta*, which forms the beginning of this part of the circulation, is really the parent of all the other arteries in the body. From the point at which it commences it bends like an arch over the base of the heart, and for the sake of description it is divided into three portions: (1) the *arch of the aorta;* (2) the *thoracic aorta*—the part lying in the thorax; (3) the *abdominal aorta*—the portion found in the abdomen.

From the first portion or arch five smaller branches are given off. These are the two *coronary arteries*, which nourish the substance of the heart, and three branches for the supply of the head and neck, and upper extremities. These last three branches come off from the top of the bend, and from right to left they are named: (1) the *innominate artery;* (2) the *left common carotid artery;* (3) the *left subclavian artery.*

The *innominate artery* after a short course divides into two branches, the *right common carotid* and the *right subclavian.* The common carotid arteries, the right springing from the innominate artery, and the left from the arch of the aorta, pass up into the neck and can be felt beating deep down by the side of the windpipe. On each side of the neck the artery divides into the *external* and *internal carotid.* The external supplies the various structures and tissues about the face, the scalp, the neck, the gullet, and so on. The internal goes inside the skull to supply the brain. In this it is assisted by a branch from the subclavian artery on each side, the branch being named the *vertebral* artery. The vertebral arteries, right and left, enter the skull separately, but once inside they unite. The resulting vessel again breaks up into numerous smaller branches which unite with branches from the internal carotid. The union of these branches is exceedingly important, since it assures the brain of a full blood supply in the event of an accident to one or other of the main blood-vessels supplying it.

The *subclavian* arteries are the vessels supplying the arms, the

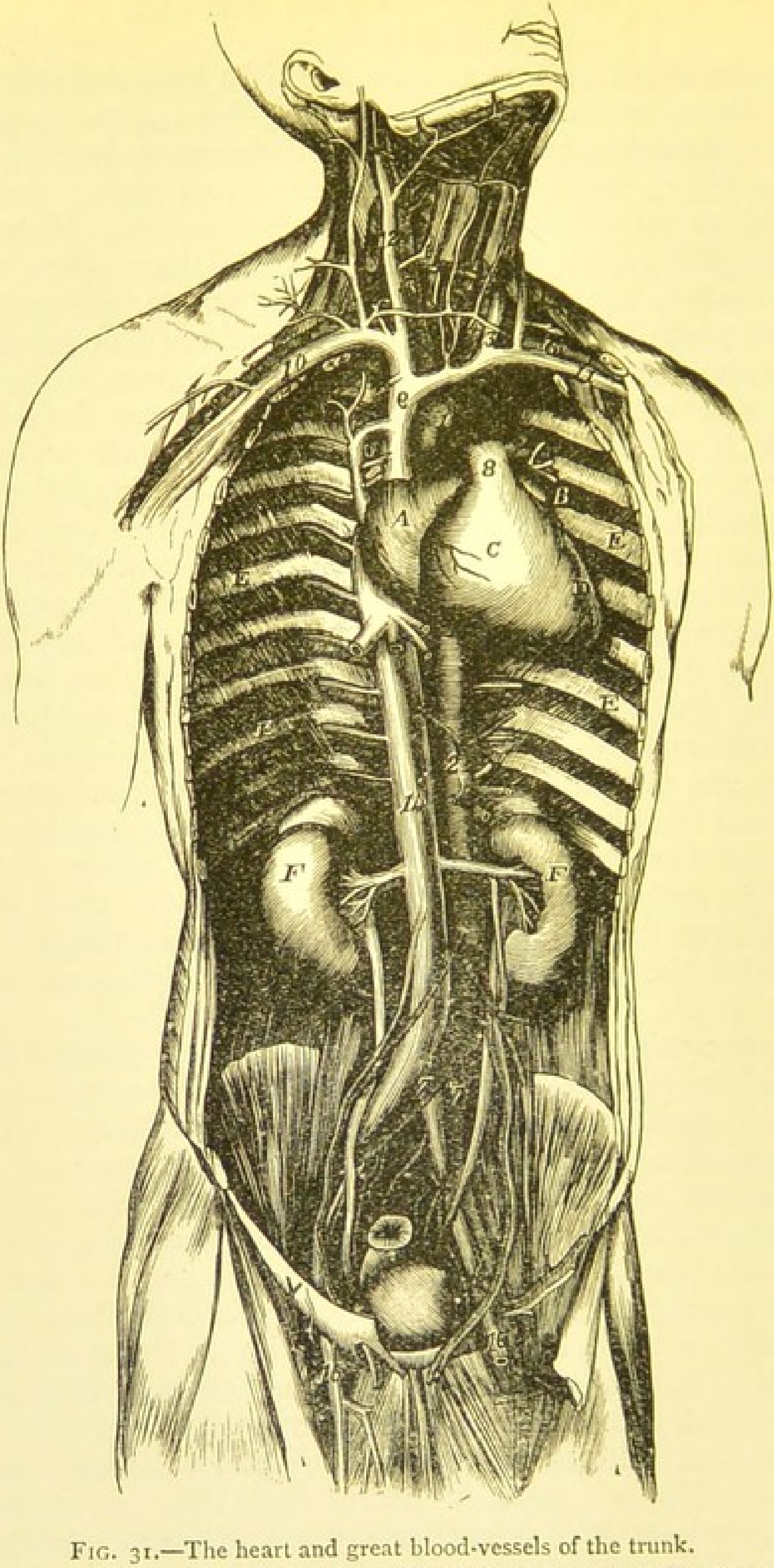


FIG. 31.—The heart and great blood-vessels of the trunk.

A, right auricle ; *B*, left auricle ; *C*, right ventricle ; *D*, left ventricle ; *E*, ribs ; *F*, kidneys ; 1, arch of aorta ; 2, abdominal aorta ; 3 and 4, right and left common carotid arteries ; 5 and 6, right and left subclavian arteries ; 7, common iliac arteries ; 8, pulmonary artery ; 9, superior vena cava ; 10 and 11, right and left subclavian veins ; 12 and 13, right and left jugular veins ; 14, inferior vena cava ; 15 and 16, veins from lower extremities.

(*From Furneaux's "Elementary Physiology."*)

right going to the right arm, the left to the left arm. The arteries pass out of the thorax by bending over the first rib under the clavicle, hence the name subclavian, giving off the vertebral artery on the way. Thence each passes into the armpit of its own side changing its name then to *axillary*, *axilla* being the anatomical name for the armpit. The numerous tissues in the armpit are nourished by branches from this artery, which then passes on into the upper arm, where again it changes its name to *brachial*. In the arm the brachial artery lies first on the inner side, and is comparatively superficial, being situated almost exactly under the inner seam of the coat-sleeve. Here it may be pressed if there should be great bleeding from the forearm or hand. Passing round to the front of the arm, having given off branches to the various muscles and other tissues, at the bend of the elbow the artery divides to form the *radial* and *ulnar* arteries. The *radial* runs comparatively superficially along the outer side of the front of the arm, nourishing the tissues by means of branches as it goes on. At the wrist it is most superficially placed, and since its pulsation at this point can be easily felt, it is here that the rate of the pulse is usually counted. At the wrist the artery bends round the root of the thumb and reaches the palm of the hand by passing between the first and second meta-carpal bones. The *ulnar* artery lies deeper than the radial. Eventually it reaches the wrist and then passes into the palm to meet and unite with the radial artery. By this union a kind of arch is formed from which branches are sent up along the fingers for their nourishment.

The Thoracic Aorta.—The second portion of the aorta or thoracic aorta runs straight down through the thorax, lying on the back wall to the left of the spinal column behind the gullet. In its course it gives off branches carrying nourishment to various structures, the chief being twelve on each side which pass along between the ribs to nourish the muscles and bones. These are named the *intercostal* arteries. At the level of the twelfth dorsal vertebra the artery leaves the thorax, passing through a special opening in the diaphragm into the abdomen to form the abdominal aorta.

The Abdominal Aorta.—The abdominal aorta gives off branches which convey blood to the liver, the stomach, the intestines, the spleen, the kidneys, and so on. About the level of the fourth lumbar vertebra it divides into two branches, the *right* and *left common iliac arteries*. These are short and soon divide into the *internal* and *external iliac* arteries. The *internal iliacs* nourish, mainly, the structures and tissues in the pelvis. The *external iliacs*, right and left, escape from the abdominal cavity into the thigh at a point midway between the tip of the prominence of the haunch bone and the symphysis pubis. At this point the artery may be pressed in the case of severe bleeding in the leg. At this point, also, the artery changes its name and is called the *femoral* artery. In the thigh the femoral artery takes a course downwards and inwards, twining round the femur, more or less, till eventually it reaches the back of the knee joint. Throughout this course it has been occupied in giving off branch arteries to the tissues of the thigh, muscles and bone alike, and at the back of the knee it divides into two. One branch goes to the front of the leg, the other keeps to the back. The former is the *anterior*, the latter the *posterior tibial artery*. These run down towards the ankle and foot, meeting to unite in an arch in the sole of the foot from which branches are given off to nourish the toes.

The Veins.—The blood having passed from the heart to the tissues through the arteries it is necessary for it to return to the heart again in order that it may be sent once more to the lungs for aeration. The journey back to the heart is made through the veins, and wherever there is found an artery there also is a vein corresponding to it, but with the blood flowing in the opposite direction. In addition to the veins corresponding to the arteries and lying fairly deeply amongst the tissues there are superficial veins under the skin. By these veins the blood from the skin and the tissues immediately under it is collected. These unite with the deeper veins which pass through the deeper tissues to reach them.

Throughout the course of every vessel communications are established with other vessels in its neighbourhood by means of small connecting branches. As a result of this communication, if one vessel happens to get blocked, it is ensured that the blood shall reach its destination, though by a more circuitous route. The names artery and vein were applied by the ancient physicians who thought that the arteries, which were always found empty after death, carried air, and that the veins, which were always found full, carried the various humours which nourish the tissues. The blood from the artery passes to the vein through exceedingly minute vessels named *capillaries*. These are produced by the continual branching of the artery and vein, the former to carry blood to every piece of tissue, the latter to collect it. These minute branches of the arteries and veins in their peregrinations finally meet and unite. Through their union a communication between the artery and vein is brought about, and the circle from the left side to the right side of the heart completed. The tiny vein capillaries themselves unite to form larger veins which in turn unite to form veins still larger till the main veins of the limbs and so on result. These main veins finally join the great veins, the superior and inferior venæ cavæ, which open into the right auricle, the starting-point of the circulation through the lungs.

Structure of Arteries and Veins.—In structure arteries and veins differ in respect of their thickness only, the walls of the arteries being the thicker. The wall of an artery or vein consists of three coats. An *inner coat* smooth and shiny which allows of the easy movement of the blood; a *middle coat* which consists of

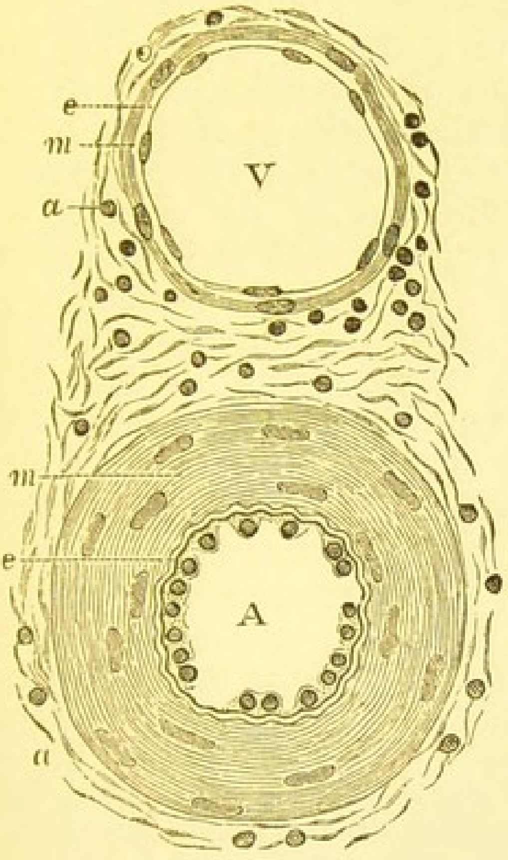


FIG. 32.—Section of a small artery and vein (magnified).

A, artery; V, vein; *e*, cells forming inner coat; *m*, middle or muscular coat; *a*, outer coat of connective tissue.

(*From Gray's "Anatomy."*)

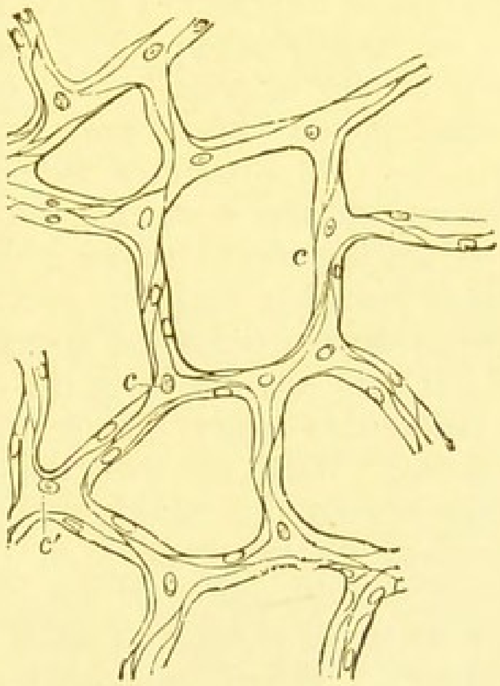


FIG. 33.—Capillary vessels (highly magnified), showing walls consisting of a single layer of nucleated cells.

c, *c*, *c'*, meeting points of adjoining vessels.

(*From Quain's "Anatomy."*)

involuntary muscle cells, spindle shaped, nucleated, and arranged to form a continuous layer around the inner coat. The *outer coat* consists of connective tissue. In the case of the larger arteries the amount of muscular tissue is less than in the ordinary sized arteries, its place being taken by tough elastic tissue. In the smaller arteries the amount of muscular tissue is comparatively greater. In the capillaries there is only one coat which consists of exceedingly delicate cells. In addition to the three coats in the interior of some veins, especially those of the limbs, there are to be found little pouches or valves, the openings of which are above, and which while permitting the blood to flow towards the heart prevent its return. These flaps tend to lessen the weight of the column of blood on the parts below by giving to it a certain amount of support. The condition known as *varicose veins* is produced as a result of these valves breaking down and failing to support the column of blood. Arteries and veins are nourished by special vessels as they, like the heart, take no nourishment from the blood contained in them.

The Heart Cycle.—The chief movements of the muscle of the heart are contraction and relaxation leading to contraction and dilatation of the cavities of the organ, or to *systole* and *diastole*, as they are usually called. The contraction begins at the base of the heart, in the auricles, which contract together, the contraction passing thence like a wave from the base to the apex of the ventricles. As a result of the contraction of the auricles the blood is driven into the ventricles, and as a result of the contraction of the ventricles, their size being diminished, the blood contained in them is forced to make its escape. By the closure of the valves between the ventricles and auricles return to the latter is prevented, and the only way out is, in the case of the right ventricle through the pulmonary artery, and in the case of the left ventricle along the aorta. When the dilatation of the heart commences there is a tendency for the blood to return to the ventricles, and this is prevented by the closure of the pulmonary and aortic valves. During the dilatation of the auricles blood from the great veins flows in to fill them, and from them the blood passes into the ventricles. When the cavities are full the contraction begins again, and so what is called the *heart cycle* of contraction and dilatation begins all over again.

In the adult the cycle is repeated somewhere about 72 times per minute, though in children it is generally more frequent. The work of the heart is done during systole, rest being obtained during diastole. When the heart is required to beat more rapidly the resting periods are diminished by a shortening of the duration of the diastole. In the child the heart beating more frequently the diastole is shorter, therefore the amount of rest obtained by the heart is less. The heart in the child gets its rest chiefly when the child is at rest, the number of beats being diminished, especially during sleep, and the periods of diastole lengthened. It is partly with the object of keeping the heart quiet and giving its muscle more lengthened periods of rest that parents are advised to put children to bed early.

The Nerves of the Heart.—The contraction of the muscle making up the heart wall is brought about involuntarily. In the wall of the heart there are nerve cells which control the muscle fibres, and which act almost automatically, though they are governed by a nerve from the brain called the *tenth cranial* or *vagus nerve*. It is supposed that these nerve cells send messages to the muscle fibres telling them to contract, being themselves stimulated to do so by the presence of the blood in the interior of the heart. It is suggested that the dilatation of the heart occurs because the cells stop stimulating the muscle fibres, and they refrain from doing so till an amount of blood enters the cavities sufficient to distend them, and stimulate the nerve cells. The chief function of the vagus nerve is to inhibit or slow down the action of the heart. If the connection of the nerve with the heart is severed, or if the nerve is paralyzed, the heart beats with tremendous rapidity. If the nerve is over-stimulated the heart slows down markedly. Certain poisons have the power of acting on this nerve stimulating or paralyzing it.

The Nerves of the Vessels.—The muscular walls of the blood-vessels are under the control of two sets of nerves. One set conveys messages calling upon them to contract; the other, messages calling upon them to relax. In this way variations in the size of the vessels are produced. These nerves are under the control of centres in the brain which are practically always in action and are not under the influence of the will. When, for any reason, more blood is required at any part messages are sent along the nerves supplying the muscles of the arteries there, calling upon them to relax, and the vessels enlarge to accommodate the increased amount of blood. The vessels being dilated the rate of flow is diminished. In the same way, if less blood is wanted the nerves bear messages calling upon the muscles to contract, and the vessels get smaller. An instance of a part requiring more blood at a certain time is found in the stomach after a meal, and of a part requiring less, in the brain, during sleep. When any one part requires more blood all other parts get less, and the arteries of these parts accommodate themselves to the lessened quantity by contracting. This is one reason why study immediately after a meal is condemned, the blood being engaged in the stomach assisting in digestion. It also explains why there is a tendency to fall asleep after a full meal, the rush of blood to the stomach leaving the brain with a diminished supply, and thus lessening the activity of the brain cells.

Affections of the Circulatory System

The chief conditions affecting the circulatory system with which the teacher should have a certain amount of acquaintance are: (1) cardiac or heart weakness; (2) anæmia or bloodlessness; (3) hæmorrhage or bleeding.

Cardiac Weakness.—With the signs of heart weakness in children it seems especially important that the teacher should be acquainted as the child so affected may easily be overworked or overexercised if the teacher is unaware of the child's condition. During the period of life between the seventh and fifteenth years, the heart is undergoing changes, and a great strain is thrown upon it naturally. So great, indeed, is this strain that children who are the subjects of heart disease frequently fail to stand it and die about the age of thirteen or fifteen. If the heart is diseased at all the child should be carefully watched, and no extra strain thrown upon that organ at that time. Extra strain may be produced in school, at lessons, or by physical or other exercises.

What is usually meant by heart disease is disease of the valves of the heart. Those most commonly affected are the valves of the left side. Such an affection arises, usually, after the age of five years, and produces what is commonly termed *organic* or *acquired heart disease*. This most commonly follows *acute rheumatism*, but it may also be a sequel of *scarlet fever* or *St. Vitus' dance*. Sometimes the valves of the right side are involved. In these cases the disease began before birth and the person affected was born with a defective heart. For this reason the name *congenital heart disease* is applied to these affections. The heart may be affected in a third way, the heart conditions being disturbed without any evidence of actual disease of the organ. To these disturbances the name of *functional affections* is given. The disturbance in such cases may take the form of irregularity in the action of the heart, or of abnormality in the rate of the beat, which may be either too fast or too slow.

When the valves of the heart are affected with disease various changes may occur, (1) they may break down; (2) they may become covered with growths resembling warts; (3) they may shrivel up and become small. In any event the result is the same. They do not close properly the openings they are set to close. If the mitral valve is affected in any of these ways blood passes from the left auricle to the left ventricle at other times than when the left auricle contracts, and some blood intended at the contraction of the left ventricle to pass through the aortic opening only, passes back into the left auricle and tends to interfere with the free passage of blood from the lungs. When the valves of the aorta are diseased, some blood runs back into the left ventricle instead of passing along the vessel to the arteries of the body. When such conditions exist interference with all systems and tissues results. This is usually described as "too little blood in front and too much blood behind the heart," *i.e.* too little fresh arterial blood gets along the arteries and too much impure venous blood is retained in the veins and the tissues. The tissues are, therefore, improperly nourished, carry out their work badly, and are more likely to be affected by abnormal conditions. The lungs, for instance, are more likely to be affected by cold and germs, bronchitis and pneumonia resulting. The stomach is more easily thrown out of order and indigestion is quickly produced. The brain is badly nourished and therefore less active.

In order to make up for the shortcomings of the valves, the heart takes on what is called *compensatory action.* The muscle of the heart increases in bulk and what the affected valves cannot do the heart itself tries to do by contracting more powerfully. In this it often succeeds in a wonderful manner, especially in children, and no signs of too little blood in front and too much behind may be noticed on a superficial examination. Compensation in such a case is said to be good. If the heart is not unduly strained, compensation may last for a very considerable time. In children it may be sufficient to tide over the period of adolescence and bring the child to manhood or womanhood. If the heart is subjected to strains, however, the compensation fails and signs are produced.

The Signs of Cardiac Weakness.—The signs likely to attract attention may be classified as follows :—

(1) *Poor development.* The child is usually undersized and may be thin and under weight. He may appear indolent and have poor muscles, because nature forbids him to exercise the muscles and so throw strain upon the heart.

(2) *Signs of poor circulation.* The skin may be pale or even a little dusky in tint. The nose may show a tendency to redness and the finger-tips may become distinctly spoon-shaped, giving rise to what is known as *clubbing.*

(3) *Signs of nervous disturbance.* The child may be dull mentally.

(4) *Signs of interference with breathing.* The child is easily exhausted by physical exercises and the breathing becomes embarrassed.

(5) *Signs of weakness of resistance to the commoner ailments.* The child may be irregular in his attendance at school and there may be frequent absences, the result of catching cold.

(6) *Fainting* in school may occur. Especially in girls of twelve or thirteen, though this may be a sign of heart trouble, it may indicate anæmia.

In addition to the above-mentioned signs the child may complain of the ordinary symptoms of rheumatism, and such complaint should give rise to suspicion. In children the signs of rheumatism are often somewhat indefinite, but frequent attacks of sore throat, vague pains in the joints, and the so-called "growing pains," are all often rheumatic in origin. Medical advice is needed in these cases. Coldness of the hands and feet, even in quite mild weather, may be complained of, and occurring in a child suspected of cardiac weakness for other reasons may be taken as further proof of interference with the circulation of the blood.

The proper course to be followed by the teacher for the protection of children who are either suffering from or are suspected to be the subjects of heart disease may be referred to. If a school doctor visits the school his attention should be called to the child and his advice obtained. If not, however, the parents, if ignorant or neglectful, should be communicated with. In any event the teacher must be careful of children suffering from heart trouble. The compensation must on no account be strained, either by overwork or overexercise. The child should be induced to take plenty of fresh air in order that the blood may be kept pure, and any tendency to spend the break periods in the classroom, in fine weather especially, should be discouraged. The importance of feeding the child well and of clothing him warmly should, if the opportunity arises, be impressed upon the parents.

Bloodlessness or Anæmia.—This condition is most common amongst the children of the poor, who receive insufficient or improper food, and who are housed in rooms that are small, overcrowded, and badly ventilated. Girls of about thirteen or fourteen are apt to suffer from anæmia, but the condition is also met with amongst quite young children and boys. The commoner signs are *pallor* of the skin and lips, a tendency to *flushing* of the face on the slightest provocation, *headaches*, *giddiness*, and *fainting fits*. The child is listless and easily fatigued, and suffers from palpitation and breathlessness after apparently only slight exertion. Amongst such children the appetite is apt to be somewhat capricious and uncertain. In young children it often takes the form of a morbid desire for cinders and pieces of chalk. A child presenting these symptoms in any degree should be under treatment. In girls of thirteen and fourteen it must be borne in mind that there is always somewhat of a tendency to poorness of the blood, and they should not be overworked or fatigued. The teacher to assist in preventing the children from becoming anæmic, should try, if possible, to avoid overcrowding of the classrooms. The bad ventilation accompanying such overcrowding must be combatted by opening the windows as much, and as often, as possible. If the symptoms are met with in very poor children, some attempt should be made to bring pressure to bear upon the parents. In most of the larger towns female sanitary inspectors are being added to the staff of the health department, and their assistance may be applied for in such cases.

Hæmorrhage or Bleeding.—In schools the teacher only rarely meets with serious cases of bleeding, but it is well to know what to do should they occur. Bleeding may take place from an artery, a vein, or capillaries, and results from a rupture of the wall of the vessel. In the case of bleeding from an artery, the escaping blood is bright red in colour, comes out in jets, and is usually greater in amount than in the case of bleeding from a vein or capillaries. In venous or capillary bleeding the blood is dark in colour, and wells or oozes out of the wound. Bleeding from an artery is to be stopped by pressure upon the vessel, for example, against a bone, on the side nearer to the heart. Hæmorrhage from veins or capillaries is to be stopped either by pressure over the bleeding spot, or, in the case of veins especially, on the side away from the heart. If the bleeding is at all extensive, and is clearly from an artery, an attempt should be made to control it, till medical assistance can be obtained, by pressure above, *i.e.* on the heart side of the bleeding point. If this is impossible, or without avail, then a pad of some kind should be firmly applied over the bleeding part. In the case of bleeding from a vessel in a limb, it is also well to keep the limb elevated.

When bleeding is less marked and is taking place from a cut on any part of the surface of the body, until this can be dressed properly, and stitched if necessary, the best temporary treatment is to wash the wound with clean water; to bring the edges of the cut together as well as possible; to apply and fix with some sort of a bandage a pad of any clean material obtainable, for example, cotton wool or lint, etc., wrung out of clean water; and to keep the part at rest. In bleeding from the nose, which is the commonest form of hæmorrhage likely to be met with in school, the old-fashioned plan of putting a cold key down the back of the child's neck, and making him sit erect, with or without the arms raised, is as good as any. The bleeding rarely lasts long and usually stops of its own accord. If not, cold applications to the back of the neck and to the nose may be tried. Syringing the nose with ice cold water or with water containing tannic acid or vinegar, and plugging the nostrils with cotton wool are useful methods of treatment. Bleeding from internal organs, for example, the lungs, is hardly likely to be met with amongst children at school; if it does occur, the best thing to do is to keep the patient quiet, lying down, if possible, till medical assistance can be procured.

CHAPTER VI

THE LYMPHATIC SYSTEM

Lymphatic vessels and glands—Lymph—Conditions affecting the lymphatic system.

ANOTHER system of importance in relation to the nutrition of the tissues, which must be referred to, is the *lymphatic system*. This consists of innumerable minute vessels and of glands called *lymphatic glands*. The *vessels* are found everywhere in the body, and carry a fluid called *lymph*. The flow inside the lymphatic vessels is in the same direction as the blood in the veins, *i.e.* towards the heart, but slower, and these vessels assist the veins by carrying waste products away from the tissues.

The work of the lymphatic system is carried out as follows:—Through the thin walls of the capillaries of the arteries the fluid part of the blood escapes into spaces amongst the cells and fibres making up the various tissues. These spaces are called *lymph spaces*. From the fluid the tissues take all that is good and nourishing. The remainder, the waste products, is collected from the lymph spaces by *lymph capillaries*, which open into lymph vessels, which eventually open into two vessels in the neck. The vessel on the right side is called the *right lymphatic duct*, and it receives all the lymph brought by the lymphatic vessels of the right arm and right side of the head and neck. It terminates by opening into the right jugular vein. The vessel on the left side is called the *thoracic duct*. It begins above the brim of the pelvis and runs alongside of the vertebral column to open finally into the left jugular vein. It collects lymph from all parts of the body except those mentioned, including that from the intestinal lymphatic vessels which are called *lacteals*, because the lymph in them, during digestion, is the colour of milk from the presence of fat taken up from the digestive tract. This milky looking lymph is called *chyle*. A special dilatation on the thoracic duct about the level of the first lumbar vertebra receives the lacteals and is called the *chyle receptacle*.

Lymphatic Glands.—The lymphatic glands are found in various

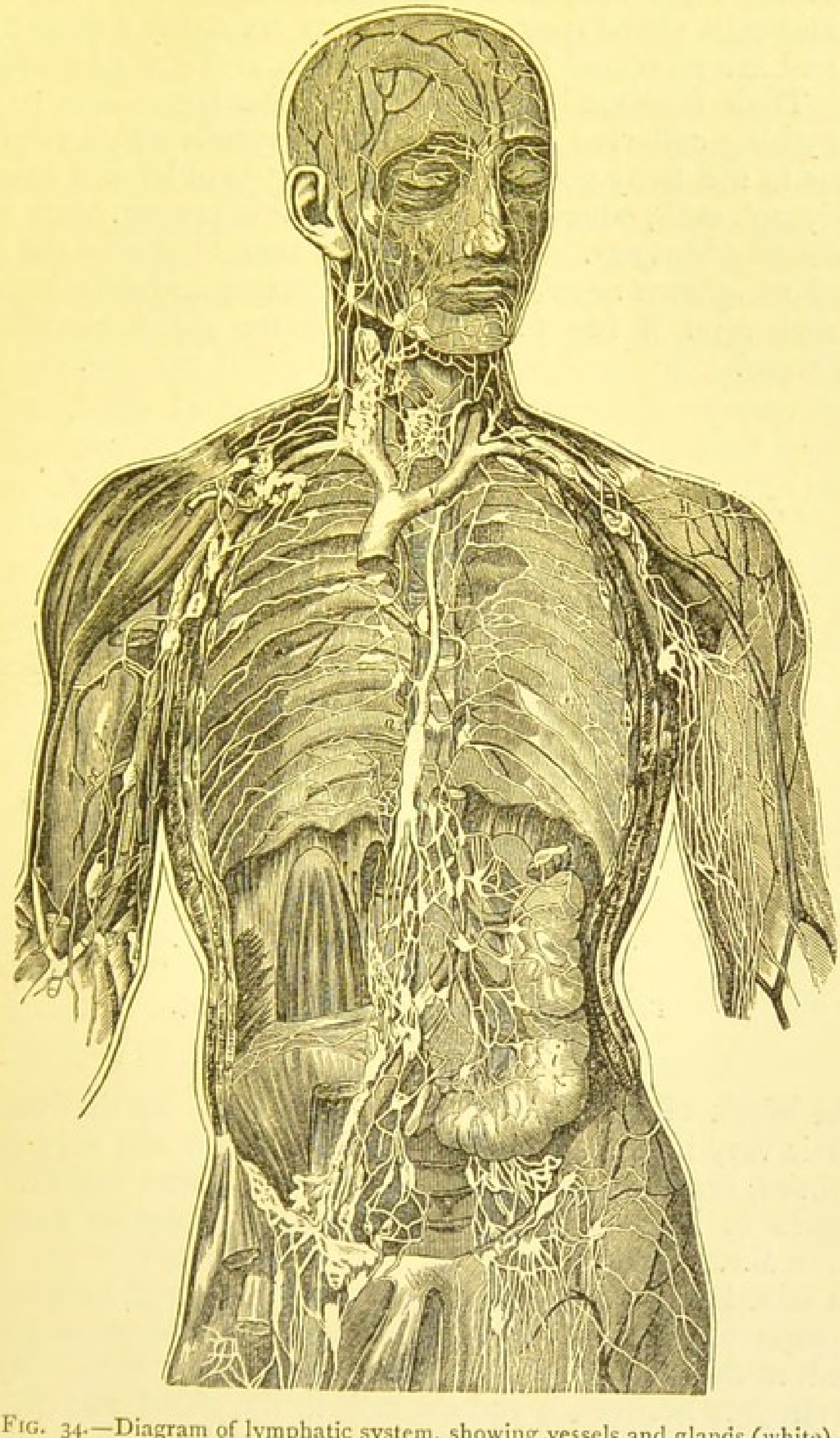


FIG. 34.—Diagram of lymphatic system, showing vessels and glands (white). *a*, thoracic duct; *v*, left innominate vein; *i*, part of large intestine with lacteals passing from it.

situations along the course of the lymph vessels, *e.g.* at the back of the elbow joint, in the armpit, at the angles of the jaw, and so on.

In the healthy condition they are very small and consist of fine tissue arranged as a network, in the interspaces of which are found lymph and cells called *lymph cells.* They are richly supplied with blood, and are protected from injury by a covering of tough fibrous tissue. Their function is mainly to filter the lymph and to keep back anything collected by the lymphatic vessels which might be injurious to the body generally. Anything kept back is eaten up by the lymph cells, which, on account of this property, are sometimes called *phagocytes.* The lymphatic vessel entering the gland is called an *afferent vessel,* the vessel collecting and carrying away the lymph after it has filtered through the gland is called an *efferent vessel.*

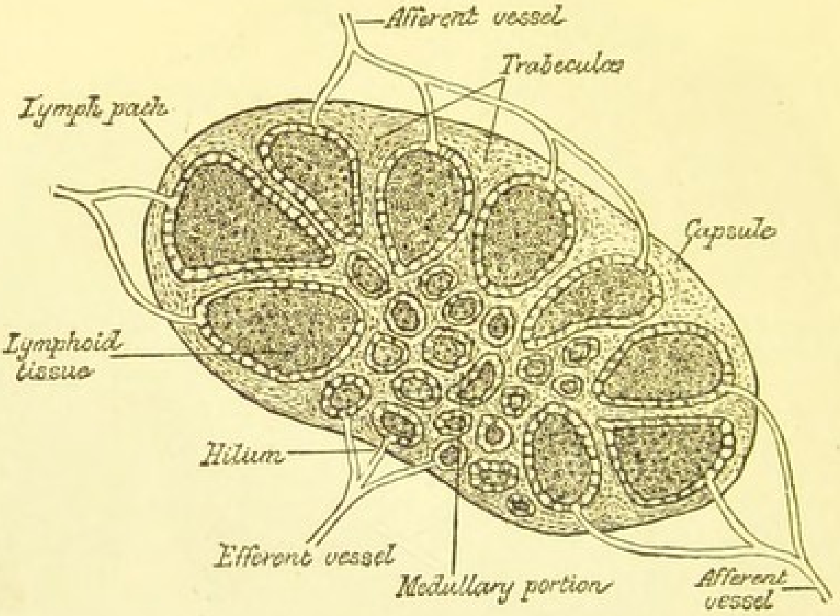


FIG. 35.—A lymphatic gland (diagrammatic).
(*From Gray's "Anatomy."*)

The Work of the Glands.—The work done by the lymphatic glands is very important, and is usually carried out very quietly. Sometimes, however, the lymph coming to a gland contains some poisonous or irritating substance which has found its way into a lymph space. This is kept back by the network of the gland, and is seized on by the lymph cells and destroyed by them, and the lymph passes on. If the poisonous substance is small in amount, nothing happens, if it is large in amount there may be a fierce struggle between it and the cells in the gland, and the gland may become large and inflamed and painful. This very often happens when the lymph contains bacteria, which have found their way into the lymph spaces from a wound. The cells attack these in the ordinary way, and if they are not numerous may conquer them. If they are numerous, a stiff fight ensues which may result in victory either for the bacteria or the gland. The gland may be destroyed even though it wins, all the cells being broken down and killed and transformed into *pus* or *matter*, the gland itself being transformed into an *abscess*.

If an abscess is not formed, the gland may be so much irritated that it becomes permanently enlarged. This is especially the case when small numbers of bacteria or small quantities of poisonous or irritating material are being passed through the gland at frequent intervals. This is seen in the case of the glands at the back of the head in children with verminous heads. It is also seen in the case of the glands at the angles of the jaw in children suffering from chronic sore throat or whose teeth are decayed and bad. In the glands found at the root of the lungs, which deal with the particles of carbon inhaled with the air by those who live in smoky cities, similar changes occur. The glands on the vessels in the neck are often affected by *tuberculosis*, and the teacher must always consider any enlargement of these glands serious, though it may be felt that the enlargement is produced not by the bacillus of tuberculosis, but by irritating material reaching the glands from the mouth or throat.

Sometimes the lymphatic vessels themselves are irritated by the poison they carry, and can be seen as thin red lines under the skin. This may be noticed sometimes in the case of a neglected wound about the hand. These red lines should be taken as a sign of danger, and an indication that bacteria have passed into the lymph spaces and are being carried to the lymphatic glands. Whenever these red lines are detected, immediate treatment should be suggested.

CHAPTER VII

THE RESPIRATORY SYSTEM

Structure of the respiratory organs—Air—Respiration—Ventilation and the principles underlying it—Effects produced by breathing bad air—Conditions affecting the respiratory system—Mouth breathing—Adenoids—Consumption—Defects of speech.

THE respiratory system is made up of the following parts :—

(1) The upper air passages, viz. the nose and pharynx.

(2) The lower air passages, viz. the larynx or voice box, the trachea or windpipe, and the bronchi.

(3) The lungs.

The Nose.—The whole cavity of the nose is divided into two halves by what is called the *nasal septum*, which consists of cartilage in front and of bone behind. The whole interior of each

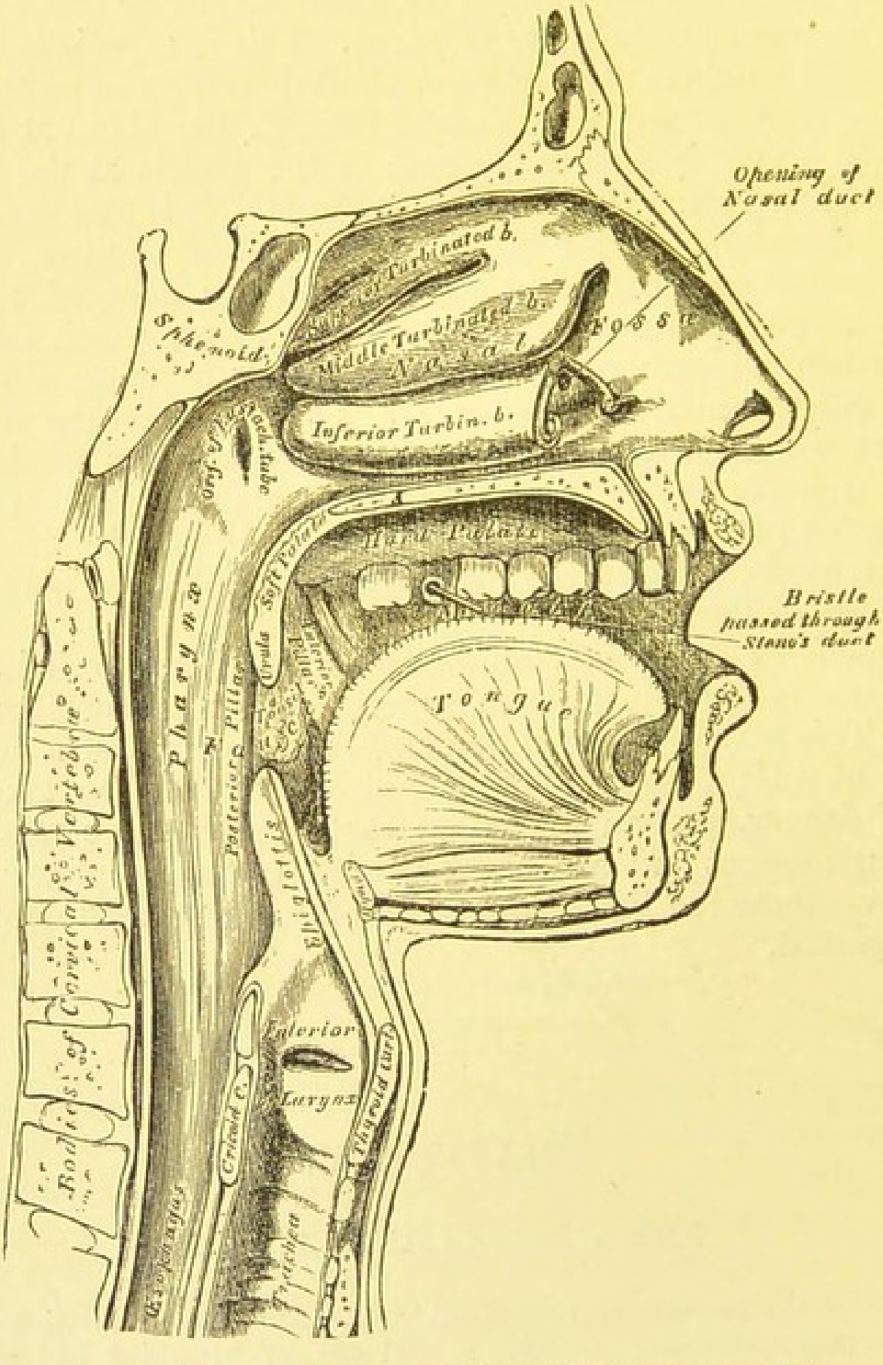


FIG. 36.—The mouth, nose, windpipe and gullet seen in section.

(*From Gray's "Anatomy."*)

half is lined by mucous membrane, which is richly supplied with blood. The upper part in each half is chiefly concerned with the sense of smell, and in this part there are found numerous branches of the nerve of smell. In the outer wall of each half there are found the spongy *turbinate bones* which contain many blood-vessels. The advantage of breathing through the nose is, that the air derives heat from the blood in the mucous membrane and turbinate bones and so is prepared for contact with the delicate larynx and lungs; in addition, the air is filtered by the hairs which are found very numerously in the lower part of the nostrils. Each cavity of the nose opens externally at the *anterior nares* or nostrils, and internally into the pharynx at the *internal* or *posterior nares*.

The Pharynx.—The *pharynx* is a thin walled muscular bag lined with mucous membrane and works in connection with both the respiratory and digestive systems. Above, it is attached to the base of the skull, and below it terminates by becoming continuous with the gullet. Besides the openings of the posterior nares there are other openings into the pharynx, viz. the opening from the mouth, through what is known as the *fauces*, and the openings of what are called the *eustachian tubes*, one on each side. These tubes form a communication between the pharynx and that part of the ear, known as the *middle ear*, which lies just within the ear drum. The eustachian tubes are lined with mucous membrane which is covered with elongated cells placed on end. At its free margin, which is towards the interior of the tube, each cell is provided with numerous bunches of delicate whip-like processes, called *cilia*, and the cells are known as *ciliated epithelial cells*. The cilia wave gently from side to side and assist in moving air and the secretion of other cells up and down from the middle ear to the pharynx. When the membrane gets inflamed it swells, and the circulation of air between the middle ear and the pharynx is prevented. As a result, the middle ear gets distended with air, the structures connected with hearing are interfered with, and deafness results. The deafness occurring in a cold in the head, or in inflammation of the tonsils, is due to this swelling of the mucous membrane lining the eustachian tubes. In scarlet fever, infection from the throat sometimes passes along the tubes and gives rise to inflammation and the formation of matter in the middle ear. In some cases the matter escapes by breaking through the ear drum and a "*discharging ear*" results.

The part of the pharynx into which the nares open is called the *naso-pharynx*, and from this part the little tumours known as *adenoids* grow. Further reference will be made to these when dealing with mouth breathing. At the lower end of the pharynx there are the openings out of it. These are two in number: (1) the *œsophagus* or gullet, which is really the continuation of the pharynx, and has the same muscular walls. It forms part of the digestive system and will be considered in connection with it; (2) the *larynx*, which lies in front of the gullet and forms the upper part of the air tube.

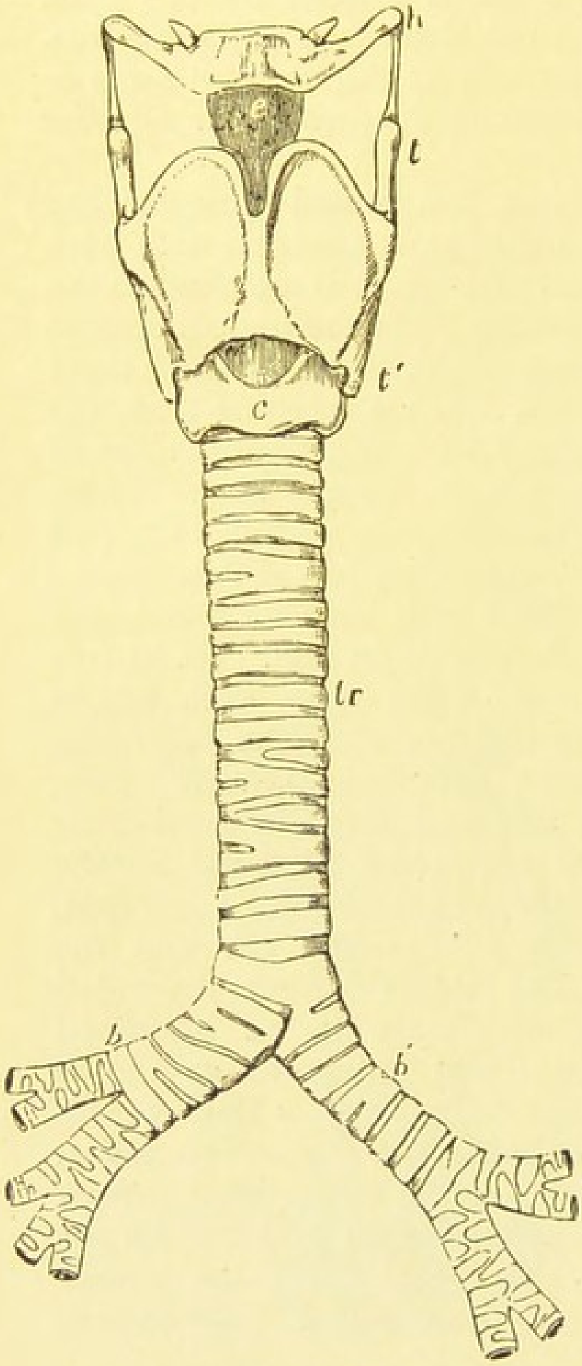


FIG. 37.—The trachea. Front.

h, hyoid bone; *tt'*, thyroid cartilage; *c*, cricoid; *e*, epiglottis; *tr*, trachea; *b* and *b'*, bronchi.

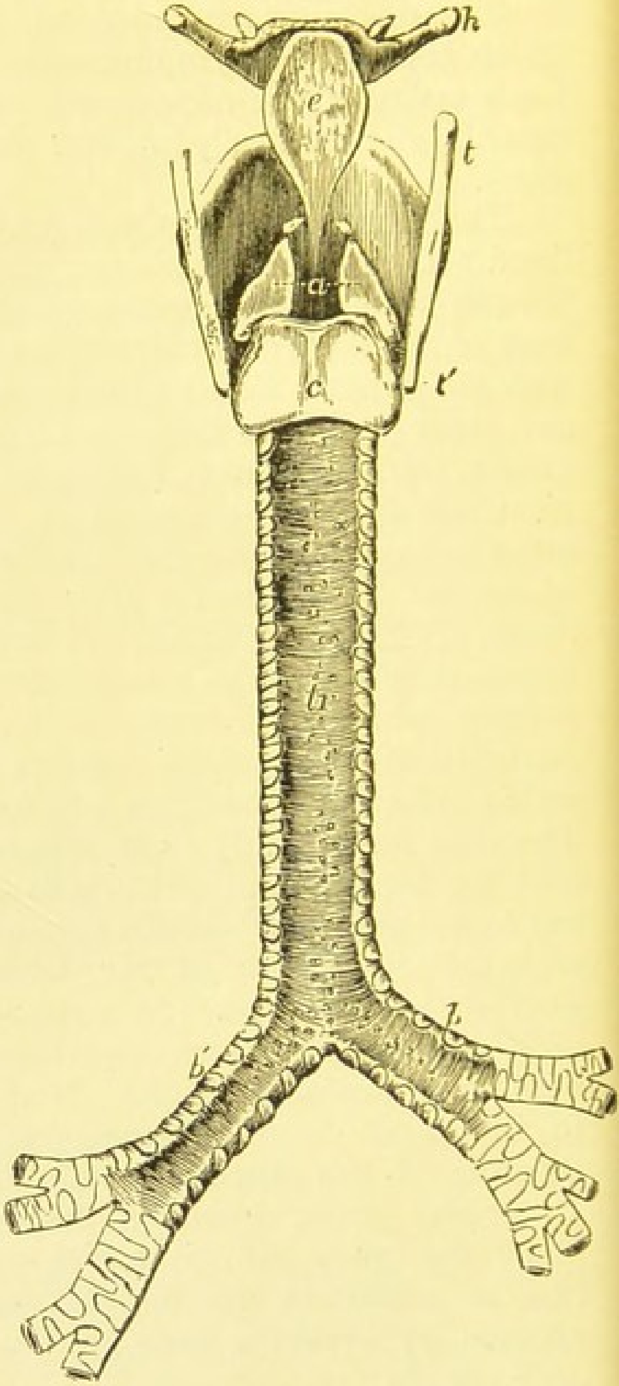


FIG. 38.—The trachea. Back.

a, arytenoid cartilages. Other letters as in Fig. 37.

(*From Quain's "Anatomy."*)

The Larynx.—The walls of the larynx consist mainly of cartilage, and the tube, unlike the gullet, is rigid and always open.

As a result of the pharynx being the passage for food as well as air, and the larynx being always open, there is a possibility of food passing away from its direct and proper route down the gullet, into the larynx. To prevent this there is provided a leaf-like flap of tissue attached at its base near to the root of the tongue, and called the *epiglottis*. This acts as a lid to the larynx, shutting down over the orifice during swallowing. It acts also, more or less, as a kind of shoot, over which the ball of food, formed in the mouth by mastication, slides into the gullet. During breathing, and when there is nothing to be swallowed, the epiglottis remains erect.

Besides being one of the air passages the larynx contains the structures concerned with the mechanical part of speech production. It consists of (1) the *hyoid bone;* (2) the *thyroid cartilage;* (3) the *cricoid cartilage.* These can readily be felt and even, in the male neck, seen. The *hyoid bone* is at the top. It is U-shaped and gives attachment to many of the muscles concerned with the movements of the larynx. The *thyroid cartilage* makes up the great part of the larynx. In males it is especially prominent, forming what is known as "Adam's Apple." In shape it roughly resembles a boat, the keel lying in front. Behind, the cartilage is incomplete, the space being filled up by a membrane. Below the thyroid cartilage, and attached to it, and also to the parts immediately below by membrane, lies the *cricoid cartilage.* This cartilage is shaped more or less like a signet ring. It forms a complete circle. The broad part of the ring is behind, and on its upper margin there rest side by side two small pyramidal pieces of cartilage named the *arytenoid cartilages.* To these are attached the *vocal cords,* what are known as the *false cords* above, and the *true cords,* which alone are concerned with voice

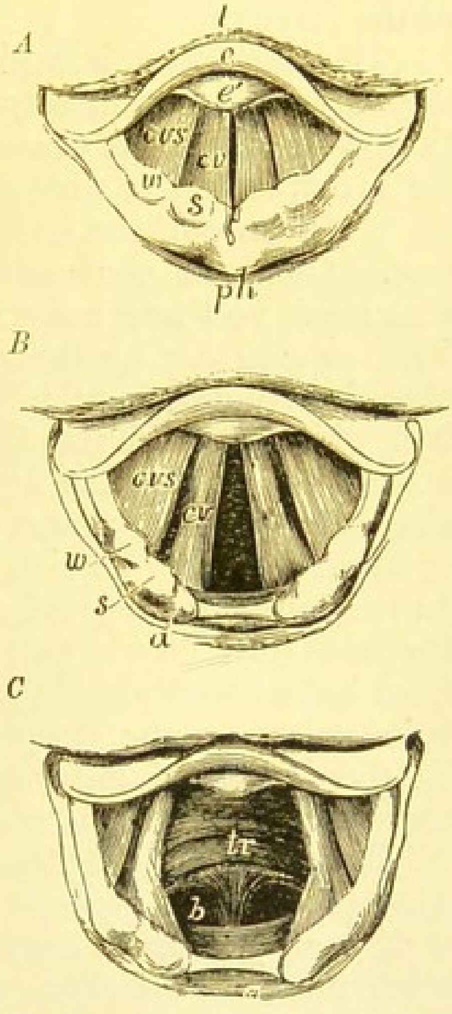


FIG. 39.—Three views of the larynx during life, as seen on examination with a laryngoscope.

A, during singing of a high note; *B*, during quiet breathing; *C*, while taking a very deep breath. *l*, base of tongue; *e*, *e'*, epiglottis; *ph*, pharynx; *a*, tip of arytenoid cartilage; *cv*, vocal cords; *cvs*, false cords; *tr*, front wall of trachea; *b*, commencement of two bronchi.

(*From Quain's "Anatomy."*)

production, below. In front the ends of the cords are attached to the internal surface of the thyroid cartilage. Between the thin edges of the true vocal cords there is a slit or chink called the *rima glottidis* or *chink of the glottis*. In speaking or singing this chink gets wider or narrower, according as the note is low or high in pitch. This variation is allowed of by the rotation or twisting round of the arytenoid cartilages, there being a small joint between each cartilage and the cricoid. This rotation is brought about by the contraction of certain small voluntary muscles, of which there are a considerable number in the interior of the larynx.

The rima glottidis, besides varying in size in speaking and singing, varies also continually during ordinary respiration. At inspiration, when the air is drawn in, the edges of the cords are pulled far apart, leaving a wide open channel. At expiration, when the air is driven out, the edges come almost together in the middle line. The vocal cords are, of course, exceedingly thin and delicate structures, and any unnecessary strain, as, for example, shouting, loud singing or speaking, may damage them by setting up a chronic irritation and inflammation, which may lead to thickening. In the child the larynx is small, and the parts described are not so readily seen and felt as in the adult. It increases in size as the years advance, changing markedly about the fourteenth or fifteenth year. In girls the change is less marked than in boys. In the latter the thyroid especially grows wider and deeper, and becomes distinctly more prominent. As a result of the deepening from before backwards the vocal cords increase in length and the voice takes on the deeper tone characteristic of the adult male. In the length of the vocal cords in the female practically no change occurs, and the voice remains therefore higher in pitch.

The Trachea.—Below the cricoid cartilage lies the trachea or wind-pipe. This is about 4½ inches long and 1 inch wide. It is composed of rings of cartilage incomplete behind, the space being filled up with membrane containing involuntary muscle fibres. The rings of cartilage are held together by fibrous tissue, which also contains involuntary muscular fibres. This arrangement permits of the trachea adapting itself to the various positions which the neck may take up without the tube being at all constricted. The trachea is lined with mucous membrane, the cells of which are ciliated like those in the eustachian tubes.

The Bronchi.—After reaching a length of about 4½ inches the trachea divides into two bronchi, the right and left, of which the right is the larger. These in structure are similar to the trachea. Each bronchus divides to give branches to the lungs, three coming from the right to pass into the right lung, and two from the left for the left lung. The difference in number of the branches between the right and left side depends upon the fact, that the right lung is divided into three pieces or *lobes* and the left into two lobes.

After entering the lung each branch divides into smaller and smaller branches, spreading in every direction throughout the substance of the organ till eventually the branches terminate in very fine tubes called *bronchioles*. These in turn end in grape-like clusters of balloon-shaped bags, microscopical in size, and named *air sacs* or *air cells*. Each cluster of air cells is called a

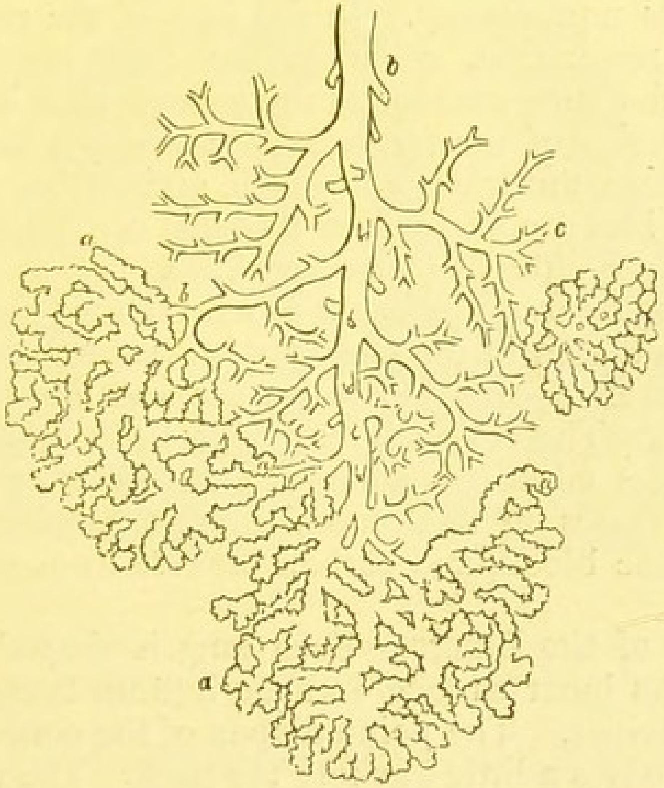


FIG. 40.—Groups of air-cells at the termination of a small bronchial tube.

lobule. The whole of the lung substance is made up of these clusters of air sacs and of the connective tissue holding the clusters together. The presence of the clusters gives the lung a spongy appearance; the lung, like a sponge on being cut into, presenting, even to the naked eye, innumerable small pores, viz. the openings of the air sacs. In addition to the finer openings of the air sacs, the larger openings of the small bronchi and bronchioles are also to be noted. Blood-vessels may also be seen, and amongst the other tissues lymphatic vessels and nerves are to be found. Healthy lung tissue, on account of the presence of air in the sacs, floats, when placed in water, and for the same reason when squeezed by the hand emits a crackling sound. The air sacs, like the rest of the respiratory tract, are lined with mucous membrane, the cells of which are flat and laid down in a single layer more or less like a pavement.

In the trachea and bronchi the cells of the mucous membrane are provided with cilia. These are continually in motion, sweeping mucus and so on upwards towards the larynx, whence it is expelled into the pharynx, and so into the mouth and out of the body. In the larynx and pharynx the cells are flat like those in the air sacs. They are arranged in several layers just as in the skin; the mucous membrane here, as elsewhere in the body, being after all merely skin, the cells in the process of development, before birth, being modified and the skin-like appearance lost, since it is unnecessary. In the part of the nose concerned chiefly with respiration, cells bearing cilia are again found. These act in the same manner as the ciliated cells in the trachea.

In the interior of the air sacs the air which has passed into the lungs through the trachea, bronchi, and so on, comes in contact with the blood contained in the fine capillaries uniting the pulmonary artery with the pulmonary vein. These capillaries are arranged in the form of a network around the air sacs, and having very thin walls the air in the sacs is only separated from the blood by the thin layer of cells lining the sac and the delicate wall of the capillaries. These two layers offer little opposition to the interchange that takes place between the gases of the air in the sacs and the gases in the blood, oxygen passing readily from the sacs into the blood, and carbon dioxide from the blood into the sacs.

Relations of the Lungs.—Each lung is shaped more or less like a cone, the inner surface and the bottom being scooped out to form concavities. The pointed apex of the cone fits under the first rib, and passes a little way into the neck. The lower concave end rests on the diaphragm and in its concavity accommodates certain of the abdominal organs, which press upwards on the under surface of the diaphragm. The inner concave surface of each lung, in the neighbourhood of the heart, is especially distinctly hollowed out in order to accommodate that organ. The heart lying mainly on the left side, the left lung is especially formed to receive it and enfold it, except at a part near the apex, where the surface is left uncovered by lung. The remaining surfaces of the lung are convex and fit into the concavity of the ribs.

The part of the lung where the bronchi and the pulmonary artery enter and the pulmonary veins emerge is called the *root of the lung*. If the chest be opened and the structures forming the root be cut, the whole organ can be removed. In addition to the structures mentioned, nerves, lymphatics, and the arteries carrying blood for the nourishment of the substance of the lung itself, and the veins bearing away the blood which has nourished the lung

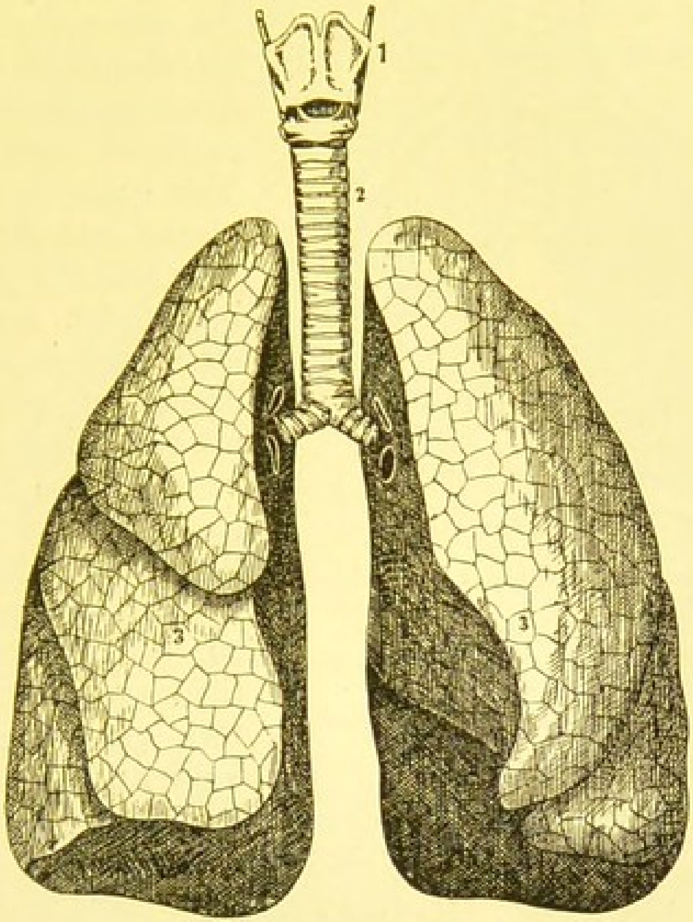


FIG. 41.—Front of lungs, etc.
1, larynx ; 2, trachea ; 3, lungs, the right with three, the left with two lobes.
(*From Furneaux's "Elementary Physiology."*)

tissues, enter into the formation of the root of the lung. At this part also a certain number of lymphatic glands are to be found.

The Pleura.—When the lungs are at rest in the interval between the taking in and the letting out of the breath they fill the cavity of the chest. When air is inspired they swell out, and the chest enlarges to accommodate them. In this swelling out the lung has to glide upon the inner surface of the ribs, and to permit of this the lungs and the inside of the ribs are coated each with a layer of smooth shining membrane. This membrane is called the *pleura*, and to lubricate the two layers a small quantity of fluid, named *pleural fluid*, is secreted by the cells covering the pleura.

The serous membrane or pleura covering the lung is continuous with that lining the ribs, and it can be traced from the root of the lung all over the surface of the lung, on the one hand, and on the other all over the ribs, the diaphragm, and the other tissues and organs, over which the lung has to glide, in the course of its expansion and relaxation. To all these surfaces the pleura is very firmly attached, and the arrangement is more or less similar to that described in connection with the pericardium and the heart. The space between the rib pleura and the lung pleura is called the *pleural cavity*, but under normal circumstances this space is exceedingly minute, the lung always being practically in contact with the inner surface of the rib. When there is any increase in the fluid in the pleural cavity, as, for example, in wet pleurisy, the existence of the space becomes more evident, the lung being separated from the wall of the chest by the fluid which collects.

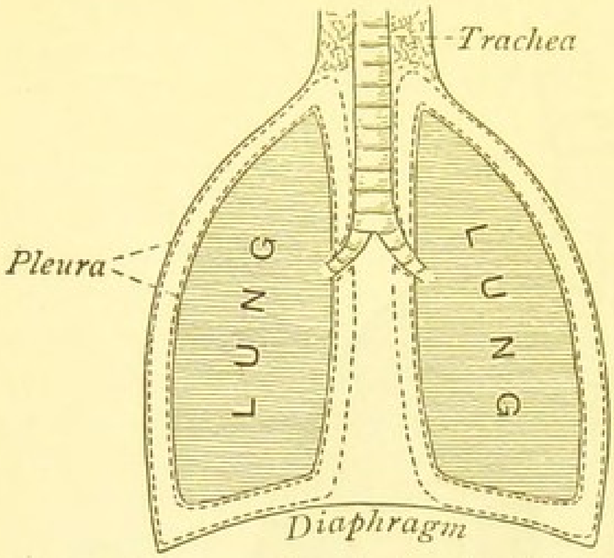


FIG. 42.—Diagrammatic vertical section of thorax, to show the reflection of the pleura from the root of the lungs. The dotted lines represent the pleura. The two surfaces should be in contact as there is in reality no space between them.

(*From Thornton's "Elementary Practical Physiology."*)

RESPIRATION

Each respiratory act consists of three parts, an *inspiration* or drawing in of air, an *expiration* or driving out of air, and a *pause*. During inspiration air is drawn in through the nose and passes down the larynx, trachea, and bronchi, to reach eventually the interior of the air sacs, where an interchange takes place between the gases in the blood and the gases of the air. With expiration the lungs collapse, and the impure air is expelled through the bronchi, and the pure oxygenated blood into the pulmonary veins. Following expiration there is a short pause before the next inspiration occurs. In health the respiratory act in the adult is repeated from 18 to 25 times per minute. In the child it is performed more frequently, and varies much more readily, both in regularity and frequency, than in the adult.

The Mechanism of Inspiration.—Inspiration is a purely muscular act, the thorax playing the part of a bellows and being opened out by muscles. In ordinary quiet inspiration the chief muscles called into play are the *intercostal muscles* and the *diaphragm*. These bring about enlargement of the chest cavity in every direction. The intercostal muscles bring the ribs to which they are attached closer together, and such approximation, on account of the shape of the ribs and the difference in level between the body of the rib and its articulations behind and in front, increases the size of the cavity from side to side. From before backwards the depth is also increased, because the breast bone is thrown forward by the twisting of the ribs and costal cartilages produced by the contraction of the intercostal muscles.

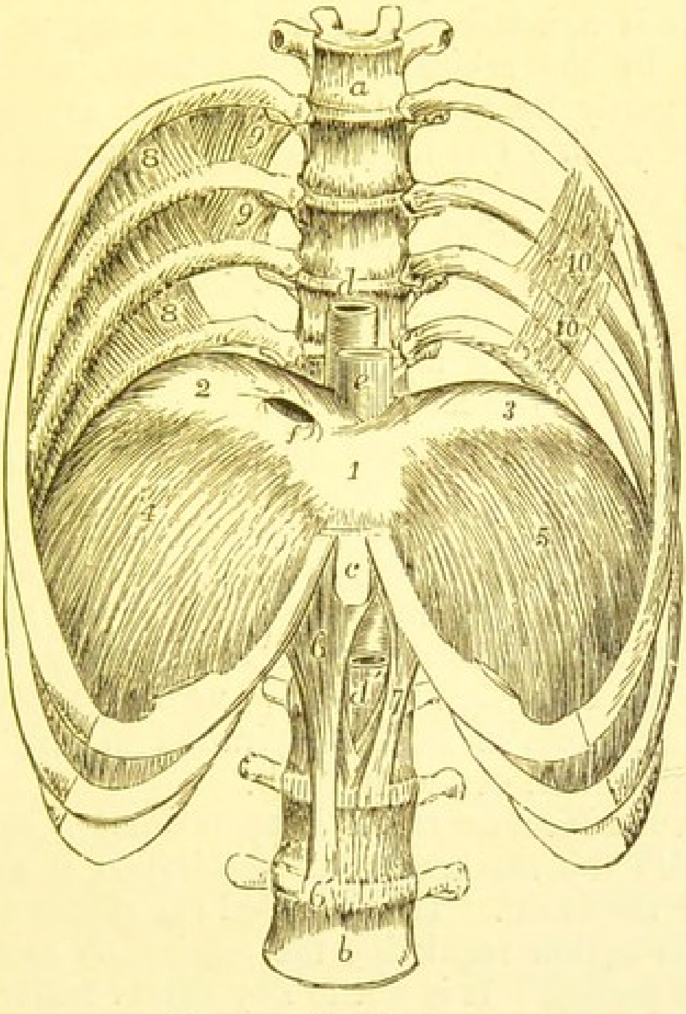


FIG. 43.—The diaphragm.

a, sixth dorsal vertebra ; *b*, fourth lumbar vertebra ; *c*, tip of sternum ; *d*, *d'*, aorta ; *e*, gullet ; *f*, opening for inferior vena cava ; 1, 2, and 3, central tendon of diaphragm ; 4 and 5, arches of diaphragm ; 6 and 7, pillars of the diaphragm ; 8, 9, and 10, intercostal muscles.

(*From Quain's "Anatomy."*)

The action of the intercostal muscles is supplemented by that of certain muscles of the back, which act as elevators of the ribs. These take their origin from the spine and are inserted into the ribs. To give the intercostal muscles purchase, the upper part of the chest is fixed by certain muscles of the neck, which originate above from the cervical vertebræ and below are inserted into the first and second ribs. The diaphragm in its contraction increases the size of the cavity in the vertical direction. This muscle takes its origin from certain of the lower ribs on each side and its fibres are inserted into a central tendon. When relaxed the diaphragm shows a double arch, one on each side, directly underneath the lung. In contraction the muscle, since its fibres become shorter, flattens, and in this way the vertical diameter of the thoracic cavity is increased, the increased space being occupied by the expanded lung.

The Mechanism of Expiration.—Expiration under ordinary circumstances is a non-muscular act, the inspired air being expelled partly by the relaxation of the lungs, which are elastic organs, and partly by the relaxation of the intercostal muscles and the diaphragm. The thorax, sinking down upon the lungs, by its weight helps also to expel the air.

In forced and hurried breathing, induced by disease or by exercise, the ordinary muscles of inspiration are supplemented by what are called *extraordinary muscles of inspiration,* and expiration also becomes muscular. The extraordinary muscles of *inspiration* are (1) those assisting in fixing the upper part of the chest, viz. the muscles about the shoulder; (2) those assisting the intercostal muscles, viz. muscles attached to the ribs—for example, the great muscles of the chest, which, though attached to the ribs, do not under ordinary circumstances act upon them. The muscles assisting *expiration* are those of the abdominal wall, which, by pulling the thorax down and pushing the diaphrogm up, assist in the expulsion of air. Coughing and sneezing may be taken as examples of forced expiration in which the muscles of the abdominal wall come into play.

The Nervous Mechanism of Respiration.—The nerve centre concerned with the mechanism of respiration is situated in the lower part of the brain. This is called the *respiratory centre*, and it is always in action regulating the respiratory movements as to depth and frequency. It is not to any extent under the influence of the will, and the respiratory movements are all involuntary. The centre is connected with what is called the *sympathetic nervous system* through the vagus nerves, which send branches to the lungs. Conditions affecting these branches may react on the respiratory centre and lead to variations in breathing. The centre is chiefly influenced by the condition of the blood; it must have plenty of oxygen, and is profoundly affected by any diminution in the amount of this or any increase in the amount of carbon dioxide. Anything increasing the amount of carbon dioxide in the blood, such as muscular exercise, leads to stimulation of the respiratory centre and to an increase in the rate of respiration. This increase affects the heart, which has to beat more rapidly in order to drive the blood through the lungs to get rid of its carbon dioxide and to pick up oxygen. When the increased carbon dioxide is got rid of and the blood is again normal, so far as oxygen is concerned, the breathing becomes quieter. If the carbon dioxide is very greatly in excess, there is a tendency for the respiratory centre, like other parts of the brain, to be more or less paralyzed. For this reason persons in a bad atmosphere yawn and are inclined to drop off to sleep.

AIR AND VENTILATION

The Amount of Air breathed.—In ordinary quiet inspiration a quantity of air equal to about 30 cubic inches is inspired. This is called the *tidal air*. In addition to this, on forced inspiration, an adult can take in about 120 cubic inches. This is called *complemental air*. On forced *expiration*, in addition to these amounts, nearly 100 cubic inches are expired, and this is called *supplemental air*. The total amount expired on forced expiration is, therefore, 250 cubic inches, and this forms what is called the *vital capacity* of the lungs. A certain amount of air always remains behind, however, and amounts to nearly 100 cubic inches, and this is named *residual air*. The 30 cubic inches of tidal air probably goes no further into the lungs than the point where the bronchi begin to subdivide into smaller branches. The oxygen contained in it, however, probably diffuses into and mixes with the air in the deeper parts, diffusing later through the walls of the air sacs into the blood in the blood-vessels.

Between inspired air and expired air, the main difference is in the proportion which the oxygen bears to the carbon dioxide. In the process of respiration, inspired air loses five volumes of oxygen, and gains four volumes of carbon dioxide. Expired air also contains more moisture as a result of coming in contact with the moist mucous membranes of the respiratory tract. For the same reason it is also warmer, being of the temperature of the body. From the air passages also it derives a certain amount of organic matter.

Composition of Air.—Air is a mixture of gases, containing, roughly, 79 per cent. of *nitrogen*, 21 per cent. of *oxygen*, and 0·04 per cent. of *carbon dioxide*. In addition, it contains traces of watery vapour, ammonia, and ozone. Other substances are regarded as impurities. The impurities in air may be either gaseous or solid. The impurities in the air of inhabited places are better, however, classified as *respiratory*, *i.e.* produced during the process of respiration, and *non-respiratory*, *i.e.* not produced in the respiratory process.

The *gaseous* impurities of air are chiefly compounds of nitrogen, such as ammonia, nitric acid, and nitrous acid; compounds of sulphur, such as sulphuretted hydrogen and sulphurous acid; and compounds of carbon, such as carbon monoxide, and carbon dioxide, the latter being an impurity when it exceeds 0·04 per cent. All these are the products of combustion of coal and of manufacturing processes, and are, therefore, most plentiful in the air of manufacturing towns.

The *solid* impurities met with are (1) *Dust*, which consists of particles of various substances, such as stone, wood, carbon, and the vegetable and animal matter found on town streets. Dust acts harmfully in two ways, being irritating to the lungs and serving as a vehicle for the transmission of germs. (2) *Bacteria*. The majority of these are harmless, and are principally members of the mould family. Harmful germs, such as the bacillus of tuberculosis, may, however, be present in the air.

The *respiratory impurities* found in the air of inhabited places may be gaseous, the chief being carbon dioxide. The other impurities are chiefly organic matter and bacteria. The *non-respiratory impurities* are those gaseous and solid substances already mentioned, with, in addition, emanations from the skin and clothing. In special places special impurities are to be found —for example, lead in file-cutting shops, and so on.

Of the normal constituents of air, oxygen and carbon dioxide are the most important. Oxygen is essential for all forms of life, and plays a leading part in the chemical changes in the tissues which make up what is called life. All the tissues in the human body require it. Carbon dioxide is not necessary for animal life, but is, apparently, necessary for the members of the vegetable kingdom, which take it in and break it up into its constituents, carbon and oxygen, in the presence of sunlight. The carbon is retained, and the oxygen is given off. The main source of carbon dioxide is the burning of carbon in the presence of oxygen. This process is continually going on in nature. In the tissues of the body, especially in the muscles during exercise, large quantities of carbon dioxide are produced in this way, and are mainly got rid of by the lungs.

An idea of the amount produced in the body may be obtained by comparing the quantity in inspired air with the quantity in expired air. In the former, it is found there is 0·04 per cent.; in the latter, 4 per cent. It has also been shown that the average total amount of carbon dioxide excreted by an adult in one hour is 0·6 of a cubic foot. Carbon dioxide is not only unnecessary for the tissues, but in certain proportions acts as a poison. When the percentage of *pure* carbon dioxide in the air rises to 10 per cent., poisonous effects are produced. A smaller percentage of *expired* carbon dioxide is capable of producing such poisonous effects, however, because there are present with it in the expired air other harmful substances; for example, organic matter. By quantities smaller than 10 per cent., unpleasant and undesirable effects are produced. Air containing up to 0·06 per cent. is fresh air, air containing 0·08 to 0·10 per cent. is close, air containing 0·12 to 0·14 per cent. is distinctly disagreeable.

The unpleasant or disagreeable effects produced by breathing such air are probably not entirely due to the carbon dioxide. They may be produced by other poisonous substances added to expired air by the mucous membrane lining the respiratory tract and lungs, or, as is now held by certain authorities, by the increase in temperature brought about by breathing and re-breathing the same air. Whatever the cause, the amount of carbon dioxide, which is easily estimated, is usually taken as indicating the purity or impurity of the air. In air, the quantity of carbon dioxide is kept at the 0·04 per cent. level by plants, the green colouring matter, or chlorophyll, of which breaks it up. In places used for human habitation, in schools and so on, means have to be adopted in order to keep the carbon dioxide within breathable limits, *i.e.* to 0·06 per cent. (0·6 per thousand), and to get rid of some, at least, of the respiratory and non-respiratory impurities. For these purposes, what is known as *ventilation* is resorted to.

The Principles underlying Ventilation.—The word "ventilation" means "wind or air bearing or carrying." The ventilation of a room means carrying of air through the room. To do this, one or other of two methods, viz. *natural* or *artificial* ventilation, may be adopted. In natural methods of ventilation certain physical forces of nature are trusted to, inlets and outlets for the air being provided. In artificial methods the physical forces of nature are assisted or superseded, mechanisms to drive the air through the inlets or to draw it through the outlets, or to do both, being adopted.

The natural physical forces depended upon in *natural ventilation* are (1) a property of gases called diffusion; (2) the wind; (3) well-marked differences in weight and bulk between heated and cold air. *Diffusion of gases* assists natural ventilation only to a small extent. The air in the room diffuses out of, the air outside diffuses into, the room. The action of the *wind* is two-fold, and depends upon the direction and the force of the wind. It may blow into the inlets through the room and out at the outlets. It may blow across the outer opening of the outlets, and suck the air through the inlets and the room, and out at the outlets. The wind is, however, not to be depended upon, as it cannot be controlled. It is too irregular both in force and in direction.

With regard to the influence of the *differences in weight and bulk* between heated and cold air. Air, when heated, becomes lighter and more bulky; when cooled, it becomes heavier and less in bulk. Hot air tends to rise, cold air tends to fall, and as a result currents are set up. The heated, lighter, more bulky air, seeking greater accommodation, tries to escape from the space in which it is contained. In a room, it makes for the outlets. If the outlets are in the positions sought by the heated air, *i.e.* in the upper part of the space containing it, the air makes its way through these. To take up the space vacated by the escaping air, new air enters at the inlets, and ventilation, or carrying through of air, is brought about.

The heat affecting the air in a room is to some extent obtained from the occupants of the room, being derived partly from the outer surface of the body, and partly from the internal surfaces in the respiratory tract. The child in school, for example, is capable of raising its 10 square feet of air 6° Fahr. in one hour. Heat is also derived, in an inhabited room, from the heating and the illuminating apparatus. The cold which may affect the air in a room, and so lead to its contraction and increase in weight, is derived from windows, walls, and doors. The draughts which are felt by persons in the neighbourhood of *closed* windows, are due to the cooling and falling down of the air of the room, which has come in contact with the cold glass. It is important to remember, regarding such draughts, that the cold air is impure air, and therefore all the more objectionable.

In *artificial ventilation*, mechanisms, such as fans, that will drive air into the inlets and out of the outlets may be resorted to, such mechanisms being known as *propulsion* or *plenum* mechanisms. Mechanisms, which may again be fans, to suck the air out of the outlets and into the inlets, the so-called *vacuum* or *extract* mechanisms, may be used. A third method of artificially ventilating may be obtained by employing a combination of the plenum and vacuum methods.

In all systems of ventilation, whether natural or artificial, certain provisions must be made: (1) A sufficiency of inlets and outlets, and care must be taken that these are properly placed; (2) a sufficiency of air that is pure; (3) a sufficiency of space to hold the air, and to allow it to circulate without producing draught.

(1) **Inlets and Outlets.**—In ordinary dwellings, the openings usually found in rooms, viz. the windows, doors, and chimneys, are trusted to to act as inlets and outlets. Of these, the doors and windows, especially the lower openings, act as inlets, the chimneys as outlets. The upper openings of the windows and doors act as outlets. The chimney is the most effective outlet, especially when

there is a fire in the grate. Sometimes it acts too effectively, drawing cold fresh air away before it has circulated, and with so much rapidity that draughts result. It also acts powerfully when the wind is blowing across the outer end. Windows and doors act best when open. Openings acting normally as outlets, *e.g.* the top openings of windows, sometimes act as inlets.

The outlets should at least equal the inlets in area. In some dwelling-rooms, but especially in larger rooms, such as those found in schools, the normal openings—doors, windows, and chimneys—are supplemented by openings in the walls, low down, to act as additional inlets, and openings high up, placed usually in the chimney breast, and provided with flaps opening only in the direction of the chimney flue, to act as outlets. By placing the openings of outlets in the chimney breast, the heat inside the chimney is taken advantage of for carrying away the vitiated air.

In **Artificial Ventilation**, where the *propulsion* or *plenum* method is in use, the natural inlets and outlets are not allowed to act, and inlets and outlets are provided. The former are placed from 6 to 8 feet from the floor, the latter a few inches from the floor, and on the same side of the room as the inlets. In this method the natural openings tend to act as outlets, and must be prevented, if possible. Where the *vacuum* method is in use, the inlets are placed low down and the outlets high up. The natural openings in this case tend to act chiefly as inlets.

(2) **Pure Air in Sufficient Amount is required.**—The air in the room should have the same composition as the air outside. So far as carbon dioxide is concerned, however, it is practically impossible to keep it down to 0·4, but it should not be allowed to exceed 0·6 parts per thousand. The 0·2 per thousand additional, which is added partly by the occupants and partly by the illuminants, etc., is called *the limit of respiratory impurity*. If this amount be adhered to, most of the other impurities, viz. organic matter and moisture, will be rendered harmless by dilution. In order to keep within the above limits, a certain amount of air must be supplied to every individual in the room. For adults 3000 cubic feet per hour are required, since each produces 0·6 of a cubic foot of carbon dioxide in that time, and raises the 0·4 per thousand atmospheric carbonic acid to the limit of impurity, viz. 0·6 per thousand. Rather less than 0·6 of a cubic foot is exhaled by a child, and for this reason it is usual to consider less than 3000 cubic feet per hour sufficient for its consumption. It should be borne in mind, however, that tissue changes in the child are more active than in the adult, and that as much, if not more, oxygen is required. Wherever possible, therefore, a child

should have a supply equal in amount to that of an adult. In practice, a half or three-quarters of this amount is generally supplied.

(3) **Space to contain the Air supplied and to permit of its Circulation without Draughts is required.**—To hold 3000 cubic feet of air 3000 cubic feet of space is required. In rooms to contain large numbers this is impossible. It is usual, therefore, to provide less. Whatever the space provided, 3000 cubic feet of air per person must enter and leave it every hour if the 0·6 per thousand limit is not to be exceeded. If there is provided 3000 cubic feet of space, the air to fill it need only enter and leave once in the hour; with 1500 cubic feet twice, and with 1000 cubic feet three times. The smaller the space the greater the frequency with which the air must enter and leave. The frequency must be limited, however, in order to prevent the occurrence of draughts. When the air is admitted directly from outside, *e.g.* in natural ventilation, draughts result if the rate of flow exceeds three feet per second, and if the air is changed oftener than three times per hour. In a room ventilated properly, 1000 cubic feet of air space should be allowed for each adult, and half this amount for a child. Where artificial methods, especially propulsion methods, are employed, and the air is warmed before it enters the room, the air space can be reduced by one-half—500 cubic feet for an adult, 250 for a child being allowed. In calculating the available air space, or, as it is called, the *cubic capacity* of a room, the height, length, and breadth are multiplied together. Height beyond ten or twelve feet is to be disregarded as unavailable for purposes of ventilation. Space occupied by furniture is to be deducted.

In class-rooms, in a school, the size has to be limited on account of certain exigencies, especially that of teaching. The minimum floor space per child is ten square feet, the minimum cubic space 120 feet. In a class-room, therefore, each child will obtain 1500 cubic feet of air only if the air enters and leaves $12\frac{1}{2}$ times per hour, and, with natural ventilation especially, draughts are certain to be produced. To get an amount of air sufficient to keep the carbon dioxide near the 0·6 limit, it is necessary to introduce supplementary inlets and outlets, and to make full use of the ordinary inlets and outlets, *i.e.* the windows and doors, by keeping them open. To obviate draughts, various contrivances to give the air an upward direction may be adopted, *e.g.* boards in front of window openings, and so on. If, as is almost certain to be the case, draughts still result, the only alternatives are to begin the session with the purest air obtainable, to leave the inlets and outlets to do what they can, and to seize every opportunity, such as intervals when the pupils are having recreative exercises or are outside, to thoroughly flush the room with air. In schools where artificial systems are installed, the problem, so long as the system is properly attended to, is simplified, since the air, being heated, can be sent through more frequently. The special advantages of artificial ventilation are that the air to be supplied can be heated and otherwise treated, and, more especially in the propulsion method, can be taken from the purest source. The objections urged against it are, that it is liable to break down, and that the children are not properly taught the value of the open window. The risks of a breakdown are overestimated, and artificial systems, if carefully chosen and looked after by persons interested in them, and properly trained, will work well. The windows need not always be kept shut, only when *full pressure* is on in a room is it necessary, and opportunities can be found for instructing the children in the use of the window in ventilation.

Effects of breathing Bad Air

Bad air may affect health directly or indirectly. *Directly*, because the impurities contained in it prevent the tissues and organs from carrying out their functions normally. *Indirectly*, because germs flourish, and are more active in impure air, and more readily affect an individual whose resistance is lowered by the action of such air. The impure air with which the teacher is mainly concerned is that fouled by respiration and the emanations from human beings, and found in rooms that are overcrowded and unprovided with proper means of ventilation. The ill effects produced by such foul air are the results of the action of the carbon dioxide and organic matter present in it, and, to a certain extent, also of the heat and the moisture which it contains.

The early symptoms are traceable mainly to the effect of the impure air on the brain. The quantity of oxygen being diminished, and the amount of carbon dioxide increased, not only is the brain not stimulated, but it is more or less poisoned by the latter gas. As a result, the individual is dull, sleepy, and languid, yawns frequently, and is incapable of concentrating his attention. In a person at all weakly, fainting or sickness may be induced. The diminution in the amount of oxygen, and the increase in that of carbonic acid, are the factors chiefly concerned in the production of these symptoms. The increase in the temperature of the air is also said to be answerable, to a certain extent.

If fresh air be supplied to an individual in this condition, the symptoms disappear, because the carbon dioxide and the temperature are reduced, and no obvious permanent ill effects are produced. If the individual, however, is compelled to breathe such air hour after hour and day after day, symptoms more serious and more lasting result. The brain suffers, and the individual becomes dull, apathetic, and stupid. The blood being badly aërated, the pale, sickly, bloodless appearance associated with anæmia is developed. The muscles suffer in tone, and there is a disinclination for muscular exertion. The appetite fails, and, the tissues being badly nourished, all the symptoms become exaggerated, and the resistance to diseases, especially infectious diseases, is diminished. Children are much more readily affected by impure air than adults. They are also, naturally, more affected by disease germs, and if compelled to breathe and re-breathe an impure air, which may contain in addition the germs of such a disease as consumption, diphtheria, influenza, or scarlet fever, they are open to attack by one or other of these. The ill effects of moisture in the air are exerted mainly on the respiratory system, the mucous membranes of which are lowered in resistance, and are readily attacked by germs of the common cold, which flourish wherever human beings are collected together. Inflammation is also likely to be set up in these mucous membranes when they are frequently exposed, now to an atmosphere warm and moist, such as is found in an ill-ventilated class-room, and now to an atmosphere that is cold, like that out-of-doors.

The preventive for all these conditions is to be found in ventilation. If a good supply of fresh air is circulated throughout the room, the carbon dioxide will be kept below dangerous limits, the organic matter will be oxidized or swept away, and the unhealthy warmth and the moisture produced by the body will have no time to affect the air to be breathed. Elaborate tests are unnecessary for the detection of impurities in the air. It is no part of the duty of the teacher to carry them out. Air that is breathed over and over again every teacher knows will be fouled by impurities, and a certain series of undesirable symptoms will be produced. This fact must never be lost sight of from the beginning of a class session till the end, especially in a naturally ventilated school. The teacher should never have to be told that the classroom is stuffy, and that the windows should be opened. He should know that it is stuffy, even though insensible of the fact. If it is necessary to demonstrate that impurities are present, the amount of moisture and the temperature may be taken as guides, using the wet and dry bulb thermometers for the purpose, and striving to keep them at proper levels, the dry bulb between 56° and 60° Fahr., and the wet bulb between 53° and 56° Fahr.

Windows and doors should be opened from time to time throughout the class session, if they cannot be kept open all the time, and if there are signs of yawning and inattention on the part of the pupils, the first pupil caught in the act should be told off to open the windows.

If in the course of a lesson there is an epidemic of yawning and inattention, it might be worth while stopping the lesson entirely, opening the doors and windows to the utmost, and giving recreative exercises for a few minutes.

Abnormal Conditions of the Respiratory System

Two conditions affecting the respiratory system to which the teacher's attention might be specially directed are—

1. Mouth breathing.
2. Consumption or Tuberculosis of the Lungs.

Mouth Breathing.—The chief causes of mouth breathing are: (1) Post-nasal adenoids, or, shortly, *adenoids;* (2) enlarged tonsils.

(1) *Adenoids.*—The condition known as adenoids is produced by an overgrowth of the mucous membrane lining the naso-pharynx, behind and around the posterior nares, and above the soft palate. As a result of this overgrowth, soft bodies, varying considerably in size and number, are formed, which more or less completely block the posterior nares and the openings of the eustachian tubes, and interfere with the passage of air through the nose and with hearing. These adenoid growths are common amongst all classes of children, and their appearance may follow an attack of influenza, measles, or whooping-cough. Once having formed, the congestion of the tissues which they themselves set up is said to be favourable to their further growth. In the majority of cases the adenoids are formed before the child comes to school, and the habit of mouth breathing is acquired, but is overlooked by the parents. The signs and symptoms of adenoids are:—

(1) Mouth Breathing.—The mouth is used as a channel for inspired air, and is kept continually open.

(2) The nostrils are small, and the bridge of the nose widened.

(3) The child looks stupid, is dull mentally, backward, and incapable of concentration.

The appearance of stupidity is due to the gaping of the mouth, elongation and flattening of the face, and obliteration of the natural folds. The mental dulness, backwardness, and incapacity for concentration, are due to the dulness of hearing, produced by blocking of the eustachian tubes, and to the fact that the blood is improperly aërated, and the brain improperly nourished.

(4) The child suffers frequently from headaches.

(5) Attacks of bronchitis are common, and the chest is usually small and badly formed.

(6) The voice is dull and flat and nasal.

(7) The child cannot blow his nose properly, and there is frequently a chronic discharge from the nostrils.

(8) The child is more liable to be attacked by infectious

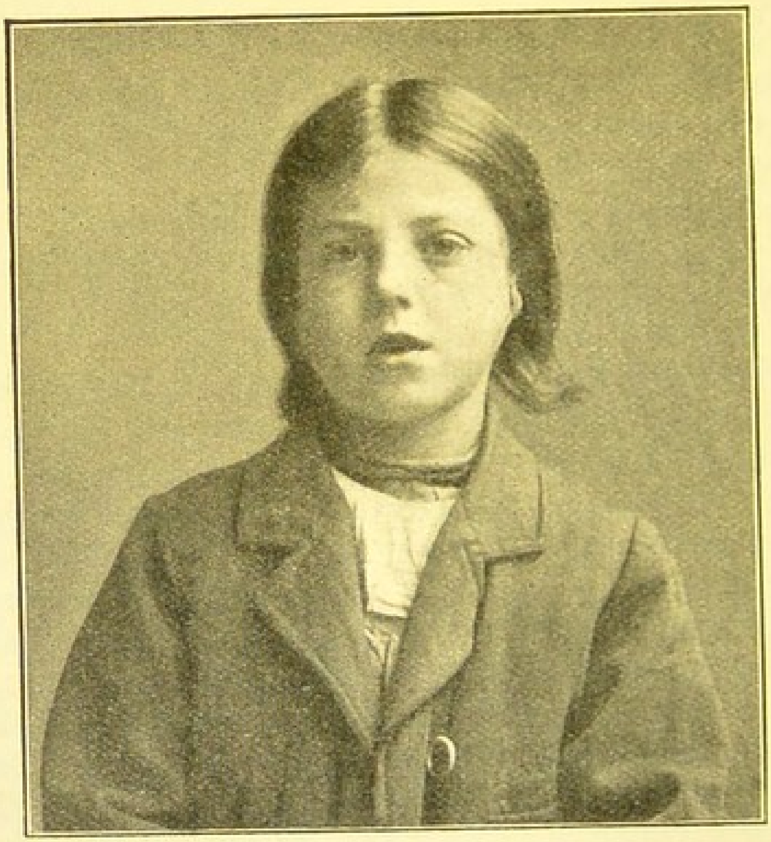


FIG. 44.—Case of adenoids. Note the open mouth, the constriction of the nostrils, and the widening of the bridge of the nose.

diseases, *e.g.* diphtheria, and may show a predisposition to tuberculosis.

(9) The glands in the neck are often found to be enlarged.

(10) The senses of taste and smell, like that of hearing, are often interfered with.

(11) The child is restless at night. He snores and dreams a great deal, because in sleep he tries to breathe through the natural passages, the nostrils, and aëration of the blood is badly carried out.

Many cases do not show all these signs and symptoms, but tremendous numbers of children are to be found presenting one or more. The teacher should always be on the watch for children affected in any degree with adenoids. During the course of physical exercises, especially, opportunities for detecting the mouth breather occur, and since the condition is one calling only for a simple operation, the results of which are, in the majority of cases, good, the teacher should be prepared to recommend the parents to have the child attended to. Breathing exercises after the operation are of great importance as the child has to learn how to use its nose properly. As a matter of fact, parents are usually recommended, after operation on the child, to insist that he shall breathe six times through his nose before he is permitted to sit down to any meal.

(2) *Enlarged Tonsils.*—Enlarged tonsils are usually associated with adenoids, and are to some extent produced by the cold air striking against the tonsils in the mouth breathing which results. Enlarged tonsils may be found apart from adenoids in rheumatic or tuberculous children, or may follow scarlet fever or frequent attacks of sore throat. They are also found in children who have got into the habit of breathing through the mouth as a result of permitting the nasal secretions to remain in the nose and obstruct the passage. The signs and symptoms produced closely resemble those occurring in children with adenoids. Mouth breathing and deafness are the commonest signs. Children with enlarged tonsils are very subject to sore throats—quinsy, ulcerated sore throat, and so on. Also they readily contract diphtheria and scarlet fever, the weakened tissue of the tonsils forming a suitable soil for the germs of these diseases. Good results follow the removal of the tonsils, and the teacher may suggest to parents that such treatment may be beneficial for children suspected of having enlarged tonsils.

Consumption or Tuberculosis of the Lungs or Phthisis.—This disease is less common in children than in adults, the tendency being for the germ of the disease in the former to attack other parts of the body, *e.g.* the bowel, the lymphatic glands, the brain and its coverings, or the joints, in preference to the lungs. Children are sometimes affected, however, commonly about the age of nine or over it. Very frequently the disease is not suspected till it is fairly well advanced, and when it is too late to do any good by treatment.

Consumption is an infectious disease, and is due to a definite organism, viz. the bacillus of tuberculosis. This germ is given off by persons suffering from the disease, and is to be found in varying numbers in their expectoration, either continually, or only now and then. Bacilli are probably discharged from the lung also during coughing, though there may be nothing expectorated. The bacilli which are contained in expectoration carelessly ejected in places used by human beings make their escape from it when the material dries, and is ground into dust, capable of being disseminated. It is for this reason that spitting is so strongly condemned, and that local authorities are making bye-laws prohibiting it. Teachers should use all their great influence over children to prevent them from spitting, and should try to teach those who, as a result of bronchitis, etc., have to spit, to avoid doing so indiscriminately. Probably few people escape swallowing or inhaling bacilli if they associate with, or enter places used by, persons suffering from consumption. Since the bacilli may be spread by kissing, the relatives of consumptives should be careful in this respect. All persons are not affected by the germ, since the way must be paved for it by one or other of what are called the "*predisposing causes*."

Causes of this kind likely to be met with by the teacher are :—

(1) Tuberculosis of the lymphatic glands, especially those of the neck, and affections of these glands rendering them liable to be attacked by tuberculosis, *e.g.* bad teeth, enlarged tonsils, affections of the scalp, etc.

(2) Bad breathing generally, but especially mouth breathing, and the chronic bronchitis induced by it.

(3) Certain infectious diseases, *e.g.* measles or whooping-cough.

(4) Insufficient feeding, and overcrowding and bad ventilation in the home or school.

(5) Previous attacks of lung disease, *e.g.* pneumonia.

In tissues undermined by such causes the tubercle bacilli have an excellent soil, and, having found an entry, are prepared to grow and flourish.

Signs and Symptoms of Consumption.—The signs and symptoms produced by the action of the organism on the lungs are often, especially in children, very indefinite, and the disease may only be detected by a careful examination of the lungs themselves. In the early stages especially, there are no definite features to which attention can be directed. Very diverse types of children may be found to be the victims of the disease, but the following are especially to be looked for and protected as far as possible.

(1) The pale, puny, listless child, who is easily fatigued, who is usually underfed, and who lives in a poor, overcrowded district. Such a child readily falls a victim to tuberculosis, and may show signs of infection in the shape of enlarged lymphatic glands in the neck.

(2) The bright, alert, energetic child, who is tall for his or her age and whose height and weight are out of proportion. Such a

child may be amongst the brightest in the class, and may be of good physique and distinctly athletic. As a result, there is a tendency not only for the child to be overworked and over-exercised, but for him or her to overwork or over-exercise. Any tendency to do so should be restrained and the child carefully watched.

(3) The dull, heavy, stupid, mouth-breathing child with enlarged glands, who is frequently away from school with a "bad cold" or "an attack of bronchitis."

(4) The flat-chested child with rounded shoulders, and the pigeon-chested child, who catch colds readily, are often attacked by the tubercle bacillus and offer little resistance to it.

(5) The child who, after an attack of measles or whooping-cough, does not seem to pick up well may have developed consumption as a sequel of the disease. This tendency to consumption in children recovering from measles and whooping-cough is to be borne in mind, and when a child is sent home from school on account of either of these diseases a recommendation to the parents to be certain to call a doctor should never be omitted.

In the later stages of consumption the signs and symptoms are so well known that the child is almost certain to be under treatment, and is, or should be, kept from school. If the child is at school, for the sake of the others, spitting must be prohibited, and for his or her own sake the amount of work and exercise must be regulated.

Duties of the Teacher in connection with Consumption.—In all cases of consumption the regulation of the work and exercise is perhaps the most important point to be attended to. Many a consumptive is hurried into his grave as a result of overwork, but more especially of over-exercise. A small amount of proper exercise assists the body to fight the disease, an excessive amount hastens the burning up of the tissues, lowers the resistance of the body, and assists in the spread of the disease. By properly regulating the work and the exercise the teacher can protect the children suffering from consumption. The others, and especially those with any tendency to consumption, are to be protected by attending to the ventilation of the class-rooms, by preventing overcrowding, and by warning the children against spitting.

Speech Defects

Since most of the structures concerned in speech have been described in this chapter, it seems advisable to introduce here certain points in connection with that function. In the production of speech three sets of apparatus are involved, they are:—

(1) The respiratory apparatus for supplying a blast of air;

(2) The larynx to transform the blast of air into voice;

(3) The muscles of the lips, tongue, and palate, to alter the shape of the passages, so as to modify the voice and differentiate sounds into words.

In order that speech shall be properly produced all the structures must act absolutely in concert. Interference with any of them or a failure in co-ordination will lead to defects of or difficulties in connection with speech. Among defects likely to be met with by the teacher, probably the most common is *stammering*, or, as it is sometimes called, *stuttering*. Cases of what may be named *false mutism* or dumbness, and defective articulation, such as *lisping* and slurring of certain letters or diphthongs may also be found, especially in the infant and junior schools.

Stammering.—Stammering is much more common amongst boys than girls in the proportion of about four or five to one. It occurs most frequently in children of an excitable disposition or whose parents are of a nervous temperament. Its presence does not indicate defective intelligence. It is sometimes associated with adenoids, and may follow one or other of the infectious diseases or a shock to the nervous system, such as a sudden fright. It may be the result merely of imitation. The defect is usually most marked when the sufferer is frightened or depressed.

The defect itself is probably traceable to some functional nervous disorder, the stammering being due to a failure on the part of the stammerer to properly co-ordinate the action of the three sets of apparatus concerned in speech production. The amount of energy to be sent to the respiratory organs, to the larynx and to the muscles of articulation, is not properly estimated and they do not act together harmoniously. With very little care and attention, respiration and phonation, or the transforming of the blast of air from the lungs into sound, easily and readily takes place, and in the normal person no effort is felt. Articulation, or the moulding of sound, requires much more care. To the stammerer the necessity for this care is particularly obvious, and he exaggerates the importance of the work of the muscles of articulation, neglecting to give even the small amount of attention necessary to bring about respiration and phonation. He produces therefore an excessive amount of energy for the muscles of articulation, and an insufficient amount for those of respiration and phonation. As a result, the muscles of the tongue and lips are over-stimulated, and are thrown into such a condition of irregular spasm that articulation cannot be brought about. From the nerve centres governing these muscles energy overflows, and, affecting centres of muscles not concerned with speech production, *e.g.* those of the eyelids, the face, the head and the limbs, leads to stimulation of these muscles, and grimacing or movements of the head or limbs. Because of the neglect of respiration only a weak blast of air is sent along the air passages to the larynx; partly as a result of this, and partly as a result of the neglect of the larynx itself, phonation is not properly carried out. Evidence in support of the above commonly accepted explanation of stammering can easily enough be obtained by watching a stammerer in the act of speaking. Practically always it will be noted that though before beginning to speak he may fill his chest with air, it is more than half empty by the time the first word is commenced. Because he is never ready to speak, and the mechanisms easily get out of his control, it is the initial syllable of the first word to be uttered that gives him the greatest amount of difficulty. It will be found further, that in singing and in the production of vowel sounds, because the larynx more than the mouth is concerned, little difficulty is experienced, and they are practically never attended by stammering. For the same reason, viz. that the attention is taken somewhat off articulation, poetry is easier than prose, and speaking in a full and rather intoning or sing-song voice is comparatively easy.

The exercise that gives the stammerer most trouble is the production of sounds which have little or no voice in them, *e.g.* the consonants. In the production of these the larynx, with one or two exceptions, plays no part, the blast of air passing straight to the mouth, where practically the whole of the work in connection with them is done. The consonants which call for a certain amount of phonation, and which therefore contain voice, are known as *voiced consonants*. They are: B, W, V, Th, Z, ZH, D, L, R, G, Y. M, N, and Ng, which resonate in the nose, and which have voice in them also, are sometimes classed as *voiced nasal resonants*. The other consonants, viz. P, F, Th, S, Sh, T, K, H, or Ch, are known as *voiceless consonants*. In the last group the letters giving the greatest amount of difficulty to the stammerer are found. Those containing voice and approaching the vowels are less difficult. Consonants which have more or less of an explosive character, *e.g.* P, T, K, B, D, and G are the most difficult of all.

Treatment.—In the treatment of stammering, the teacher, there is no doubt, can do a great deal of good, provided he can and will give the time. Probably the first thing to do is to explain to the stammerer exactly what the fault is, and for this reason it is usually said that the best time to begin treatment is about the age of twelve or thirteen. In younger children, to whom it may be found difficult to explain what is wrong, there is no reason why an attempt should not be made to remedy the defect. The elements of proper voice production, with which teachers are supposed to be acquainted for the purpose of giving instruction in reading and singing, may be taught. The habit of speaking on a half empty chest should be discouraged, and the child urged to throw back his head and thoroughly fill his lungs before beginning to speak and at intervals during speaking, and to economize the breath as much as possible.

By all the means in his power, by exercising gentleness and tact, the teacher should try to increase the stammerer's confidence in his ability to get control of his speaking apparatus. There must be no scoffing at his defect, and any tendency on the part of the other scholars to laugh at the sufferer or to mimic him should be put down. He should take part in the reading and singing lessons and should be encouraged to answer questions. Answers given in a weak voice with little or no air behind it and markedly stuttering should be refused. He should be made to employ a full resonant voice, and to attack his words boldly. He may be directed to intone more or less. An attempt may be made to find the letters with which there is the greatest difficulty, and sentences containing these letters plentifully may be given to him to practise. If the parents of the child can be seen and spoken to regarding him they should be advised to encourage the boy to read aloud at home, first poetry and later prose. Reading or reciting in front of a mirror is strongly recommended by some authorities, as in this way the stammerer can see where his difficulties are, and may learn how to overcome them and how best to produce sounds. If the child is nervous and out of health the parents may be recommended to get medical advice and treatment for him.

Other Defects of Speech.—False mutism, lisping, and other defects in articulation likely to be met with are usually more or less temporary. The former, which is generally not associated with deafness, will often be found to disappear if the child is taken apart and talked to quietly, though it is quite content to sit in class and play with the other children without uttering a word. Lisping and slurring of certain letters or combinations of letters are often merely remnants of a "baby talk" which has been encouraged and kept up too long at home. They may, however, be due to a want of control over the tongue and other muscles of articulation. Exercises for the tongue muscles are sometimes recommended, and will be referred to when dealing with the tongue. The defects usually disappear as the child gets older and is taught how to read and pronounce words.

CHAPTER VIII

THE DIGESTIVE SYSTEM

Structure of the digestive system—Digestion—Choice of foods—The feeding of infants and children—Conditions affecting the digestive system.

THE digestive system includes: (1) the mouth with the teeth, the tongue, and the salivary glands; (2) the pharynx; (3) the gullet or œsophagus; (4) the stomach; (5) the small intestine; (6) the large intestine; (7) certain glands in the abdomen, viz. the pancreas and the liver.

The Mouth.—The mouth is bounded in front by the lips, at the sides by the cheeks, and behind by the fauces, through which the food passes into the pharynx. Above, the roof of the cavity is formed by the hard palate in front, and the soft palate behind, while the floor of the mouth is occupied mainly by the tongue. The whole interior is lined by mucous membrane consisting of cells resting on fine tissue containing nerves, blood-vessels, lymphatic vessels, and so on. The cells are delicate and are arranged in thin layers through which the blood in the blood-vessels shines, giving the red colour to the membrane. In the cheeks and lips, between the mucous membrane and the skin, layers of muscle are to be found.

FIG. 45.—The upper surface of the human tongue.
(*From Furneaux's "Elementary Physiology."*)

The *tongue* lies in the floor of the mouth and is a muscular organ. The muscle fibres are covered by the mucous membrane of the mouth, which, over the upper surface of the tongue, is roughened by projections called *papillæ*. These papillæ are of three kinds, and are named according to their shape, *filiform*, *fungiform*, and *circumvallate*. The *filiform*, or thread-shaped papillæ, are the smallest and are found all over the upper surface of the tongue. The *fungiform*, or fungus-shaped papillæ, resemble a mushroom in form. They are rounded and larger than the filiform and less numerous. The *circumvallate* papillæ are few in number and are the largest of the three. They occur only at the back of the tongue where they can be seen quite readily, arranged more or less in the shape of a "V." Each consists of a large pit with a projection in the centre. The circumvallate papillæ are chiefly concerned with taste, and in them fibres from the nerve of taste are to be found, each fibre being swollen at the end to form what is called a *taste bud*. Taste buds are found also in the fungiform papillæ, and, apart from papillæ, in the mucous membrane of the tongue along the side and at the back. In the soft palate, and on the upper surface of the epiglottis a few are also distributed.

The tongue is fixed in front to the floor of the mouth by a fold of mucous membrane attached to its under surface. The point at which this is fixed varies in different individuals. When it comes too close to the tip the so-called "tongue tie," or "short tongue" occurs. This condition, however, is very rare, much more rare than is generally supposed. The movements of the tongue in various directions are brought about by muscles springing from the hyoid bone. The variations in size and shape of the organ, such as pointing, when the tongue is protruded, are brought about by the action of the muscle fibres making up the organ itself. Certain speech defects are due to a lack of control over the muscles of the tongue and may be remedied by exercising these muscles. An exercise strongly recommended is protrusion of the tongue as if to lick an imaginary crumb from the tip of the finger.

The roof of the mouth is formed by the hard palate in front and the soft palate, hanging down like a curtain between the mouth and the pharynx, behind. The *hard palate* consists of bone covered by the ordinary mucous membrane lining the mouth cavity. It forms an arch which, in the well-formed skull, is broad both in front and behind and is not too high. A narrow high-arched palate is often found associated with a high-bridged nose, and a badly formed, weak, rather receding, pointed chin. Very often in such a case the upper jaw bones at the point where they meet in the middle line form an acute instead of an obtuse angle, and the upper teeth are very prominent. When these are combined, what is called the *bird-like profile* is produced. By many persons the high-arched palate is taken as evidence of poor development, mental and otherwise. It may be associated with defective vision and adenoids. What is known as *cleft palate* is a sign of defective development, the two halves of the soft palate, and sometimes also of the hard palate, to a greater or less extent, having failed to unite before birth. It is sometimes found associated with *hare lip*.

The Soft Palate.—The soft palate consists of mucous membrane and contains the muscular fibres concerned with its movements during eating, speaking, and singing. At its centre behind it is prolonged downwards to form a more or less pointed process the *uvula*. During singing the soft palate rises for the taking of high notes, and in swallowing it is raised in order to shut off the nasal openings from the fauces. The nerves supplying its muscles are sometimes paralyzed after an attack of diphtheria, giving rise to difficulty in swallowing, and to a nasal tone of voice. This condition is sometimes met with in undetected and untreated cases, and should be borne in mind by the teacher for this reason.

The Fauces.—The back of the mouth, which is the narrowest part of the cavity, is formed by the *fauces*. The opening of the

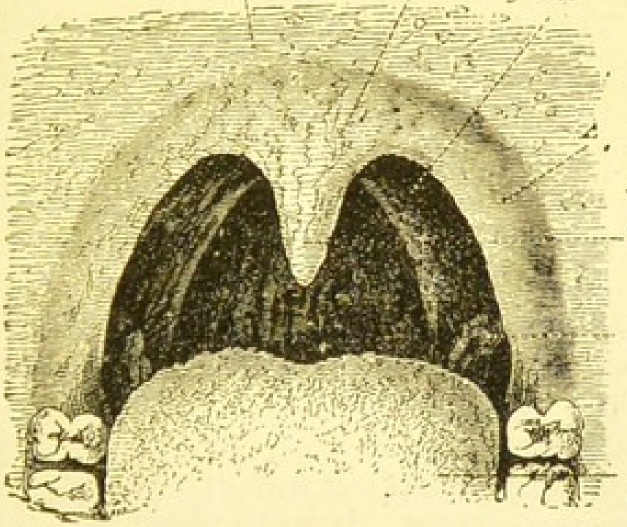


FIG. 46.—The fauces.

fauces is bounded above by the uvula, below by the base of the tongue, and at the sides by what are called the *pillars of the fauces*, between which, on each side, lies the *tonsil*. The pillars of the fauces lie, one in front of the tonsil on each side, the *anterior pillar*; the other behind, the *posterior pillar*. They consist of muscle fibres covered with mucous membrane. During swallowing the muscle fibres contract and help to drive the food into the pharynx.

The Tonsils.—The tonsils are small, soft masses, consisting of tissue slightly resembling lymphatic gland tissue, and varying considerably in size in different individuals. In some cases they may be so small as not to be visible, while in other cases they may be so large as to project far beyond the pillars of the fauces, narrowing the opening out of the mouth. The normal tonsil shows numerous small depressions on its free and visible surface. These communicate with the deeper parts of the tonsil and from them small quantities of a thickish fluid escape. The function of the tonsils is practically unknown. Apparently they are not of any great importance since their removal gives rise to no unpleasant symptoms. In persons with enlarged tonsils, removal may prove a decided benefit.

The Teeth

The teeth are provided for the purpose of masticating the food, and to that end two sets are developed during the course of a lifetime, viz.: (1) the *temporary* or *milk teeth;* (2) the *permanent teeth.* The *temporary* or *milk teeth* form the first set, and are the only teeth found in children under the age of six or seven, when they begin to disappear making way for the permanent set. The teeth in this set are smaller and more delicate and fewer in number than those in the permanent set, nature supposing that the work they have to do in mastication will be less heavy than that required of the permanent teeth. Temporary teeth begin to appear usually about the sixth or eighth month, in children who are properly fed and taken care of, and who are not the subjects of rickets. Being a natural process, teething should be practically painless, and the majority of the ills ascribed to teething do not originate from it, though they may disturb the process. The first group of teeth to appear are two in the middle of the lower jaw called the *central incisors.* The second group makes its appearance in the upper jaw between the eighth and tenth month. In this there are four teeth, all *incisors.* In the third group there are six teeth, and these appear between the twelfth and fourteenth month. It is made up of two *lateral incisors* in the lower jaw, and four teeth called the *front molars*, one on each side of both jaws. By the end of the twelfth, or at the latest the fourteenth month, a child who has gone through the teething process regularly should have twelve teeth. Every girl, and more especially every young mother, should be aware of this fact. The remaining temporary teeth come out in two groups. One consists of four teeth called *canines*, which are situated one on each side of both jaws between the outer incisor and the front molar. This group appears at the eighteenth or twentieth month. The other group consists of the four *posterior molars*, one on each side in each jaw. They appear about two or two and a half years after birth, and complete the temporary set of twenty teeth.

The *permanent set* appears gradually. The first to show is a molar, at the sixth or seventh year, and thereafter more and more of the permanent teeth, which have been lying ready made in the jaws under the temporary teeth, make their appearance, pushing out the milk teeth to do so. The last permanent tooth to cut the gum is the so-called *wisdom tooth*, and it does so any time after the eighteenth year. It completes the set in the adult, which consists of thirty-two teeth. In each half of each jaw there are two incisors, one canine, two bicuspids, and three molars.

Structure of the Teeth.—The teeth, both temporary and permanent, are set into sockets in the jaws, where they are held by a cement substance somewhat resembling bone. The part of the tooth in the socket is known as the *fang*. The incisors and canines are provided each with one fang, the molars of the upper jaw have three fangs, those of the lower jaw two. The part of the tooth visible above the gum is called the *crown*. Between this and the fang there is a somewhat constricted portion to which the name *neck* of the tooth is applied.

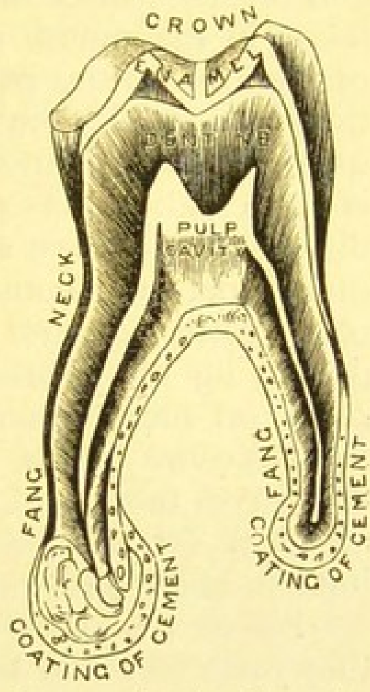


FIG. 47.—Section of a tooth. (*From Barnett's "Making of the Body."*)

The teeth in both sets are developed from the mucous membrane lining the mouth. Though hard, like bone, they are quite differently constructed. On section from the crown to the top of the fang the following parts become visible :—

1. A central cavity filled with what is called the *tooth pulp*, a jelly-like substance consisting of fine soft tissue, rich in blood-vessels and nerves, which reach it through a tiny opening at the tip of the fang.

2. A hard substance, like bone, called *dentine*. This is made up of fine, delicate, microscopical tubes between and around which there is deposited a large amount of mineral matter, consisting chiefly of lime salts. To these salts the dentine owes its hardness.

3. Outside the dentine, at the crown of the tooth, there is a layer of a very hard substance called *enamel*. Outside the fang there is the hard cement substance which fixes the tooth in its

socket. This closely resembles bone, and receives its nourishment from the blood-vessels in the periostium lining the interior of the tooth socket. The enamel consists almost entirely of mineral matter arranged in the form of minute prismatic columns. It is thickest over the crown where the food is broken up, and becomes thinner, and finally disappears when it reaches the neck of the tooth. It plays a very important part in protecting the dentine and pulp from the action of certain germs which flourish in the mouth, and which are always striving to penetrate the enamel and to destroy the dentine.

Hygiene of the Mouth and Teeth

The mouth, like many other parts of the alimentary tract, is greatly favoured by bacteria, since it contains everything necessary for their growth and development, viz. warmth and moisture, and organic matter for their nourishment. Many of the organisms found in the mouth are harmless, but since the mouth must be opened for various purposes germs that are not harmless may find their way in also, either with the air or the food. Some of these organisms are distinctly harmful, and capable, provided the body is in a condition favourable to their action, of producing definite diseases. Amongst such organisms may be classed the germs of diphtheria, of pneumonia, of tuberculosis, and probably of most other germ diseases as well. Certain organisms are capable of destroying the enamel of the teeth, producing what is called *caries* or, more commonly, *decay* of the dentine, and leading to the exposure of the pulp, and, consequently, to inflammation of the nerves there, and to toothache. Sometimes, if the gum tissues are weak for any reason, the organisms attack these, producing inflammation, and what is commonly termed a *gum-boil.*

Before the decay-producing bacteria can reach the dentine, they must first find their way through the enamel. In this they are assisted by the fact that the mineral salts of which the enamel consists can be dissolved by acids, and by the fact that as a result of accidents, small pieces of enamel are chipped off, and the dentine is exposed. The acids are produced by the organisms of decay themselves, and by other bacteria in the mouth during the process of destruction of particles of food, especially starchy and sugary food like bread and potatoes. It is possible, however, that the germs themselves can dissolve or destroy the enamel, because they are said to form small masses at certain points about the crown and neck of the tooth where the enamel is thinnest, and where they are less likely to be disturbed during the process of mastication, and by the tongue or the tooth-brush. The thinner and less well developed the enamel, and the softer the dentine, the more rapidly does decay take place. In some persons the teeth seem to be naturally soft, the enamel being thin and the dentine poor in mineral matter. In others, the same conditions are seen and are the result of improper feeding, more especially in childhood, articles of diet rich in starch and sugar, and poor in salts and bone-forming substances, having been used. In such persons, if the teeth are neglected and the organisms uninterfered with, decay takes place rapidly. It is to be borne in mind that the temporary teeth are as likely to be attacked by germs as the permanent teeth, and the results of such an attack may be most serious. Not only may the infected temporary teeth lead to the infection of the permanent set, but the growth and development of the child may be interfered with, since the toothache and inflammation in the mouth prevent proper food from being taken, and the foul substances produced pass into the stomach, and by damaging it disturb digestion. To ensure that a child shall have a good set of temporary teeth, and thereafter a good permanent set, and to prevent caries, certain precautions must be taken. (1) The child must be fed properly, not only after the teeth have appeared, but in early infancy as well. (2) The mouth and teeth must be kept clean and free from collections of food and germs, and decay-producing organisms must be prevented from remaining for any length of time in contact with the teeth.

With regard to the feeding of the child, the great point is to see that it gets food containing plenty of lime salts and bone-forming substances, and a minimum of starch and sugar. This is especially important in infancy; but after the teeth have formed starchy foods are injurious, not only because they help very little in the growth and development of the tissues, but also because they are readily broken up by such organisms as are found in the mouth, enamel-destroying acids being amongst the substances produced. To keep the mouth and teeth clean, and to get rid of any collections of germs, nature has provided the tongue, and has made its upper surface rough. Unfortunately there are many parts of the teeth which the tongue cannot reach, and its efforts have to be assisted. For this purpose the tooth-brush is, or should be, employed, the tooth-brush in turn being supplemented by the tooth-pick and the silk thread.

The tongue begins to clean the teeth as soon as there are any to clean, and probably succeeds by itself so long as the teeth are few in number. As the teething process goes on, however, assistance is required, and for this purpose a small piece of some soft material may be used at first. After a time a soft tooth-brush may be substituted, and when the child finds its hands and begins to understand a little, it may be taught to use the brush itself. The child at school can easily, of course, learn how to use a tooth-brush, and how to attend to the teeth. The chief points regarding which instruction is necessary are—

1. The time to use the tooth-brush.
2. How to use the tooth-brush.

When to use the Tooth-brush.—Practically, the teeth should be brushed after each meal, and, in addition, in the morning as part of the toilet, and at night, just before going to bed. This is, in most cases, a counsel of perfection, but it should not be impossible to brush the teeth morning and night; the rule being, "brush them for your own sake in the morning, and for their sake at night." The majority of people are content with using the brush once a day, in the morning. If it is only possible to use it once, it would be better to let that once be at night, in order to get rid of accumulations of food collected during the day.

How to brush the Teeth.—The backward and forward movement across the teeth leaves the majority of the tooth-destroying organisms undisturbed. The haunts of these organisms are the sides and crown of the tooth, and to the backward and forward movement across the front must be added an up and down movement between the teeth, and a movement along the top of the crown. The tongue may be left to attend to the back of the teeth. To assist in the dispersal of the germs on the sides, the tooth-pick is to be recommended, and the scraping or "silking" of the sides with a silk thread passed between each pair of teeth, and moved up and down along the adjacent sides five or six times. Silking is recommended as an additional safeguard against caries, and should be carried out once or twice a week, or oftener, care being taken to avoid cutting the gums. In conjunction with the tooth-brush some form of dentifrice in the form of a powder, a paste, or a liquid is generally employed. To these dentifrices is usually added some disinfectant or antiseptic, and the powder or fluid is called an "antiseptic dentifrice," and is supposed to be capable of killing the germs in the mouth and about the teeth. The powders are supposed also to be capable of imparting a polish to the enamel. It is practically certain that these antiseptic powders and fluids are quite without action on the germs. If the germs are affected at all, it is by the bristles of the brush. The powders may polish the enamel, but they probably scratch it in the process. If a powder is required, precipitated chalk may be used, or sodium bicarbonate, or ordinary common salt. The bicarbonate of soda is especially good for the morning cleansing, since it cleans the mouth and dissolves any material that may have collected during the night. The brush alone, indeed, is probably sufficient, and in order to strengthen the gums it is better to use cold instead of hot water. For the cleaning out of cavities in the teeth special tooth-brushes are made and sold. These should be unnecessary, the proper course to follow, when the enamel has been perforated and a hole formed, being to have the hole cleared out and filled by a dentist. In any lesson on the hygiene of the teeth and mouth given to school children, the importance of having holes in the teeth stopped should always be mentioned.

In the case of the children of the poorer classes it is probable that instruction as to when and how to use a tooth-brush will be productive of little good. By the parents of such children the teeth are not, as yet, regarded as a possession of any value. They are looked upon merely as things that ache at more or less regular intervals, and call occasionally for extraction. To them, also, the tooth-brush appears unnecessary, and brushing the teeth mere foppishness. So long as the parents hold such views it is hardly likely that the children will have much opportunity of applying the instruction obtained in school, further than writing essays concerning the number, arrangement, and structure of the teeth, and the importance of keeping them clean. These essays, doubtless, have their value, but mainly as exercises in composition. Like the majority of essays on hygienic subjects by children they consist merely of a more or less correct *resumé* of the lesson given by the teacher, the child writing down what he or she believes the teacher will be pleased to have written down. And that is not the object of the instruction in hygiene. The full value of the lesson is not obtained until it is applied, and the application should be seen, if possible, by the teacher. In day schools, and especially in the elementary schools of a large city, it is impossible to see that all the lessons in hygiene are applied. The application of the lesson on the hygiene of the teeth, like that on cleanliness generally, might, however, be seen in the school, and according to certain persons tooth-brushes should be supplied by the State, and each child should brush its teeth in school in imitation of the "tooth-brush drill" carried out in some German schools. The reason for suggesting the State as a tooth-brush provider is that it has most to gain; soldiers with bad teeth being undesirable.

The Salivary Glands

There are three pairs of salivary glands, and like other glands in the digestive tract, they are what are called *secretory* glands. The function of such glands is the manufacture from the blood of substances called *secretions*, which perform some definite duty in the body. They have to be distinguished from certain other glands called *excretory* glands, which separate waste products from the blood and see to their discharge from the body. The kidneys and the sweat glands of the skin are examples of excretory glands.

The salivary glands are named according to their position.

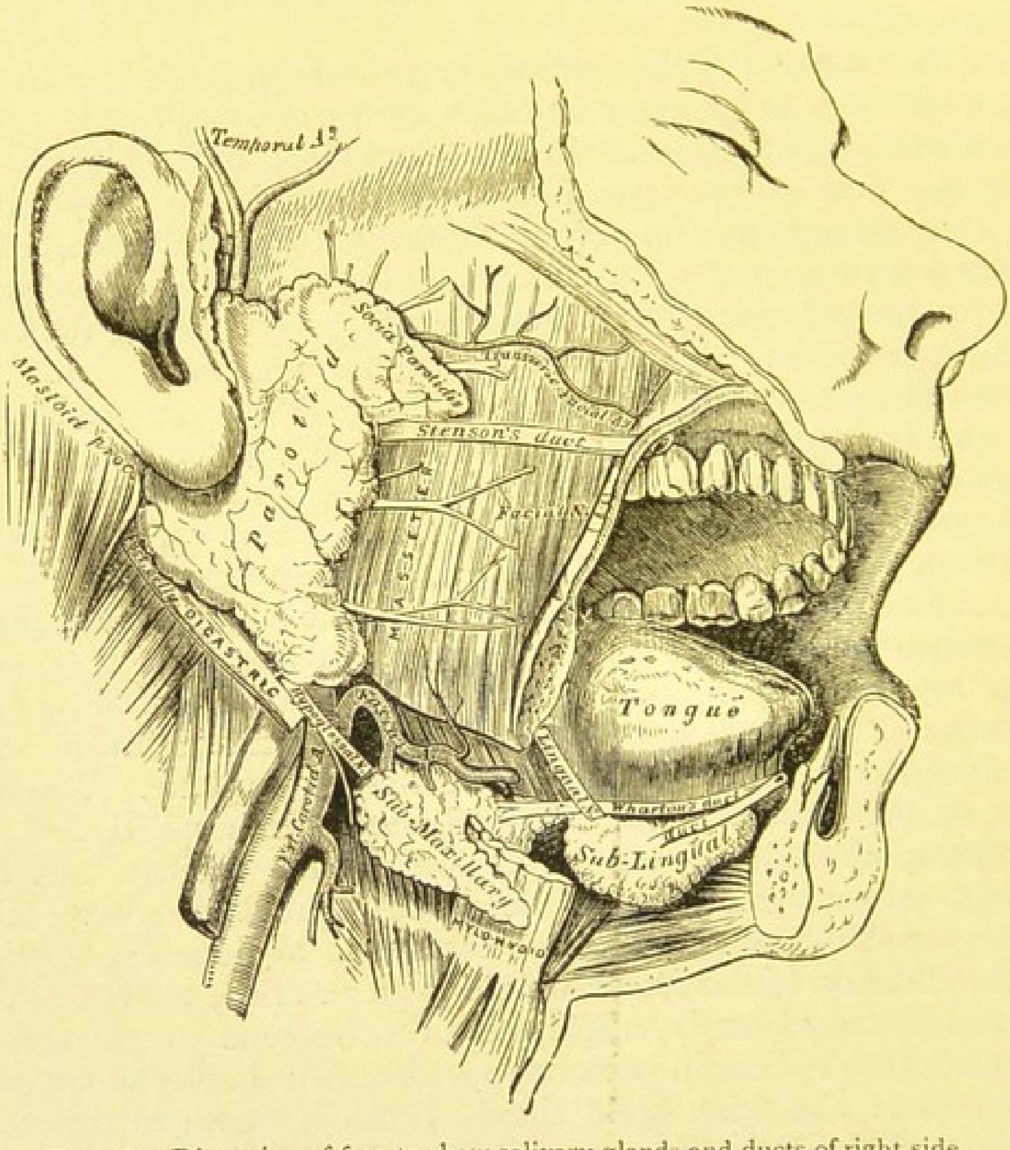


FIG. 48.—Dissection of face to show salivary glands and ducts of right side. (*From Gray's "Anatomy."*)

(1) The *parotid* glands, which lie one on each side in front of the ear. They are the largest. (2) The *submaxillary* glands, which lie under the maxilla close to the angle of the jaw, and which are slightly smaller than the parotid glands. (3) The *sublingual* glands, which lie under the tongue. They are the smallest of the three. As the name implies, the three pairs of glands secrete a fluid called *saliva* which they pour into the mouth, and which has

for its function the moistening of the mouth, and the moistening and dissolving and digesting of certain food stuffs. Probably the most important function is the moistening of the mouth and the food.

Each gland consists of a secreting portion which is the gland proper and a duct which conveys the secretion into the mouth. The duct opens, on the one hand, in the mouth, and on the other, spreads out in every direction in the substance of the gland terminating in little grape-like clusters of minute tubes. These tiny tubes are lined with cells, and form the secreting portion of the gland. The remainder of the gland is made up of connective tissue binding the clusters together; of blood-vessels, which are especially numerous round the clusters, and of nerves. Because of these grape-like clusters the salivary glands are called *compound racemose glands*. The parotid gland on each side opens through a duct (*Stenson's*) inside the cheek close to the second upper molar tooth; the ducts (*Wharton's*) of the submaxillary glands open in the floor of the mouth under the tongue. The sublingual glands have several small ducts which open under the tongue.

Saliva.—The salivary glands are practically always secreting saliva and pouring small quantities into the mouth. They are specially stimulated to secrete, however, by the taste of food and by its presence in the mouth. The movement of the jaws during chewing also stimulates secretion, and assists in the discharge of the fluid. The sight or thought or smell of food may also bring about secretion. The flow of saliva may be stopped by fear and is diminished in fevers. In infants the quantity secreted is larger than in older children and adults. Saliva consists partly of mucus and partly of an albuminous fluid, the latter being secreted mainly by the parotid glands, and the former by the sublingual glands. The secretion of the submaxillary glands contains both the albuminous fluid and mucus. From the presence of certain salts the saliva is alkaline in reaction. In contains also a ferment named *ptyalin*, which, in an alkaline medium, is capable of acting upon and dissolving starch granules. In the mouth the saliva is mixed with the food in the process of chewing, and the ptyalin begins the digestive process by attacking the starch. It is doubtful whether this ferment assists digestion to any extent since it is only small in amount. The saliva of infants, especially, contains only a minute trace of ptyalin, but it increases in amount as the teeth appear. This suggests that only substances containing little or no starch should be given before the teeth are cut. Of these milk is, of course, the most suitable.

The Pharynx and Gullet or Œsophagus

The pharynx has already been considered in connection with the respiratory system. It is reached immediately after passing through the fauces and conducts food into the gullet or œsophagus. The *œsophagus* is the direct continuation of the pharynx, and is a muscular tube lined with mucous membrane. In the adult it is about 10 inches long and 1 inch wide. It terminates by opening into the stomach, passing through a special opening in the diaphragm to do so. Except when food is passing through, the tube is collapsed. The muscular fibres of the gullet are involuntary, and are arranged partly as circular bands round the tube, and partly as longitudinal bands running the length of the tube. The longitudinal bands lie outside the circular fibres. In swallowing either solids or liquids, the muscular fibres are stimulated to contract, the contraction running the whole length of the tube from above downwards. This contraction, because it somewhat resembles wave motion, is sometimes called a *peristaltic wave* or *peristalsis*. The fibres above the portion of food or fluid contract in order to push it down. Because of this contraction above the food, animals, and man too, if he chooses, can eat and drink, even though the food or fluid has to travel uphill to reach the stomach. In ruminant animals contraction of the muscle fibres can take place in the reverse direction also, *i.e.* from the stomach towards the mouth. The peristaltic wave in man and non-ruminant animals normally only passes from above downwards.

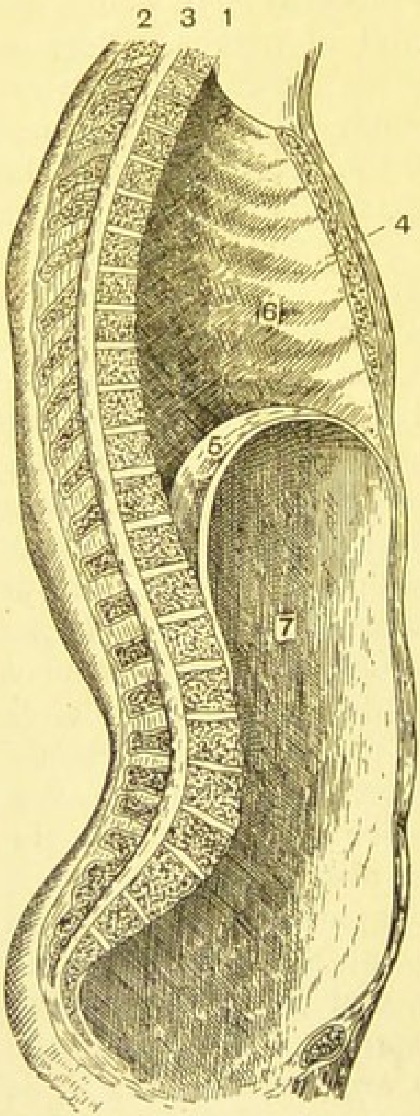


Fig. 49.—Cavities of the body.

1, bodies of vertebræ; 2, spinous processes of vertebræ; 3, spinal canal; 4, sternum; 5, diaphragm; 6, thorax; 7, abdomen.

(*From Furneaux's "Elementary Physiology."*)

The Abdominal Cavity

The remainder of the alimentary tract and the organs connected with digestion lie in the *abdomen*, or, as it is sometimes called, the *abdominal cavity.* Before considering these it will be well to say a few words concerning the cavity itself.

The abdomen is bounded above by the diaphragm, below by

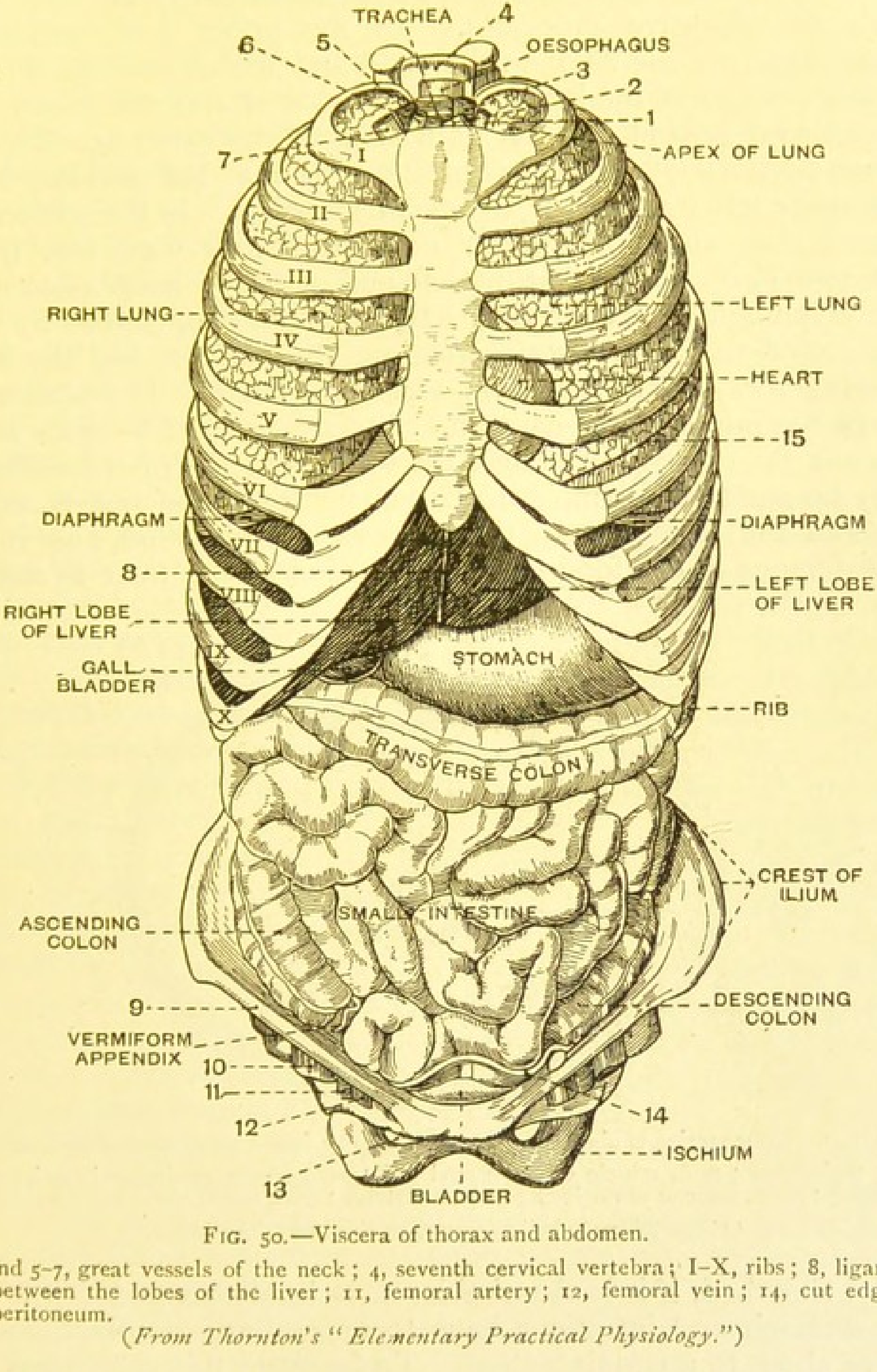


FIG. 50.—Viscera of thorax and abdomen.

1–3 and 5–7, great vessels of the neck; 4, seventh cervical vertebra; I–X, ribs; 8, ligament between the lobes of the liver; 11, femoral artery; 12, femoral vein; 14, cut edge of peritoneum.

(*From Thornton's "Elementary Practical Physiology."*)

the bony pelvis, and the muscular and other tissues closing the outlet of the pelvis, and forming what is called the *floor of the pelvis.* The back wall is formed by the bodies of the lumbar vertebræ and the sacrum and coccyx, the sides and front wall by the abdominal muscles, which stretch from the ribs above to the pelvis below, and by the fat and skin covering them. The majority of the organs filling the abdominal cavity are concerned with the digestive processes. In the upper part, under the diaphragm, are the *liver* on the right and the *stomach* on the left, with a portion of the large intestine below it and the *pancreas* or sweetbread behind it. On both sides of the cavity are disposed other portions of the large intestine, and in the middle, filling the space left by these, is the small intestine. In the abdominal cavity also, and not directly concerned with digestion, is the *spleen*. This organ lies at the left end of the stomach close up to the diaphragm under the ribs. In the back wall, capped by what are called the *supra-renal bodies*, are the *kidneys*, and the tubes bearing away their secretion, viz. the *ureters*. The abdominal aorta, the inferior vena-cava and the thoracic duct lie quite at the back of the cavity. Amongst the other contents of the abdomen may be mentioned lymphatic glands, nerves, blood-vessels, etc.

The Peritoneum.—In the processes of digestion, and in the transference of the food from one portion of the tract to another

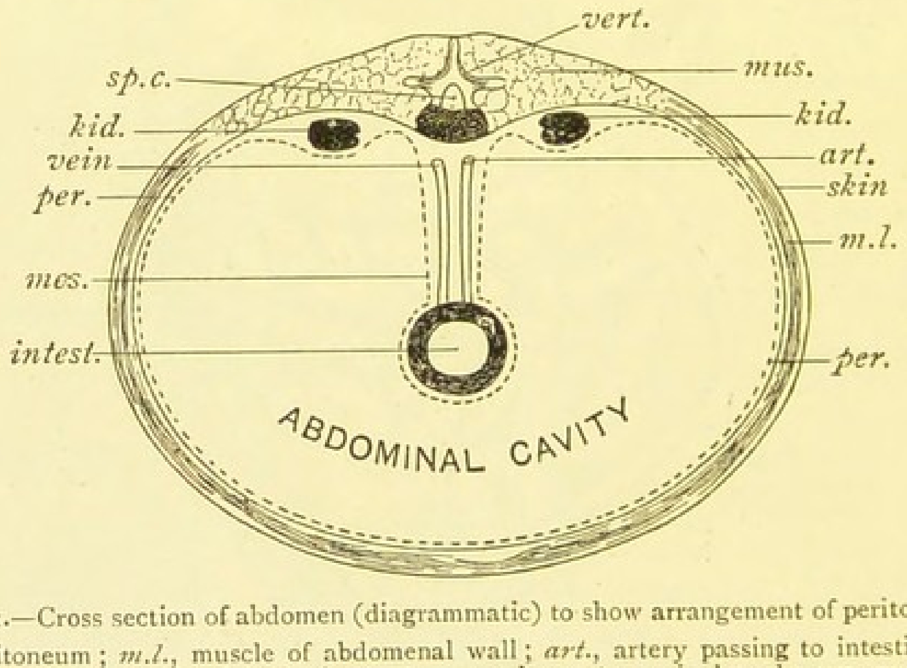


FIG. 51.—Cross section of abdomen (diagrammatic) to show arrangement of peritoneum. *per.*, peritoneum ; *m.l.*, muscle of abdomenal wall ; *art.*, artery passing to intestine ; *kid.*, kidney ; *mus.*, muscles of the back ; *vert.*, a vertebra ; *sp.c.*, spinal cord ; *mes.*, mesentery.

(*From Thornton's "Elementary Practical Physiology."*)

to be absorbed, if it is absorbable, or to be discharged if it is not, the stomach and intestines have to expand and contract, and to move about to a certain extent. To facilitate this movement and to permit the various parts to glide one over another and over the other abdominal organs, all are covered with a smooth, delicate, glistening membrane resembling the pleura and pericardium in structure. This is named the *peritoneum*. In order that the movement may be uninterfered with by friction, the walls of the cavity and the organs which are at all in contact with the various portions of the alimentary tract are also covered with peritoneum. In order still further to diminish friction, the cells of the peritoneum secrete a fluid called *peritoneal fluid*. The peritoneum, like the pleura, is a double bag, and the bag covering the walls of the cavity is continuous with that covering the alimentary canal and the other organs. Just as it was possible to trace the pleura over the lung and over the ribs and diaphragm and find the connection between the lung and rib pleura, so the peritoneum can be traced over the walls of the abdominal cavity and over the various organs inside these walls. In the cavity of the pelvis it can be traced over the bladder, the lower part of the large intestine, and certain other organs there. Where the peritoneum passes away from the abdominal wall to surround or enfold an organ or portion of the tract, what is called a *ligament* is formed by the union between the layer passing away from the wall and the layer returning to it after surrounding the organ. The length of this varies with the distance between the wall and the organ, and its chief use is the support of the organ. In all instances the peritoneum passes away from and returns to the back wall of the cavity. The majority of the ligaments, therefore, are attached to the posterior abdominal wall. In the case of the small intestine the ligament supporting the coils is called the *mesentery*. In its folds lie the arteries and nerves passing to the intestine and the veins, and lymphatics carrying the impure blood and digested substances away from it. In order to protect these coils of the small intestine, the peritoneum covering the portion of large intestine occupying the upper part of the cavity is prolonged downwards to form what is called the *omentum*, because it resembles an apron. Between the peritoneum covering the stomach, bowels, and various organs, and that lining the walls of the cavity, there is a space called the *peritoneal cavity;* into this space the peritoneal fluid secreted by the cells is poured.

The Stomach.—The stomach lies in the upper part of the abdomen, the greater part under the left arch of the diaphragm. It is a bag more or less resembling a pear in shape, and is bent upon itself into the form of the letter "U." The upper curve of the "U" is short, and, of course, concave, and forms the lesser curvature of the stomach; the lower curve is larger, and forms the large or greater curvature. The broad end of the pear is towards the left, and on account of its proximity to the heart, is called the *cardiac end* of the stomach. At this end the gullet enters the stomach, its opening forming the *cardiac orifice*. The narrow end is called the *pyloric end*, and here the stomach becomes continuous with the intestine. The opening into the intestine is known as the *pylorus*.

The size of the stomach varies with the individual, and with the amount of material which it contains. In the adult it measures, on an average, 10 inches in length, and is 5 inches broad and 3 inches deep. The holding capacity is between 2 and 3 pints, but, being elastic, it may hold more. At birth it is difficult to distinguish between the stomach and the remainder of the alimentary tract, and the capacity is only about an ounce or an ounce and a half. The stomach of an infant six months old has a capacity of about 5 ozs., or a quarter of a pint, and at twelve months, half a pint. In young infants the stomach occupies almost a vertical position, and the "U"-shape is not distinct. For this reason the contents of the stomach are more easily got rid of than in older children.

Structure of the Stomach.—The wall of the stomach is made up of four coats. The outermost is formed by the peritoneum, and is called the *serous* coat. Inside this is the *muscular* coat, which consists of two layers of involuntary fibres arranged as in the œsophagus. These fibres are thrown into action when food enters the stomach, and the circular and longitudinal fibres acting together, a churning and mixing of the stomach contents is produced. At the pyloric and cardiac orifices the circular muscular fibres are more numerous than the longitudinal. They remain contracted until the end of digestion in the stomach, when those at the pyloric end relax and permit the food to pass into the intestine. Internal to the muscular coat is what is called the *submucous* coat. This is made up of loose tissue containing numerous blood-vessels, lymphatics, and nerves. The innermost or *mucous* coat is formed of mucous membrane. When the stomach is empty, the

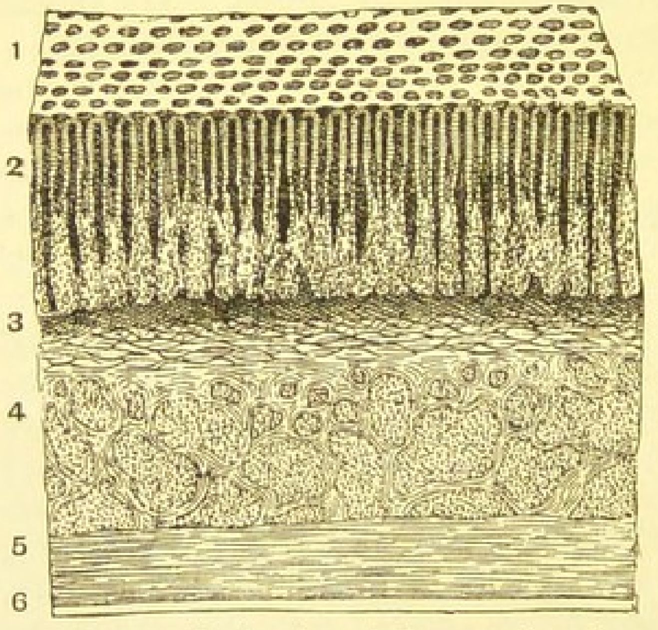


FIG. 52.—Section through the stomach wall (magnified).

1, surface of mucous membrane showing openings of gastric glands; 2, mucous coat, showing glands; 3, submucous coat; 4, circular, and 5, longitudinal fibres of muscular coat; 6, serous or peritoneal coat.

(*From Furneaux's "Elementary Physiology."*)

membrane is folded into numerous wrinkles; when full, the wrinkles, on account of the dilatation of the stomach, disappear. In the depressions between the wrinkles there can be seen innumerable minute holes, which are the openings of the *gastric glands*. These glands lie embedded in the mucous membrane, surrounded by blood-vessels, nerves, and lymphatics sent in from the submucous coat, and secrete the *gastric juice*. They consist of secreting cells which produce the various substances forming the digestive fluid. Some secrete *hydrochloric acid*, others either a ferment called *pepsin*, or a milk curdling ferment called *rennin*. Together these three form a clear, colourless fluid, with a distinct acid taste and smell. In the intervals between meals, the fluid is secreted by the cells of the glands from the blood, and when the gland is stimulated, generally by the presence of food in the stomach, it is poured out through the gland duct into the stomach to bring about digestion. The secretion of gastric juice may be brought about by the sight or thought of food, or even by the mere chewing of food.

The Small Intestine

The portion of the alimentary tract immediately beyond the stomach is the small intestine. It begins at the pyloric end of the stomach, and terminates by opening into the upper end of the large intestine. For the purposes of description, it is divided into three parts, viz. (1) the *duodenum*, (2) the *jejunum*, (3) the *ileum*.

The *duodenum* is the first part, and is 10 inches, or twelve fingers' breadths, long, as the older anatomists sought to indicate by the name duodenum. It begins on the right of the pylorus, bends round more or less in the form of a horseshoe, and passes into the jejunum. In the horseshoe-shaped bend lies the head of the *pancreas* or sweetbread. The *jejunum* and *ileum* together are about 20 feet long; but in order that they may be accommodated in the abdominal cavity, they are closely coiled up, the coils being held together by peritoneum, and the whole fixed to the back wall of the cavity by means of the mesentery.

Structure of the Small Intestine.—Like the stomach, the small intestine has four coats. The peritoneal or serous coat is the outermost, under it there are the two layers of the muscular coat with the submucous coat, and, lastly, the mucous coat internal to them. The mucous coat is smooth and velvety in appearance as a result of the presence of innumerable minute finger-like projections called *villi*. In the interior of each villus there lie minute branches of blood-vessels and lymphatics or *lacteals* held together by a very delicate connective tissue. Covering the intestinal surface of the villus there is a layer of cells. Between the villi lie the openings of the glands which secrete the intestinal juice. This juice is secreted by cells lining the glands, and is poured into the interior of the intestine. It consists mainly of mucus, and plays only a small part in digestion. Throughout the small intestine, but especially in the lower part of the ileum, collections of tissue similar to that making up the lymphatic glands are to be found forming small nodules in the inner wall. These are called *Peyer's patches*, and they are the

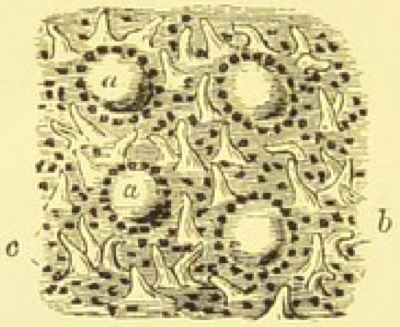


FIG. 53.—A small portion of the mucous membrane of the small intestine (magnified). *a*, Peyer's glands; *b*, villi; *c*, openings of intestinal glands.

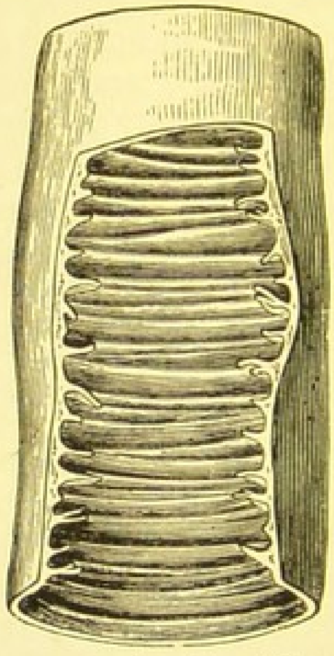


FIG. 54.—Portion of small intestine laid open to show the valvulæ conniventes. (*From Quain's "Anatomy."*)

parts chiefly attacked in typhoid fever and consumption of the bowels. The chief function of the small intestine is the absorption of the food which has been digested by the gastric juice and the secretions of the pancreas and liver, and which is carried down by the peristaltic contraction of the muscular coat. As absorption is a very slow process, the small intestine must of necessity be of a considerable length. In order that the length may be taken full advantage of, the tube is coiled upon itself, and the passage of food in this way delayed as much as possible. The superficial area of the small intestine is roughly about half a square yard, but the absorptive surface is tremendously increased by folding or wrinkling of the mucous membrane. These wrinkles, or, as they are called, *valvulæ conniventes*, run almost completely round the tube, and are found especially in the jejunum.

The Large Intestine

The *large intestine* begins in the lower right-hand corner of the abdominal cavity. The small intestine opens into the side of the tube a short distance from the point where the large intestine begins. Below the point of entry there is a short piece of the large intestine forming a blind end, and called for this reason the *cæcum*. The opening of the small intestine is called the *ileo-cæcal opening*, and it is protected by a valve of mucous membrane named the *ileo-cæcal valve*. Opening into the bottom of the cæcum there is a short twisted tube called the *vermiform appendix*. The function of this appendix is unknown. In persons who habitually eat too much and exercise too little, and who permit waste products to remain longer than twenty-four hours at a time in the intestine, it is apt to become inflamed, leading to *appendicitis*. The large intestine is about 6 feet long, and is considerably wider than the small intestine. It consists of the blind end or *cæcum*, the *colon*, and the *rectum*. The *colon* is divided into three portions, named the *ascending*, the *transverse*, and the *descending colons*. The three parts together form a curve more or less resembling a horse-shoe in shape. The ascending colon lies on the right side, and extends from the right flank up to the under surface of the liver. The transverse colon runs across the upper part of the abdomen from right to left. The descending colon extends from under the lower ribs on the left side to the brim of the pelvis. At this point the large intestine takes an "S"-shaped bend, forming what is called, therefore, the *sigmoid flexure*, and terminates in the straight part or *rectum* which lies entirely in the pelvis, and opens externally at the *anus*.

FIG. 55.—The ileo-cæcal valve.
a, ileum; *b*, ascending colon; *c*, cæcum; *d*, junction of cæcum and colon; *e*, ileo-cæcal valve; *g*, vermiform appendix.

Structure of the Large Intestine.—The wall of the large intestine is made up of the usual four coats. The longitudinal fibres of the muscular coat, instead of being arranged all round the tube, are collected to form three separate bands running the whole length of the large gut. On account of the presence of these bands the interior of the large intestine is not circular, but somewhat resembles in shape the "club" found on playing-cards. Since these bands of muscular fibres are shorter than the intestinal tube, the latter is somewhat crumpled to form small projections or saccules. At the outer opening of the rectum the circular fibres are collected to form a strong ring called the *sphincter* of the anus. The process of absorption of the digested food is completed in the large intestine. Any glands found in the mucous membrane secrete mainly mucus, which assists in the passage of the waste materials through the duct and out of the body.

The Abdominal Glands

The Liver.—The liver is the largest gland, indeed the largest organ in the body. In the adult it weighs about 60 ozs. In the child it is much larger, in proportion, than in the adult. It is reddish brown in colour and quite firm to the touch. Its outer surface is smooth and shiney, the organ, like the other abdominal organs, being covered with peritoneum. The greater part of the

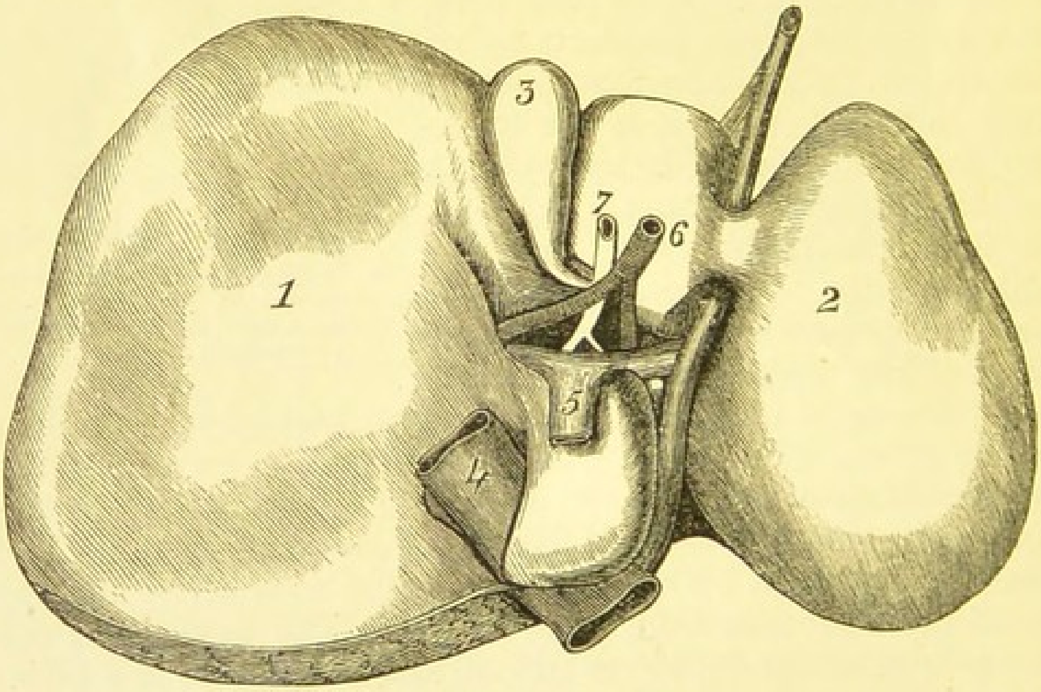


Fig. 56.—Under surface of liver.
1, right lobe; 2, left lobe; 3, gall-bladder; 4, inferior vena cava; 5, portal vein; 6, hepatic artery; 7, hepatic duct.

(*From Furneaux's "Elementary Physiology."*)

liver is on the right side of the abdomen, the upper surface being convex to fit into the concavity of the diaphragm, the under surface concave to accommodate certain parts of the alimentary canal. It is divided into two lobes, a right and a left, of which the former is the larger and thicker. Being a secretory gland the liver consists of cells, each somewhat cubical in shape, and measuring about $\frac{1}{600}$ inch. These cells are closely packed together to form the small lobes or lobules of which the lobes consist. In the centre of each lobule is a fine branch of the hepatic vein, receiving the blood from the capillaries of the portal vein, which run amongst the liver cells and give up to them the digested substances absorbed from the intestine. Besides those of the portal vein other capillaries are to be found amongst the cells forming the lobules. These are: (1) the fine branches of the hepatic artery which bring blood to nourish the substance of the liver; and (2) the tiny vessels collecting the bile formed by the liver cells. These latter, known as *bile capillaries*, eventually unite to form one large vessel or duct called the *common bile duct.* This opens into the duodenum about 3 inches from the pyloric end of the stomach, and has upon it, connected by means of a short duct, a pear-shaped sac called the *gall bladder*. The gall bladder is about 3 inches long, and lies on the under surface of the right lobe of the liver. It acts as a storehouse or reservoir for the bile secreted by the liver cells, and discharges it into the duodenum during digestion.

The principal functions of the liver are: (1) To absorb digested materials from the portal vein, to store them up, and to return them into the general circulation after transforming them into substances readily absorbable by the tissues; (2) to secrete bile; (3) to act as a sort of filter for the blood returning from the digestive tract to the heart, destroying such substances as may be harmful, *e.g.* poisons either chemical, *e.g.* arsenic, or those produced by disease germs in the digestive tract.

The Bile.—The chief use of bile in the alimentary canal is found in connection with the digestion of fats. These it attacks and modifies so that they can be readily absorbed and passed into the lacteals to ultimately reach the general circulation through the thoracic duct. The modification, or *emulsification* as it is called, of the fats takes place only in an alkaline medium, and the alkali required is found in the form of sodium in the bile itself. Bile acts to a certain extent as an antiseptic, killing off some, at least, of the germs in the bowel. It also stimulates the movements of the intestinal muscles and assists in the passing down of waste matters.

The Pancreas.—The pancreas or sweetbread is an elongated gland about 7 inches in length, running transversely behind the stomach. The right end or head of the gland is the thickest portion, and lies in the bend formed by the duodenum. The gland gradually becomes thinner till the left end or tail is reached. The tail lies close to the spleen, which is found under cover of the left lower ribs. In structure the pancreas resembles the salivary glands and its secretion, which to a certain extent resembles that of these glands also, is collected from the secreting portion by

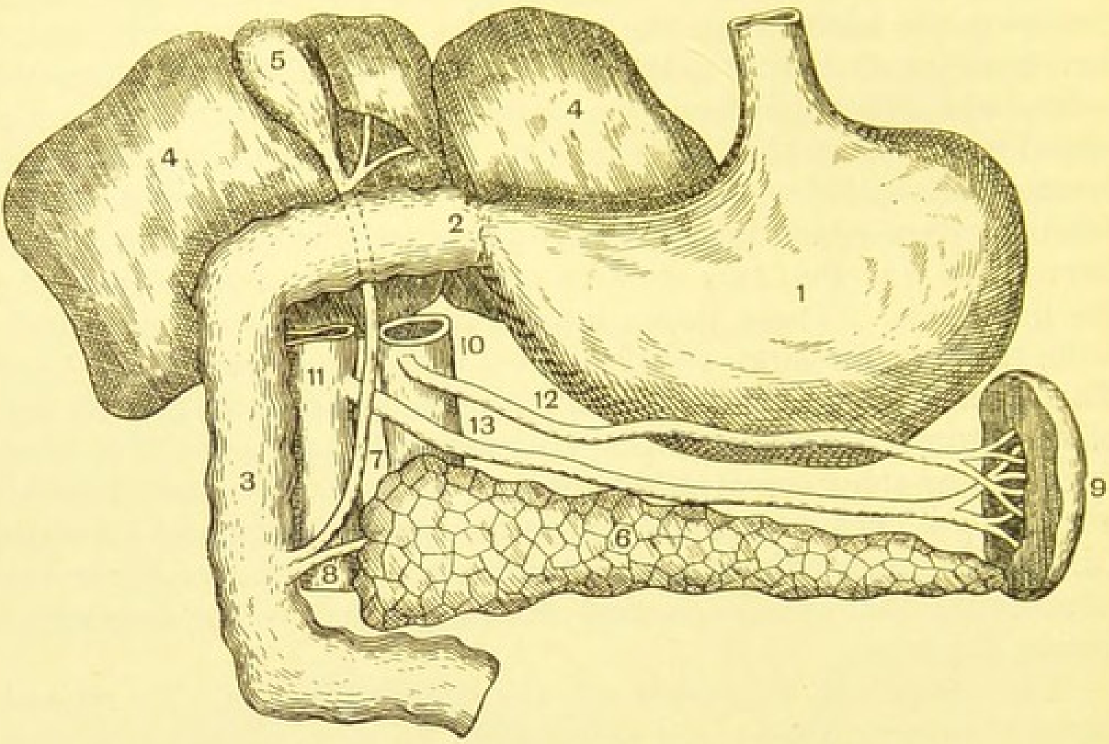


Fig. 57.—The stomach, duodenum, liver, spleen, and pancreas.

1, stomach ; 2, pylorus ; 3, duodenum ; 4, liver (under surface) ; 5, gall bladder ; 6, pancreas ; 7, bile duct ; 8, pancreatic duct ; 9, spleen ; 10, aorta ; 11, portal vein ; 12, artery to spleen ; 13, vein from spleen.

(*From Furneaux's "Elementary Physiology."*)

short ducts opening into a main duct running from end to end. This main duct terminates by opening usually into or near the common bile duct, the pancreatic juice and bile being mixed in this way before they enter the duodenum. The pancreatic juice is a clear colourless fluid, alkaline in reaction. It consists of three ferments, one acting upon starch and converting it into sugar in much the same way as does the ptyalin of the saliva. A second, named *trypsin*, acts upon proteids in much the same way as pepsin, but unlike it, it is assisted by alkalies and not by acids. A third ferment acts upon fats and prepares them for emulsification by the bile.

Digestion and its Objects

All food consists partly of inorganic substances and partly of organic bodies. The chief inorganic substances are water and salts, for example those of sodium, calcium, and potassium. The chief organic bodies are *proteids*, *carbo-hydrates*, such as starch and sugar, and *fats*. Most of these substances, especially the organic bodies, as presented to the body in the food taken, are not fit to be used, partly because they are unabsorbable in the alimentary canal, and partly because they are mixed with other substances unsuited to the needs of the body. The chief objects of digestion are to prepare the suitable substances for absorption, and to separate out those that are unabsorbable. The whole process of preparation and separation is described under the term *digestion.* In the various parts of the digestive tract the test of suitability or unsuitability of food is digestibility and indigestibility. Throughout the whole tract, practically, the process of preparation and separation is carried on, substances digestible in any one part being digested there, those found indigestible being passed on to the other parts. In addition, in certain parts, however, the absorption of the materials prepared either in the part itself or in those above it is carried out.

Process of Digestion.—The process of digestion begins in the mouth. By the action of the teeth the food is broken up. Dry particles are moistened by the saliva which has been poured into the mouth cavity by the salivary glands, stimulated to do so by the presence of the food in the mouth, and by the movements of the jaws. The ptyalin of the saliva picks out the only materials suitable or digestible in the mouth, viz. the starches, and by altering them into malt sugar prepares them for absorption. The other substances which cannot be digested in the mouth are moistened by the saliva, and are afterwards moulded into a *bolus* or ball by the tongue to be sent to other parts of the tract. Substances judged to be unsuitable for any part of the tract, *e.g.* bones, are rejected on their behalf by the mouth and are expelled. Formed into a bolus, the food, by the muscular action of the fauces, is shot over the epiglottis into the pharynx and thence into the œsophagus. These are mere channels, and suitability or unsuitability are not considered. Stimulated by the bolus the muscular fibres of any part of the canal touched contract and drive it rapidly downwards until it is eventually shot into the stomach.

Digestion in the Stomach.—In the stomach the substances digestible by the gastric juice are digested. These substances are the proteids of the food which, being unabsorbable, are converted into an absorbable substance called *peptone.* The indigestible substances, namely the carbo-hydrates and fat, are unaffected by the gastric juice proper. When the bolus of food enters the stomach it acts more or less as an irritant stimulating the gastric glands to express the hydrochloric acid, pepsin, and rennin, which they have secreted. These substances, however, do not begin to act at once, and for about half an hour after the entry of the food into the stomach probably the ptyalin of the saliva continues to act upon the carbo-hydrates. At the end of this time the gastric juice, having accumulated in sufficient amount, begins to act, and the ptyalin, on account of the presence of hydrochloric acid, ceases to affect the starches. To assist in the incorporation of the juices with the food the muscular fibres of the stomach are thrown into action and lead to wave-like movements running backwards and forwards in the wall of the organ. To prevent the escape of the contents during the mixing or churning up of the contents which results, the muscular fibres of the cardiac and pyloric orifices remain tightly closed.

The *peptone* produced by the action of the pepsin and hydrochloric acid upon the proteids is a form of albumen soluble in water. In this condition it is absorbed by the gastric mucous membrane and eventually passes into the blood-stream to be carried to all the tissues of the body. Before passing into the blood-stream, however, it undergoes a change rendered necessary by the fact that the tissues cannot absorb peptone. The substance into which it is transformed is another form of albumen called *serum albumen*, and this is readily taken up by the tissues from the blood. This change is brought about by the cells of the gastric mucous membrane. Fats and carbo-hydrates are not suitable and are not affected by the gastric juice. In the case of fat a certain amount of breaking up of the masses of which it is composed is brought about by the digestion of the connective tissue holding them together. The work of emulsification by the bile and pancreatic juices in this way is made easier. Most of the work of digestion in the stomach is done by the pepsin and the hydrochloric acid working together. The rennin merely curdles milk, the pepsin and the hydrochloric acid afterwards digesting the curd.

The time required for the conversion of the proteid substances in the food into peptone varies with the nature of the food. In some foods the proteids are readily acted upon, and the process may be completed in a few minutes. With other foods the proteids are more slowly converted, and the process may take four, five, or six hours. During the time the juices are acting, a certain amount of absorption is carried out by the mucous membrane. Some of the peptone, dissolved in the water of the food, is absorbed, and with it any carbo-hydrates that may have been converted into malt sugar during cooking or by the action of the ptyalin. When the work of the stomach is completed the pylorus opens, and the mixed-up mass of food forming what is called *chyme*, and consisting of the unaffected, unsuitable substances, and such of the prepared substances as have not been absorbed in the stomach, pass into the small intestine.

Digestion in the Small Intestine.—In the small intestine the bile and the pancreatic juice, discharged from the glands when the chyme leaves the stomach, begin their work of separating the suitable from the unsuitable, digesting the former and leaving the latter to be acted upon lower down, or else to be discharged as waste. The reaction of the mixed bile and pancreatic juice is alkaline. They attack: (1) Such proteids as have been found unsuitable by the stomach, transforming them into peptone. (2) The fats, which they convert into an emulsion consisting of fine globules readily absorbable by the intestinal mucous membrane. In the formation of the emulsion the bile plays the chief part, but the pancreatic juice also acts to a certain extent. (3) The carbohydrates are also attacked by the pancreatic juice, and are converted into an absorbable sugar. The bile and pancreatic juices continue to act after the chyme has left the point where they came in contact with it, and while the mixture is being pushed along by the peristaltic movements of the wall of the intestine. As the chyme passes along, the absorbable portions are absorbed, the peptone and sugars passing into the blood-vessels to be carried in the blood to the liver, the emulsified fat into the lacteals to be poured into the chyle receptacle on the thoracic duct. In the intestine itself the juices of the intestinal glands do very little in connection with the separation of the suitable from the unsuitable substances, although, to a certain extent, they assist in digestion by converting the ordinary cane sugar of the food into a more absorbable form, namely, grape sugar.

Digestion in the Large Intestine.—When digestion and absorption have been completed in the small intestine, what remains of the chyme passes into the large intestine through the ileo-cæcal opening. In the large intestine absorption alone takes place, and substances found unsuitable and indigestible higher up prove unsuitable in this part of the tract also, and are simply passed on to be discharged with the *fæces* or refuse of the food. The large intestine has great power of absorbing fluids, and by the time the refuse is cast off it has been deprived of practically all its water.

Destination of the Substances absorbed

The ultimate destination of the peptone, sugar, and fat absorbed from the digestive tract is the various tissues of the body. These they reach in the blood-stream. The route taken by the peptone and sugar differs from that taken by the fat. The peptone absorbed by the lining membrane of the gut is changed by its cells into serum albumen, and passes in this form into the portal vein, in which it is carried to the liver. In the liver a certain amount is removed, and is stored up in the cells in the form of *glycogen*, a substance closely allied to sugar, and readily converted into it, and returned to the blood-stream through the hepatic vein when the body requires it. The remainder of the albumen passes on through the liver into the hepatic vein, the inferior vena cava, and the heart. Thence it passes to the tissues where the cells take it up from the blood plasma, which consists almost entirely of this albumen. By the cells it is used as nourishment, being broken up in the process, waste products, viz. carbon dioxide and a compound of nitrogen named *urea*, being produced and got rid of by the excretory organs.

The sugar produced from the carbo-hydrates follows the same route as the peptone, but the greater part of it remains in the liver, and is stored up as glycogen. The glycogen is again re-transformed into sugar and passed into the blood-stream when the quantity of sugar in the blood falls below a certain proportion, and the tissues require it. The tissues chiefly using this substance are the muscular tissues. These, assisted by oxygen obtained from the blood, burn up large quantities of sugar during their action. In the burning up the sugar is oxidized into carbon dioxide, the process resembling that seen in the combustion of coal, energy being produced by the burning of carbon in the presence of oxygen. The carbon dioxide is got rid of by the lungs.

The fats absorbed from the intestine in the form of chyle pass into the lacteals, thence to the chyle receptacle, and thence by the thoracic duct into the blood-stream. From the blood they are absorbed by the tissues. A certain proportion is used to supplement sugar and albumen, undergoing changes similar to those undergone by the former. The remainder is stored up to be used in the case of a shortage of sugar or albumen.

The water and salts absorbed from the intestine also pass into the blood-stream. The water keeps the salts and other substances, both nourishing and waste substances, in solution. From the blood, part of the water is absorbed by the tissues, though most of it is excreted by the skin and the kidneys, carrying with it urea and other waste materials. The salts are absorbed by such tissues as require them, but large quantities seem never to be used at all, and are excreted unchanged by the kidneys. A certain amount of salts assists in the manufacture of acid where that is required, as in the stomach. The salts assist also in the formation of alkalies—for example, in the blood, the bile, and the pancreatic juice. The salts necessary for these purposes are obtained from the food. Lime salts may be used by the bone cells, especially in children.

The Fate of the Absorbed Substances

The principal uses found for the absorbed substances by the tissues in the carrying out of the functions of the body are in (1) the production of energy, (2) the production of heat, (3) the growth of the body, especially in childhood. To these may be added (4) the replacement of the waste which takes place in the tissues as a result of the carrying out of the other three functions.

Energy Production.—The energy required for the carrying out of the work of the body is produced by the breaking down of the substances making up the tissues. These substances are exceedingly complex, and are built up largely of the materials absorbed from the blood and obtained from the digested food. Probably the sugar absorbed is the great producer of energy, but to a great extent it is assisted by the fats and the peptone, and in the absence of sugar the tissues fall back upon these two.

Heat Production.—Heat production is brought about also by the breaking up of the tissues and of the materials absorbed. Most heat results from the breaking up of fat and sugar.

Growth of the Body.—In the growth of the body probably all the substances absorbed, inorganic as well as organic, play a part. Of the organic it seems most likely that the albumen, the result of the digestion of the proteids or nitrogen containing substances, is the most important. These assist in the reproduction of new cells and in building up the constituents of the various cells. In bone-formation, though the lime and other salts are popularly supposed to be most important, they probably do very little, the small quantity of phosphorus contained in the proteids being much more active in this respect.

Replacement of Waste.—In the replacement of waste all the constituents again play a part. Probably this goes on at the same time as breaking down takes place. Usually, however, a certain amount of the material absorbed is set aside as a store in the form of fat. On this the tissues can draw in the event of the amount offered for absorption being diminished.

Food and Dietaries

In choosing foods and in constructing dietaries the points which have to be considered are: (1) the functions that have to be fulfilled; and (2) the substances that can fulfil them. For the carrying out of the functions of heat and energy production, of growth and replacement of waste, the tissues rely chiefly upon proteids, carbo-hydrates, and fats. These are regarded, therefore, as the chief essential constituents of any diet. The part played by the salts and water is mainly subsidiary. By experiment and experience man has learned the amount of energy obtainable from the essential constituents, and also which functions each is most capable of carrying out. As a result of these observations, it has been found possible to calculate, not only the amount of each constituent required under normal conditions, but the variations which have to be made in the amount of any or all of them, in accordance with the varying needs of the body. The chief circumstances under which variations in the amount of any or all of the essential constituents become necessary are: (1) the age of the individual; (2) his state of health; (3) his occupation; (4) the climate; (5) the season. Under such circumstances the variation may be called for, either because the tissues cannot make use of the substances after they are absorbed, or because the digestive tract cannot prepare them for absorption.

Age Variations.—The variations rendered necessary by age are of the utmost importance to the teacher. In infants and young children the dietary has to be specially considered, both on account of the special needs of the body and on account of the inability of the digestive tract to deal with certain substances. In infancy, the tissues require such substances as will assist growth, viz. the proteids, and substances also from which heat can be produced, viz. fat. In the dietary of infants, these must be given the chief place. Because of the peculiarities of the digestive system, these substances must be small in amount and carbo-hydrates, not only because they are very little required by the tissues, but also because they are only slightly digestible should be especially small. In young children, the requirements of the tissues are the same as in infants. For these, therefore, proteids and fats are chiefly required. The power to digest carbo-hydrates having been acquired, however, the amount of these may be increased.

Occupation Variations.—The variations rendered necessary by occupation are dependent chiefly upon the ability, or the want of it, of the tissues to make use of the substances supplied. When special activity is not called for, the substances are broken up merely to produce heat and replace waste. Smaller quantities, therefore, need only be provided. If quantities in excess of what is necessary be supplied, they will either be stored up or treated as waste, and the organs of excretion will be called upon to get rid of them. When work has to be done by the tissues, the amounts of all the constituents will have to be increased in order to provide for the energy production required.

Climate and Season.—The variations necessary for different climates and seasons need only be mentioned. In cold climates and seasons, the heat-producing substances must be increased in proportion to the others, and in the warmer climates reduced.

Under ordinary conditions, the usual proportion of proteids to the other constituents is 1 to 3 or 4. For an ordinary man doing moderate work, the amount of each necessary per day is stated to be 5 ozs. of proteids, 15 ozs. of carbo-hydrates, and 3 ozs. of fat. In connection with these, 1 oz. of salts is taken. For a person doing no work, the amounts may all be diminished without risk to the tissues, and as little as 2½ ozs. of proteids, 12 ozs. of carbo-hydrates, and 1 oz. of fat may be found sufficient. In infancy, and before the teething process is completed, a diet containing of proteids ¾ to 1¼ ozs., fat 1 to 1½ ozs., and carbo-hydrates 2 to 2½ ozs. is required. After the teeth have formed, and between the ages of two and fifteen, quantities up to about those mentioned for persons doing no work may be employed. The above figures take no account of water and refer to dry food. In most foods there is about 50 per cent. of water, and the total quantity of food will have to be double the total amounts mentioned in order to obtain the amount of proteids, fats, and carbo-hydrates named.

In the foods ordinarily used, a certain amount of all the essential elements are found, but not in the above proportions. In some, the proteids are in excess of the body's requirements, in others, the carbo-hydrates or fats. In some, indeed, so greatly is one element in excess that the food is practically a proteid, a carbo-hydrate, or a fat food, as the case may be, and is so called. Because of the difficulty of finding one form of food containing the proper proportions of the essential elements, man has had to resort to a mixture of foods, and has had to take to a *mixed diet* in order to avoid injury to health by offering the tissues too much of one essential element with the object of obtaining a sufficiency of another. In the ordinary mixed diet, the flesh of various animals is depended upon mainly for proteids; the starchy vegetables, like potatoes, corn, and so on for carbo-hydrates, and animal fat for fat. These are, or should be, taken in such quantities that there is one part of proteid to three or four of the other constituents, and the quantities can be varied as circumstances require.

The most important example of a food containing all the essential elements is *milk*, which is an emulsion of fat, in water containing proteids, carbo-hydrates, and salts in solution. The fat contained in the milk is in the form of very minute globules. The proteids occur chiefly in the form of a substance called *casein*, but there is a certain amount of *serum albumen*, and another albuminous body called *globulin*. The carbo-hydrate of milk is *milk sugar*. In all milks used for food these substances are present, though the proportions in which they occur differ. In cows' milk the proteids are present to the extent of 4 per cent., the fat 3·5 per cent., and the sugar 4·5 per cent. In human milk, which with cows' milk is the most important, so far as dietary is concerned, the proteids reach 1·5 per cent., the fats 4 per cent., and the sugar 6·5 per cent. The fact that it contains all the necessary elements makes milk the one form of food that could be used alone and be sufficient for all the purposes of the tissues. In the case of an adult, the objections to its use alone are, that it is deficient in sugar, and in order to obtain the quantity of food necessary, some nine pints of milk would have to be taken in the twenty-four hours, and rather more water and fat than necessary would have to be swallowed. In the case of the child, however, milk, *especially human milk*, is a perfect food, containing everything required by the tissues. Cows' milk is less perfect and has to be modified, partly by the addition of water, before it can be made suitable, since it contains more proteid than the child can deal with, and less fat and sugar than it requires. One very important difference between cows' milk and human milk is with regard to digestibility. In the stomach the casein of the milk, acted upon by the rennin of the gastric juice, curdles, and is then digested by the hydrochloric acid and pepsin. The casein of the cows' milk coagulates into a solid mass, and is not easily acted upon by the digestive juices, whereas, that of human milk forms a fine frothy curd, and is easily acted upon. Indeed, it has been shown that while human milk can be digested in from one to one and a half hours, modified cows' milk takes two or three hours, and raw cows' milk four hours.

The Choice of Foods

In choosing articles of food to make up the dietary of adults various points have to be taken into consideration. Though the great object is to obtain articles which will, when mixed, provide the essential elements, they must at the same time be palatable and digestible, and in many cases also, unfortunately, the cost has to be considered. The chief source of proteids is the flesh of various animals. *Beef* and *mutton* are most commonly employed. Of the two, mutton is the more easily digested, and also the cheaper. *Pork* is difficult to digest, and the quantity of fat it contains also constitutes a further objection. *Poultry* and *game* are easily digested. Ducks and geese, on account of the fat they contain, are somewhat indigestible. *Fish* is a fairly cheap food, and is easily digested, especially if one or other of the white-fleshed varieties be used, *e.g.* whiting, cod, and such-like. The red-fleshed varieties, like salmon, and the greasy-fleshed, like herrings, are less easily digested. Shell-fish, *e.g.* crab, lobster, etc., are difficult of digestion. Raw oysters, mussels, and cockles are rich in proteids and easy of digestion, but are to be eaten with caution. Milk and cheese will also supply proteids. Cheese is very rich in these, but is objectionable because it is concentrated and indigestible.

The carbo-hydrates are chiefly derived from the vegetable kingdom, though many of the edible vegetables are rich in proteids, and when price is a consideration, might well be used to supplement meat as proteid providers. Of these, the chief are *peas* and *beans*, and for cheapness may be compared with cheese, the cheaper cuts of meat, the coarser forms of fish, and skim milk. *Oatmeal* also, if properly cooked and taken with milk, yields a great deal of proteid material. The cheapest sources of carbo-hydrates are bread and sugar. They are also sources of considerable energy. In addition to carbo-hydrates, bread contains a fair amount of proteids, especially if the flour is not too fine.

The fat may be taken in the form of *butter*, *margarine*, *dripping*, or *suet*. If cheapness is the chief consideration, margarine is to be preferred to cheap and therefore inferior qualities of butter. For the sake of variety, dripping may be used, if the source be known.

Cooking and the Arrangement of Meals

Cooking.—With regard to cooking, it need only be said that the chief object is to make the food more palatable and tempting. In addition, however, the majority of foods are softened and broken up, and made more easy to masticate. The digestibility, especially of the starchy and vegetable foods, is increased. The digestibility of others is also increased, because warm food is more easily digested than cold, and the activity of the gastric mucous membrane and muscles is stimulated.

By killing off germs or worms which may possibly be present in the food, cooking allows of meat being kept longer, and diminishes the risks of infection of the body by these. It must be borne in mind that it is not always safe to believe that all germs are killed off. Those in the deeper parts may escape. Moreover, if the food has gone bad under the action of germs, the poisons produced by their action on the food will be unaffected by the cooking. Heat may kill the germs, it cannot kill the poison.

Arrangement of Meals.—The quantities of proteids, etc., to be taken should be spread over the twenty-four hours. It is usual to have three or four meals a day, and to take a certain quantity of each of the elements in the morning, in the middle of the day, and in the evening. In order to permit of the digestion of one quantity before taking the next a period of at least three hours should be allowed to intervene. In order to encourage the tendency which the digestive organs have to automatic and methodical activity the meals should be taken regularly at the same hours every day. To lighten the work of the stomach the food should be eaten slowly. The mechanical powers of the teeth should be taken full advantage of. The longer the food is kept in the mouth and the more thoroughly it is masticated the lighter becomes the task of the stomach. The pancreatic juices are also assisted since the ptyalin of the saliva gets an opportunity of acting on the starches. To chew every particle of food thirty-two times before swallowing it, as is commonly suggested, is no great strain, and probably most people do so. The difficulty is to chew it oftener, and the oftener it is chewed the better. Another point of considerable importance in connection with the taking of meals is the necessity for avoiding excessive exertion, bodily or mental, immediately after their conclusion. The reason for this has already been given.

It is equally important to remember that if good work is to be hoped for it should not be commenced in the morning until food of some kind has been taken. The heaviest meals of the day should be the morning and midday meals. The evening meal should be light, and if any food is taken between this and the midday meal it should be small in amount, light, and easily digested.

Feeding of Infants and Children

Most of what has gone before refers chiefly to adults. The feeding of infants and children is much more important, as these are less discreet, and are less likely to look after themselves. For this reason it is necessary for the parents, and those who have influence with parents, to be discreet. Discretion is to be exercised in the choice of food and in the arrangement of meals. The results of an absence of discretion with regard to these may be very disastrous to the child.

Infant Feeding.—It has already been shown that milk is the most suitable food for infants. Human milk is the best because it is nature's food, because it is easy of digestion, and because it is cheap. Till the infant is eight or nine months old it requires nothing else, and, indeed, cannot satisfactorily digest anything else. If, unfortunately, human milk is unobtainable, and the mother cannot nurse her child, some substitute will have to be employed, either to supplement the human milk obtainable, or to take its place in its absence. The substitute commonly recommended is cows' milk. Because they are believed to be cheaper and easier to prepare, condensed milk and patent foods are largely used, especially by the poorer classes. Most brands of condensed milk, being made from separated milk, are deficient in fat, and as sugar is usually added in considerable amount this constituent is far in excess of what is required and digestible by the infant. The best type is *condensed whole milk;* but it, even, should only be used when no other milk is obtainable, or when it is ordered by a medical man, and then in the proportions directed. The patent foods employed consisting chiefly of starch and sugar are quite unsuitable for infants without teeth. They should never be used till the teeth have appeared, or until they are ordered by a medical man.

Cows' milk is the best substitute, but it has to be modified to make it as like human milk as possible, from which it differs, it will be remembered, in containing more proteid and less fat and carbo-hydrate. To reduce the quantity of the first, and to increase that of the other constituents, it is usual to dilute the milk with water or barley-water, and to add fat, in the form of extra cream, and sugar in the form of milk sugar, or ordinary fine sugar. A mixture commonly recommended as being "humanized" is 30 parts of new milk, 2 parts of cream, 1 part of sugar, and 18 parts of water. By persons in poor circumstances the only modification possible is brought about by the addition of water, the quantity added being diminished as the child gets older. In this method of modification the poorer persons are unfortunately imitated by those who can afford the extra substances required, and who ought to know better, and the children of such persons are underfed without reason. To increase the resemblance to human milk and to stimulate digestion, modified cows' milk should be warmed before administration. When substitutes for human milk become necessary and artificial feeding has to be resorted to, very special precautions have to be adopted to ensure that the milk shall be free from germs.

In the case of human milk the fluid passes straight from the mother to the child, and contains no bacteria. In the case of cows' milk, however, the milk has many opportunities for becoming infected before it reaches the child. In the process of milking it may be contaminated by the hands of the milker or by hairs or dust from the cow, despite regulations which may be made regarding the grooming of cows and the washing of the milker's hands. It may receive contaminations from the milking pail, which may have been washed with water containing germs, for instance, of typhoid fever. It may receive contaminations during transit from the cowshed to the person selling the milk, and it may be contaminated after it has been purchased for the baby and before the baby gets it, as for example in the larder, and so on. Milk is one of the most suitable soils for the growth and multiplication of bacteria of all kinds, and though milk derived from a healthy cow as it leaves the udder is practically free from germs it soon swarms with bacteria, unless the greatest precautions are taken to exclude them. The majority of the germs found in milk are harmless, and many neither affect the milk nor the person swallowing them. Others, however, cause curdling of the milk, and others still are capable of causing disease.

The commonest diseases conveyed by milk are *typhoid fever*, *scarlet fever*, *diphtheria*, *epidemic diarrhœa*, and probably also *tuberculosis*. In order to kill off the germs in ordinary dairy milk it is practically always necessary to sterilize it by boiling before diluting it or humanizing it. The boiling of milk has a tendency to alter its qualities to some extent and to make it less valuable as a food for infants. If proper precautions are taken to protect it, however, boiling should be unnecessary. If the cows are properly groomed; if the milkers' hands and the cowshed and all accessories are clean; if the milk is strained, and, more especially, if it is *cooled* immediately after leaving the cow and is stored in clean vessels, the chances of germs entering and multiplying in it are greatly reduced. Unfortunately, these things are not by any means always done, and if they are done tend to raise the price charged for the milk. It becomes necessary, therefore, to resort to boiling.

In connection with artificial feeding the mode of administration is of the utmost importance, and for the purpose various feeding bottles are made. The best type is the so-called "Lamb Feeder," which possesses the advantages of being simple in construction and easily cleaned. It is so shaped that the whole inner surface can easily be reached for cleansing purposes: it has no tube, and the teat simply fits over the mouth of the bottle. The old-fashioned tube bottle, with its hiding-places for dirt and old milk in the interior of the glass tube and the rubber tube, and about the screwed-on top and the teat, is passing away, it is to be hoped, for ever. Its passing cannot be too rapid.

Times and Quantities of Feeds.—If regularity is important in connection with the meals of adults, it is infinitely more so in connection with the infant's meals. The practice frequently adopted by mothers of feeding babies when they cry, and not at stated intervals, is essentially a bad one, and likely to lead to digestive disturbances. From the very beginning of life the meal-times should be fixed, and should be adhered to. As the stomach in the early months of life is but small, the meals should be small, and should be given fairly frequently. Till the end of the *second month* the feeds should be given every two hours during the day, and twice during the night. The quantity of each feed should be from about 1 oz., that is, two table-spoonfuls, in the earlier days of life, to about 3 ozs. at the end of the second month. From the *end of the second month to the end of the fifth month* the child should be fed every three hours, and should receive from 3 to 5 ozs. at a feed. During the *sixth and seventh months* there should be an interval of about three and a half hours between the meals, the quantity at each meal being 6 ozs. From the *end of the seventh month to the end of the first year* the child should be fed every four hours. During this period the food should be principally milk, about 8 ozs. of human milk, or of modified milk, being given at each meal. The milk diet may, however, be supplemented by the addition of a little starch in the form of cornflour, soft bread, or one or other of the better known and more reliable infant foods. A little piece of potato mashed in gravy may be used, and is greatly relished by the infant. The weaning process should begin at the ninth month, the place of the mother's milk being taken by cows' milk sterilized by boiling, especially during the warm summer months, though it is better to avoid weaning in these months, and modified slightly, if possible, by the addition of cream and sugar and water. A satisfactory mixture consists of 4 ozs. of milk, ½ oz. of cream, 1½ ozs. of water, and a teaspoonful of sugar.

From the *end of the first year till the child is about eighteen months old* it should still get milk chiefly for its meals. In addition, it should have a certain amount of starch, fat, and proteids in the form of biscuits, bread and butter, potatoes, or bread-crumbs and gravy, or even bacon fat. The milk taken in the twenty-four hours should amount to about two pints. This amount should be continued till the end of the second year. In the second half of the second year, fish, finely minced beef or mutton in small quantities, bread and bacon fat, and so on, may be added once a day. After the second year any light and easily digested food is allowable, and green vegetables and fruit may be added to the diet.

For the infant who is artificially fed, either wholly or partly, the times of feeding and the quantities of food are the same as those mentioned above. The preparation of the food is exceedingly important, and cleanliness of the feeding-bottle no less so. The modification of the cows' milk by dilution and the addition of cream and sugar should be possible for all but the poorest classes. Unfortunately, amongst the fairly well-to-do the process of modification is often not properly carried out, and most commonly not till the child has developed symptoms of digestive disturbance, and medical advice has become necessary. The item most commonly omitted, because it is expensive, is the cream, and the child is given milk diluted with plain water, or lime-water, or barley-water, and sweetened with a little sugar, generally a teaspoonful. When proper modification is impossible, it is usual to recommend that the milk used should be diluted with not more than half its bulk of water at first, and that the quantity of water should be gradually diminished, till, by the end of the sixth month, the child is taking whole milk. Not uncommonly the dilution is carried too far, and kept up too long, and the child's tissues are starved, and its growth interfered with.

The number of children killed by improper feeding is very high, and the number of artificially fed children passing through infancy unscathed is comparatively low. To prevent this "slaughter of the innocents," as it has been called, many local authorities are now opening municipal milk depôts, and supplying milk mixtures suitable for children of all ages in suitable quantities, and in special bottles. Every care is taken to supply the infant with a wholesome and suitable food. The milk is obtained from specially selected dairies and cows. To prevent contamination at the dairy scrupulous cleanliness is enforced. The milk is filtered and made clean, and to prevent the growth of germs is cooled at once to a temperature below that at which they thrive. It is collected in scrupulously clean vessels, and conveyed to the milk depôt. Here it has cream and so on added, and is put in thoroughly clean bottles, each holding one feed. The bottles are plugged or corked and, with their contents, sterilized. Little crates, capable of holding a sufficient number of feeds for twenty-four hours, are filled, and the mother receives a crate each day. The mouth of each bottle is so shaped that a rubber teat, supplied with the crate, can be slipped over it, and all that the mother need do on receipt of the feeds is to slightly warm the contents of the bottle, remove the plug, slip on the teat, and feed the baby. At the end of the twenty-four hours the crate of empty bottles, which the mother is supposed to clean, is returned to the depôt, and a fresh supply obtained. The charge is generally somewhere about one shilling per week. The advantages of this method are many, both to the mother and the infant. For the mother there is a diminution of work, and for the infant a proper food. The charge is not extortionate.

Feeding of Young Children.—A certain amount of care must be exercised in the feeding of young children. All the essential elements must be supplied in the food given. Proteids are very necessary as growth is going on actively. Fats are essential for heat production, and carbo-hydrates are required. Easily digested meat in small quantities, eggs and milk supply the proteids; butter, dripping, margarine and bacon supply the fat, and for the carbo-hydrates, bread, sugar, jam, treacle, and so on, are employed.

The increase in the proteids in the food of children should be carefully managed. Till the child is four years old meat should not be given every day, and only in small quantities once, on the days chosen. Eggs and oatmeal porridge and milk will provide proteids for the child; but they must be carefully cooked, the former not too much, and the latter not too little. Fats are of great importance, and the aversion which most children evince towards fatty foods is traceable, mainly, to the manner in which they are presented. Butter and bacon fat and suet in the form of suet puddings are generally liked by children, but it is important to consult the taste of the child in the matter of fat. The carbo-hydrates usually present little difficulty, and the child must be prevented from going to excess with these. Sweets, if possible, should be taken only at meal-times. After the age of five the diet of children may be varied considerably, but, till puberty is reached, the dieting of the child must be carefully attended to by those responsible for it. In growing children regularity in meals is of the greatest importance, and four meals a day at suitable and regular intervals should be given.

Beverages

For the supply of the water necessary for the various processes in the body, the amount contained in the more solid articles of diet is generally insufficient, and additional fluids have to be taken. Milk consisting so largely of water, infants generally get quite enough, but sometimes additional water is required, and mothers should know that babies sometimes are thirsty, and cry for this reason. To relieve the thirst plain water or barley water is better than milk, since it throws no strain on the digestion. For infants who are entirely bottle-fed, water containing a little orange-juice or grape-juice is likely to be found useful. Apart from water no other beverage should be given to infants, and indeed children, under the age of five or six, should be allowed to obtain all the water they require from milk, and be given only water as an additional beverage. In these days, however, even the youngest children are permitted to share in the more stimulating beverages, tea and coffee, and even beer, or other alcoholic beverages taken by the parents. Of these the alcoholic beverages should never be given in health, at any rate, and if given during illness only when ordered, and in the quantities prescribed, by a medical man. Tea and coffee, if given, should only be allowed in very small quantities, diluted with milk. As a substitute for these, cocoa made with milk is to be recommended, and will be found beneficial, especially if a good non-medicated brand is used. It is less stimulating than tea or coffee, but in the healthy child there is no need of stimulation.

Beverages for Adults.—For adults water is still the only beverage really necessary, and other beverages are only taken because they are more pleasant, and because they are more stimulating. *Tea* owes its pleasant taste and aroma to certain volatile substances extracted from the leaves in the course of infusion. Its stimulating properties it owes to the presence of an alkaloid called *theine*, and to the fact that it is taken warm. To improve the taste, and to get rid of a bitter flavour dependent upon the presence of tannin, milk or cream alone, or milk or cream and sugar may be added. The pleasant taste of *coffee* is also due to extractives, and its stimulating power to an alkaloid, analogous to theine named *caffeine*. *Cocoa* may be used as a substitute for tea and coffee. It is less stimulating than these, though it contains a stimulant called *theobromine*. It is more of a food than tea or coffee, since it contains proteids, fats, and carbo-hydrates.

The Alcoholic Beverages.—Beer, wine, and spirits are taken because the taste is less insipid than that of water, from the presence of certain aromatic bodies, and because they are more stimulating, on account of the alcohol which they contain. In most of them some of the essential elements of food required by the tissues are present, but, on account of the contained alcohol, which interferes with the activity of the tissues, they are unsatisfactory articles of diet. That alcohol itself is capable of acting as a food is doubted by many, the tissues being unable to use it, and being unable to properly oxidize other more suitable substances in its presence. Other observers hold that alcohol is valuable as a food, since if it is not used itself, it prevents the waste of other substances. Even these latter persons, however, agree that to get the full benefit of the alcohol only small quantities should be used, at the most 2 ozs. in the 24 hours. The quantity of alcohol contained in various alcoholic beverages varies from about 5 per cent. in beer to about 60 per cent. in brandy. The chief action of alcohol is as a stimulant, and this action is best produced, like the nutritive action, by doses not exceeding 2 ozs. per day. For the normal human being such a stimulant as alcohol is not really necessary; but in these days there seem to be many who require some additional stimulant. In such cases the quantity should be the least possible, and should certainly not exceed the amount mentioned. For children in health there is no need at all for an alcoholic stimulant. If the assistance of alcohol is required in sickness it should be given only under medical direction. To the ethical aspect of the alcohol question it is hardly necessary to refer in such a book as this.

Conditions affecting the Alimentary System

Though there are no diseases of the alimentary system to which attention can specially be directed, there are several conditions affecting it which the teacher might help to prevent by giving instruction and advice. These are produced mainly by faults in relation to the quantity and quality of the food taken. Conditions due to faults in connection with the *quantity* of the food may result either from the taking of too much or of too little. If too little food is taken, starvation, varying in intensity, results. If the quantity taken is insufficient to provide for all the functions of the body, the tissues first fall back upon any that may be stored, and eventually the tissue cells are attacked. The body may be able to go on for quite a long time, though insufficient food is given. Death results when starvation is carried to such an extent that about half the body weight is lost. Babies, especially hand-fed babies, very often get insufficient food and are starved, because ignorant mothers dilute the cows' milk too much or give articles of diet which the child's organs cannot digest, and which, therefore, are not food at all. Young children often also are more or less unwittingly starved through receiving wrong articles of diet. In the elementary schools of the poorer districts of a large city, starvation of the tissues, as a result of the want of or deficient food, or the giving of unsuitable articles, is too often seen. The signs are: (1) dulness and backwardness, because the brain is badly nourished; (2) anæmia, from poorness of the blood; (3) stunting of growth and loss of weight.

The *effects of excessive food* are traceable to the retention in the body of waste products. All the natural functions are interfered with. The tissues cannot use up the food supplied. Some is stored in the liver, which becomes overloaded and goes in occasionally for what has been termed a "bonfire," or, more commonly, an attack of "liver," or "chill on the liver." Part of the food is transformed into fat, which is deposited in various places. Large quantities become waste products, and the organs of excretion, being strained, failing in their efforts to discharge them, some are retained in the circulation poisoning such delicate tissues as those of the brain.

Effects similar to those produced by taking excessive quantities of food may result from permitting the waste of food and the bye products of digestion to remain too long in the alimentary canal. By the peristaltic movements of the bowel these waste substances are carried down to be discharged, lodging till this occurs in the rectum and lower part of the descending colon. The carrying down of these materials is brought about involuntarily and regularly and at a rate varying in different individuals and with different forms of food. The more concentrated forms of food move slowly, those containing much waste move rapidly. The discharge from the rectum is a voluntary act. The passage into the rectum, though involuntary, is helped, and the process stimulated by the voluntary discharge from that part of the gut. The more regularly and frequently the rectum is cleared, the more regularly will other parts of the intestine pass on the waste substances to it. Even though the quantity in the rectum be small, the mere effort to discharge this quantity assists in bringing down waste from above. No matter how small the amount of waste to be brought down, and how slow the rate at which it is brought down, an amount sufficient to be discharged will collect in twenty-four hours. Once in twenty-four hours, at least, the voluntary effort to unload the rectum should be made, if only for the sake of stimulating the action of the upper portions of the intestine. The more regularly the attempt is made, the more regularly and rapidly will the intestine act. The intestine, like the stomach, tends to act automatically, and the whole system benefits if automatic action is taken advantage of and encouraged. The automatic action of the stomach is taken advantage of by taking food at regular intervals. The automatic action of the bowels can be taken advantage of by voluntarily discharging at regular intervals the materials brought down by involuntary action. The interval should not exceed twenty-four hours, and the habit of carrying out the voluntary action once in every twenty-four hours should be acquired early. Children should be early instructed as to the importance of voluntarily emptying the rectum, and should be compelled to attempt this action even in the absence of desire to do so. The best and most suitable time is immediately after breakfast.

The bad effects produced by failure to get rid of the waste of food are due to the passage into the portal vein of bye products of digestion, and of substances produced by the action on the waste materials of bacteria, of which there are always large numbers present in the intestine. The outstanding signs and symptoms of this absorption are: (1) disturbed digestion; (2) headache; (3) impairment of intellect; (4) disinclination for exertion, mental or otherwise. Anæmia also may result, and one form of anæmia, viz. *pernicious anæmia*, is traced by some to the absorption of poisonous substances from the intestine. Appendicitis is also most common in persons who do not attend to the hygiene of the intestine.

Conditions due to the Defective Quality of Food.—Certain parasitic diseases are traceable to the food consumed. Food, especially butchers' meat, may contain animal parasites in the shape of worms. Other foods and beverages may contain vegetable parasites or bacteria, or the products of the action on the food of bacteria.

The chief parasitic diseases traceable to food are: (1) tapeworm disease; (2) trichinosis.

Tapeworm disease is produced by *measly* flesh, especially measly pork, *i.e.* pork containing young worms measled or scattered throughout the fibres of the meat. These young worms, if not killed by cooking, on reaching the human intestine develop into tapeworms.

Trichinosis is produced by eating pork infested with young worms called *trichinæ.* Trichinosis is rare in this country. In the human intestine these trichinæ develop into full-grown worms, which enter the blood-stream and, lodging in the muscles, set up symptoms frequently mistaken for rheumatism.

Both these conditions are to be prevented by the careful examination of the meat, and by seeing that it is properly cooked. Certain worms gain entrance into the human body with water. Amongst these, the most common are the *round worm* and *thread worm* found in children in the condition usually referred to as "worms." These do little harm usually to the infected person, and may set up no symptoms. The only proof that a child is infected is to be found in the discovery of the worms themselves. An infected child may be excitable, irritable, and restless.

Diseases produced by Bacteria in Food.—These are much more important. The most common bacterial diseases traceable to the infection of food are diphtheria, typhoid fever, scarlet fever, tuberculosis, and epidemic diarrhœa. The food most commonly infected is milk. The germs of typhoid fever usually find their way into the milk as a result of the addition to it of water containing them. Other articles of diet that may contain these bacilli are oysters, cockles, and mussels, which are eaten raw, and which become infected from sewage in the beds where they are cultivated. Water-cress, lettuce, and other vegetables eaten raw may also act as carriers of the infection of typhoid fever. Water, of course, may also be contaminated with the germs of this disease. Scarlet fever and diphtheria organisms may enter the milk either directly from the cow, or during handling by persons suffering from one or other of these diseases. Tuberculosis may be conveyed either by meat or milk. The flesh of tuberculous animals may contain the tubercle bacillus and is usually condemned. The milk of cows suffering from tuberculosis, especially of the udder, may contain these germs also. The chances of organisms finding their way into the body with milk are very great, and unless the source of the milk is known, that given to children should certainly be boiled, in order to kill off any that may be present.

Epidemic Diarrhœa.—Epidemic or infantile diarrhœa, or summer diarrhœa, is probably due to bacteria, although the definite germ has not been found. Where they obtain entry into the milk is disputed. Some say at the farm, others at the home. The disease is most common in summer, and affects chiefly bottle-fed children, those of careless mothers, especially, who neglect to clean the feeding-bottle after each feed, and to sterilize and protect the milk from contamination. It is commonest in dirty houses and in houses in crowded districts abutting on unpaved courts and yards. In all probability contamination takes place at the home. The death-rate from summer diarrhœa is very high. The disease can be prevented by care on the part of mothers, and improved sanitation always results in a diminution of the death-rate from it. It is most common and most fatal in warm, dry summers, when the germs flourish in polluted soil, such as is found in unpaved courts and yards. The death-rate is always lowest in wet summers, the germs in the soil probably being drowned out.

The flesh and milk of cattle affected with *pleuro-pneumonia*, and *foot-and-mouth disease*, are apt to prove unwholesome to children. The poisons produced by the action of germs on food may give rise to very alarming symptoms, such as diarrhœa and vomiting. Cooking has no effect on these poisons, and tainted food is to be avoided. Foods sold prepared for eating are also to be avoided, for example, tinned foods, potted meats, and pork pies.

Sterilization of Milk by Boiling.—Several references have been made to the boiling of milk, and it seems advisable to mention here the method most commonly recommended for carrying this out without altering the flavour of the milk. Put the milk in a covered vessel; place this in a pan containing water. Boil the water for from 20–30 minutes. At the end of this time remove the vessel containing the milk and place it in several changes of cold water, in order to cool the contents rapidly. Keep the milk covered in a cool place till required. It will remain sterile and sweet for a long time.

CHAPTER IX

THE EXCRETORY SYSTEM

Structure of the kidneys and skin—Functions of the skin—Care of the skin—Conditions affecting the skin.

THE organs of excretion are the *lungs*, the *kidneys*, and the *skin*. The chief substances to be excreted are *compounds of carbon*, chiefly carbon dioxide; *compounds of nitrogen*, in the form of urea and uric acid, which are derived from the proteid food materials; *hydrogen*, in the form of water, and, in addition, certain of the *salts* of the food.

The lungs have already been considered. They excrete water and carbon dioxide, the latter brought by the blood-stream from the tissues generally, but more especially from the muscular tissues. Carbon dioxide is produced as a result of the breaking down of such tissues, and of organic food materials by them during their activity.

THE KIDNEYS AND URINARY SYSTEM

The kidneys form part of the urinary system, and the substances chiefly excreted by them are the nitrogenous compounds, urea and uric acid, and salts dissolved in water. The urinary system consists of the *kidneys*, with their ducts, the *ureters*; the *urinary bladder*, into which the ureters open, and the *urethra*, which forms the outlet of the bladder.

The kidneys lie on the back wall of the abdominal cavity, one on each side of the vertebral column, fairly high up. They are dark in colour, smooth and firm to the touch, and are covered in front with peritoneum. On the top of each kidney rests what is known as the *suprarenal body*. Each kidney is surrounded with and embedded in fat, which protects the organ from cold and from injury. Immediately under the fat there is what is called the capsule of the kidney, which consists of tough fibrous tissue and is readily detachable. From this capsule there pass into the substance of the kidney, blood-vessels to nourish it. In shape the kidneys are oval, and measure $4\frac{1}{2}$ inches in length, $2\frac{1}{2}$ inches in breadth, and $1\frac{1}{2}$ inches in thickness. Each weighs about 4 ozs. The anterior and posterior surfaces are more or less rounded. The outer edge is convex, and the inner edge is marked by a distinct depression about its centre. This depression is called the *hilum* of the kidney, and at this point several structures connected with the functions of the kidney or its nourishment are found. The chief of these structures are, the artery carrying blood to the kidney for purification, viz. the *renal artery*; the *renal vein* which carries blood away from the kidneys to the inferior vena cava after it has been purified; the ureter

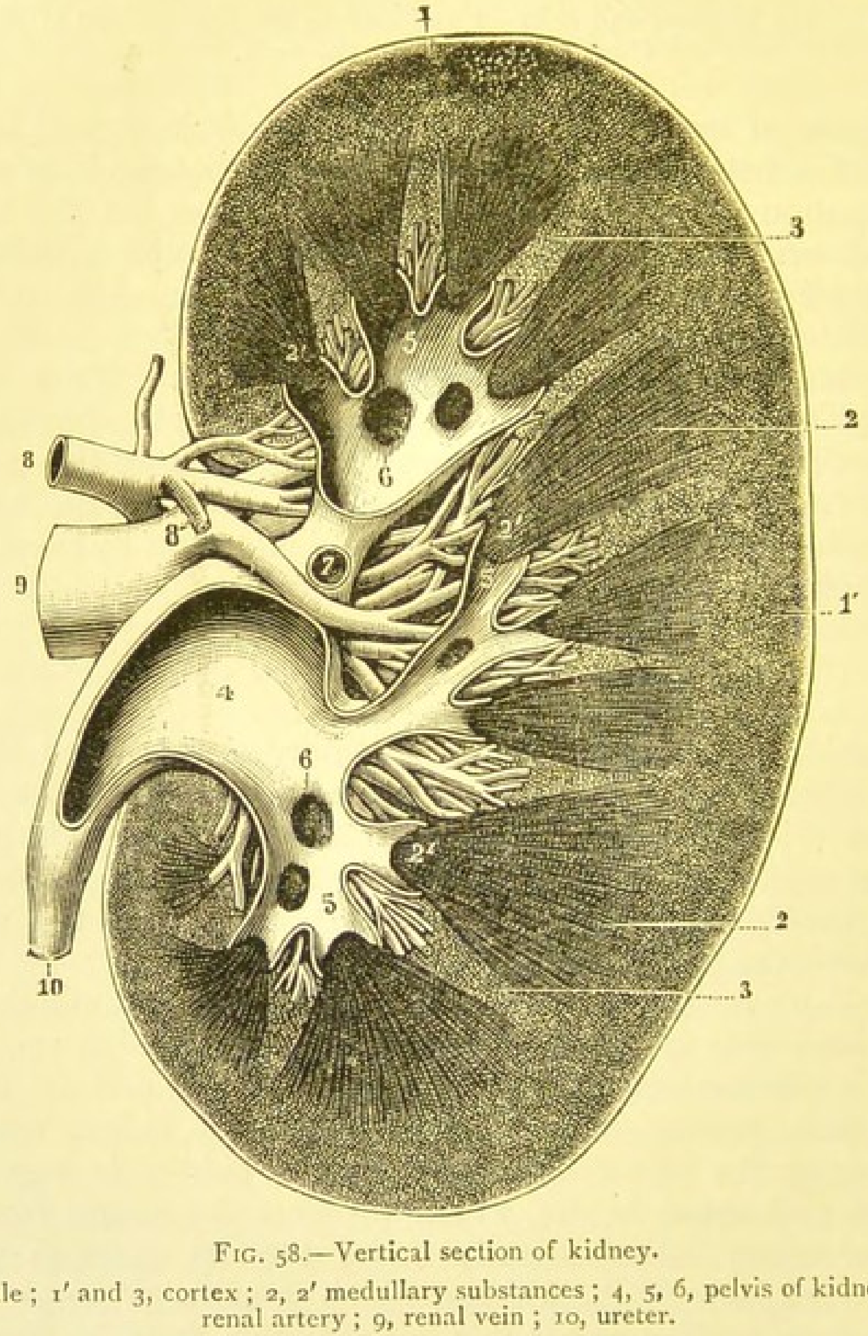


FIG. 58.—Vertical section of kidney.

1, capsule; 1′ and 3, cortex; 2, 2′ medullary substances; 4, 5, 6, pelvis of kidney; 8, 8′, renal artery; 9, renal vein; 10, ureter.

or tube which bears away substances derived from the blood; and, in addition, nerves and lymphatic vessels.

The ureter is a fibrous tube which begins in the interior of the kidney in a funnel-like expansion, and terminates by opening into the urinary bladder. The funnel-shaped expansion of the ureter is called the *pelvis* of the kidney. Into it there open the minute tubes or tubules, which collect the waste materials or urine, and which make up the chief bulk of the kidneys. The tubules begin at the outer part of the organ close under the surface, in what is known as the *cortex* of the kidney. Each tube follows a somewhat tortuous course, but eventually terminates by entering into a larger tube which runs straight through the substance of the kidney to open into the funnel-shaped pelvis. These larger straight tubes or tubules are very numerous, and are found mainly in the central part or *medulla* of the kidney. Into each, several of the smaller tubes open. The terminal branches of the renal artery run alongside the straight tubes, and each sends a branch into the end of the tube which is expanded to receive it. Inside the expanded end the tiny artery breaks up into smaller branches. From the blood in these the cells lining the end of the tube withdraw the waste products forming the urine, namely urea, uric acid, water, and salts. The cells lining the tube below the expanded end are also, probably, capable of withdrawing waste substances from the blood, and the minute branches in the end of the tube finally unite again to form a single artery, which breaks up into small capillaries around the tube. These capillaries communicate with capillaries of the renal vein, which carries the purified blood back to the inferior vena cava. The urine collected by the kidneys reaches about 40 or 50 ozs. in the twenty-four hours. It passes slowly along the tubes to reach the pelvis of the kidney, and getting into the ureter is conducted thence into the urinary bladder.

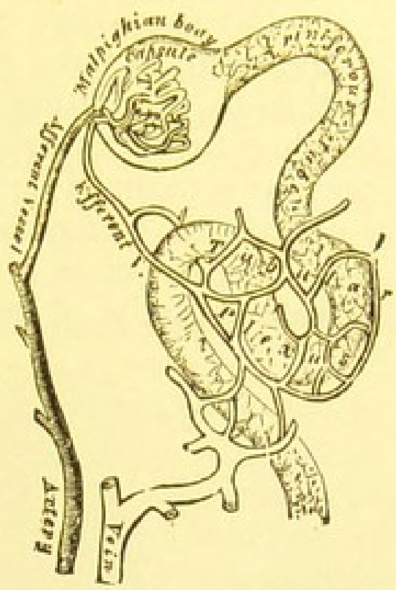


FIG. 59.—A kidney tubule and its blood supply.
(*From Gray's "Anatomy."*)

Urinary Bladder.—The bladder lies in the pelvis behind the pubis. It is a muscular bag, consisting of several layers of involuntary muscle fibres, covered externally with fibrous tissue, and lined internally with mucous membrane. The upper surface is covered with peritoneum. Leading away from the bladder, and serving as an outlet for the urine, is the *urethra*. The point where the urethra begins is called the *neck* of the bladder, and at this point the muscle fibres are very numerous, forming a ring or *sphincter* round the neck. This is always contracted, save when the urine is to be discharged. The emptying of the bladder is a somewhat complex action, since two things happen at the same time, viz. relaxation of the sphincter and contraction of the muscle fibres in the wall of the bladder.

The Skin

In the discharge of waste materials the kidneys are assisted by the skin, certain glands in it, viz. the *sweat glands*, being capable of separating urea and water from the blood and discharging them as sweat. The skin consists of two layers, an upper or superficial layer, and a lower or deep layer. The former is called the *epidermis*, the latter the *dermis*, or true skin. The epidermis, or as it is sometimes called the scarf or scurf skin, consists entirely of cells arranged in several layers. The most

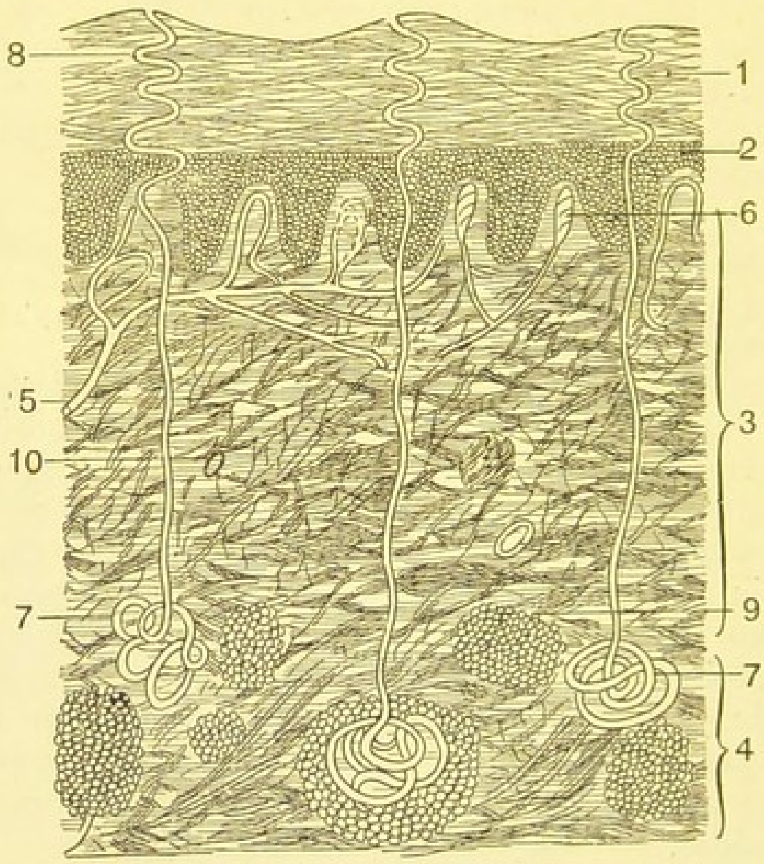


Fig. 60.—Vertical section of the skin (diagrammatic).

1, epidermis; 2, malpighian layer of epidermis; 3, dermis; 4, subcutaneous tissue; 5, blood-vessels giving off loops into the papillæ of dermis; 6, touch corpuscle; 7, sweat gland; 8, duct of sweat gland; 9, cluster of fat cells; 10, cut end of blood-vessel.

(*From Thornton's "Elementary Practical Physiology."*)

superficial layer is made up of flat scale-like cells of an almost horny nature. These are for the protection of the deeper cells and are continually being rubbed off. They are replaced by the cells of the deeper layers which are more oval and less flat. The most deeply placed cells are cubical in form and have each a distinct nucleus. They form what is called the *malpighian layer*, and as the cells above are cast off they become altered in shape and character to replace them. The epidermis is devoid of blood and receives its nourishment from the fluids in the tissues beneath. It acts chiefly as the protector of the dermis.

The *dermis*, or true skin, consists of connective tissue distinctly compact at its upper part, looser and less compact below. It is richly supplied with blood-vessels, lymphatics, and nerves. All over the body it is thrown into tiny folds, and corresponding with these there are to be found folds in the epidermis. These latter are most distinctly seen on the palms of the hands and the soles of the feet, and about the fingers and toes, in the form of ridges.

From the upper surface of the dermis there arise distinct projections or *papillæ*, which project into the epidermis. Each papilla contains numerous capillaries and nerves. Some of the latter are arranged to form *touch corpuscles*, or touch bodies. Exposure of these papillæ by destruction of the epidermis and irritation of their contained nerves leads to the production of pain. In the spaces of the deeper, looser parts of the dermis, collections of round fat cells are to be found. These vary in size and number with the leanness or otherwise of the individual.

Skin Glands.—In the dermis two kinds of glands are to be found: (1) *sebaceous glands*, which secrete an oily fluid, and which are found in connection with the hairs; (2) the *sweat glands*. Each sweat gland consists of a very much coiled-up tube closely surrounded by capillaries, the duct of the gland being simply a continuation of the coiled-up tube. The duct passes up through the dermis and epidermis to open on the surface of the skin. Sweat glands are found numerously all over the body, but are chiefly numerous on the forehead and in the armpits. The ducts and glands are lined by epithelium, which in the gland is capable of secreting from the blood a fluid consisting of water containing various waste substances. This fluid or sweat is poured out on to the surface of the skin, and is carried off by evaporation, unless it is very large in amount when it collects in drops on the surface. The sweat which evaporates is known as *invisible sweat*, and under normal circumstances constitutes the great bulk. That collecting on the surface of the skin is the *visible sweat*. The quantity secreted depends on the amount of blood in the capillaries round the sweat glands, *i.e.* upon the size of the capillaries and whether they are contracted or dilated. When the heart is beating rapidly, as is the case during exercise, the capillaries of the skin, like those elsewhere in the body, dilate in order to accommodate the more rapidly flowing blood. By the increase of blood the sweat glands are stimulated, and larger quantities of perspiration are secreted. This is partly evaporated and partly deposited on the skin. The small drops of perspiration evaporating carry away heat from the body surface, and in this way part of the heat produced by the activity of the various tissues is got rid of and the body temperature kept down. In most persons the amount of perspiration secreted varies with the needs of the body. It is small in amount when the skin capillaries are small and no extra cooling of the body is required, for example, in cold weather. When the capillaries are large and full of blood and a great deal of heat has to be got rid of by the skin, for example, in warm weather and during exercise, it is large in amount. In some persons the glands are less active, and the amount secreted is small. In others, the glands are too active and the skin is kept always bathed with sweat. Excessive secretion often takes place at one or more parts of the body, viz. the hands, the feet, the armpits, and so on. Very frequently, in such cases, the skin is infested with germs which have the power of attacking and breaking down the sweat and other secretions of the skin and producing substances with a distinct and unpleasant odour. This amounts almost to a disease and is to be cured by washing away the skin secretions at frequent intervals; by frequently changing any articles of clothing impregnated with the secretions, and by endeavouring to kill the germs by applying to the skin such an antiseptic as boracic acid.

Appendages of the Skin.—The appendages of the skin which have to be referred to are the *nails* and the *hair*. These are both produced from the epidermis, and consist of modified epidermic cells. The nails are made up of these cells transformed into a horny substance. Growth in length takes place from the cells at the root or inner end of the nail. The bed of the nail is formed by the dermis, which contains numerous nerves and touch bodies, and is therefore very sensitive. For this reason the name "quick" is applied to it.

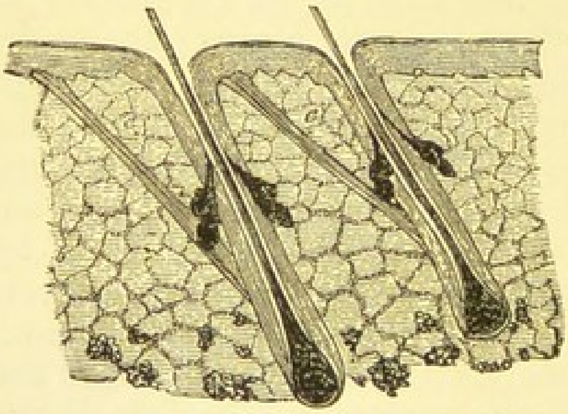


FIG. 61.—Section of skin showing hair follicles, sebaceous glands and muscles of hairs.

a, epidermis; *b*, dermis; *c*, muscle; *d*, sebaceous glands.

(*From Quain's "Anatomy."*)

The hairs are also produced from the epidermis. At the point where a hair exists the epidermis is folded in to form a pit extending into the dermis. From the cells in the centre of the pit the hair grows and projects beyond the surface. At the bottom of the pit, where the root of the hair is situated, there is a projection upwards of a papilla from the dermis carrying blood-vessels to nourish the hair, and to assist in its growth. In connection with each hair there is a small muscle. Contraction of this muscle causes the hair to stand on end, and also assists in the casting off of the hair when it is to be shed.

The *sebaceous glands* lie beside the hairs, and their ducts open into the pits in which the hairs lie. The secreting portion is situated in the dermis and is surrounded by capillaries. They secrete an oily material named *sebum*, which reaches the surface of the skin alongside of the hair. It keeps the hair glossy and the skin soft, and assists in the separation of the scarf skin. Sebaceous glands are most numerous at the back of the neck, between the shoulders, and at the sides of the lower part of the nose. Their ducts are apt to be blocked if the skin is not kept clean.

The Functions and Hygiene of the Skin

The functions of the skin are (1) to protect the underlying tissue. This, contrary to common opinion, makes up only a small part of its duties. (2) To act as an organ of excretion. It assists the kidneys to get rid of urea and salts, and the lungs to get rid of carbon dioxide. (3) The skin is one of the sense organs. The dermis contains many nerves and touch corpuscles, the organs of common sensibility. Normally stimulated, the sensation of a touch is produced; if over stimulated, pain results. Certain parts of the skin are concerned largely with the recognition of heat and cold, and are specially sensitive to these. (4) It is one of the chief regulators of the body temperature. Heat is produced under the direction of the brain, the various tissues acting in certain definite ways. Heat is lost indirectly with various secretions from the kidneys, bowels, lungs, and skin, and also directly by radiation from the surface of the body. The amount radiated varies with the amount of blood in the skin and the size of the vessels. The amount also varies with the size of the skin surface exposed.

Heat production and loss go hand-in-hand, increasing and diminishing together under the influence of special automatically acting centres in the brain. The average normal temperature of the body is from 98° to 98·5° Fahr., but may be a little higher. As a result of the regulation by the centres, the body temperature is kept even, no matter what the external conditions may be. If radiation is favoured by external conditions, viz. cold, and a high cold wind, heat production is stimulated, and, at the same time, heat loss is reduced by diminishing radiation from the skin, the blood-vessels there contracting to keep down the quantity of the blood. In warm weather, heat production is diminished, and the loss of heat is encouraged by dilatation of the skin-vessels and increased radiation.

Hygiene of the Skin.—If properly attended to, the skin is encouraged to carry out all its functions. When the functions are properly carried out, the skin itself primarily benefits; but, since it is one of the component organs of the body, the whole body also benefits. So far as the protective function is concerned, this can be favoured best by preventing injury to the skin in any way. Its activities as an organ of excretion are to be encouraged by attention chiefly to the parts concerned with this function, viz. the sweat glands and ducts. Anything interfering with the freedom of the flow of sweat is harmful as tending to the retention of waste products. The freedom may be interfered with by blocking of the ducts of the sweat glands. The obstruction may be mechanical, for example, by means of dirt. In order to prevent such obstruction, the skin must be kept clean. For this purpose nature has provided water; but water alone is insufficient for cleansing, on account of the presence of the oily fluid secreted by the sebaceous glands which tends to form a cake with the dust particles from the air, dead cells of the epidermis, particles of clothing, and perspiration.

This mixture constitutes dirt of the skin, and forms a cake, which, if left to itself, will close up the sweat ducts and form a soil for the growth of organisms. The organisms most commonly found are those concerned with the production of skin diseases, but the germs of other diseases may also be found. By this cake also such functions of the skin as the secretion of sebum and heat regulation are markedly interfered with. For the removal of the dirt, in addition to water, something that will dissolve the cake is necessary. *Soap*, which is a mixture of fatty matter with an alkali, is usually employed. As a result of the mixing of the fatty matter and alkali, *saponification* results. The fat is broken into its constituents, glycerine and fatty acids, and the alkali uniting with the acids, soap is formed. If the alkali used is potash, soft soap results. If soda, hard soap. Soap is soluble in water, and gives an alkaline mixture. Applied to the skin, this alkaline solution of soap renders some of the oil in the dirt soluble. By emulsifying some other part, it renders it more easy to be got rid of by means of the water. For the solution of the soap and the removal of the emulsified and dissolved oil, hot water is more useful than cold. In the case of the exposed skin surfaces, this process should be carried out frequently. The face and neck should be washed at least twice a day. The hands should be washed at these times also, and, in addition, before meals and after exposure to contamination of any kind. For the removal of the caked secretions and dirt from the remainder of the body, a daily bath is necessary. Warm water acts more effectively than cold, but cold water, if soft naturally, or softened by the addition of an alkali, like ammonia, forms a good enough lather, and does well enough for those who follow clean occupations and bathe regularly every day. The daily cleansing with warm water should be carried out at night. The temperature of the water should be between 94° and 104° Fahr. The *cold bath* is usually taken in the morning; the temperature should be between 55° and 65° Fahr. The chief advantage of the cold bath over the warm bath is that it is more stimulating to the skin, toning up the muscular walls of the blood-vessels and increasing the power of reacting to variations in the temperature. It is stated also to be a preventer of colds. Only those who react to the cold water, *i.e.* who feel warm and comfortable after leaving the bath, should use it. For those who shiver and go blue, the cold bath is unsuitable, and should not be taken. The *hot bath* has a temperature of between 104° and 110° Fahr. Water at this temperature more thoroughly cleanses than water at a lower temperature. A hot bath should be taken at intervals by those who bath daily. For those who do not do so, a hot bath should be taken once if not twice a week, at night before going to bed. Russian and Turkish baths encourage the activity of the skin, and should be followed by a shampoo.

For infants and young children, the care of the skin and cleanliness are of immense importance. In these too much attention cannot be given to the choice of soap, and to the drying of the skin after the bath. The kidneys must be relieved of as much work as possible. This is best done by encouraging the excretory functions of the skin. The delicacy of a child's skin renders it liable to attack by germs, and must therefore be kept healthy to resist these, and must also be kept free from collections of germs. A daily bath is essential for children. A warm bath at bedtime is best, with an occasional hot bath. They should not have a daily cold bath before the fifth year. After this time they may have a cold bath in the summer, provided they react thoroughly. They should not have cold baths all the year round until after the tenth year.

It is very important to impress the necessity for cleanliness on children. They are very apt, especially boys, to neglect the cleansing of the hands before meals, and when there has been contamination. Children of well-to-do parents are bad enough in this respect. Children of poor parents, for some reason, are infinitely worse. Water is cheap enough, and soap is not particularly expensive. The parents are primarily to blame, and do not attempt to teach their children. The teaching of cleanliness falls commonly upon the teacher, and he has to show them a good example. Instruction in the cleansing of exposed parts can easily be given at school. The authorities must provide lavatory basins, soap, and towels. The lavatories should be in close proximity to the offices, and should be used in conjunction with these. The best type of lavatory basin is that in which the same water cannot be used by two or more children. Many patent wash-hand basins, especially designed for schools, are on the market.

The question of towels is very important. The general experience is that school authorities are very niggardly in this respect. Towels frequently act as carriers of infection. *Infectious eye troubles* especially are apt to be spread in this way, and children suffering from sore eyes should never be allowed to use the same towels as the others. Instruction in washing the whole body, and opportunities of carrying out the same, could be given at school. Very little in this direction is attempted in this country, though it is carried out in parts of Germany and America. Systems of hot shower baths are introduced, and the children are permitted to use these. Shower baths take up little space, are not expensive, and risks of infection by two or more children using the same water are absent.

Care of the Skin Appendages.—The hair and the nails have to be attended to no less than the skin. To keep the hair in good condition, it should be washed and brushed frequently and regularly. Hair very rapidly gets dirty, as it provides a lodgment for particles of dust, which are held by the oil secreted by the sebaceous glands. With the dust, germs and vermin may obtain a lodgment in the hair. These latter may lead to the production of eczema of the scalp, the irritation of the skin leading to scratching, the scratches afterwards becoming infected with germs. The hair in childhood should be washed at least once a week, and if short may be washed even oftener. In order to increase the supply of blood to the roots of the hair, the brush should be used twice a day.

Up till the age of thirteen or fourteen, girls should have their hair cut short like boys. The advantages of this are that the hair is more easily kept clean; the scalp is more easily attended to; and there is less risk of infection with vermin through contact with an infected head. For girls with long hair, many teachers insist that it shall be arranged in a pigtail, or that, in school at least, it shall be tied back, to prevent infection. For the cleansing of the hair, soap and water are best. No dressing should be applied unless specially ordered. Curling pins, tongs, papers, and crimpers are bad.

The nails of the fingers and toes require attention. The nails should not be allowed to grow too long, since dirt, which may contain germs, is apt to collect under them. For trimming the nails, a file is preferable to either a knife or scissors. Children should be warned that the teeth are not to be used for this purpose, as dirt from under the nails may get into the mouth. The trimming of the nails at the sides is important, especially in the case of the toe nails, to prevent *ingrowing toe nail.* With this same object, it is recommended that the toe nails should be cut straight across, and if necessary a V-shaped notch may be cut about the middle of the edge of the nail. For the cleansing of the nails, soap and water and a brush are best. Any dirt not removed in this way is best got rid of by means of a pointed piece of wood, a knife being less satisfactory. The skin over the root of the nail should always be pushed back when drying the hands. The toe nails require especially to be kept clean, as dirt, which may be decomposed by germs, has a tendency to lodge under them.

Clothing

The remaining function of the skin to be encouraged is that of regulating the temperature of the body. The amount of heat lost by radiation from the skin surface depends chiefly upon the amount of skin exposed; upon the atmospheric temperature; upon the amount of moisture in the air; and upon the wind. In temperate climates, some limit is necessary to the amount of surface exposed to radiation. There are other reasons also for limiting the amount of surface, one of the most important being the necessity for protecting the skin from injury. The parts usually exposed are the face and hands, but if radiation takes place too quickly from these for any reason, or if the atmospheric conditions are such that the blood-vessels are contracted, and the supply of warming blood greatly diminished, they may be covered up more or less completely. In some parts of the world, not always the savage and tropical parts, it is customary to expose larger areas of the skin—for example, of the legs and arms,—especially in children of tender years. Children are most unsuitable objects for exposure of this nature, and the idea that by such methods the strength and resistance of the child can be increased is quite erroneous. For the covering of other parts of the skin, clothing is necessary, and its chief objects are: (1) protection from the weather and injury; (2) regulation of heat; (3) decency;

(4) personal adornment. Of these the first and second are the most important. The kind of clothing used is largely a question of climate, habit, convenience, and civilization.

Materials used for Clothing.—Various materials are used in the construction of clothing, the chief being *cotton*, *linen*, *wool*, and *silk*. Any of these will serve as protectors against the weather and injury. Some of them are better regulators of heat than others, because they conduct *badly*, and therefore hinder radiation from the body surface. Certain of the materials also possess advantages with regard to their behaviour to the moisture given off by the skin. In determining which of the materials mentioned is to be chosen for clothing, various points have to be considered: (1) whether the substance is a good or bad conductor; (2) whether it absorbs much or little fluid; (3) whether or not it retains odours and organic matter; (4) whether or not it is permeable to air.

Cotton is found to be a good conductor of heat, to be greedy of moisture, to retain odours strongly, and to be fairly permeable to air. It does not particularly attract or hold organic matter. *Linen* resembles cotton, except that it does not absorb moisture so readily, and is a little less permeable. *Wool* is a bad conductor. It is greedy of moisture, and is permeable. It does not retain odours. *Silk* resembles wool in being a bad conductor; it differs from it in absorbing less moisture.

In every respect wool is the best material, either for garments to be worn next the skin, or for those for outward wear, especially in the colder climates. The chief advantages of woollen garments are, that they are soft, warm, elastic, and permeable. They readily take up moisture and retain it, and require therefore to be washed frequently. Great care has to be expended in the washing, as there is a tendency for the material to become hard and to shrink, if this is not properly carried out. For under garments silk is also suitable. Its chief advantages, in addition to its bad conductivity, are its lightness and its cleanliness. The objections to it are its expense, and its lack of the quality of durability. Cotton and linen are not suitable for garments to be worn next the skin, because they absorb moisture and readily get wet. Being good conductors of heat the fluid evaporates rather quickly, and the body temperature is too rapidly reduced, chills in this way being produced. For underwear cotton is more used than linen, and has certain advantages, especially in the form of the so-called "cellular underwear." In this form spaces are left between the fibres of the cotton during manufacture, and radiation is discouraged, since the air itself is a bad conductor. There is a certain amount of truth in the statement made with regard to this material that the body is "clothed in air." There is also a certain amount of advantage in being so clothed. When used for underwear, linen is generally adopted for the purpose of personal adornment.

No matter what materials are chosen for under garments these should never fit the body too closely. Since it is a bad conductor of heat, it is always an advantage to have a layer of air surrounding the skin, and between it and the garment, whether it be constructed of good conducting or bad conducting materials. Tight under or other clothing, besides doing away with this layer of air, also interferes with the circulation of the blood. It especially interferes with the return of the venous blood, and with the freedom of the movements of the muscles and limbs.

The outer garments are of less importance, so far as health is concerned, than the under garments. For their construction similar materials may be used, except in the case of the feet, where something extra in the way of protection against injury and the weather is required. The outer garments in cold climates are best made of wool. On account of the chances of being exposed to moisture in the form of rain, the permeability of the outer garments to moisture is a point of some importance. While making garments impermeable to moisture, however, the permeability to air should not be interfered with, if possible, since the layer of air next the skin must be changed regularly. *Waterproof clothing* is unsatisfactory and uncomfortable, because it is impermeable to air as well as moisture. The so-called "rainproof" cloths are rather better, since the salts with which they are treated to make them rainproof do not interfere with the passage of air. Leather clothing may be used on account of its impermeability to moisture. Like waterproof, it is somewhat impermeable to air. It is a suitable material for use in very cold climates. It is also exceedingly durable. Leather is used for foot wear because it is impermeable, durable, and capable of protecting from wounds, parts so much exposed to injury.

In connection with the outer garments the question of colour is important, apart altogether from the æsthetic point of view. White and light-coloured garments absorb much less heat than those of a darker colour. Their affinity for organic matter and germs is also much less marked. Because of their behaviour towards heat, white and light-coloured materials are worn in warm climates and in summer, dark-coloured in winter.

Garments and their Arrangement.—In infants and children the question of clothing is a very important one. The freedom of the movements and of growth must not be interfered with, and excessive radiation of heat must be prevented. For infants, loose garments are essential all over the body, and bad conducting materials next the skin. In addition to being loose, the garments must also be light and easily removable. The old-fashioned plan of using the baby as a sort of pin round which clothing was wound is very bad. All the garments should button or tie in front. The buttons and strings should be easy of access without the necessity of twisting the infant about in various directions. Foot wear for infants should be warm, light, and very flexible.

In the case of young children the same rules apply. The practice of many parents of leaving a large part of the legs in boys uncovered, and of the legs and arms in girls, should be combated. The avowed object is to harden the child. In this the experimenter usually fails, since the child either dies outright before the process is completed, or develops rheumatism in the form of growing pains, and has to be properly clothed. The children usually brought forward as examples of the success of the method, in the majority of instances, prove nothing. Other conditions have been favourable to hardness in such children, and they cannot be taken as examples.

Another tendency of parents, viz. that of *over* clothing those who are at all weakly, should be referred to. The multiplication of garments is bad. This practice is found most commonly amongst the very poorest classes, who have a great tendency to overburden their children with odds and ends of clothing. A suit of under garments, covering the whole body, but not too tightly, and varying in thickness with the season, and a suit of outer garments, are really all that is necessary. In the colder months, if the body loses too much heat, additional outer garments may be added. These, it should be noted, keep the body warm, but cannot make it warm. They should be put on, therefore, before too much heat has been lost. Mufflers of various kinds, and chest-protectors in the majority of cases, are quite unnecessary, and may even be harmful.

In the clothing of girls, the reforms introduced by people of the better class seem to be only slowly accepted by the poorer classes. The plan of diminishing the number of the under garments and of suspending the simple plain frock from the shoulders, instead of from the waist, does not seem to appeal to the poor, and even to the fairly well-to-do. Stays, that torture the unfortunate child's waist, and interfere with all the internal organs, are still in vogue, and the waist, in spite of all that has been said regarding twisting of the spine, is still used as the suspending-place for the heaviest part of the clothing. If people could only be brought to realize that if the girls were dressed in a rational manner they could be dressed more cheaply, and that overdressing, especially in tawdry finery, very often second-hand, was bad for the health as well as the morals of the girls, a very great advance would be made.

Foot wear for Children.—The foot wear of the children of the poor and of persons earning fair wages is a matter regarding which a few words should be said. The ideal covering for the child's foot is something light, strong, flexible, and perfectly fitting. The boot, or preferably, except in very wet weather, the shoe, should be made as far as possible to fit the foot, and not the foot to fit the boot. Ready-made boots and the boots handed down from the older to the younger members of the family, or, in some instances, purchased second-hand, are rarely satisfactory. Few children have feet exactly alike. Even in members of the same family it is uncommon to find them so. The boot should be adapted to the natural outline of the foot. The toes, and more especially the great toe, should be allowed a certain amount of play, and rigid soles and high heels are to be avoided. The clogs occasionally worn are particularly unsuitable, on account of their rigidity, for growing children.

The *head coverings* of children should be light. Bonnets, etc., that fit tightly and closely to the head are to be avoided.

Clothing at Night.—The underclothing worn during the day should be completely removed at bedtime. It should be replaced by a light, loose woollen nightdress, or, if the skin will stand it, a nightdress of flannel may be used. In the case of children, the highly inflammable flannelette is to be avoided.

With regard to bedding, a hair mattress is to be preferred to anything else. Flock is apt to be dirty and lumpy, and feathers are much too warm. The head should be low, one pillow only being used if possible. The covering should be light but warm. The bed should be so placed that air can circulate all round it. Infants should be given a separate cot, on account of the risks of "over-lying."

Diseases affecting the Skin

The diseases to be considered may be classified as *infectious* and *non-infectious*. The chief infectious disease likely to be encountered by the teacher is *ringworm*. This may be found affecting either the hairy scalp or the skin of some other part of the body. Both of these forms are infectious, but the former is the more serious since it is the more enduring. It is the type most commonly found in children. Ringworm of the scalp consists of one or more circular patches, red in colour or covered with dry scales. The hairs over the patch are scaly, short, and irregularly broken. If the disease has lasted any time, the whole scalp may be more or less covered with scales or more or less bald patches. The hair is thinned, but may be fairly long, and under it numerous broken stumps of hairs may be detected. Teachers are usually directed to exclude children suffering from ringworm from school until the condition is certified as cured. It is often exceedingly difficult, however, to decide when ringworm is cured. It may be said, indeed, that a decision can only be arrived at after a microscopic examination of the hairs. The disease is an exceedingly infectious one, and when it affects the scalp is difficult to get rid of, unless it is taken very early and is properly treated. In the vast majority of cases, especially in the elementary schools of the poorer districts, proper treatment and advice are not sought till the disease has taken a firm hold and has spread widely over the scalp. The home treatment is usually useless, because it is not thorough enough. Most frequently it results only in spreading the disease over the head. *Every scale from a ringworm patch and every broken hair is capable of infecting unaffected parts of the affected scalp, and also the scalp of an unaffected person.* If thorough treatment is applied, a cure may be brought about in a comparatively short time. If untreated, it may take months or even years. It may be left to nature, even, to cure the condition, and this nature does by causing the spontaneous disappearance of the ringworm at about the age of thirteen or fourteen. The infection of ringworm may be acquired directly from the infected head, or indirectly, caps, combs, or hair brushes intervening. If the head of the infected child could be kept covered up with a bandage or a closely fitting paper cap, or if a fresh lining of paper were placed daily in the ordinary cap, the child might be allowed to attend school. Parents will not usually, however, take so much trouble, and for the sake of the other children the only safe thing to do is to exclude the child.

Another infectious condition of the scalp is that known as *favus*. This is a much more serious disease than ringworm, and is practically incurable. It occurs amongst the very poor and in badly nourished children in the form of bright yellow cup-shaped patches on the head. From these patches a curious mousey odour is given off and is very characteristic.

An infectious form of eczema is frequently found amongst children. It is known as *impetigo*, and is most common in children under twelve. It affects especially the face and hands. It occurs as small patches covered, in the later stages, with dirty, yellowish-brown, raised scabs. The disease rarely lasts more than a week at the outside, but while it lasts it is distinctly infectious. When one child in a family gets it, usually all the others are infected, and this fact should make the teacher suspicious. Infected children should be excluded, and medical treatment recommended.

Itch or *scabies* is due to an insect, and is commonest about the hands. It is stated to be non-infectious during the day.

Eczema is the only non-infectious condition likely to be met with. Affecting the scalp, it may occur in children, especially girls, with vermin infected heads. Such a condition may be associated with enlarged glands and even abcesses at the back of the neck. The mode of production of these has already been explained. The teacher's duty in these cases is to recommend the mother to have the hair cut out and to have proper treatment applied. The following cards have been found exceedingly useful by the teachers in Sheffield, in cases in which vermin have been detected, and may be recommended. The instructions for cleansing the heads are printed on both forms.

CITY OF SHEFFIELD EDUCATION COMMITTEE

Medical Inspection of School Children

Private Notice

To the Parents or Guardians of

Your attention is drawn to the condition of this child's head which has been noticed in School.

By attention to the directions given on the other side, it can be rendered perfectly clean within a week.

If cleansing is not effected by that time, the child will have to be kept separated from the others in School until the unclean condition is remedied.

Date

INSTRUCTIONS FOR CLEANSING HEADS

1.—Get twopennyworth of Carbolic Oil from a chemist and rub it all over the head and hair. Tie a cotton handkerchief over the head and leave it on all night.

2.—Next morning wash the head well with soft soap and rinse with water. Then comb the head with a fine tooth comb.

3.—Repeat this treatment daily until the head is quite well and all signs of lice are gone.

4.—Where there are sore places or scabs, the hair should be cut short, and in cases of scabs a linseed or bread poultice should be applied to the head.

5.—Where there is difficulty in keeping a child's head clean the hair should be worn short.

[NOTE.—The worst head, if properly attended to, should be well in ONE WEEK.]

CITY OF SHEFFIELD EDUCATION COMMITTEE

MEDICAL INSPECTION OF SCHOOL CHILDREN

Date

Second Warning.

To the Parents or Guardians of

A Private Notice regarding the state of this child's head having been sent to you, and this condition, which could be remedied in a week, still being allowed to persist, the child has now been separated in School as unfit to be in the ordinary class. You are required to take steps to cleanse its head within the next week, failing which the child will be excluded from School, and you will be liable to prosecution and fine for not sending it in a fit state to School.

[The means for cleansing heads is given on the other side of this card.]

A condition affecting the scalp in which bald patches rapidly form is sometimes met with amongst school-children. It is apt to be confounded with ringworm, and should be mentioned. The patches, however, are smooth and clear, and free from scales, and are thus distinguishable from those of ringworm. By some observers this disease, which is known as *alopecia*, is regarded as infectious, but if it is, is so only to a very slight extent.

CHAPTER X

THE NERVOUS SYSTEM

Structure of its various parts—Functions and development of the brain, etc.—Conditions affecting the nervous system—Overstrain and fatigue—Defective children—Certain diseases.

THE nervous system consists of the following three parts :—

(1) The *central nervous system*, viz. the brain and spinal cord.

(2) The *peripheral nervous system*, viz. the nerves.

(3) The *sympathetic nervous system* made up of numerous small swellings, found at intervals along the front of the spinal column, and of nerves. It chiefly governs the internal organs, such as the heart, lungs, stomach, and so on, and is connected with the central nervous system by means of certain nerves.

THE CENTRAL NERVOUS SYSTEM

The Brain.—That part of the central nervous system which is formed by the brain occupies and almost completely fills the cavity of the skull. In the adult it weighs, on the average, about 50 ozs., and measures 7 inches from front to back and 5 inches from side to side. It is divided into two parts to form the great brain or *cerebrum* above, and the little brain or

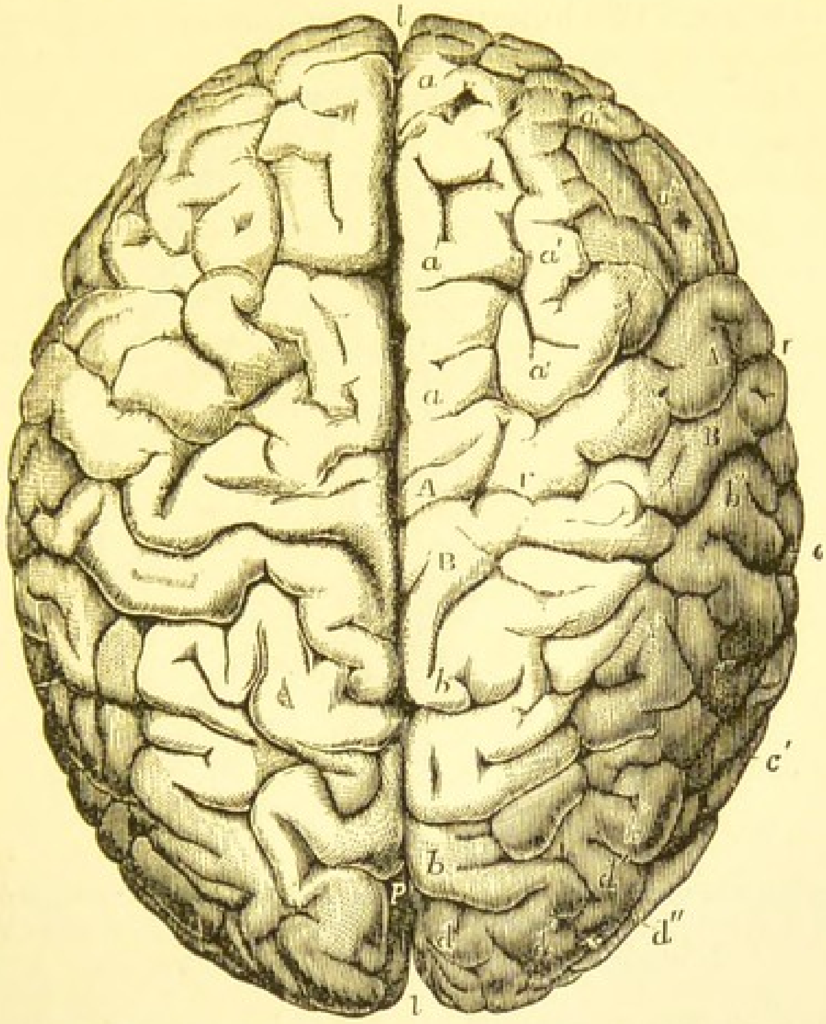


FIG. 62.—Upper surface of the cerebrum showing the two hemispheres, the convolutions and fissures.

(*From Quain's "Anatomy."*)

cerebellum below and behind, lying in the base of the skull. Both the cerebrum and the cerebellum are divided incompletely in the longitudinal direction into two equal halves, or as they are usually named *hemispheres*, right and left.

The two hemispheres of the cerebrum are held together by a broad band of brain tissue named the *great commissure*. The inner surface of both hemispheres is flattened, the remaining surfaces being rounded. The anterior ends are narrow and somewhat pointed, fitting into the concavity of the frontal bone. The posterior ends are broad and rounded, fitting into the occipital bone. All the surfaces are marked by numerous folds and furrows forming what are called the *convolutions.*

Covering the brain tissue proper, and separating it from the inner surface of the skull, which they assist in protecting the brain, there are three layers of membrane. The outermost of the three is composed of tough fibrous tissue and is known as the *dura mater.* It is the thickest of the three and somewhat loosely enfolds the brain. The innermost is the thinnest and most delicate,

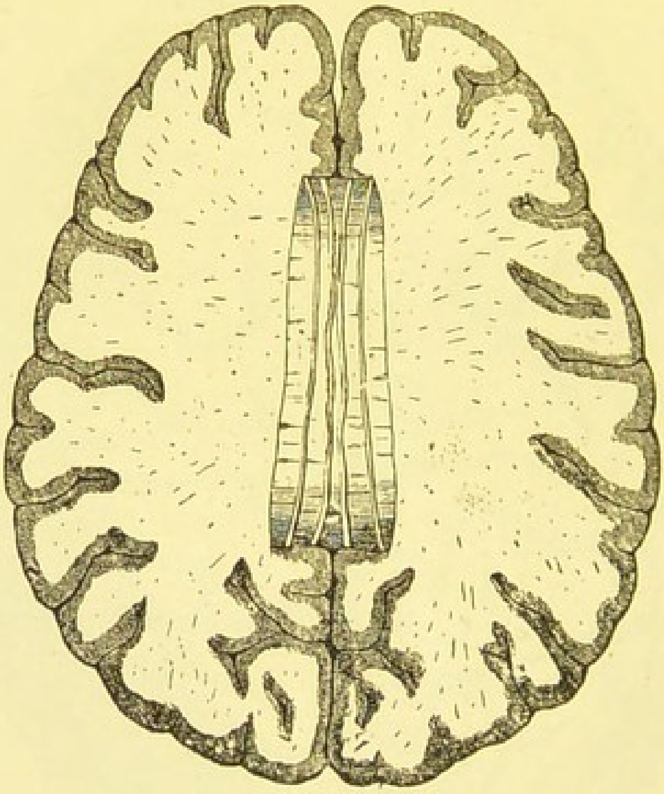


FIG. 63.—Section through the cerebral hemispheres showing the arrangement of the white and grey matter. In the middle, part of the lateral ventricles is shown.

(*From Furneaux's "Elementary Physiology."*)

and is more or less firmly adherent to the surface of the brain, sending prolongations between the convolutions. It is called the *pia mater*, and contains numerous blood-vessels which run into the brain substance and help to nourish it. Between the dura and pia mater is the third layer of membrane named, because it resembles a spider's web, the *arachnoid.* Immediately outside the pia mater there is a small space containing a clear fluid secreted by the cells of the membranes and forming a sort of water bed for the brain. This clear fluid, because it is found also in the spinal cord, in a similar position, is called *cerebro-spinal fluid.*

Structure of the Brain.—When examined with the naked eye the brain, like the rest of the central nervous system, is seen to consist of two kinds of material, differing in colour. One is more or less of a dirty grey colour, and is known as the *grey matter*. The other is in comparison white, and is called the *white matter*. In the brain the grey lies outside and surrounds the white matter, forming the brain *cortex* or *rind*. The grey matter of the cortex is about one-eighth of an inch thick, and is very much folded forming the convolutions already mentioned. The grey matter is a highly developed tissue, consisting almost entirely of the cells forming the *centres* connected with the functions with which the brain is concerned. The depressions between the convolutions formed by the infolding of the grey matter are known as *fissures*, and to some of them special names are applied. One of the most important is the *fissure of Rolando*, which runs upwards and backwards about the middle of the outer surface of each hemisphere. It is an important landmark, because in its neighbourhood several important centres have been found, *e.g.* those concerned with the movements of the legs, arms, and face.

Structure of the Grey Matter.—The cells, or as many prefer to call them, the *neurones*, forming the grey matter are of a com-

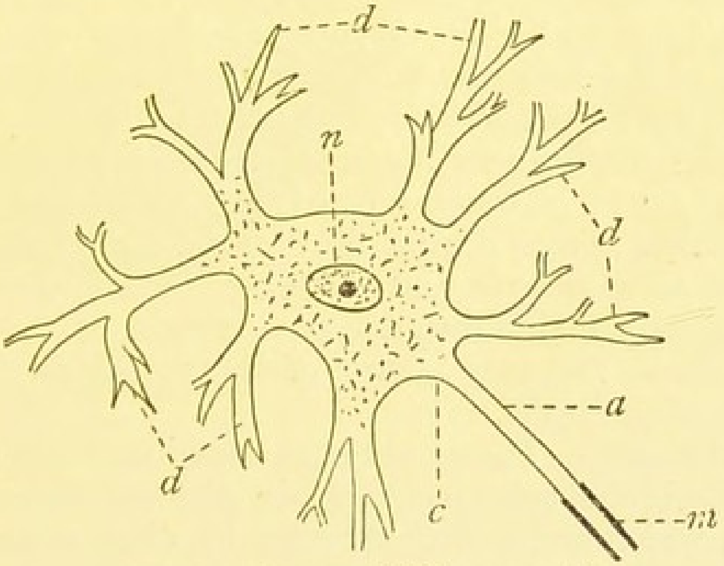


FIG. 64.—A nerve cell (diagrammatic).
a, axon or axis cylinder process; *m*, medullated sheath; *c*, body of cell; *n*, nucleus with nucleolus; *d*, dendrites or branching processes.
(*From Thornton's "Advanced Physiology."*)

paratively large size. Each has a nucleus and is provided with many branches or processes acting mainly as the carriers of impulses or messages to or from the cell. Some of these are short, and do not pass beyond the grey matter but terminate in the neighbourhood of the cell in numerous minute branches. These are called *dendrons*. One branch from each cell, known as the *axis cylinder*, is thicker than the others and passes into the white matter and joining with other axis cylinders forms a nerve.

Structure of the White Matter.—The white substance of the brain is made up entirely of fibres from the nerve cells. The whiteness is due to the fact that each fibre is surrounded by a special layer of more or less fatty insulating material called the *medullated sheath.* Some of these axis cylinder fibres pass away to form the nerves, others unite one hemisphere of the brain with the other forming the *great commissure.*

The white matter does not form one complete mass, but in the middle of each half there is a distinct space of a considerable size known as the *lateral ventricle.* Each ventricle contains a large bundle of blood-vessels covered with very fine cells. These cells secrete a fluid similar to the cerebro-spinal fluid. In the middle line of the brain in the white matter there are two other ventricles, the *third* and *fourth* respectively. Through these, mixing of the cerebro-spinal fluid outside the brain with that inside in the lateral ventricles can take place. By means of this way of communication, also, variations in the size of the brain are permitted. During thought the brain expands, and to make way for its expansion the cerebro-spinal fluid outside flows away through the third and fourth ventricles into the lateral ventricles. During rest the brain diminishes in bulk, and to fill up the space left between it and the inner surface of the skull the fluid from the lateral ventricles runs back through the third and fourth ventricles.

In the white matter near the base of the brain several patches of grey matter are to be found formed by the infolding and cutting off of the cortical tissue during development. These form what are called the *basal ganglia*, and probably contain some important centres. Through their substance pass certain of the fibres from the nerve cells in the grey matter of the cortex on their way to various parts of the body.

The Cerebellum.—The cerebellum constitutes about one-sixth of the whole brain substance. It is divided into two lateral hemispheres, which are united together by what is known as the *pons.* Structurally it consists of grey matter externally and white matter internally. The grey matter is comparatively large in amount and the convolutions are more distinctly marked than in the cerebrum. The grey matter penetrates very deeply into the white matter, and the fissures between the convolutions pass well into it. On cutting into the cerebellum the appearance produced by the spreading of the grey matter through the white closely resembles the branching of a tree, and this led to the application to it of the name *tree of life*, or *arbor vitæ.*

The *pons* consists of grey matter and white matter. In it the grey matter is *inside*, and the white matter outside. Into the formation of the pons there enter two bands or columns of fibres from the cerebrum on their way to the spinal cord, and here mixture or crossing of the fibres takes place, the fibres from the right hemisphere crossing to the left, and those from the left hemisphere to the right side of the pons. Projecting backwards and downwards from the pons is a sort of solid tail. This is known as the *medulla* and passes through the foramen magnum in the occipital bone to become the spinal cord. In the pons and medulla the cells of the grey matter form certain important centres, the chief being the centres connected with the organs of respiration and circulation, and named the respiratory and circulatory centres.

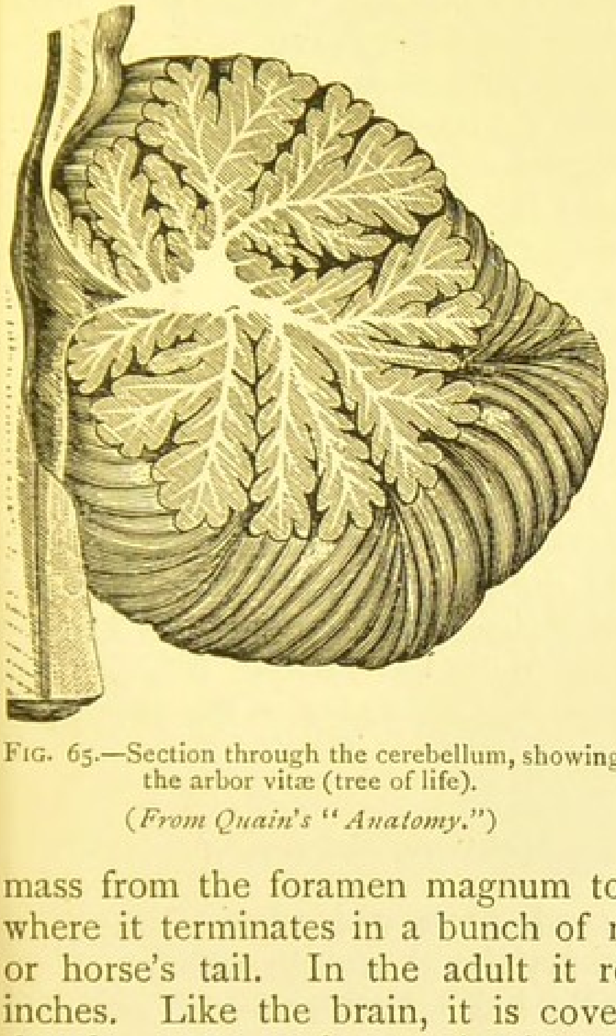


FIG. 65.—Section through the cerebellum, showing the arbor vitæ (tree of life).

(*From Quain's "Anatomy."*)

The Spinal Cord.—The spinal cord extends in the form of a soft, thickish

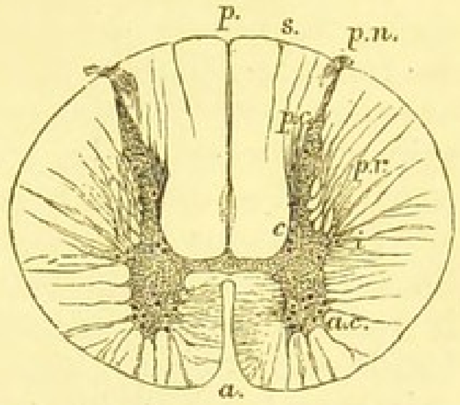


FIG. 66.—Transverse section of the spinal cord.

a, anterior fissure; *p*, posterior fissure; *c*, grey matter; *a.c*, anterior horn of grey matter; *p.c*, posterior horn; *p.n*, posterior nerve root.

(*From Quain's "Anatomy."*)

mass from the foramen magnum to the second lumbar vertebra, where it terminates in a bunch of nerves called the *cauda equina* or horse's tail. In the adult it reaches a length of about 18 inches. Like the brain, it is covered by the three membranes, the dura mater, the arachnoid, and pia mater, which protect and nourish it. Between the arachnoid and pia mater lies the cerebro-spinal fluid. Like the brain, also, it consists of grey and white matter, but in it the grey matter forms the inner and the white matter the outer layer. The white matter almost completely surrounds the grey. It is nearly divided into two lateral halves by a notch in front and a notch behind. These are known as the *anterior* and *posterior fissures*, and into them dips the pia mater just as it did in the case of the fissures of the brain. The white matter consists of nerve fibres running longitudinally, connecting the brain with the cord or different parts of the cord with one another. The grey matter is arranged in the middle of the cord to form something resembling in shape a capital **H**. The two limbs of the **H** lie one on each side of the cord, and point directly backwards and forwards. The ends pointing forwards are called the *anterior horns* of the grey matter, those pointing backwards the *posterior horns*. Of the two the anterior are somewhat the thicker. The bridge joining the two limbs is called the *commissure*. It runs across the cord, and is perforated about its middle by a minute hole. This perforation runs the entire length of the cord forming a canal which contains cerebro-spinal fluid and communicates with the ventricles in the brain.

The grey matter of the cord is similar in structure to that of the brain, being made up of cells giving off fibres and branches. From the anterior horn, at different levels throughout its course, spring the nerves going to supply the muscles in various parts of the trunk and limbs. For this reason it is called the *motor horn* or *motor root*. To the posterior horn come the nerves from the skin, etc., bearing what are called sensory impulses produced by touch, and so on. It is known as the *sensory root*.

Throughout its course the cord varies in thickness, being thicker at some parts than at others. Inside the dorsal vertebræ it swells out a little to form what is called the *cervical enlargement*. Inside the lumbar vertebræ it swells again to form the *lumbar enlargement*. With the cervical enlargement the nerves of the arms are connected, both motor from the anterior horn, and sensory to the posterior horn. With the lumbar enlargement the nerves of the legs and certain of the organs in the pelvis are connected.

The Peripheral Nervous System

The nerves of the spinal cord, along with twelve pairs connected with the brain, form the peripheral nervous system.

The nerves connected with the brain, twelve on each side, are called the *cranial nerves*. Some of them carry impulses towards the brain, and are sensory or *afferent* nerves, others carry impulses from the brain, and are mainly motor or *efferent* nerves.

They are all found on the under surface of the brain.

The *first pair*, counting from the front, are concerned with smell, and come from the nose.

The *second pair* are the optic nerves, from the eyes, and are concerned with vision.

The *third*, *fourth*, and *sixth* are motor nerves, for the small muscles moving the eyeballs.

The *fifth pair* are mixed nerves, containing both sensory and motor fibres. These are the nerves most commonly affected in neuralgia of the face. They supply motor fibres to the muscles of mastication. They are chiefly sensory, and are concerned with taste and sensation, and connect the tongue, the teeth, and the skin of the face, head, and neck with the brain.

The *seventh pair* are motor nerves for the muscles of expression.

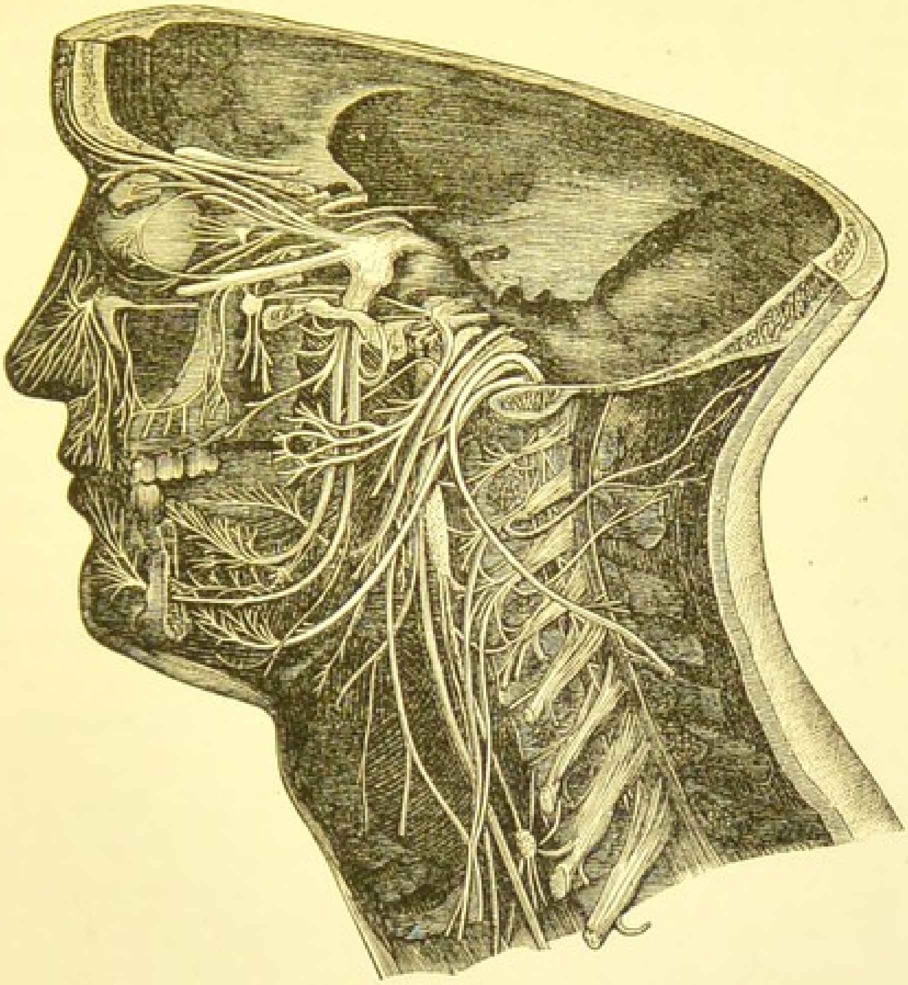


FIG. 67.—The cranial nerves of the left side.
(*From Furneaux's "Elementary Physiology."*)

The *eighth pair* are the auditory nerves, and carry impulses from the ear.

The *ninth pair* are concerned with taste, and are connected with the tongue, the palate, and pharynx.

The *tenth pair* are the vagus nerves, already mentioned. They are afferent nerves from the lungs, heart, liver, and stomach.

The *eleventh pair* are motor nerves to the muscles of the neck and larynx.

The *twelfth pair* are motor nerves to the muscles of the tongue.

Spinal Nerves.—The spinal nerves number thirty-one on each side. They are mixed nerves, and contain both afferent and efferent fibres. The afferent fibres pass *to* the posterior horn of grey matter; the efferent fibres pass *from* the anterior horn of grey matter. The areas of grey matter to which the nerves are traceable are called roots. The anterior horn contains the motor roots; the posterior horn the sensory roots.

Each mixed nerve is made up of fibres connected with a fairly large area of the cord, and escapes from the canal through an opening between two adjacent vertebræ. Some of the lower nerves escape through holes in the front of the sacrum.

After leaving the canal, several of the nerves going to the same part of the body unite to form what is called a "nerve trunk." When followed, this nerve trunk is found to give off branches as it proceeds on its way. Some of these can be traced to muscles, and are motor nerves. They terminate in what are called *motor end organs* among the muscle fibres. Other fibres can be traced to the skin, and are sensory nerves. They end in *sensory end organs*, such as touch bodies. Other fibres can be traced to various glands, and so on, every kind of tissue being connected with the central nervous system through the peripheral nerves.

Structure of Nerve Trunks and Nerves.—Each nerve trunk to the naked eye seems to be simply a cord, varying in size,

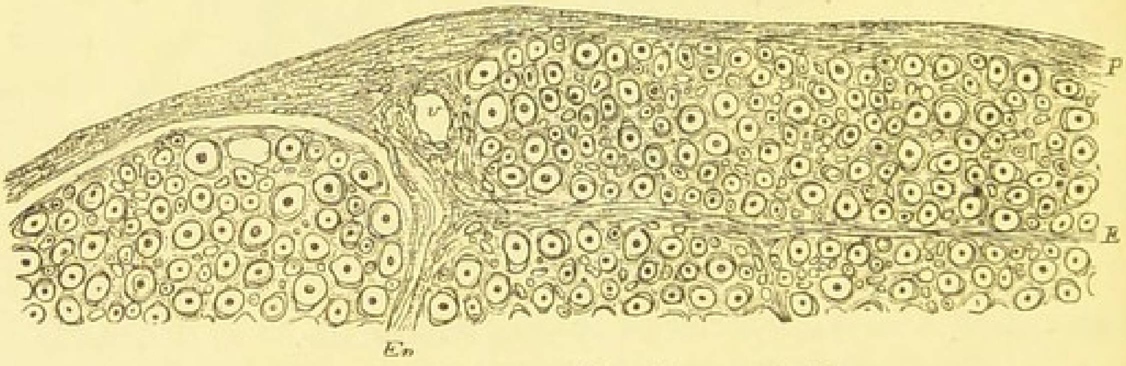


FIG. 68.—Part of a section of a nerve trunk.

P, capsule; *v*, vessel; *En*, capsule of a nerve. The nerve fibres are represented by a ring with a dot in the centre. The dot is the axis cylinder and the clear space the medullary sheath.

according to the number of nerves it contains. Each has a tough fibrous capsule, which holds the various nerves together, and which contains blood-vessels. Each nerve in the trunk has a capsule also, separating it from other nerves in the same trunk. Each nerve is made up of large numbers of nerve fibres which have been derived from a nerve cell. Each fibre is a process of a cell, and each is covered by a layer of medullated substance, which acts as a sort of insulating material preventing the impulses in one fibre from passing to another fibre in the same nerve. Each nerve trunk contains blood-vessels for the nourishment of its connective tissue. The nerve fibres are apparently nourished by the nerve cell from which they have sprung, since separation of a fibre, *e.g.* by cutting, from its mother-cell leads to its degeneration and death. It leads also, of course, to paralysis of the muscle supplied, in the case of a motor nerve, and to loss of sensation in the case of a sensory nerve.

The Sympathetic Nervous System is represented by two greyish-coloured cords lying one on each side of the bodies of the vertebræ, and presenting a beaded appearance. These beads are called *ganglia*. The ganglia are connected by means of fibres with the spinal cord, and also with the walls of blood-vessels generally and the various internal organs, the heart, the lungs, the stomach, and the intestines. The fibres from the cord to the ganglia, and from the ganglia to the organs, are sensory and motor. The former connect the sympathetic system with the central nervous system. The latter bear impulses to and from the ganglia, which can act independently of the central nervous system.

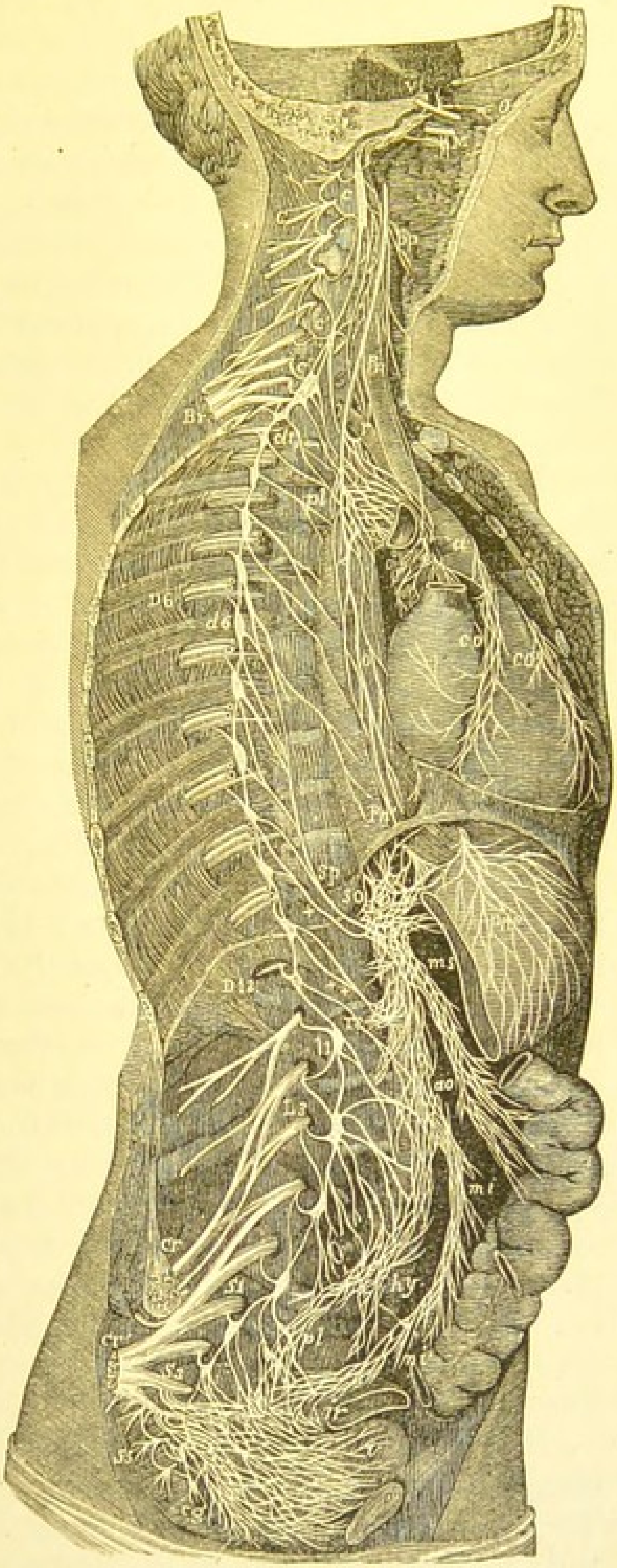


FIG. 69.—Sympathetic chain of the right side, showing distribution of fibres and connections with cranial and spinal nerves.

(*From Furneaux's "Elementary Physiology."*)

Functions of the Nervous System.

The functions discharged by the various parts of the nervous system have next to be considered. Those carried out by the central nervous system are, of course, the most important, those discharged by the brain being the most important of all, those of the spinal cord being of secondary importance. So far as function is concerned, the peripheral nervous system occupies the position of least importance. Its component parts, the nerves, have merely mechanical duties, uniting the various tissues and organs with the brain, and acting as the carriers of messages or impulses to or from the brain or the tissue.

The Functions of the Brain.—The functions carried out by the brain are exceedingly numerous and complex. It is concerned with thought, with action, with sensation, and memory. It originates impulses leading to motion, it receives impulses, and transforms them into various sensations such as touch, pain, sight, and sound. It stores up impressions of various sensations; and it is connected with every other part of the nervous system, controlling and regulating the action of these parts. To the grey matter of the brain cortex is entrusted the carrying out of these functions. Some of its cells are capable of acting as originating centres for impulses, others as receiving centres. The cells are grouped together to form the centres, and each is known, or is supposed, to be connected with one part of the body or another, or with one function or another. The centres are located, it is believed, in some certain parts of the grey matter in relation to certain of the convolutions, whose presence increases the extent of the grey matter, and offers accommodation for many centres. The number of centres the exact position of which is known, is comparatively small. Most of these have been located as the result of experiments on the lower animals. A few have been discovered as the result of observations on persons suffering from diseases of the brain. Some are concerned with sensation and are called *sensory centres*, others are concerned with motion and are called *motor centres*.

The sensory centres, whose positions are known, are those concerned with smell, taste, common sensation, hearing, and sight. To these centres the nerves bear the impressions obtained from without the body, and in the centres *perception* results, the sensation of smell, taste, touch, and so on being produced. The exact position of these centres is perhaps not a matter of any very great importance, so far as the teacher is concerned. It may be said, however, that the sight centre is chiefly in the back part or occipital portion of the brain; the centres for taste and smell in the convolutions on the inner surface of the lower part; the hearing centre in the outer convolutions of this part; and the touch centres on the inner surface of the upper part. All these centres are bi-lateral, and are found in both cerebral hemispheres. In addition to receiving and translating impressions, the centres seem to have the power of storing them, so that even without the external stimulus the sensation of taste and so on may be obtained. It would also appear that there is a certain amount of connection between the different centres, since the reception and perception of one sensation may evoke the recollection of another. The sensory centres are also connected with the motor centres originating the impulses resulting in voluntary motion. These impulses are usually only originated after the reception of sensory impulses.

The motor centres which are known are those concerned with the motion of the head, the trunk, the legs, the arms, the face, the tongue, and the lips. These are mainly found in the neighbourhood of the fissure of Rolando, some on the outer, some on the inner aspect of the brain. They are bi-lateral; but there is one peculiarity to be borne in mind, viz. that the centres in the right half of the brain are concerned with the movements of the limbs and so on, on the left side of the body, and those in the left half with the movements of the right side. This is brought about by the crossing of the nerve fibres from the centres from one side to the other in the pons. The centres in the left half in a right-handed person are better developed than those in the right half, chiefly because they are more largely employed, and the cells more frequently stimulated. The nerves from the centres do not in all cases pass directly to the muscles whose contraction brings about the motion willed by the centre. Most of them pass to the cells of other centres situated mainly in the anterior horn of the spinal grey matter, whose cells transmit to the muscles, along the nerve fibres to which they give origin, the message received from the higher centres. In the same way, many of the sensory impulses are not brought directly from the external parts to the cells in the sensory centres. The cells in the posterior horn of the grey matter of the cord in most instances receive the impulses first, sending them on to the brain cells afterwards for translation and perception. By means of this connection between the brain centres and the cord centres, the function of the brain known as *inhibition* or the *inhibitory function* is carried out.

Reflex Action.—Any action following the perception of a sensation is known as a *reflex action*, and practically every act of daily life is a reflex act. First there is applied some stimulation. This stimulus is conveyed along a nerve to a sensory centre where it is perceived. From the perceiving centre an impulse is sent to a motor centre or centres concerned with the production of the appropriate action, and from these centres the message is conveyed by the nerves to the muscles whose contraction will bring about the action. The spinal cord, like the brain, is capable of carrying out reflex actions, since its posterior horn receives sensory impulses, and its anterior horn can generate motor impulses. These spinal reflexes, however, have this peculiarity that they have a tendency to be exaggerated. The pulling up of the leg, or the drawing away of the foot, which follows tickling of the sole of the foot, becomes exaggerated into a series of spasms of the leg if the connection between the brain and the spinal cord be severed. If both are intact, the impulse is carried by the sensory nerves from the sole of the foot to the cells in a certain part of the posterior horn. These cells are excited, and communicate their excitement to the nerve fibres from the cells in the touch centre in the brain. The cells in the touch centre receive the message, translate it, and estimate its value. They communicate with the cerebral motor centres, which communicate in turn with the spinal motor centres in the anterior horn. These generate just so much activity as they are directed by the brain to generate, and send impulses along the motor fibres to the muscles of the foot and leg, in accordance with the instructions received. This modification by the brain of the excitability of the spinal centres constitutes the inhibitory action of the brain. What is known as *volition* or the *will* comes into play also, since the brain has willed that the foot should be drawn up. If the brain had considered the irritation insufficient it would have willed, of course, that the foot remain at rest, and impulses would not have been sent to the cord and

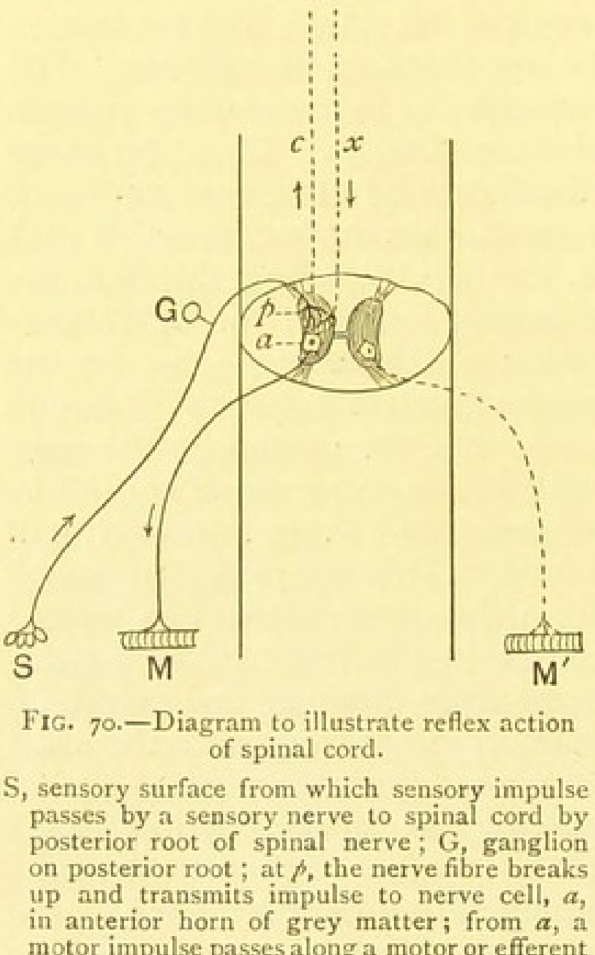


FIG. 70.—Diagram to illustrate reflex action of spinal cord.

S, sensory surface from which sensory impulse passes by a sensory nerve to spinal cord by posterior root of spinal nerve; G, ganglion on posterior root; at *p*, the nerve fibre breaks up and transmits impulse to nerve cell, *a*, in anterior horn of grey matter; from *a*, a motor impulse passes along a motor or efferent nerve to muscle M. The arrows on the dotted lines *c* and *x* show direction taken by impulse when the brain is involved.

(*From Thornton's "Elementary Practical Physiology."*)

muscles. In the absence of the brain, the excitement of the spinal sensory centres passes directly to the motor centres of the cord. These being uncontrolled, send out unnecessarily strong impulses to the muscles of the leg and foot. Inhibition in this case is absent, and the drawing up of the leg and foot is practically involuntary or not under the influence of the will.

Though most of the acts carried out by human beings are reflex acts, it is not easy to explain them so simply as the instance just given. The mechanism of swallowing, for example, which is also a reflex act, may be somewhat similarly explained. The food particles stimulate the sensory nerve endings in the fauces, the pharynx, or gullet. Impulses travel along the nerves to the sensory centres in the central nervous system. From these, impulses pass to the swallowing centre, and from it to the centres of the nerves supplying the muscles of the gullet, etc. These centres send impulses along the nerves to the muscles; contraction takes place, and swallowing or pushing down of the particles of food results. Just as the pulling up of the leg takes place in the absence of the brain, so swallowing can take place, as can be seen in the unconscious or sleeping person who swallows if fluids are brought into contact with the sensory nerve endings of the fauces, pharynx, or gullet. Such an action seems to be almost automatic, or involuntary, or unconscious, the volition or will of the brain not being called into play at all. Actions carried out consciously are carried out under the control of the centres in the grey matter. Actions carried out unconsciously or involuntarily, because they are not exaggerated, and because they may be complex acts requiring the working together or *co-ordination* of many muscles, must be under the control of something more highly developed than the cord. Such actions, it is supposed, are controlled by centres in the collections of grey matter in the base of the brain forming the basal ganglia. In most of such acts what is called *memory* plays a part. It may be that as a result of frequently performing the acts and of being concerned in them the centres in the basal ganglia become capable themselves of controlling them, and the higher centres in the cortex leave them to do so. These centres have been named the *centres of the middle level*, the centres in the cortex being the *centres of the highest level*, those in the cord the *centres of the lowest level*. In the earlier stages of life, when the acts are being learned, the highest centres do the controlling, but later this is taken in hand by the middle centres. The importance of bearing this in mind in connection with the teaching of the commoner acts to children is tremendous, for those concerned with education. The right way to do anything can be as easily learned as the wrong way, but when once the wrong way has been fixed in the middle centres it is difficult to unlearn.

Apart from centres acting apparently automatically from time to time, there are others which seem to be more or less truly automatic, and requiring no stimulus from the outside. These are the centres concerned with respiration and circulation which lie in the medulla, and which are uncontrolled by the cortical centres. Under normal circumstances these centres are continually acting, keeping up the movements of the heart and of respiration. Variations in their activity may be produced by alterations in the condition of the blood nourishing them, the respiratory centre particularly being readily stimulated by an increase in the quantity of carbon dioxide in the blood.

Other centres besides those automatic ones are, of course, affected by the state of the blood. The centres of an ill-nourished person do not work so well, because the blood is poor in quality and the brain cells are not properly nourished. The blood of a person confined in impure or contaminated air is deficient in quality, and poor especially in oxygen. The brain cells are therefore deprived of nutriment. When the cells and centres thus starved happen to be those of a child, their power of learning their duties is diminished, and education becomes practically impossible. The greater the supply of blood to the brain cells, and the better the quality of the blood, the better the results of instruction. Mental activity increases the amount of blood to the brain, and therefore improves its nutrition.

The Speech Centres.—The centres concerned with speech are four in number, and are named—

(1) The auditory word centre.
(2) The visual word centre.
(3) The motor speech centre.
(4) The writing centre.

These are all parts of centres already mentioned, but they are not bilateral, being found only on the *left side* of the brain. The auditory and visual word centres are sensory or *receptive* centres. The former is part of the centre for hearing on the left side of the cerebrum. The visual word centre is in the visual centre in the back part of the left cerebral hemisphere. The motor word or motor speech centre is part of the centre for the lips and tongue. The writing centre is in the arm centre, like the others, on the left side of the brain. These latter two are *expressive* or motor centres.

The two sensory centres lie comparatively close together, and are closely united. The two motor centres are also close together, and are united. In addition, the sensory centres are united by means of fibres with the motor centres, so that impulses may be transmitted after perception by the former to the latter for expression. The motor centres depend for their education upon the sensory centres, the auditory being responsible, chiefly, for that of the speech, the visual for that of the writing centre. In the sensory centres impressions or memories of words seen and heard can be stored up, just as the memories of objects seen and sounds, other than words, heard are stored up in the visual and auditory centres. These memories are drawn upon in the course of silent thought, words being revived simultaneously in both centres. For the teacher no centres are more important than these, since they are the centres he hopes chiefly to affect and to train and develop. The development of these and other centres will be referred to later.

Functions of the Cerebellum.—The functions of the cerebellum have not so far been accurately made out. In some way it seems to be concerned with the balancing of the body, since disease of this part of the brain is usually attended by giddiness.

The functions of the sympathetic and peripheral nervous systems have been already sufficiently referred to.

The Nervous System in the Child

To the naked eye there is little difference between the nervous system in the child and that in the adult. The brain is a little larger in proportion to the size of the body in the infant at birth than in the later years of life, but it is made up of grey matter and white matter in certain proportions as in the adult. Examined microscopically, the grey matter is seen to consist of cells or neurones as in the adult, but whereas, in the latter, each neurone is provided with a well marked axis cylinder and numerous dendrons, these, especially the dendrons, are less well marked and less numerous in the infant. The axis cylinder processes also, close up to the centres, are not so well surrounded by the medullated sheath as in the adult, and do not become well covered for some time after birth. The spinal cord is well developed and the cells and peripheral nerves connected with them are also well formed, and are capable of carrying out their functions, which are purely reflex, quite satisfactorily. Because of the incomplete development of the cells and fibres in the brain, motor impulses originating there, though induced reflexly, do not occur, or at least no outward indication of their occurrence is given. Certain centres in the brain are already well formed at birth, such as the respiratory, the circulatory, and others capable of acting automatically, or without the necessity for the intervention of the highest centres in the grey matter of the cortex, *e.g.* the centre for sucking. This latter centre is readily stimulated in the child, and anything brought into contact with the mucous membrane of the mouth throws it into action.

With the passage of time the cells and fibres become better formed and, as they develop, the power of the centres over the parts of the nervous system below becomes evident. The various movements come to be much less obviously reflex, and the infant lives a less detached existence, being more influenced by and responding to external stimuli, though the reaction may be crude and clumsy. The centres become more receptive and perceptive and the child begins to "take notice." The order in which the motor and sensory centres develop depends largely on heredity. The centres first developing are those concerned with self-preservation, and development is based largely on selfishness. So far as perception is concerned the child first acquires the power of recognizing its mother, because it is from her that sustenance is obtained, and from this onwards the visual centres, in the normal infant, continue to develop.

Development of the Motor Centres.—The motor centres first developing are those concerned with the obtaining of sustenance. Those controlling the coarse movements of the large joints become active and even develop very slowly throughout infancy and early childhood. Though they may be directed in their development from without, these centres develop largely unassisted, and any impressions acquired are very enduring. The centres concerned with the finer movements only develop late in childhood, and their mode of development is greatly influenced by external stimuli. Those concerned with the movements of the lips and eyeballs, for instance, develop best under direction. The delay in the development of these centres is due to the difficulty of co-ordinating the small muscles concerned with their production. The co-ordinating of the muscles concerned with the large and coarse movements is less difficult and the power of doing so is easily acquired.

Development of the Sensory Centres.—As with the motor centres so with the sensory centres, development is gradual. Delicacy of perception is not to be expected till late in childhood. To the infant, at first, every woman is its mother, and every man its father. Every voice is its mother's voice or its father's voice. The visual and auditory centres have little delicacy of perception and little power of discrimination at first. Their development is brought about entirely from without. Of immense importance in their growth is, of course, their nourishment; but stimulation by impulses through their nerve processes is of considerable importance also. The more frequently impulses traverse the nerves the better it is for the nerve and for the neurone. The nerve as the channel is kept open; the neurone, as a receiver and a perceiver and originator, learns its duties and responsibilities, and develops accordingly.

The effect of use on the growth of centres is well seen in the development of the visual and auditory centres. In the earlier days of life, probably neither light nor sound have any effect upon the terminations of the optic and auditory nerves, either in the eye or the ear, or in the brain. In time, however, as a result of continual stimulation, the outer terminations become impressed, and the sensations of light and of sound are received by these. Later they are passed along the nerves to the centres, and the sensations are perceived. Then objects begin to affect the terminals in the eyes, viz. the retina, as something interfering with the passage of light, and nothing more. These impress the terminals in a different way from the light. The stimulus given to the terminals is borne along the nerves and the objects are perceived as shadows or objects. With time the receptive and perceptive powers improve, and objects obtruding themselves upon and stimulating the retina cease to be merely interferers with light. The mother's face becomes more than a shadow. The *details* of the shadow produce impressions. The loving look, the tender smile, make impressions that are received and perceived.

Next these impressions are stored, the whole object, its outline, its details, the look, the smile. These impressions are learned and become permanent. They are, of course, elementary and are unassociated with any idea, though they may be associated with certain actions, at first possibly only of the muscles of expression, leading to the production of a smile. And every object with similar outlines and additions will produce a similar action until very much later, when delicacy of perception begins to develop.

Development of the Auditory Centre.—In much the same way the hearing develops. At first no impression is either received or perceived. Then sound as sound makes an impression, and is received and perceived. Then follows a very elementary analysis of sounds, and the reception and perception of these, and the development of the auditory centre, is begun. Impressions are received and stored, and the first lessons are learned.

Association of the Visual and Auditory Centres.—Next comes the first great triumph, the association of the visual and auditory centres, and of visual and auditory impressions. Objects and sounds begin to mean something. An object has a sound associated with it. With one object the sound "mamma" is associated, and with another "dadda." After the association of words with objects, the next step is the associating of words with ideas, and the development of the auditory word centre.

Development of Motor Word Centres.—No sooner is the auditory word centre fairly on its way than it begins to instruct and attempt to develop another centre, viz. the motor word centre. The connection between the auditory and motor word centres becomes more marked; stimuli pass from the auditory word to the motor word centre, and the power of speech is acquired, the sounds heard being more or less accurately imitated. The visual centre becomes linked up with the others and the process becomes more complicated; objects are seen, names are applied to them, and the motor speech centre reproduces the name—the power of mimicry being strongly marked in all the centres of the child. Then there is the storing of the impressions in the centres and the development of memory. Following this there is *ideation*, and the drawing upon the stored impressions.

When the brain has reached this stage of development, and is highly impressionable, it is usual, properly or improperly, to entrust the further development to the teacher, and to send the child to school. To the teacher is allotted the task, especially, of strengthening the union of the auditory and the visual centres, and of the auditory word, the visual and the motor word centres, and of continuing their development. More important still, centres as yet practically untouched are entrusted to him, namely, the visual word centre and the writing centre, and the connection between them. These last are entirely at the mercy of the teacher. In the vast majority of cases, the parts of the brain where they are situated are entirely virgin soil, and the teacher can choose the seeds that are to be sown therein in the form of stimuli. In the case of the other centres there has already been interference, and impressions have been received and stored, and may be wrong impressions. Nevertheless, there is always room for correct impressions and also for delicate impressions. The visual centre can be developed and trained to admire beautiful things, the auditory centre to like only pleasant and beautiful and rich sounds, and the motor speech centre to imitate only such sounds.

But in the training and development of these centres the teacher's object should be to adhere to the plan of "making haste softly." The centres can develop perfectly only slowly; they are capable only of receiving and dealing with a small number of impressions at a time, and if too many are imposed upon them they tend to become at first excited, and later even paralyzed.

To the excitement the name usually applied is *nervous* or *nerve strain;* to the paralyzing effect, the name *nerve fatigue* is applied. The best teacher is the one who can stimulate the centres most and so develop them most without producing the signs either of strain or fatigue. Some of the signs of nervous overstrain and of fatigue have already been mentioned. Their indications are not limited to the centre or centres which are at the moment being subjected to over-education, but are to be found in the excitability or partial paralysis of other centres, motor and sensory, throughout the central nervous system.

Signs of Overstrain.—The most obvious signs of overstrain or over-pressure are to be found in the activity of other centres, which are stimulated by the overflow of energy from the centres under pressure. Very common indications are over-activity of the small muscles of the forehead and mouth. The grimaces and contortions, and the general fidgetiness and restlessness, the screwing up of the face, the working of the lips, the protrusion of the tongue, and the cramping of the fingers, seen in young children using a pen, or a pencil, or a needle, are common signs of over-pressure or overstrain. Failure to sleep well, headaches, interference with growth and nutrition, are all important signs which may be noted either by the teacher or the parents. There are very few, especially of the junior classes, but contain children showing signs of overstrain. The school doctor is continually having his attention drawn to such cases. Sometimes the teacher suspects that the child is suffering from St. Vitus' Dance, and in many ways cases of overstrain do resemble cases of this disease. There is, though to a lesser extent, the same jerkiness and fidgetiness, and want of control over the hands and arms. It is difficult, indeed, to say that such cases may not pass on to the more serious disease. Certainly, since St. Vitus' Dance is now regarded as a germ disease, a child suffering from overstrain might be considered distinctly liable to infection with the germ.

The cause of overstrain is to be sought in the methods of education now in vogue. There is still too great a tendency to hurry on the development of the centres. The written speech centre is too early expected to be ready for instruction and stimulation. This centre controls the activities of many small and delicate muscles, and co-ordinates the action of many groups of such muscles. The amount of energy that has to be expended by it in throwing into action even the muscles that are to grasp the writing instrument is tremendous, and the smaller the implement the greater the amount of energy required. To bring about the movement of the writing implement necessary in writing, a greater expenditure of energy still is necessary. The energy expended may result in the holding of the implement properly, or it may not. Usually it does not, and a clumsy attitude is taken up by the fingers and hand. If the instruction of the centres on these lines is continued, the lesson is wrongly learned, and the clumsy attitude becomes fixed and permanent. At the same time, other centres are affected by the overflow of energy, and there occur the twitchings and twistings of the face, the protrusion of the tongue, and so on, which most teachers have seen. No serious attempt should be made to teach children the use of fine instruments with fine points, like pens, and pencils, and needles, before the age of six at the very earliest. The centres are very, very immature, and are quite incapable of delicacy of action. Because a child watches the fine point of the instrument and focusses for it needlessly, a strain is thrown on the muscles of the eye also, and on their centres. It was to express this that the saying, "Pens, pencils, and pointed instruments are all out of place in the infant school," was originated.

The elements of writing can be taught if coarse instruments and the coarse movements which the young child can carry out are made use of. Give the child a piece of chalk or wood, and a blackboard, or piece of brown paper, or a tray of sand, and let it work its shoulder, its elbow, and its wrist joints and muscles, and develop thoroughly their centres. The finger joints, muscles, and centres will receive a certain amount of indirect instruction at the same time, and in due course more delicate movements and more delicate and perfect co-ordination will become possible, and the pencil and the pen fit instruments for use. There would be fewer ugly cramped hands in writing, fewer grimaces, and fewer cases also of short-sightedness if this were regularly done.

A child showing any signs of overstrain or over-pressure should always be given a certain amount of consideration. It may require special and individual attention from the teacher, who should try, if possible, to ease the pressure on any centre, such as the writing centre, which may be specially affected.

Signs of Fatigue.—When the nerve cells are maintained in a state of activity, or are subjected to over-pressure for too prolonged a period, the signs of fatigue begin to appear. The commonest of these are—

(1) Failure of or inability to concentrate the attention. Carelessness in answering simple questions, and in carrying out simple acts.

(2) Listlessness and careless attitudes, for example, drooping of the head, and sinking down in the seat. A tendency to drooping of the hands when the arms are held straight out in front of the body may also be shown.

(3) Yawning, puffiness of the eyelids, and drowsiness.

Most of these signs are produced, like the signs of muscular fatigue, by a poison, generated in all probability by the nerve cells themselves in the course of their activity. This poison is excreted during rest; but until it is excreted it is present in the blood, and is capable of acting upon all nervous tissue, paralyzing it and interfering with its function. The intensity of the fatigue and the signs produced, depend upon the quantity of poison formed. Upon this, also, depends the time taken to get rid of the poison, and the duration of the signs. The quantity produced depends upon the length of the period of activity of the cells. This period varies markedly in different individuals. It depends upon age, and to a certain extent upon sex. It is influenced by the general condition of the individual, by the external surroundings, and by the character of the work which the cells are called upon to perform.

Prevention of Fatigue.—Just as it was the teacher's duty to so arrange matters that there should be produced no signs of over-pressure, so it is his duty to arrange that there shall be no fatiguing of the pupil. He must know exactly how far it is possible to go with the child's brain at various ages, and must be prepared to stop there. He must know what external conditions are likely to affect the activities of the child's brain, and how they are likely to affect it, and he must work the brain accordingly. As a result of observations and experiments made and carried out chiefly by physiologists, teachers, and others interested in school hygiene, several important facts have been elicited in this connection. The most important observations have been with regard to the amount of time during which children at various ages can fix their attention. According to such authorities—

An average child of		6	can fix its attention for		15	minutes.
"	"	7 to 10	"	"	20	"
"	"	10 to 12	"	"	25	"
"	"	12 to 16	"	"	30	" .

If an attempt be made to prolong the period during which the attention is fixed, and to increase the length of the lesson, the brain centres involved may themselves refuse to act, or at least seek repose in snatches. As a result the attention wanders, and inaccurate work is obtained. These are the first indications of fatigue; others appear if the prolonging of lessons continues. The length of lessons on any subject should be based on the figures given above. Even in the infant school these periods are generally exceeded; but the plan followed by the ill-used centres of snatching repose is, in these cases, adopted by the remainder of the brain, and the infant drops off to sleep.

The periods mentioned, it will be noted, refer to the average child and to ordinary subjects. Some children cannot fix the attention for periods at all approaching those given, but inasmuch as the present method of teaching compels the teacher to regard only the average pupil the figures must be allowed to stand. Some subjects requiring a greater amount of concentration than others, naturally the attention cannot for long be fixed upon them. Mathematics and arithmetic may be taken as examples of such subjects. The external conditions again affect the length of the period very greatly. So do also the general condition of the body, its freshness and its nutrition. The classroom, its size, its ventilation, and the lighting, and so on, produce also an effect. With regard to the size, the ventilation and the lighting of the classroom little need be said. On these matters the teacher, and usually also the sanitary expert, are rarely consulted, and what is planned by the architect has to be used. The best use of what is provided must be made, and the teacher can try to prevent the period being shortened by giving attention to the ventilation, at least, in the manner already indicated.

So far as the effect on the periods of the general condition of the body is concerned, that produced by malnutrition is, to a large extent, beyond the control of the teacher. The brain in an ill-nourished body is sure to be ill-nourished also, and cannot be expected either to concentrate, or to react to stimuli as can a properly nourished brain. In the matter of the freshness of the body and brain the teacher can exert some influence, and his aim should always be to keep the brain fresh. This is to be done: (1) by regulating the length of the lessons, and (2) by allowing periods of rest. The lessons must not be too long, and wherever possible the length should not exceed the period during which the attention can be fixed. When the attention wanders, the brain cells are probably rebelling and seeking repose.

Rest is to be obtained in a variety of ways. Only during sleep are the highest centres absolutely at rest, though even then their cells are probably at work, to a certain extent, taking up nourishment. The cells of the middle and the lowest levels may be even more active than this, and may betray their activity in restlessness, sleep walking, sleep talking, and dreaming. Rest for the brain in school can only be obtained for a certain number of centres, and certain parts at one time; but a considerable amount of rest may be obtained for one set of centres by throwing it out of action and calling another into play. One set of intellectual centres can be rested by calling into action another set of intellectual centres, or certain of the motor centres. Conversely, the motor centres can be rested by calling into action intellectual centres. To obtain rest, therefore, the lessons must not only not be too long, but they must be varied.

To avoid as far as possible fatigue of all the intellectual centres, they must all be rested by shifting the activity from them to the motor centres. According to many authorities, the intellectual centres should be left, and the motor centres resorted to after, at the outside, *two periods* of intellectual activity. The motor centres may be called into action in the classroom by giving the pupils recreative physical exercises. Better still, they may be set to work by allowing the children to indulge in free play in the playground. It need hardly perhaps be mentioned again, that the ventilation of the classroom is to be remembered during the periods of activity of the motor centres.

Despite the efforts of the teacher to provide rest, signs of diminution in the freshness of the brain are almost certain to be shown. From hour to hour of the school day, from day to day in the school week, and from week to week in the school term, there is progressive falling off in freshness. And failure of freshness is to be found not only in pupils, but in teachers as well. The brain is freshest after a period of rest, either complete, of the whole brain, or partial, of the intellectual centres only. The first half of each hour; the first half of each day; the first half of each week; the first half of each term sees the brain at its freshest, and advantage should be taken of this freshness in the choice of subjects. Those requiring most concentration and most intellectual effort should be taken in the forenoon, and the best work should be expected on Mondays and Tuesdays, after the Saturday and Sunday rest. By Wednesday, signs of falling off in freshness are to be expected, and there is much to be said in favour of granting a half-holiday on Wednesday, and another on Saturday, instead of a whole day on Saturday. There is also much to be said in favour of shortening the school day, either as a whole, or by lengthening the breaks. With the length of the dinner break and the break in the afternoon session little fault can be found. The forenoon session is somewhat less satisfactory, and probably it would be more satisfactory and more restful to break it into three, by means of two intervals of five or seven minutes each, than into two, by one interval of fifteen minutes. If the teacher can arrange his time-table and his lessons, however, so as to give, more especially in the junior classes, a few minutes of recreative exercises at intervals in addition to the playtime, probably little harm will result from the length of the morning session, and the children are likely to benefit to the greatest possible extent from the intellectual instruction.

With regard to the duration of the school terms it is hardly necessary to speak. The length of the vacations seems to give satisfaction to the most captious. They should be spent, of course, rationally, and chiefly in obtaining intellectual rest. Holiday tasks are to be avoided, and the time should be spent in improving the general condition of the body and in resting the brain, as should all periods of rest. A great deal of harm is done in this way by parents who set the children to do work at home in connection with music, or who, for the sake of gain, set them to various occupations, when they should be resting the intellectual centres either by means of sleep, or while exercising the motor centres.

Sleep.—Only during sleep is absolute rest obtained for the brain and the nervous system generally. Not only are the cells and centres relieved from the necessity of reacting to stimuli, conveyed to them by the nerves, but the heart beating more slowly and the blood-vessels being diminished somewhat in size, the rate of blood-flow and the quantity of blood are both diminished. In this way the cells and centres are subjected to less stimulation also. Both for adults and children the time to be allowed for sleep in proportion to the work done is of the utmost importance, and the habit, especially common among adults engaged in mental work, of curtailing the hours of sleep in order to make time for other occupations or for amusements is to be condemned.

No rigid rules can be laid down as to the number of hours of sleep necessary for various types of persons. Some people require more sleep than others, and children certainly require more than adults generally. The infant should spend most of its time in sleep; the child of four at least half of its time. The child of seven should have at least eleven hours; the child of nine, ten hours or more. From the twelfth to the fourteenth year nine or ten hours may be sufficient, and after this at least nine hours should be spent in sleep. Most people, adults as well as children, require more sleep in winter than in summer, and in children this necessity should be recognized. The best kind of sleep is obtained in the first few hours after going to bed. That of the later hours of the morning is less beneficial, and that obtained in hours snatched from the day the least beneficial of all. Children especially should retire early to bed, and the habit of going early should be forced upon children. The brain benefits from regularity in work and rest, no less than the stomach from regularity in meals.

A certain amount of preparation for sleep is necessary. The centres do not benefit from the rest obtained if they are over-excited or over-fatigued before rest is sought. Neither work nor play should be continued up to the last moment before retiring to rest. And in the case of children, "good-night romps" are a mistake.

The *hygiene of the bedroom* is a matter of some importance, and must be touched upon since the teacher should certainly give instruction in this subject. Good pure air is as necessary for the brain during sleep as during activity. The bedroom should be airy and should be well ventilated. The body will not suffer if it is well and properly clothed. If consumptive persons and babies can sleep in the open air and thrive on it, there is no reason why children and healthy adults should not do so also. The air of bedrooms is often vitiated by closing the windows and lighting the gas some time before the room is to be occupied. The gas should either not be lighted till the room is entered for the night or the window should be kept open. If contaminated or bad air is breathed during sleep it will produce effects no less serious than those produced by breathing such air during the waking hours. The sleep is likely to be disturbed, and to the poisonous effects will be added those produced by insufficient sleep.

The *signs of insufficient sleep* are mainly mental, but largely also physical. They are most marked in the case of the child, and children who get too little sleep are readily recognized. They are anæmic, languid, dull, drowsy, and stupid. The appetite is poor, the growth is stunted. The face is pale; the eyelids are heavy; the eyes sunken and dark ringed. The children are disinclined for muscular activity and are incapable of learning. Occasionally children showing such signs are found in the upper standards of a school. They are often hard working, clever children. When found, they should be spoken to and advised, and the parents also warned of the risk of overworking the brain. A diminution in the amount of study or an increase in the amount of recreation and of sleep will often work wonders in such cases. The children of the very poor often show such signs; neglectful parents permitting them to roam the streets selling newspapers and so on till midnight. The children of quite well-to-do people often also suffer from the effects of insufficient sleep, kindhearted but thoughtless parents permitting and encouraging late hours and visits to entertainments, quite unsuitable in every respect for children. Teachers also on occasion interfere with the child's sleeping hours by means of the apparently, in some cases, necessary school concert. In most cases the remedy is not in the hands of the teacher unfortunately, but instruction on this very important subject, and advice in suitable cases, should certainly be given.

Defective Children and Diseases of the Nervous System

Defective Children.—Having considered the normal brain and nervous system and their development, it becomes necessary now to refer to certain abnormalities of the brain and certain diseases affecting the nervous system. Children in whom the brain is abnormal are generally referred to as "defective children." In these the affection of the brain, especially of the intellectual part, varies in *extent* and in *degree*. In the idiot and the imbecile the affection is great in both respects. In the feeble-minded the extent may still be considerable, but the degree less. In other cases the extent may be limited while the degree is either slight or considerable. In such cases one or more of the important centres concerned with speech,—the visual word, the auditory word, the motor speech, or the written speech centre may be affected, or the communications between them may be defective. If the visual word centre is affected the condition known as "word-blindness" results, and the child is unable to recognize or to retain the impression of even the simplest words or figures. If the auditory word centre is affected, "word-deafness" results, and the child is unable to understand or remember even the most elementary facts. If the motor speech centre or the writing centre is affected, the child cannot speak or write, as the case may be. If the connections between the centres are interfered with various defects result; for example, if that between the auditory and the written speech centre is involved the child cannot write to dictation, and so on.

To the teacher, children who are either idiots or imbeciles are really of little importance, since detection of these is usually comparatively easy, and their stay at school short, after detection. Children who are feeble-minded, or who are affected in one or other of the speech centres, do attend school, and are met with commonly enough. The recognition of these children is usually easy for the teacher, but their differentiation is difficult and their instruction in ordinary classes no less so. The tendency, nearly always, is for the teacher to exaggerate the defect. The child who is feeble-minded is regarded as imbecile, and the child who is word-blind, and so on, as much more defective than he really is. More important still there is a tendency at times to class with such defective children others who are not truly defective, but who are dull and backward and intellectually inferior to their fellows, because the brain is neglected, underfed and overworked, or a defect of some important organ, like the eye or the ear, is overlooked.

The distinguishing of the spuriously defective from the truly defective, and the seriously defective from the slightly mentally defective, are matters of tremendous importance. The sooner it is done the better for the child, since the earlier can a remedy be sought and applied, or proper methods of instruction commenced. If the defect can be traced to deafness or short-sightedness, so much the better. The ears can be examined and some remedy found, provided the defect is not too serious. The eyes can be tested, and again, perhaps, improvement brought about by means of suitable glasses. If the child is neglected or overworked, and the brain starved or fatigued, pressure may be brought to bear upon the persons responsible, and some means of improving the child's condition found. If the child is a true mental defective, then it should be separated from its fellows and given special instruction.

For the instruction of such a child Local Education Authorities have been empowered by the Elementary Education (Defective and Epileptic Children) Act, 1899, to provide special schools. To these schools admission is obtained on the certificate of a specially appointed medical man. Here the children are retained and taught in small classes till they are fit to return again to the ordinary school, or till they reach the age of sixteen. The type of children to be admitted to such special schools is clearly defined. They must be incapable, by reason of some mental or physical defect, of receiving benefit from ordinary instruction; they must not be imbecile or merely dull and backward. It depends upon the reading of the Act how much good is done. In some places only a narrow view is taken, and practically only children who are feeble-minded are admitted to the benefits of this special instruction. In other places children with one or more of the important centres defective, such as the word-blind or the word-deaf, are admitted, and are given special attention. The latter method is certainly to be preferred. The word-blind or the word-deaf, in many cases, can be greatly improved and made fit to join their fellows in the upper standards. The feeble-minded practically are never made fit to do so. They may be made more or less useful members of society, but they are always more or less of a danger to society, since they may become the parents of children even more defective and unfit than themselves.

The instruction of the partially defective is a matter of the highest importance. A child so defective requires special and individual instruction. In the large classes in the elementary schools this is impossible, and unless means for obtaining it are provided the unfortunate child is kept year after year in the lower standards, going over the same ground without benefit, with fresh lots of young children, or, in desperation, is passed on to the higher standards to exhibit his incapacity and to fill other teachers with despair. In some cases the teacher does attempt to give special attention to such children, and a certain amount of improvement occasionally follows. What is really required, however, is a double graded defective school, the lower grade for feeble-minded children, the higher grade for the less defective.

Epilepsy.—Epilepsy is a disease found sometimes amongst children of school age. It is important for the teacher to know something regarding it, since its manifestations in the form of fits may be seen in school, and children who are the subjects of the disease require special consideration. Most commonly the disease does not show itself till after the age of ten, and the child who is afterwards to be an epileptic may appear perfectly normal or may be of a nervous and excitable disposition.

Signs of the Disease.—True epilepsy is of two kinds; the first form is that known as *epilepsy minor*, the second that known as *epilepsy major*. The minor is distinguished from the major by the fact that in it there is no distinct fit. There is merely a temporary loss of consciousness for a few seconds, without convulsions, and apparently only a sudden cessation of the activity of the brain. These attacks may attract little attention, since there is merely a momentary interruption of the work in hand. In some cases the face becomes pale, and the person leans slightly to one side, or staggers a little. Very rarely is an object held in the hand dropped. Reading, writing, or conversation is usually taken up at the point where it was left off. Sometimes after the seizure the person may behave in an extraordinary manner; for example, a child may get up from its seat and walk about, or commit some violence upon its neighbour.

The most characteristic feature of the major form is the fit. In this there is loss of consciousness, during which the body is at first held absolutely rigid, and then thrown into convulsions, usually very violent. In most cases the fit is preceded by a cry. At first the face is pale, but later it gets blue. The eyes are turned to one or other side, and are absolutely insensitive to light and touch. There may be foaming at the mouth. Towards the end of the fit the convulsions become less marked and gradually cease, the patient lying unconscious and exhausted for a longer or shorter time. The blueness gradually leaves the face, and the person wakes up feeling and looking very much dazed. These fits occur at intervals regular or irregular, longer or shorter.

Sometimes once a week, sometimes once a month, or once in three months. The less frequently they occur the better. Sometimes they occur during the day, sometimes during the night. Those cases in which the fits occur during the night are the worst. Children who suffer from epilepsy may be somewhat mentally defective, especially if the fits occur at frequent intervals. Those who have fits only at long intervals may be apparently quite normal. Those having frequent fits should not attend the ordinary school, and special provision may be made for them under the Act already mentioned. Children who have fits at long intervals may attend school, but the impression created upon the other children by the occurrence of a fit in the school is apt to be unpleasant. If possible, therefore, the epileptic child should be excluded. Sometimes in the milder forms, where the fits are rare, it is possible to recognize when a fit is about to occur, by an alteration in the temper or habits of the child. In such a case the child should be excluded till the fit is over.

If a fit does occur in school the only thing to be done is to let the child work his way through it. No attempt should be made to restrain him, and stimulants and cold douches are to be avoided. Try to prevent him from biting his tongue by introducing something between his teeth, and from injuring his body or limbs by clearing obstacles out of his way. Lay him flat upon his back, loosen tight clothing, especially at the neck, and interfere no more. The chief danger is injury to the body during the convulsions. Death rarely occurs, except as a result of such injury.

Epileptic fits have to be distinguished from *fainting fits* and *hysterical fits*. In the former there is loss of consciousness without convulsions. In the latter, which sometimes occur in girls and boys, there may be all the signs of an epileptic fit. Consciousness is not truly lost, however. The eyelids are usually firmly closed, and resist all efforts to open them. The eyeballs are turned up and are not insensible to touch. The fainting fit may be seen in anæmic, underfed children, or in those the subjects of heart disease. In boys the subjects of a form of kidney trouble, they are said also to be common. The best thing for the person who feels faint to do is to stoop down in the attitude usually taken up in tying the boot laces. During the fit give the person air and stimulate the heart in some way or other, *e.g.* by means of smelling salts or *sal-volatile*. The parents of the child who faints in school should be advised to get medical advice regarding the condition.

In hysterical fits, when it is settled that they are hysterical, cease to be sympathetic and try the effect of a cold water douche.

St. Vitus' Dance or Chorea.—This disease is most common after the age of seven, and is one occasionally first detected by the teacher. In it there is disturbance of the nervous system leading to irregular and jerky movements of the whole body or of one or more parts of the body. Its causes are not very well known. It seems to be related to rheumatism, and sometimes follows that disease. Like rheumatism, it sometimes gives rise to heart disease, and it is especially important for this reason. By many it is believed to be due to a germ.

Signs of the Disease.—In the early stages, and in the milder forms of chorea, there may be merely signs of clumsiness and awkwardness. The child lets things fall; trips over and bumps against obstacles; is fidgety and restless. As the disease advances these signs become more marked. If the face is specially affected there are curious grimaces and twitchings of the face, and difficulty in speaking. The tongue is quickly protruded and quickly retracted, and the skin of the lips often becomes red and irritated and inflamed. If the arms are affected there is shrugging of the shoulders, tossing about of the arms, and twitching of the fingers. If the legs are affected, they are never at rest. The outstanding features are fidgetiness and restlessness, and these become more marked if the child discovers that he is being watched, or if he is called upon to do anything. Usually the brain suffers at the same time from the general jerkiness. The child cannot concentrate for any length of time, and is irritable and easily disturbed.

Chorea usually lasts ten or twelve weeks, and during this time the child is quite unfit to be at school, since the only proper treatment is absolute rest. The earlier the condition is recognized the much better the results of treatment, and the much less likely the risk of development of complications, and of the recurrence of the disease. All children showing signs of nervous irritability should be medically examined. They may be suffering from nervous overstrain, but they may also possibly be in the early stages of St. Vitus' Dance.

Headaches.—The important subject of headaches, naturally almost, falls to be taken into consideration in connection with the nervous system. The conditions likely to lead to headache in children of school age are very numerous; but as the headache may be the only indication of serious trouble, the teacher should be acquainted with some of these.

The headache due to *eyestrain* is perhaps the most important of all, and the child who is suffering from some very serious defect of vision, and whose sight is being overtaxed, may complain of no other symptom than this. Conditions affecting the *throat and nose*, *e.g.* adenoids, may give rise to headaches, and so also may conditions affecting the ears or the teeth. Headaches may indicate that the child is *anæmic*, or that it is rheumatic or of a highly nervous disposition. They may indicate that the stomach is out of order. Children who are *neglected* at home, who get too little to eat, too little fresh air, and too little sleep, may also suffer from headaches. Headaches may also occur in children kept in classrooms that are stuffy, overcrowded, and badly ventilated. In such cases many children will suffer and the teacher also will be affected. It is always well to think of the classroom as a possible producer of headache.

CHAPTER XI

THE SPECIAL SENSES—SIGHT AND THE EYE

Structure of the eyeball—Vision—Refraction—Errors of refraction—Inflammatory and other conditions affecting the eye—Effect of certain school conditions upon the eyesight.

Of the special senses sight and hearing are the most important, from the teacher's point of view. Mention has already been made of the centres in the brain concerned with these functions, and now the external organs and the outer terminations of the nerves bearing the impressions to these centres have to be considered.

Sight

The organ of sight on each side, which contains the outer terminations of the second or optic nerve, forms what is practically a complete sphere or ball, viz. the eyeball, which occupies a special bony cavity, pyramidal in shape, and formed by several of the bones of the face and skull. This is known as the *orbit*, and in this the eyeball lies protected, except in front, by a wall of bone and packed in all round with fat containing nerves and blood-vessels, and lymphatics, for its nourishment. For the protection of the front of the eyeball, there are the *eyelids*, upper and lower, with their fringe of lashes, and the *eyebrows*.

The Eyelids.—In both eyelids there are several layers of tissue. Outside there is a layer of skin : inside there is a smooth delicate membrane, which is a continuation of that covering the white of the eye, and known as the *conjunctiva*. The conjunctiva consists of cells and its surface is kept moist, and the two layers, that lining the eyelids and that covering the front of the eyeball, are permitted to glide the one over the other, by the *tears*, secreted by a special tear gland or *lachrymal gland*, situated in the upper and outer part of the orbit. At the free edge of the lid, where the skin and conjunctiva meet, there is a narrow band of fibrous tissue which gives form to the edge of the lid and renders it more or less firm. From the edge of the lids there spring the *eyelashes*. These serve to intercept dust particles, which, if they reached the conjunctiva, might give rise to irritation and inflammation. On the edge, also, there open the ducts of certain small glands, resembling sebaceous glands, and called *meibomian glands*. If

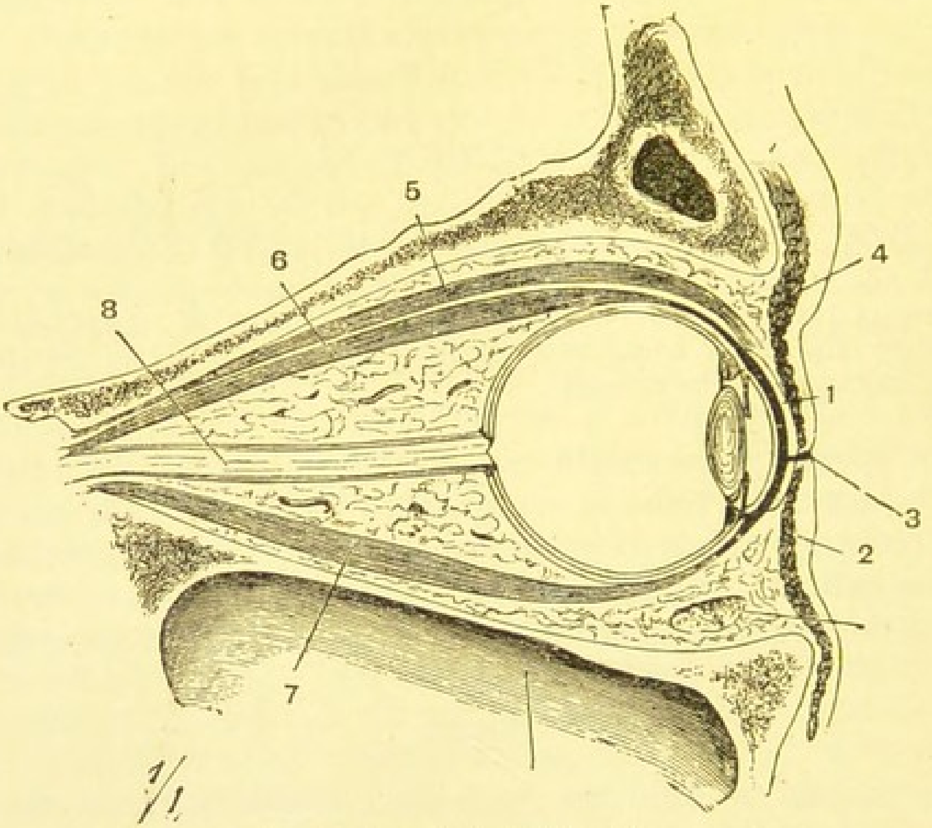


FIG. 71.—Section through the orbit and its contents.

1, upper eyelid; 2, lower eyelid; 3, chink between lids; 4, the orbicular muscle; 5, elevator muscle of upper eyelid; 6, superior rectus muscle; 7, inferior rectus muscle; 8, optic nerve.

one of these gets blocked inflammation of the gland, or a *stye*, may result.

At the inner end of the eye-opening, or *internal canthus*—the outer end being the *external canthus*—there is, in each eyelid, a distinct opening known as the *punctum lachrymale*. Each opens into a short duct, the *lachrymal* or *tear duct*, into which the tears are collected after having passed across the eye, from the lachrymal gland, washing the conjunctiva and being distributed by the movements of the lids. After a short course the two tear ducts join to form a larger duct, known as the *nasal duct*, which opens into the lower part of the nose. Sometimes this duct gets blocked, and then the tears, having no proper outlet, overflow down the cheek. The same thing happens if the secretion of tears, for any reason, is stimulated and the ducts become incapable of dealing with the increased amount. Sometimes irritating germs pass along the tear ducts from the nose to the conjunctiva, and give rise to inflammation there.

Between the skin and conjunctiva there lie the fibres of the muscle which brings about the closure of the eyelids, namely, the *orbicular muscle.* This forms practically a circle round the eye-opening, or *palpebral fissure* as it is called. In the upper eyelid, in addition to the fibres of the orbicular muscle, there is the tendon of the muscle that raises the lid. This muscle rises at the back of the orbit, and its tendon is inserted into the edge of the upper

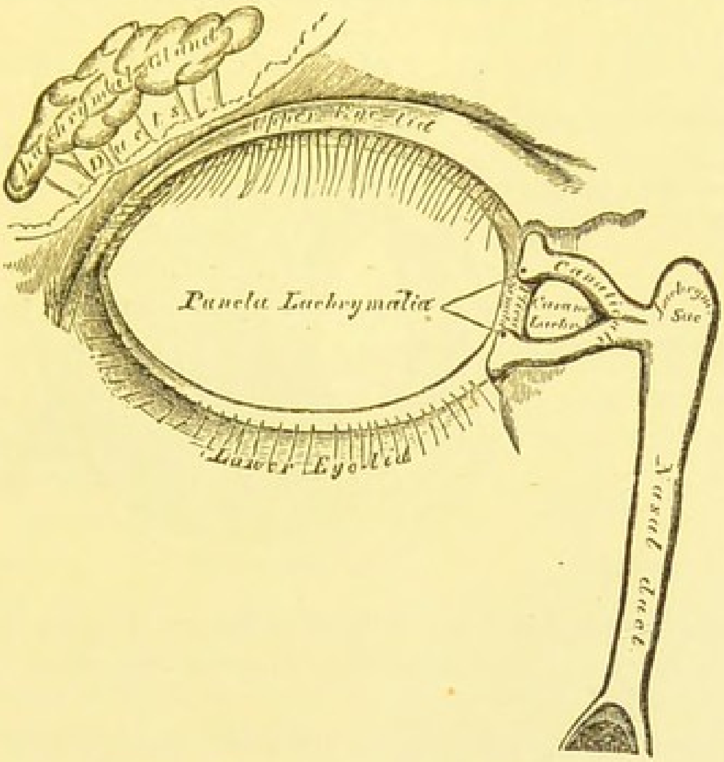


FIG. 72.—Lachrymal apparatus of right side.
(*From Gray's "Anatomy."*)

lid. Sometimes it is paralyzed, and drooping of the upper lid results. Some children are born with this muscle paralyzed. In other cases, however, paralysis follows an attack of diphtheria. Like paralysis of the soft palate, paralysis of this muscle may follow a mild and even unrecognized attack of diphtheria.

In both eyelids, giving them firmness and form, these is placed, between the skin and conjunctiva, a firm piece of almost cartilaginous tissue, known as the *tarsal plate.* In the upper lid the plate is very much thicker and firmer than in the lower lid. Particles of dust and other foreign bodies that may have lodged on the conjunctiva lining the upper lid may be reached by pulling down the eyelid and folding it backwards over a pencil or match, at the level of the upper edge of this tarsal plate.

In the protection of the eye the eyebrow is of less importance than the eyelids. It does, to a certain extent, assist, however, by preventing fluids, such as perspiration, from running into the eye, and by cutting off excessive rays of light.

The Eyeball.—The eyeball is not quite globular in shape, measuring less from front to back and above downwards than from side to side. The average measurements in the adult are, from side to side, just under an inch, from back to front nine-tenths of an inch.

It is divided internally into two unequal portions, usually named *chambers*, anterior and posterior, which contain each a fluid,

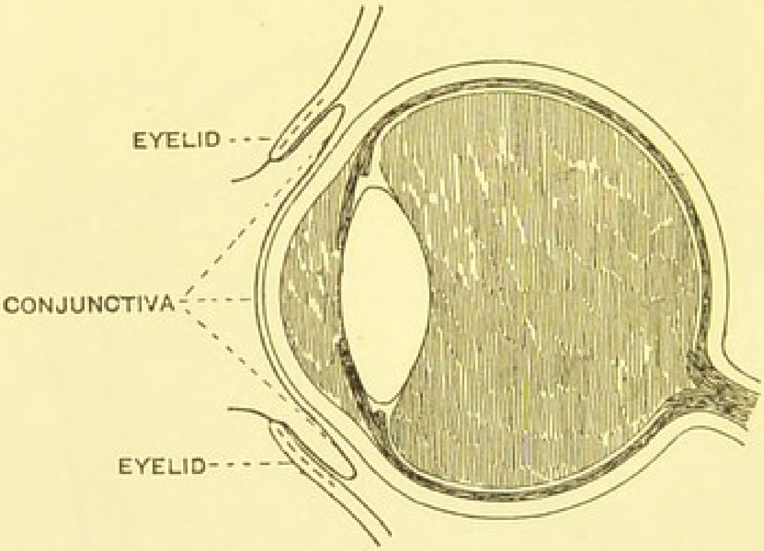


FIG. 73.—Section of eyeball to show relation of conjunctiva to eyelids and front of eye. (*From Thornton's "Elementary Practical Physiology."*)

named a *humour*, and playing a part in connection with vision. The wall of the eyeball consists of *three* layers, each with a special function. To the outer coat or *sclerotic*, which is the thickest, the eyeball owes its form. The middle coat, or *choroid coat*, contains large numbers of blood-vessels, and it nourishes to a great extent the other coats. The innermost coat, or *retina*, is the most important of all. Upon it impressions of light are received, the other coats merely serving for its protection or nourishment, and the other structures in the eye existing merely as mechanical aids to the carrying out of its functions.

The *sclerotic coat* consists of tough fibrous tissue. It makes up the whole of the outer covering, except at a point behind, where the optic nerve perforates it, and a part in front where the ball is made transparent to permit light rays to enter the eyeball. This front portion of the eyeball is named the *cornea*, and, as its name implies, the cornea is of a horny consistence. It is made up of numerous layers of transparent fibres and is devoid of blood-vessels. It plays a small part in connection with the focussing of light rays. Into the sclerotic are attached the six small muscles which, arising within the orbit, hold the eyeball in position, and bring about its movements in various directions. Of these muscles, four only need be particularly mentioned. They are inserted, one on the inner side of the ball, one on the outer side, one into the upper and one into the under surface. They are named, the internal, the external, the superior, and the inferior straight muscles or *recti*, and move the eyeball inwards, outwards, upwards, and downwards, as the case may be. The remaining two are named the *oblique* muscles, and usually act in conjunction with the others.

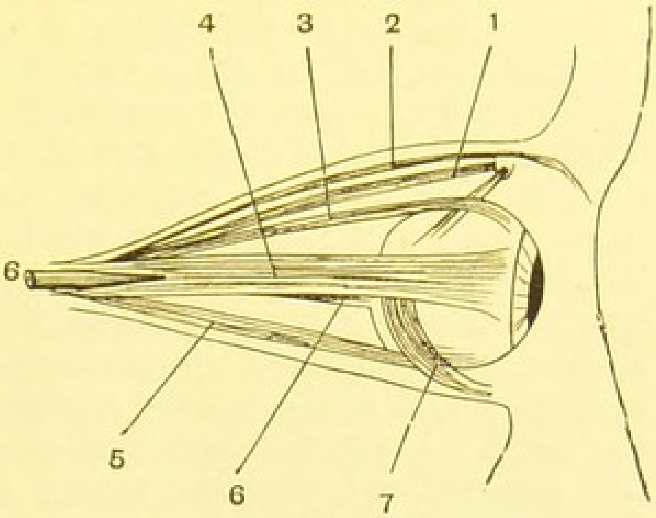


FIG. 74.—Muscles of the eyeball (diagrammatic).

1, superior oblique muscle; 2, elevator muscle of upper eyelid; 3, superior rectus; 4, external rectus; 5, inferior rectus; 6, 6, optic nerve; 7, inferior oblique muscle.

The *choroid coat* lies internal to the sclerotic, and is loosely attached to it. It consists largely of blood-vessels, and is covered internally by a layer of black pigment, which, acting in the same way as the blackened interior of the bellows of a camera, prevents the reflection of light. Like the sclerotic the choroid is perforated posteriorly by the optic nerve. At a point about one-third of the length of the eyeball from front to back, the tissues composing the choroid become irregularly folded or pleated and being much increased in thickness by the addition of muscular fibres, form a distinct ring round the interior of the eyeball.

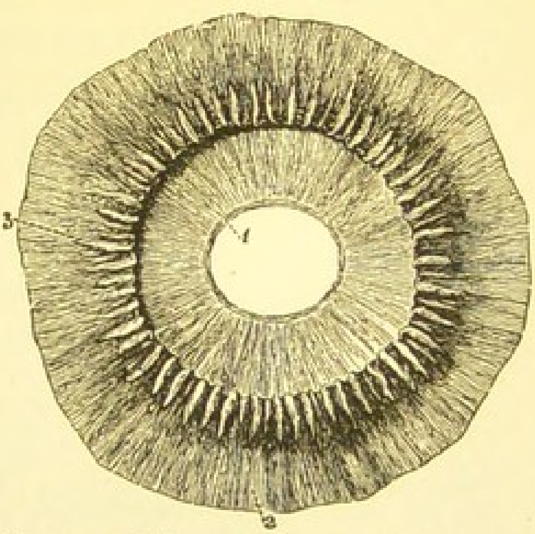


FIG. 75.—Ciliary processes and iris as seen from behind. Twice natural size.

1, posterior surface of iris with sphincter muscle of pupil; 2, anterior part of choroid; 3, ciliary processes.

(*From Quain's "Anatomy."*)

To this thickened ring the name of *ciliary body* is given, and to the folds or pleats the name *ciliary processes.* The muscular fibres in the ciliary body are involuntary and are arranged, some in a circle round the ring, others radially. These fibres make up a muscle known as the *ciliary muscle.* From the ciliary body forwards the choroid again becomes thin, and to the thinned portion, which hangs like a curtain from the edge of the ring, dividing the interior of the eyeball into its anterior and posterior chambers, the name *iris* is given. Into the structure of the iris there enter muscular fibres, which are again arranged either circularly or radially round a central opening in the iris. To this central opening the name *pupil* of the eye is given. To the circular muscular fibres the name *sphincter* or closer of the pupil is applied, and to the radially arranged fibres the name *dilator* of the pupil. Upon the inner surface of the iris there is a layer of the pigment or colouring matter of the choroid. Upon the thickness, or otherwise, of this layer and its position in the iris, depends the colour of the eyes.

The Retina.—Covering the inner surface of the choroid, and only loosely attached to it, is the third layer of the eyeball or

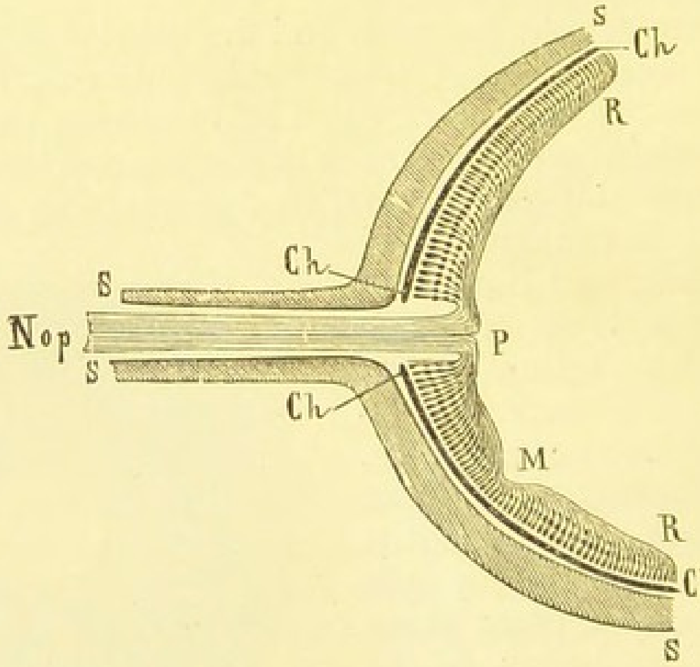


FIG. 76.—To show connection ot optic nerve with rods and cones.
Ch, choroid ; S, sclerotic ; R, retina ; *Nop*, optic nerve ; P, point of entrance of optic nerve, blind spot ; M, yellow spot of retina.

retina. This lines about two-thirds of the whole interior of the eyeball and is exceeding complicated in structure, except in the neighbourhood of the ciliary body and iris, where it becomes modified somewhat. It is really a purely nervous tissue, and is now recognized as an outgrowth from the brain with which it is connected by means of the optic nerve. By this nerve impressions are received from the bodies of which the retina, to a large extent, consists and are conveyed to the brain. The bodies making up the retina are of two kinds—one, the more numerous, somewhat resembling a cone in shape; the other being more or less rod-shaped. These are known as the *rods and cones* of the retina, and they are the structures first affected by light. They vary in number and sensitiveness in different parts of the retina. At the back part they are much more numerous and sensitive than in front. At the point where the optic nerve leaves the eye there is an absence of rods and cones, and this part is named the *blind spot.* At another point, in the human subject especially, there is an area over which the sensitiveness is increased. This spot, situated in the *optic axis* or middle line of the eye, is known as the yellow spot or *macula lutea,* and it is here that practically all light impressions are received, all the muscles concerned with the movements of the eyeball and the focussing of objects, acting so that the rays shall be brought to this point. The fibres of the optic nerve which convey impressions to the visual centres in the brain vary in the route which they take, with the side of the eye from which they spring. Those fibres coming from the outer half of each retina pass to the visual centre on the same side as the eye to which they belong. The fibres from the inner half pass to the centre on the opposite side of the brain.

The Lens and Vitreous.—In the interior of the eyeball the structures present are concerned with what is known as *refraction* or bending of the light rays, so that they shall be brought to a focus and produce a distinct impression on the retina. In front of the iris, occupying the anterior chamber, is a clear fluid, comparatively small in amount and named the *aqueous humour.* Behind the iris there are two structures, viz. the *crystalline lens*—or, shortly, the lens—and the *vitreous humour* or *vitreous body.*

The *lens* is perfectly transparent. It is convex both in front and behind, though the shape varies somewhat with the age of the individual. In the adult the convexity behind is the greater, while in the young child the shape is more spherical, and in old age both surfaces are much flattened. The fully developed lens measures about one-third of an inch across and a quarter of an inch from front to back. The posterior surface fits into a depression in the vitreous body, and the anterior lies in contact with the iris at the opening of the pupil. Structurally, the lens is composed of transparent, rather elastic, fibres, arranged in layers. These are enclosed in a capsule which is also transparent and elastic. Into this capsule there are inserted certain fine fibrils which stretch between the lens and the ciliary processes, and which form part of what is known as the *suspensory ligament* of the lens. This helps to hold the lens in position. The lens plays a very important part in connection with vision, and the variations in its curvature, in order to enable it to bring to a focus on the retina rays from objects either near to or distant from the eye, are brought about mainly by variations in the tension of the suspensory ligament. These variations are induced by muscles.

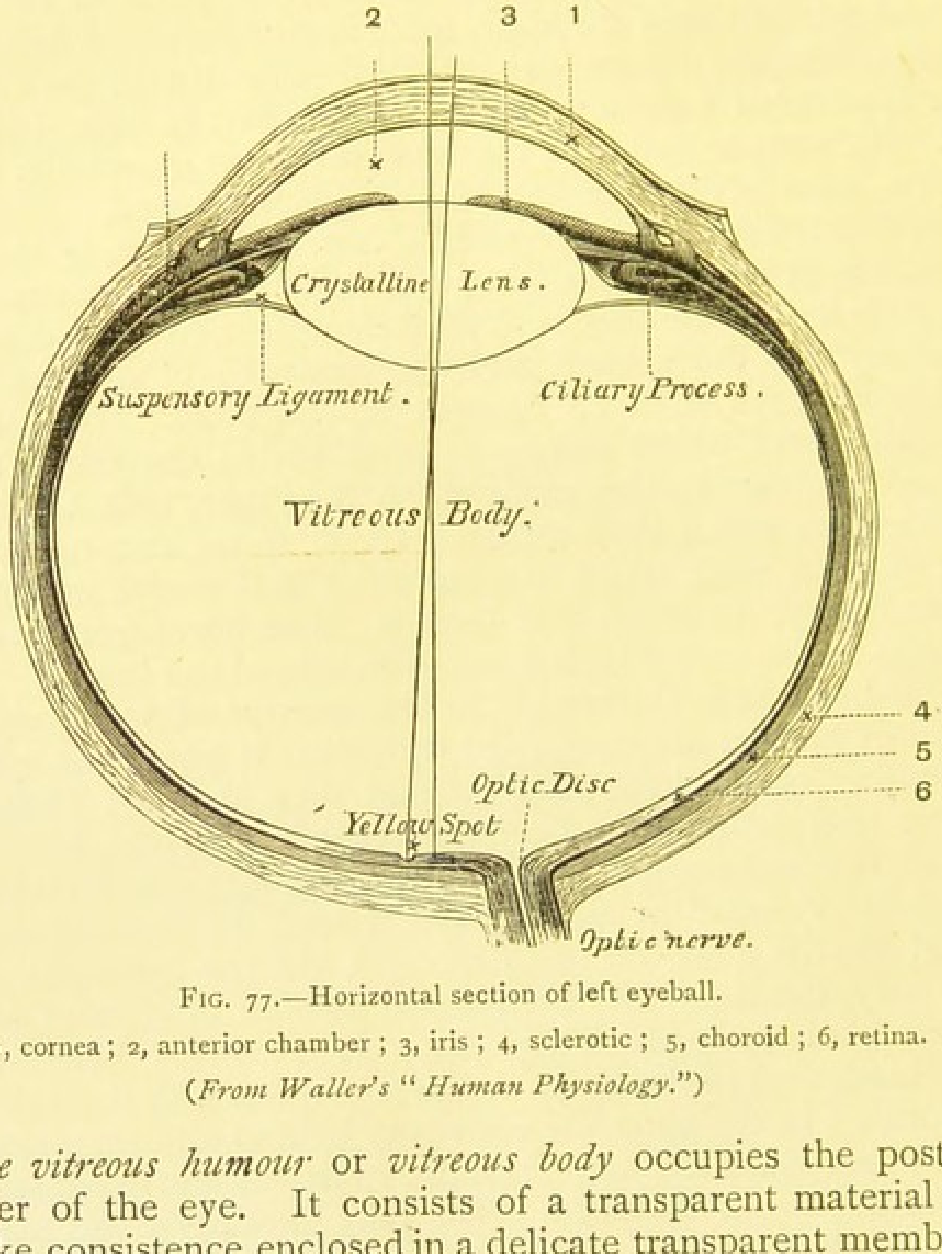


FIG. 77.—Horizontal section of left eyeball.

1, cornea; 2, anterior chamber; 3, iris; 4, sclerotic; 5, choroid; 6, retina.

(*From Waller's "Human Physiology."*)

The vitreous humour or *vitreous body* occupies the posterior chamber of the eye. It consists of a transparent material of a jelly-like consistence enclosed in a delicate transparent membrane, the so-called *hyaloid membrane.* In front the vitreous is hollowed out to accommodate the lens, and its membrane is connected with the suspensory ligament of the lens. Behind, it rests against and helps to support the retina. Like the cornea, the aqueous humour, and the lens, the vitreous plays a part in the refraction of rays destined to fall upon the retina.

Vision

Before an object can make an impression upon the retina and produce an image the rays from it must *converge* upon the retina. Inasmuch, however, as the rays from an object, if near at hand, are divergent, and if distant, practically parallel, they must be subjected to a certain amount of bending or refraction in order to transform them into convergent rays. By the use of a lens which is convex on both surfaces divergent or parallel rays can be bent or converged; and by the use of lenses of definite convexities rays from objects at various distances *in front* can be converged to points within varying short distances *behind* them. In the case of the normal eye the area within which convergence must take place, *i.e.* between the front of the cornea and the front of the retina, is about nine-tenths of an inch, and if a clear image is to be obtained a lens must be provided capable of bending rays to a point within this distance.

In certain of the structures of the normal eyeball, viz. the cornea, the aqueous humour, the lens and the vitreous, but especially the lens, there has been provided the equivalent of such a lens. Acting together they are capable, in the normal eye, of converging all rays, parallel or divergent, from objects distant or near at hand, upon the retina and producing a clear impression. In the case of a distant object, the rays, which are practically parallel when they reach the front of the cornea, are slightly bent in passing through it. In passing through the aqueous humour further bending takes place, though not sufficiently for the whole bundle of rays to pass through the pupil. Most of the outer rays are cut off by the iris, the remainder passing on to the lens, the strongest refractive body in the eyeball. By the lens the rays are strongly converged and pass on through the vitreous, by which they are probably only slightly further bent, to fall on the retina and produce a clear image of the object. At the point where the image falls, stimulation is produced, varying in character with the colour and strength of the rays. This is communicated to the fibres of the optic nerve, and is borne away to the visual centres where *perception* or *conscious vision* takes place.

Since the media of the eyeball have to deal with rays coming from objects at very varying distances, and since the point at which they have to be converged is always the same distance from the front of the eye a certain amount of complication is introduced. The matter is further complicated by another set of difficulties, viz. (*a*) that in both eyes the field of vision, *i.e.* the amount seen with each retina, is practically the same, and overlapping takes place to a certain extent; (*b*) that if the object is to be seen clearly it must be focussed on the yellow spot, which is very small, and if it is to be seen as a single object it must be focussed on each yellow spot. The yellow spot being in the optic axis or middle line of the eye, the object will only be seen singly if the optic axes intersect in the object looked at. To overcome these difficulties special provision is made.

Accommodation.—To ensure that divergent rays coming from a near object shall be converged to the same point as the parallel rays from a distant object, and not behind that point, as would be the case if a lens of the same convexity were used in both cases, the crystalline lens is made elastic and capable of being increased in convexity. This alteration in convexity is brought about by the action of the muscular fibres in the ciliary body

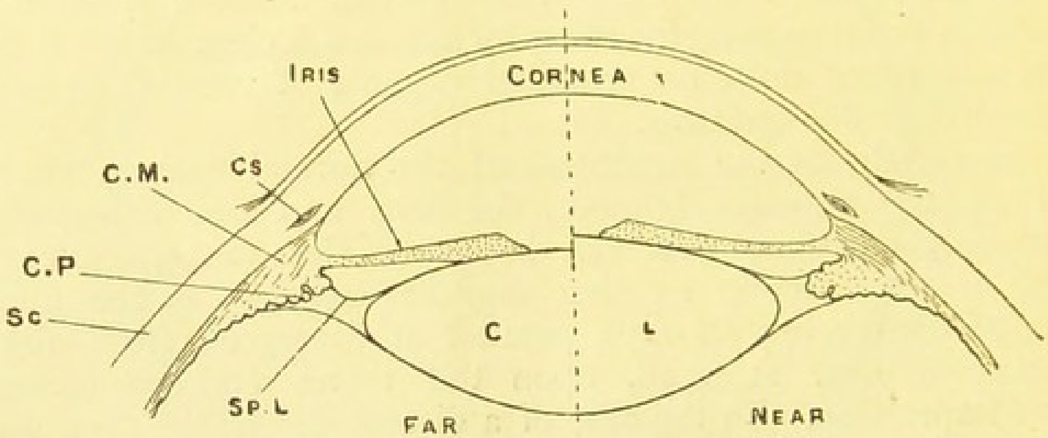


FIG. 78.—Diagram to illustrate accommodation. On the left, the form taken by the lens at rest and viewing distant objects is shown; on the right, that when accommodated for near objects.
Sc, sclerotic; C.P, ciliary processes; Sp.L., suspensory ligament; C.L, crystalline lens.
(*From Thornton's "Advanced Physiology."*)

upon the suspensory ligament, and through it upon the capsule of the lens and the lens itself. The lens being elastic is readily affected. The amount of variation in the convexity of the lens required, depends upon the distance of the object from the eye, and for different distances different convexities are necessary. These variations are continually taking place, and taking place very rapidly, the lens, on account of its elasticity, returning always to its original shape. To the whole of this process the name *accommodation* is given. Accommodation is distinctly a muscular act, as can be shown by the fact, that if the eye, after being at rest, is made to fix a near object, a distinct effort is felt. Also, if certain substances having the power of paralyzing involuntary muscle fibres be applied to the eye, the power of accommodating for near objects is lost, the fibres of the ciliary muscle having been thrown out of action.

In the treatment of rays from various distances the iris plays a certain small part, its muscular fibres diminishing the size of the pupil when a near object is looked at, and so ensuring the cutting off of many of the outer or peripheral rays. This leads to a general "sharpening" of the outline of the object. In looking at a distant object, or when the light is dull, the size of the pupil is increased so that the rays are little interfered with.

Convergence.—To overcome the other ((*a*) and (*b*)) difficulties mentioned, there have been provided the straight or recti muscles, which are capable of moving the eyeballs in various directions. Provision has also been made, by the association of the brain centres governing the muscles of the two eyeballs, for the acting together or co-ordination of the muscles of both eyes. In this way it is assured that the two superior recti and the two inferior recti shall always act together in looking upwards or downwards, as the case may be. In looking sideways, the external rectus of one eyeball acts with the internal rectus of the other, in order to bring about the required movement. Further than this, however, the two internal recti are also capable of acting together, and in the normal eye invariably do so when the gaze is fixed upon an object, the activity increasing with the proximity of the object to the eye. In this way the intersection of the optic axes in the object looked at is ensured.

To the drawing inwards of the eyeballs, which results from the contraction of the internal recti, the name *convergence* is given, and convergence and accommodation being most required in looking at a near object these two actions always take place together. Convergence, like accommodation, being due to the action of muscles, a certain amount of effort has to be expended to bring it about. If this effort is continued for any length of time there is a tendency to fatigue of the muscles, especially in children. Also, since the convergence and the amount of the accommodation necessary, increase with the nearness of the object to the eye, the smaller the object, the greater the effort and the more intense the fatigue produced, if the effort be prolonged. The distance from the eye most suitable, and that throwing least strain on the muscles of accommodation and of convergence, is 12 *inches*. Rays coming from an object at this distance can be focussed with the least amount of strain, and, indeed, it is only by the expenditure of a great deal of muscular energy that rays from an object nearer than this *average near point of vision*, can be brought to a focus at all, and can be seen with the same part of each retina, and therefore as a single object.

The tendency to bring the object nearer than the average near point is not uncommonly met with among young children who work with fine-pointed instruments and small objects. This they do in order to increase the size of the object and of the image on the retina. The strain thrown on the muscles of accommodation and convergence by so doing is very considerable, and the resulting impression is far from clear. Young children should never be allowed to exercise this tendency, and this is only to be done by withholding small objects from them, and by insisting upon 12 inches as the nearest working point.

The Eyeball in the Child.—Many of the difficulties which young children experience in connection with accommodation and convergence depend, to a great extent, upon structural differences between their eyes and those of adults. It is safe to say, also, that many of the defects of vision produced in childhood result from the fact that these structural differences are unknown to teachers, or are forgotten in choosing the work for young children. The great point of difference is in connection with the length of the eye. In the child the eye is, relatively, much shorter than in the adult, the area within which rays can be brought to a focus being distinctly less. The tendency will, therefore, be for the focussing of parallel rays from a distant object to take place not exactly on the retina, as in the adult, but at a point distinctly beyond it. To ensure that the rays shall be bent and focussed on the retina, the muscles of accommodation have to be called into play to alter the convexity of the lens. The lens in the child, though more elastic, is also more convex than in the adult, and a considerable amount of energy may have to be expended. In the adult no accommodation for distant objects is necessary, and in this respect, therefore, the child is worse off. For the focussing of rays from near objects accommodation is, in the child, as necessary as in the adult, and energy has to be expended by the ciliary muscles, which are small, delicate, and readily fatigued. In association with accommodation, as in the adult, convergence occurs, and the internal recti are called into play. These, again, are small muscles, and are easily fatigued if they are at all overworked. In the child, in any case, there is always a tendency for these recti muscles to be overworked, since convergence and accommodation go hand-in-hand, and accommodation in the child is, necessarily, much more called for than in the adult.

Defects of Vision

Apart from the tendency to fatigue of the muscles which may occur in the child as a result of the overaction of the muscles, and the nervous overstrain that may be induced if the immature nerve cells connected with the muscles are overworked, *defects of vision* may also result.

Squint.—The condition known as *squint*, or squinting of the eye, may be produced as a result of overstraining the muscles of convergence. The squint most commonly seen, especially in the infant and junior departments of the school, is the *internal squint* of one eye. It is supposed to be dependent for its production upon the fact that one internal rectus is inferior, either in function or in elasticity, to the other; and while the eyeball with the sound normal internal rectus converges only to the proper amount, and returns to its correct position after convergence, that of the weak side gets too much drawn in, or does not return to its proper position. The fact that, as teachers frequently notice, two or more members of one family develop a squint during the school period, may be taken as an indication that there is the same abnormality in the internal rectus in each, and the muscles suffer in the same way from the school conditions. An internal squint may be produced by giving children too much fine work, requiring excessive convergence, and is most likely to be induced in children who are not physically strong. Such a squint may be permanent, especially if associated with a serious defect of vision, but may pass off if proper glasses are provided. In some cases operative treatment may be required.

The defects of vision met with are due, usually, to faults in connection with the dimensions of the eye, leading to difficulties in focussing the rays properly upon the retina. Some of these defects, which are called usually *errors of refraction*, are produced at school. The conditions calling for chief mention are—

(1) Long-sightedness or Hypermetropia.
(2) Short-sightedness or Myopia.
(3) Astigmatism.

Long-sightedness or Hypermetropia.—In this condition there is a tendency for rays of light, even from distant objects, to be focussed *behind* the retina, since the eye is *too short* from front to back. To overcome this tendency the muscles of accommodation have to be brought into play. Persons, children especially, suffering from this condition usually have little difficulty in seeing distant objects, the amount of accommodation necessary being carried out quite easily. In looking at near objects, however, in order to overcome the shortness of the eyeball and to make the lens as convex as possible, the object is brought close up to the eye, and great strain is thrown on the muscles concerned with accommodation and convergence. Of this great strain in children very little evidence may be shown, and the condition may not be detected, without special tests. Children, however, who habitually work within the average near-point distance should be suspected of being hypermetropic, and should be examined. Associated with the impaired vision there may be other signs, such as headache, as a result of strain and fatigue, squinting, congestion of the eyes, and inflammation of the eyelids.

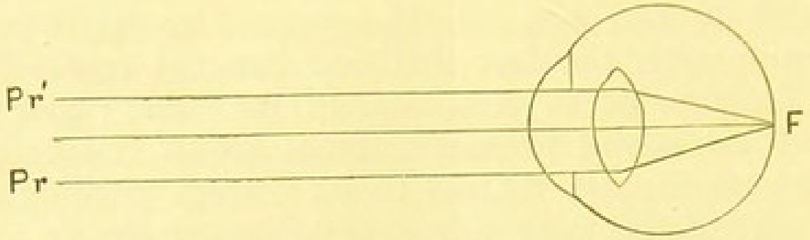


FIG. 79.—Emmetropic or normal eye. Parallel rays focussed on retina.

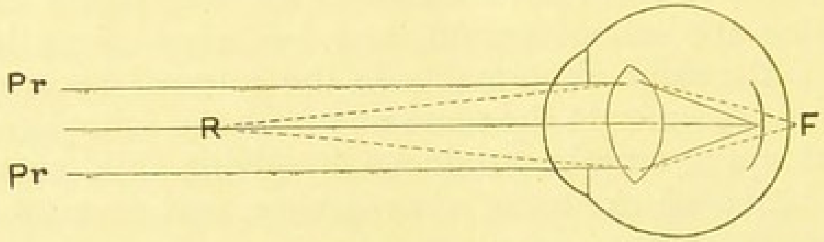


FIG. 80.—Myopic or short-sighted eye. Rays of light focussed in front of the retina.

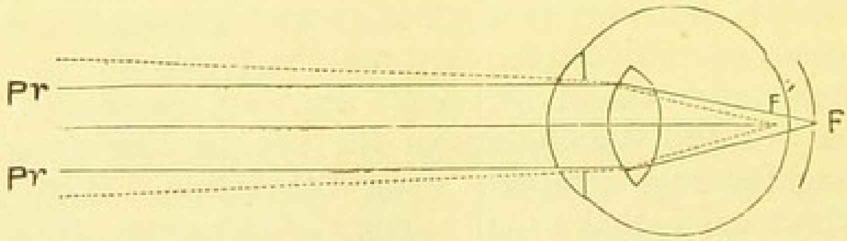


FIG. 81.—Hypermetropic or long-sighted eye. Rays of light focussed behind the retina. (*From Longmore's "Optical Manual."*)

Myopia or Short-sightedness.—This is an error of refraction due to a condition of the eyeball exactly the opposite of that found in hypermetropia. In myopia the eyeball is *too long*, and rays of light from distant objects focus in front of the retina. To bring them properly to a focus the muscles of accommodation are called into play, and the lens altered in convexity. To further assist the focussing the eyelids are closed to a chink, and the eyebrows are drawn down to cut off as many of the peripheral rays as possible and sharpen up the outline of the object. As a result, the peering look, so characteristic of myopia, is given to the face of the person suffering from this defect. In addition, however, as a result of having to call so many muscles into activity, to alter the lens and to modify the rays of light, a considerable strain is always felt, and fatigue is rapidly produced. Fatigue may also result from looking at near objects in such a case, the muscles of accommodation having to act strongly to produce the proper curvature of the lens. Usually the muscles are quite equal to the task, and no sign of defective vision may be detected in, nor complaint of fatigue made by, a myopic person engaged in near work. The increase in the length of the eyeball producing myopia would almost seem to be due to over-development, the eyeball increasing in length more rapidly than in other directions. In some cases it undoubtedly is produced by giving children who are young, or in a poor state of health, work requiring a great amount of convergence and accommodation. As a result of the strong and continued contraction of the muscles producing these actions, the coats of the eyeball get stretched and the whole globe is lengthened.

Apart from the regular contractions of the accommodation muscles, a kind of spasm or cramp may be set up in them, and distant objects are not well seen. Such spasms may occur in children who are hypermetropic, but are also met with in those who have quite normal eyesight, but who are of a nervous disposition, and who are given too much fine work to do. Girls, especially, who do much fine sewing, occasionally suffer from this condition, and may be suspected of being myopic. Since true myopia may be produced as a result of the pull upon the tissues of the eyeball, medical advice and treatment should be obtained.

The visible signs of myopia, which may assist the teacher in the detection of children suffering from this defect, may be mentioned. In the myope the eyeball is usually prominent and distinctly big. The pupil is usually dilated. In looking at distant objects there is a distinct tendency to peer through the smallest possible opening in the eyelids, and closing of the lids, drawing down of the eyebrows, and wrinkling of the forehead are very characteristic of myopia. So also is an almost continuous rhythmic blinking of the eyelids.

Astigmatism.—The defect in astigmatism is due to an inequality in the curvatures of the cornea, the vertical being greater or less than that of the transverse. In the astigmatic eye the cornea has the curvatures of the bowl of a teaspoon, in the normal eye those of a saltspoon. As a result of this defect, rays of light passing in in the transverse meridian are not focussed on the same part of the retina as those passing in in the vertical meridian ; a blurred image is therefore produced. In looking at the face of a clock or watch, the person with the irregularly curved cornea does not see all the figures with equal clearness, either those in the vertical meridian—the twelve and the six—or those in the transverse meridian—the three and the nine—being indistinct and blurred. Astigmatism is an exceedingly distressing form of error in refraction. In a small degree it is not at all uncommon, and hypermetropic persons are frequently also astigmatic. In a high degree it is apt to give rise to severe eyestrain and headache, though persons with a low degree often also suffer in this way. Its correction is often a matter of very great difficulty, and special care has to be exercised in the preparation of proper glasses. Sometimes astigmatic school-children show a tendency to vary the distance at which the reading-book is held, sometimes bringing it quite close up to the face, sometimes placing it at some distance off. The writing of a child with astigmatism may be very irregular. The child may also state that though he can see the blackboard well for a time a haziness tends to develop as the lesson advances.

In this connection it is well for the teacher to recognize the importance of noting statements made by the children regarding their ability to see or not to see well. The hypermetrope may complain that he cannot see his book clearly unless he holds it very close to his face, whereas he can see the blackboard quite well. The myope may make statements entirely the opposite. But in very many cases where there is an undoubted defect of vision no complaint whatever is made, and as it is important to detect these cases early, before the defect has been exaggerated by straining the child's powers of accommodation, tests must be applied. And in order to make sure that no case escapes detection every child must be tested.

Methods of testing Vision

For testing the acuteness of vision, cards showing letters of a standard size are procurable. The accompanying card is that used by the teachers in Sheffield and supplied by the Education Committee. Each letter is of the size and type that a person with normal vision can read at a known distance. These types are known as "Snellen's Types." The letters are arranged in lines, and under each line the distance at which the letters are readable, by a person with normal vision, is marked, either in feet or metres, 20 feet being equal to 6 metres. When the test is to be carried out, the card should be hung on the wall or blackboard in a good light. Twenty feet from the card a line should be marked on the floor. The child is told to toe the line, and is requested to read the letters in the various lines, with each eye in turn, the eye not under examination at the time being closed. A record should be kept of each eye, and is usually represented by a fraction. In front of the fraction for the right eye the initials

A C Z N F

CURRY & PAXTON, LONDON

60 feet — 40 feet

U X P O V

30 feet

H T U F S L

20 feet — 18 feet

E C A D J N

16 feet — 14 feet

G F K N O Z

13 feet — 12 feet

H A U P T R

11 feet — 10 feet

▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪

10 feet

(For use in sight-testing, this sheet may be detached and fixed to a board of stout card or wood.)

A child has normal vision if able to distinguish at a distance of 20 feet the letters prescribed for that distance. If at a distance of 20 feet the child can only distinguish the letters prescribed for the 30 feet distance, the parents should be informed that the vision is defective. If the child cannot distinguish at the 20 feet distance the letters prescribed for 40 feet, the parents should then be informed that the vision is seriously defective, and unless attended to at once will prevent the child following a large number of occupations. Each eye should be tested separately.

[*To face page* 202.

R.V. are placed—R. for right, V. for vision. In front of the fraction for the left eye the initials L.V. are set down. The numerator of the fraction is always the distance of the line on the floor from the test card; in this case, therefore, 20 (feet) or 6 (metres). The denominator is the figure under the *smallest* letters read by the child under examination. If the vision is normal, the fraction will read, R. V. $\frac{20}{20}$, L. V. $\frac{20}{20}$. If the vision is defective, the denominator will be something greater than 20, for one or both eyes, and the fractions may read, R. V. $\frac{20}{40}$, L.V. $\frac{20}{40}$, or $\frac{20}{30}$, and so on. Children with such irregular fractions should be sent to be tested medically. The parents of such children should be warned against having them tested by opticians, chemists, and persons who deal in spectacles. Such unqualified persons cannot test the eyesight, especially of children, properly, since it is usually necessary to paralyze the muscles of accommodation before carrying out the test. Atropine, a substance sometimes employed for this purpose, takes, in children, a week to act, and the effects do not wear off for another week. During this time the child cannot focus for near objects, and should therefore be kept from school. The accompanying forms are those used in the elementary schools in Sheffield to draw the attention of parents to defects in vision.

Form A

CITY OF SHEFFIELD EDUCATION COMMITTEE

School,

19 .

Dear Sir (Madam),

I am requested by the Committee to inform you that is suffering from defective vision, which if not properly treated now will interfere with progress in School work, and may lead to very serious difficulties later on, and I am strongly to recommend you to consult a medical man with regard to treatment or spectacles. It is not advisable to buy glasses in shops from opticians or dealers without first having obtained advice from a medical man ; but if you are unable to consult one privately, you would be able to obtain the necessary advice at one of the Sheffield hospitals.

Yours faithfully,

Head Teacher.

Form B

CITY OF SHEFFIELD EDUCATION COMMITTEE

Dear Sir (Madam),

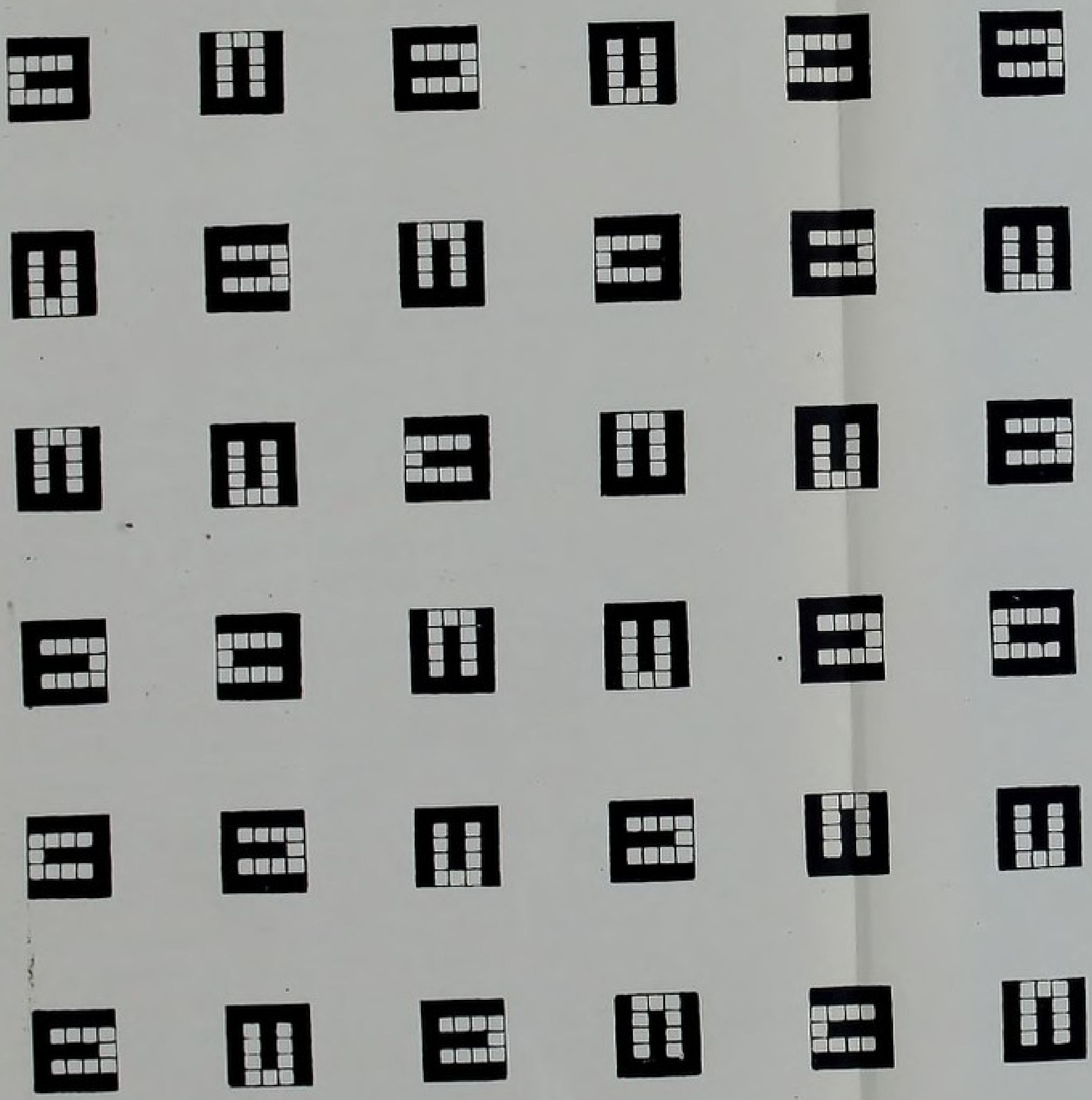
Your attention having been called by the Head Teacher of the School to the defective vision of your child , and as the defect still continues and is interfering with the progress of the child at School, the Committee urges that you should have medical advice on the matter as soon as possible.

Clerk to the Education Committee.

19 .

Form B is only sent to the parents of children who have neglected the advice given in Form A. In a considerable number of cases, spectacles are obtained for children as a result of sending these notices. If both warnings are neglected, however, further pressure is brought to bear upon the parents by means of notices sent by the medical officer visiting the schools, and in other ways. It is probable that in many cases the parents who fail to provide glasses for their children do so because they are unable to afford to purchase them. It is to be hoped that in the future some means of assisting, the more deserving at least, will be devised. Since it is generally held that Education Committees have no power to supply spectacles for the school-children, something of the nature of a "spectacle fund" will have to be raised for the purpose. That something will have to be done is only too clear to any person who is acquainted with the state of affairs in the elementary schools.

For children under the age of eight Snellen's types are less useful than for older children. Much more satisfactory are those known as Cohn's types, of which an illustration is given. In employing these the child, as before, is placed 20 feet from the card, and is asked to indicate the direction in which the limbs of the letter E point. If unable to do so, he is moved nearer to the card, and the distance at which he is able to tell noted. A record is made, in the form of a fraction, using 20 as the denominator, the other figure as the numerator.



COHN'S TEST TYPE.

[*To face page* 204.

Inflammatory and other Affections

Apart from errors of refraction, there are certain other disease conditions which the teacher may encounter in school, and with the signs of which it is well for him to be acquainted. These may be divided into—

(1) Conditions affecting the eyelids: (*a*) Stye; (*b*) Inflammation.

(2) Inflammation of the eyeball.

(3) Opacity of the lens or cataract.

Stye.—The stye has already been mentioned and its mode of production described. The presence of a stye may indicate that the child is run down and in need of tonic treatment, fresh air, and better food. It may indicate, however, that there is an error of refraction and defective vision, and if the teacher does not make a regular examination of all the children, it might be worth while making a rough test of children affected with styes. The same remark applies, as a matter of fact, to all inflammatory conditions affecting the lids.

Inflammation of the Eyelids may be due to an error of refraction, and in all cases of long standing, where the edges of the lids get thick and red, and the eyelashes cast off, an examination is indicated. Like the stye, the existence of this condition indicates also very often the necessity for a tonic. In neglected and dirty children, inflammation of the edge of the lids is often seen, the eyes being slightly reddened, and scabs collecting about the roots of the eyelashes. Care and ordinary cleanliness will often lead to the disappearance of the inflammatory signs.

Inflammation of the Eyeball.—The most common signs of such inflammation are *congestion* or *redness of the conjunctiva*, *watering of the eyes*, and *fear of the light*. The child keeps the eyelids as close shut as possible, and draws down the eyebrows in order to exclude irritating rays of lights. There may be complaint of *pain in the eyes*, and also of a feeling of *roughness*, as if grains of sand had found their way under the lids. The chief conditions of which these may give indications are—

(1) Inflammation of the conjunctiva.

(2) Errors of refraction.

(3) Ulceration of the cornea.

(4) Inflammation in the deep tissues of the eyeball.

Since all these conditions are more or less serious, and call for treatment, the teacher should be prepared to recommend that medical advice be obtained in any case in which signs of inflammation are detected.

In *acute inflammation of the conjunctiva* the signs mentioned are usually very marked, and there may be a considerable amount of discharge from the eye. If such be the case, it is well to recommend immediate treatment, since a great deal of injury may be done to the eyes if the condition is neglected. Again, as the condition may be infectious, and infection may be spread in a variety of ways in the school, *e.g.* by means of towels, it is always preferable to exclude any child suffering from a distinct inflammation of the conjunctiva till at least the discharge has ceased and the more acute signs have disappeared. In such a case the teacher will often find, on careful inquiry, that more than one member of the family is suffering or has suffered from sore eyes, and such evidence should be taken as proof of the infectious nature of the inflammation, and of the necessity for the exclusion of the child. *Chronic inflammation of the conjunctiva*, or chronic congestion, may follow repeated attacks of acute inflammation, and is not uncommonly seen amongst neglected and weakly children. These cases are frequently very difficult to treat and cure, and the longer they endure the more intractable they become. Treatment should be recommended as early as possible. The fact that such chronic congestion may be an indication of an error in refraction has already been mentioned, and should be borne in mind.

Ulceration of the cornea may be met with amongst school-children. It may be evidenced by signs of inflammation of the conjunctiva; but in unhealthy and neglected children no signs whatever may be seen. Since, if neglected, it may give rise to opacities of the cornea, medical advice and treatment should be obtained regarding it. Opacities of the cornea are exceedingly difficult to remove, and may cause considerable interference with vision.

The commonest deep-seated inflammation of the eye that may be evidenced by signs of congestion of the conjunctiva is *inflammation of the iris*. This is not common amongst children of school age, but it may occur. Fear of the light is usually marked in this condition. The child should not be at school, and treatment is urgently required.

Congestion of the conjunctiva and watering of the eyes are not uncommon signs of measles. Other signs of the disease are usually also present, and will be mentioned later.

Opacity of the Lens or **Cataract** is a condition fairly common in childhood. One or both eyes may be affected, and there is usually considerable interference with vision, the light rays being unable to pass through the opaque lens. Since the whole lens may not be opaque, some light may pass through, and the child may succeed in seeing a certain amount by inclining the head to one or other side. A child with cataract should be under medical supervision.

School Conditions conducing to Defects of Vision

In order to ensure that there shall be no impairment of the child's vision there are certain matters in connection with the school that require special attention. The chief of these are—

(1) The lighting of the classrooms.
(2) The seating arrangements for the children.
(3) The work and working materials provided for the children.

The Lighting of the Classrooms

Natural Illumination.—Both natural and artificial illumination have to be arranged for in each classroom. The artificial illuminant is only to be resorted to when the natural light fails, but it should be plentiful and good in quality. The natural light must also be good and plentiful, and to ensure this the windows must be of a sufficient size and properly placed. The window area should be at least *one-sixth* of the floor area and preferably, especially on the lower floors, *one-fourth* of the floor area. With regard to the placing of the windows in the ordinary classroom, the front and the back walls should always be blank walls. Lights in the roof are prohibited by the Education Code. If possible, the windows providing the main light should be in the wall on the *left* of the classroom. The wall on the right may be used for windows to provide a supplementary light. If the light from the left is likely to be unsatisfactory for any reason, *e.g.* the proximity of buildings, the main light may be derived from the right and the supplementary from the left. In any case care must be taken that the main light *is* the main light, and that the supplementary light admitted shall not overpower it and so lead to the production of shadows.

The objections to top lights are chiefly that they tend to throw a shadow, are apt to be obscured in winter by snow, and to permit the sun's rays to beat down upon the pupils in summer. They are, also, rather difficult to keep clean. The chief objection to the front light is the strain thrown on the eyes of the children by the glare. The objections to the rear light are the strain thrown on the eyes of the teacher and the shadows thrown on the pupils' work. Under no circumstances should the main light come from behind the class, and even its use as a supplementary light is very objectionable.

The *height*, *width*, and *glazing* of the windows are very important. The windows should always go as close to the ceiling as possible, and the space between each pair of windows, and between the end windows and the back wall of the classroom, should be the smallest the safety of the wall will permit. To ensure that children under the windows shall not work in a shadow, the distance between the window-sill and the floor, in the case of the main light windows, should not exceed 4 *feet*, and in those admitting the supplementary light 5 *feet*.

With regard to the glazing of the windows, probably the best kind of glass for lighting purposes is the ordinary translucent glass. The panes should be large, and as little woodwork should be introduced as possible. The necessary uprights and so on should be bevelled so that rays of light may not be cut off. The sills and sides should be rounded also. For windows opening on streets or places frequented by the public, ribbed, or, better still, prismatic glass is to be preferred to the ground or painted glass or wire netting sometimes introduced to baffle the inquisitive outsider. These prismatic glasses break up and diffuse the rays of light and increase the effective lighting very considerably, in some cases to the extent of one-half. They are specially recommended in cases where the skyline is obstructed by adjacent buildings. They are valuable also in wide rooms, *e.g.* those exceeding 20 feet in width, which are apt to be insufficiently lighted on the side furthest from the windows. One objection to this kind of glass is that it is rather trying to the eyes, the diffused rays affecting large areas of the retina and leading to fatigue and headache. Also it is rather difficult to keep clean. For windows provided with such glass, and for ordinary glazed windows also, blinds are necessary to modify the glare of sunlight. These should be of some light-coloured material and should be washable, since they may act as dust and germ collectors. In some places blinds to pull up from below are in use, and are preferred as interfering less with the lighting power of the window.

In order to make the most of the light entering the classroom, and to assist in its diffusion, the walls should be painted of a light colour, the ceiling should be white, and the furniture should also be light coloured. Dingy walls and dingy furniture absorb the light rays. Some delicate shade of green or yellow is recommended for the walls, and a dull smooth surface is to be preferred to a shiny smooth surface. In infant schools, and schools for defective children, where the blackboard space is or should be large, many recommend that when not in use the blackened surfaces should be covered with screens of some light-coloured material. Blackboards, it is also recommended, should be black only on one side, the other being of the same colour as the walls of the room. In large classrooms, where two or more classes meet, and curtains are in use, separating one class from another, the material used for the curtains should be light in colour, and should be washed regularly and frequently.

Artificial Illuminants.—Of the artificial illuminants electric light is undoubtedly the most satisfactory. If coal gas is used, incandescent burners, as heating the air less and using up less oxygen than the naked fishtail flame, are to be preferred. They should be provided with globes of prismatic glass in order to diminish the glare and diffuse the light. Shades to throw the rays well down, and to assist in their diffusion, should be provided. The lights should be distributed over the room, and not collected at one point. Roof lights act well if properly shaded.

Lighting in Existing Schools.—In the older schools, where, in many instances, the common-sense rules with regard to lighting seem to have been neglected, the teacher must try to make the best of what is provided and introduce modifications wherever possible. Most teachers are aware that the light should come from the pupil's left. A certain number seem to be unable to recognize that, in some instances, by rearranging the seats in the classroom they can make the light to come in from the left. In many cases, of course, the lighting is unspeakably bad, and practically nothing in the way of rearrangement is possible, but anything that can be done in this way should certainly not be omitted. Sometimes bad lighting is made worse by neglect to keep the windows of the classrooms clean. This is a fault capable of being remedied, and the teacher should not be a party to its occurrence. When the lighting of some of the classrooms happens to be better than that of others, an attempt should be made to arrange for the taking of special subjects requiring as much light as possible, *e.g.* sewing, in the best lighted rooms.

Seating Arrangements for the Children

Seats and Desks.—Defective seats and desks are a very fruitful source of injuries to eyesight and, as this is now well recognized, efforts are being made to provide such arrangements as will minimize as much as possible the risks of injury. To seats as well as desks exception can be taken. The *ideal seat* is one that permits or compels the pupil to sit upright, with the head and trunk erect, with the work at the average near-point distance, with the thighs at right angles to the trunk and legs, and both feet flat upon the floor, *not* on foot rests, at right angles to the legs. The ideal seat is a single seat to diminish risks of infection. It is made on anatomical principles. It is provided with a back which is concave above and below to accommodate the upper and lower parts of the back; convex about the middle to fit into the concavity in the lumbar region, or small of the back. The convexity may, with advantage, be exaggerated slightly, providing what is known as a "hip-rest," and this be made capable of being varied in position to suit the difference in position of the concavity in boys and girls. The seat itself should slope slightly, the front edge being a shade higher than the back edge, in order to prevent the child from

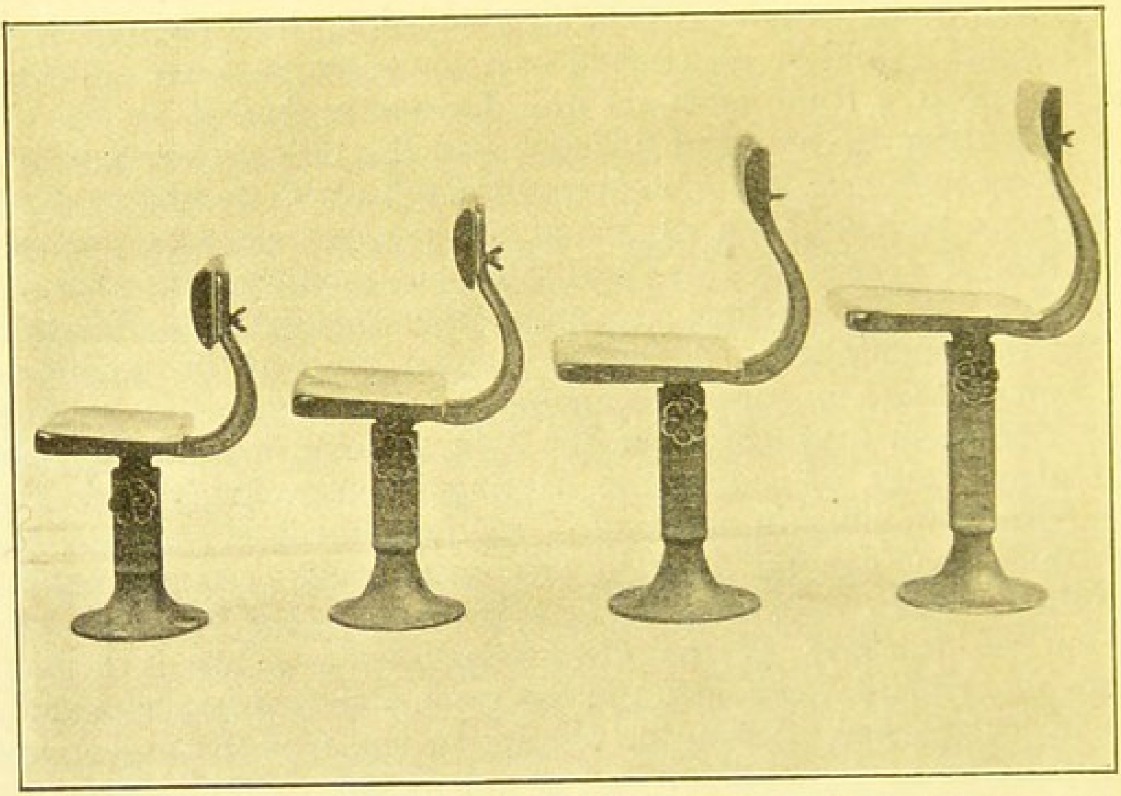


Fig. 82.—Adjustable seats in various sizes. The seat can be raised or lowered, and the back rail, which is intended to reach to just below the shoulder blades, can also be varied in height.

exercising a tendency to slide forward. In length the seat should be about two-thirds that of the pupil's thigh, and the front edge should be rounded so that there may be no pressure upon the large vessels at the back of the bend of the knee. The whole seat should be supported on a pedestal to permit of easy access for cleansing purposes.

The *ideal desk* is one that will assist the ideal seat in forcing the child to maintain the erect attitude and the correct working distance, no matter what the work may be. It must, therefore, be of a proper height for the child who is to use it, and it must be capable of variations of slope so that it may be used for various school purposes. For writing, the slope of the desk should be from 15° to 20°, and for reading from 35° to 40°. The ideal desk should be capable of providing these two slopes at least. In the infant school and the girls' school a flat surface is

FIG. 83.—Anglo-Swiss adjustable desk adjusted for writing.

necessary at times, and the ideal desk may, with advantage, be made to give this also.

Distance and Difference.—A point of very great importance in connection with desks is, the relation of the edge of the desk to the edge of the seat. This relation bears the technical name of *distance*, just as the space between the upper surface of the seat and the under surface of the desk is referred to as the *difference*. Three distances are recognized, viz. *zero*, when the edge of the desk is in a line with the edge of the seat; *minus*, when the edge

FIG. 84.—Anglo-Swiss adjustable desk arranged for reading.

of the desk overhangs the edge of the seat; and *plus*, when there is an interval between the two edges. In the ideal desk it should be possible to get any of these three distances when required, the plus when the child is asked to stand up in or to move out of or into his place, the zero or a slight minus in writing or reading.

Such variations are very desirable, since practically no *fixed* distance will suit all purposes. If the distance is a *fixed zero*, the child is compelled to stoop too much in reading and writing, and cannot

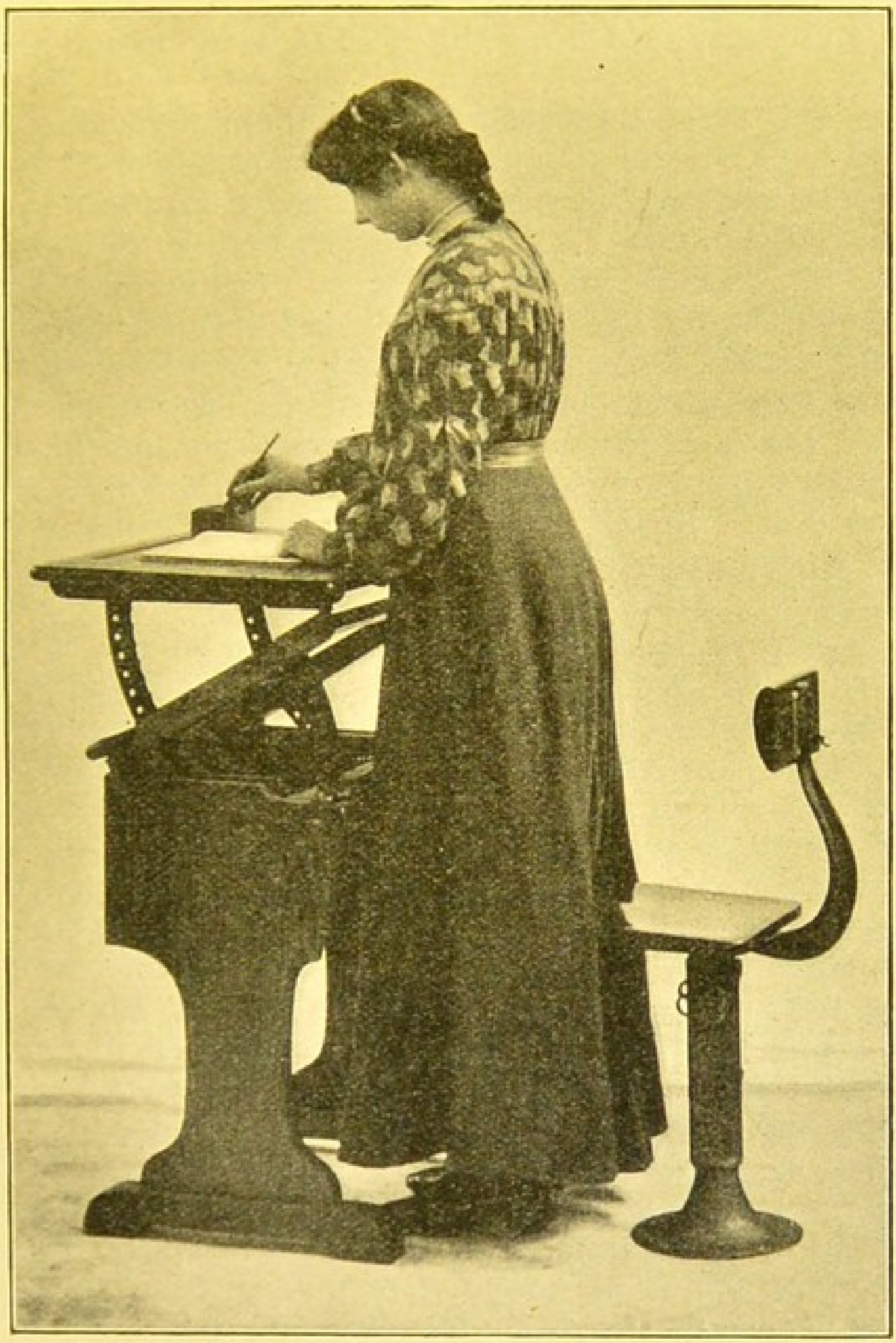


FIG. 85.—Anglo-Swiss adjustable desk adjusted for drawing.

stand up comfortably in his place. If it is a *fixed minus* distance the stooping is less; but if the minus is exaggerated there may be pressure of the edge of the desk upon the anterior surface of the body, and, again, the child cannot stand up comfortably, or get out of or into his place easily. If it is a *fixed plus* distance, the proper posture and the 12-inch working distance cannot be maintained. To sum up with regard to ideal seats and desks: (1) they must be single; (2) the seat must be of a proper height and anatomically correct; (3) the desk must be of a proper height, and capable of being varied as to its slope and as to its distance.

Seats and desks approaching the ideal are obtainable, but are objected to on several grounds. (1) Because they are expensive. (2) Because they take up a great deal of space, lead to a scattering of the children, throw a strain on the teacher's voice and on the eyes of the children who sit far back. (3) Because they are unnecessary since no seat invented could ever prevent children, especially weakly children, from taking up a wrong attitude or ensure a comfortable one throughout the course of a class session. These objections, though of course not insurmountable, have, in most places, prevented the general adoption of the ideal seat and desk. In the newest schools usually all that is done is to provide single unadjustable seats and desks, or, what is much less satisfactory, desks and seats to accommodate two pupils. In the older schools the arrangements made when little or no thought was given to the matter, are almost of necessity allowed to stand.

Existing Arrangements.—In connection with both of these arrangements, the new as well as the old, the teacher has to exercise ingenuity in order to protect the pupils. In both cases he must see to it that improper postures are not taken up and persisted in; that one set of muscles is not kept too long on the strain, but that others are called into play by means of a change of occupation or by exercise; that so far as possible the correct working distance is maintained. In the newer schools, where sometimes the single desks and seats are provided in more than one size for each classroom, the task of the teacher is much simplified, and each child can be given a seat and desk more or less suited to its height. It will not always, however, be found advisable to put the largest size of seat in the back rows and the smallest in the front rows, since it may just happen that a tall child is short-sighted or deaf, and requires to be accommodated with a seat near the teacher. To overcome this difficulty it is better to arrange the seats so that the increase in height is from side to side of the classroom rather than from front to back.

In the older schools the teacher is likely to have more difficulty. The seats and desks in most cases have little to recommend them. Children of assorted sizes are compelled to use seats and desks of one size. In reading, the back has to be bent and the eyes brought close up to the book. In writing, there is either stooping or "hunching" up of the shoulders and twisting of the body and approximation of the eyes to the paper. In many instances the teacher can do absolutely nothing to prevent these things, and even correction is useless. There remains for him but to vary occupations and to give physical exercises. Structural alterations are necessary in these cases. Either the desks and seats must be removed and be replaced by single seats and desks, ideal or modified, or the seats must be removed and single seats, anatomically correct or with a concavity below and a convexity above to fit into the lumbar region, and of assorted sizes, be provided. These should be so placed with regard to the desk that there is a slight minus distance between the edge of the seat and desk. The desk may be given a slope suitable for writing or a little more, and the child must hold the book in the hand when reading.

The Work and the Working Materials

Near Work.—The work naturally throwing the greatest strain on the eyes is that kind that has to be carried out close to the eyes. It includes, therefore, reading, writing, and sewing. The working materials used for such work are those that have to be most carefully watched, viz. the print of books, pens, pencils, slate-pencils, paper, ink, and slates; and needles, thread, and material.

Reading and Print.—The print employed for school-books should be such as will ensure the book being held no nearer to the eye than 10 to 12 inches. On the whole, in this country, there is little to complain of in connection with the size of the print employed, though occasionally, in the infant school, books are met with the print of which is too small for infant use. The size recommended for the upper standards is that known as *pica*, each letter being about $\frac{1}{6}$ inch high. The letters should be clearly printed and well "leaded," *i.e.*, there should be a sufficient space between the words in each line and between the letters in each word. The space between the lines should also be fairly wide, and the lines should not be too long. Certain letters require special attention in printing, viz. a, b, c, e, h, n, o, s, v, and z, which are apt to be confusing, unless clearly printed with good and fresh type. The colour of the paper has to be attended to also, in order to obtain a good contrast. The surface of the paper should be dull, not glossy, but should be smooth, as a rough surface tends to retain germs and dust. For the junior classes a larger print than pica is necessary, and those known as *double pica* and *great primer*, which are about twice the size or a little more than that of pica, are generally employed. Leading is especially necessary in these classes. In infant classes books are unnecessary, and the best teachers wisely prefer to do without them, teaching reading from wall cards or the blackboard.

Mathematical and arithmetic books and test cards should be carefully printed, since confusion may arise amongst the figures and symbols. Test cards especially should be carefully chosen. They are often badly printed, and no attention whatever seems to be given to the obtaining of the contrast necessary between the lettering and the card. Music also is often not so clearly printed as it might be, and the teacher should watch it and complain when necessary.

Writing and Writing Materials.—Slates and slate-pencils should not be used. Slates become greasy; the contrast between the writing and the background is not sufficiently marked; and the friction to be overcome by the pupil, between the pencil and the slate, interferes with co-ordination and increases the difficulty in writing. Apart from these objections there is the further objection that slate-pencils act as carriers of infection. Paper is to be preferred to the slate, and the lead-pencil or the pen and ink to the slate-pencil, because they are more cleanly, and because a better contrast is obtained and less strain is thrown on the eyes. The pen is preferable to the lead-pencil because, provided a good ink is used, the contrast is more marked. In connection with the choice of writing materials, however, many important points have to be considered. Reference has already been made to the difficulty which young children experience in co-ordinating the fine muscles concerned with writing, and the marked tendency which they have to throw a strain on the muscles of accommodation and convergence by focusing for the point of the writing instrument. These points must be remembered, especially by infant teachers, and from young children fine pointed writing instruments must be withheld. How to make letters can quite well be learned and taught with coarse instruments, *e.g.* crayons and brown paper, chalk and a blackboard, or pointers and sand trays. The passing from these instruments to the finer instruments, the pencil and the pen, must be carefully managed by the teacher. After the age of seven or eight, if the child has been taught how to form letters, there is plenty of time for it to learn how to make words and write with a pencil or pen.

In connection with the choice of writing materials the tendencies of the child must also be borne in mind. Papers ruled with squares are not now, fortunately, often used, but there still remain note-books and writing-books ruled into spaces of varying size with faint blue lines. These are objectionable on account of the strain thrown upon accommodation and convergence and on account of the stooping rendered necessary by the small size of the spaces and the faintness of the lines. As to the ink to be used; only one marking black should be permitted. Inks of other colours, and especially the so-called "dichroic" inks, which become black only after a time, are to be avoided, as giving less satisfactory contrasts.

The attitudes taken up by children in writing are answerable not only for such deformities as curvature of the spine, but also for eye troubles, squints, and errors of refraction, by leading to a diminution of the working distance. Also, because the child does not look straight at the writing, the muscles of the eyeball are improperly used in such improper attitudes. To overcome mal-postures and to diminish the strain upon the eyes, the so-called *vertical script* was introduced, and the slanting script condemned as a producer of deformities and defects of vision. In producing vertical writing the pupil sits straight in front of the desk, occupying what is called the "straight central position;" the paper is placed straight in front of the pupil, its top edge parallel with the front edge of the desk, and the pen is held so that the holder lies between the upper joint of the thumb and the index finger, the palm of the hand looking to the left. The point of the pen should be about 1½ inches from the tip of the middle finger. If the directions for producing this style of writing are properly carried out, twisting of the body and strain upon the eyeball muscles are much less likely to result. Whatever script is used, however, the writing lesson should not be too long. The lesson should be broken up, either, as some suggest, by making the children stand up in their places and go through a few movements, or by transferring the pen from the right to the left hand from time to time.

Sewing, Needles, and Material.—Sewing as a producer of defective vision is very much condemned. The needle with its fine point and its tiny eye, strains convergence and accommodation. The thread, especially if it is fine, also tempts the child to diminish the distance between the eye and the work. The material used, if it does not offer a good background for contrast between itself and the thread, or if it is too fine, may induce approximation of the work to the eye and strain. To the size of the stitches objection is also taken. In sewing there is always a tendency for bad postures to be taken up, especially among very young children, and the result always is that the work is brought near to the eye. Sewing in infant schools is now an optional subject, until after the age of five, and the infant teacher should be glad that it is so. The amount of strain thrown on infant eyes is tremendous in sewing, and probably most of the girls with defective vision in the upper standards have the sewing lessons in the infant school to thank for teaching them the habit of working within the average near-point distance and for beginning the alterations in the shape of the eyeball leading to the defect.

CHAPTER XII

HEARING

Structure of the ear—Conditions affecting the ear and hearing—Discharging ears—Deafness—Tests for hearing.

In connection with the sense of hearing the auditory centres in the brain and the eighth or auditory nerve have already been considered. The organ of hearing, which consists of (1) the *external ear*, (2) the *middle ear* or *tympanum*, and (3) the *internal ear* or *labyrinth*, has next to be referred to.

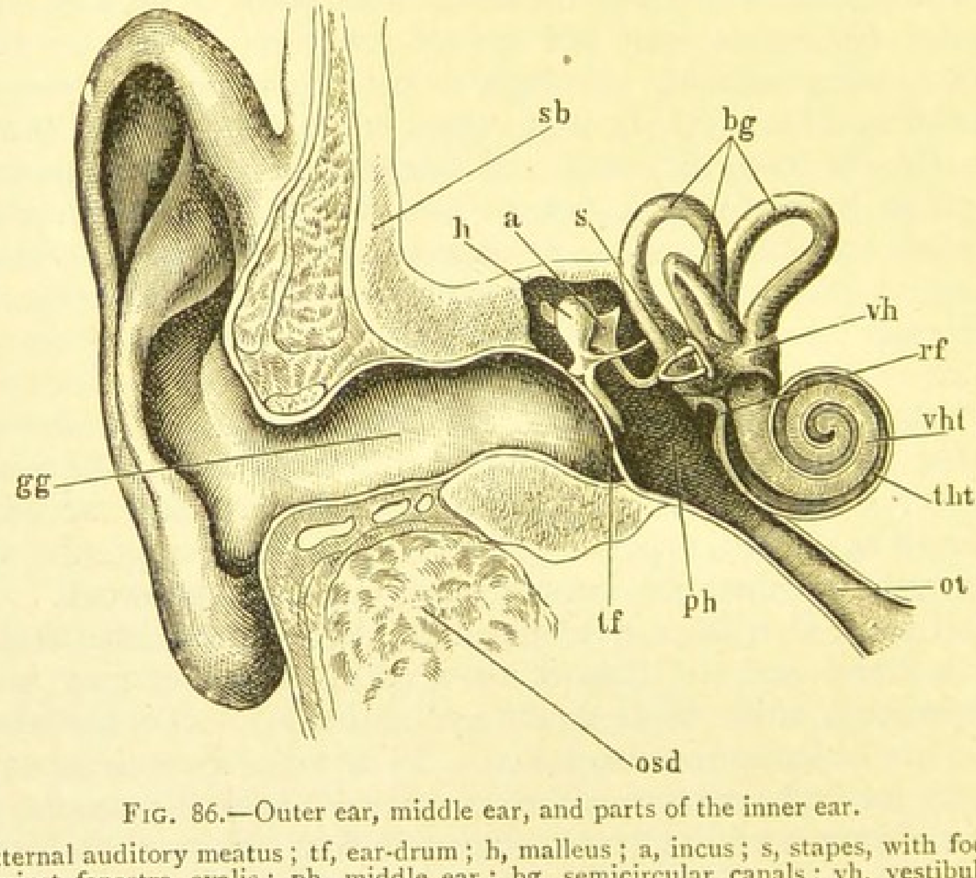


Fig. 86.—Outer ear, middle ear, and parts of the inner ear.

gg, external auditory meatus; tf, ear-drum; h, malleus; a, incus; s, stapes, with foot-plate against fenestra ovalis; ph, middle ear; bg, semicircular canals; vh, vestibule; tht, cochlea; vht, interior of cochlea; rf, fenestra rotunda; ot, eustachian tube; osd, bone.

The External Ear.—The external ear consists of the *auricle* or external ear, which serves to collect the air vibrations constituting sound, and the *external auditory canal*, which conveys them to the other structures concerned with hearing. The *auricle* consists of cartilage covered with skin and connected with the surrounding parts by means of ligaments and muscles. The *external auditory canal* is about an inch and a quarter long. The first portion of its wall consists of cartilage; the inner portion is bony, and is situated in the temporal bone of the skull. It runs obliquely inwards and forwards, and the whole canal presents a slight bend near the middle of its length. It is lined throughout by a thin delicate layer of skin, which contains numerous glands, whose function is the secretion of the *earwax*. This wax serves to catch particles of dust, insects, and so on, which might reach and irritate the *ear-drum* or *tympanic membrane*, the thin, delicate piece of tissue which closes the inner end of the canal and forms the outer wall of the middle ear.

The Middle Ear.—The middle ear or tympanum is an irregularly shaped cavity situated in the temporal bone. It is lined

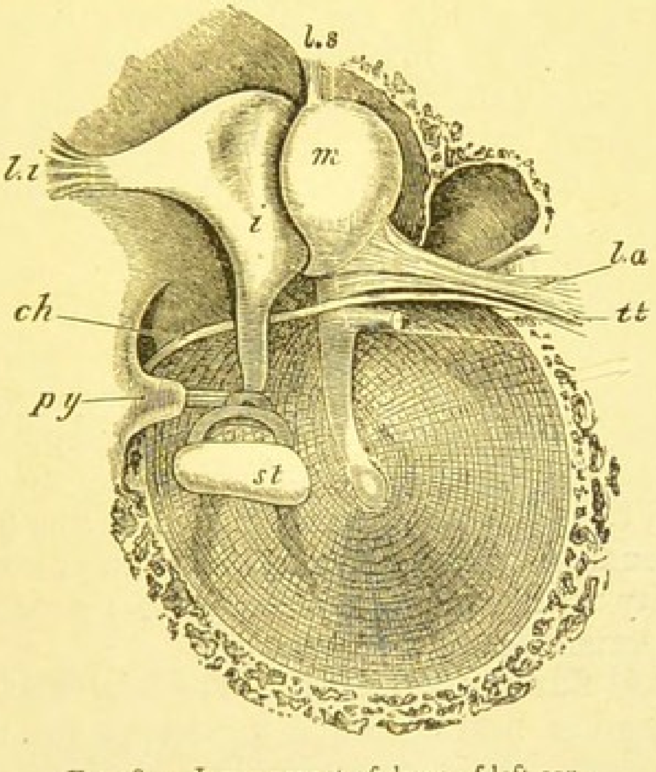


FIG. 87.—Inner aspect of drum of left ear.

m, malleus; *i*, incus; *st*, stapes; *py*, pyramid through which tendon of muscle of stapes emerges; *tt*, tendon of a muscle attached to handle of malleus; *l.a*, *l.s*, and *l.i*, ligaments holding the bones; *ch*, a nerve.

(*From Quain's "Anatomy."*)

with mucous membrane and is filled with air. This is continually being changed through the *eustachian tube*, the channel of communication between the ear and pharynx. Through this canal air is allowed to escape into the pharynx when loud noises, which might otherwise rupture the delicate membrane, strike the ear-drum. In order to prevent injury to the drum and to make the eustachian tube as wide as possible, the mouth should be opened when a loud sound is expected.

Through a small opening in the back wall of the middle ear a communication between the cavity and certain small spaces in the mastoid process of the temporal bone, is also brought about. These spaces are lined with mucous membrane, and are known as the *mastoid cells*. As a result of the presence of the eustachian tube, inflammation and infection may pass up from the throat and pharynx to the middle ear and an abscess be produced there. The matter formed may escape by bursting through the ear-drum; but, as a result of the communication between the middle ear and the mastoid cells, infection may reach these also, and an abscess in the bone result.

In the inner wall of the tympanum there are two small openings, one oval in shape, the *fenestra ovalis*, the other round, the *fenestra rotunda*. These are covered with membrane by means of which the middle ear is separated from the inner ear. Within the cavity of the middle ear, stretching between the ear-drum and the inner wall, there is a chain of small movable bones. These are covered with mucous membrane and help to convey sound waves to the internal ear. They are named from their shape the *malleus* or hammer, the *incus* or anvil, and the *stapes* or stirrup. The outermost of the three is the malleus, which is attached by means of its handle to the ear-drum; the innermost is the stapes, the foot of the stirrup occupying the small oval fenestra ovalis. The incus forms the middle link of the chain. Connected with these bones there are two small muscles capable of producing variations in the tension of the ear-drum and of the fluid contained in the internal ear. In addition to reaching the inner ear along these bones sound vibrations may also be conducted through the air in the cavity to the membrane covering the fenestra rotunda, and so to the structures in the inner ear.

The Internal Ear or Labyrinth.—The labyrinth is the essential part of the organ of hearing, since it contains the terminations of the auditory nerve. It is exceedingly complicated in structure, hence the name labyrinth. It is made up of three parts occupying the interior of the temporal bone, and containing a certain amount of fluid. The three parts are named respectively, (1) the *vestibule*; (2) the *cochlea*; (3) the *semicircular canals*. The *vestibule* lies between the other two, and both open into it. In its outer wall is the fenestra ovalis. Its inner wall is perforated for the passage of fibres of the auditory nerve to the brain. The *cochlea* lies in front of the vestibule and resembles a snail shell in shape. Part of its wall is formed by the membrane covering the fenestra rotunda. In the interior of the cochlea, occupying a special part of the spirals, there is a tiny canal called the *cochlear canal*. This contains a clear fluid and the terminations of the fibres of the auditory nerve concerned with hearing. These fibres are connected with the special "end organ" of hearing, just as the fibres of the optic nerve were connected with, and received their impressions from a special end organ, viz. the retina. The end organ of hearing is known as the *organ of Corti*, and is somewhat complicated in structure. It consists essentially of cells, each provided with numerous delicate bristles. The nerve fibres are connected with the cells, passing through the cell wall to reach almost to the nucleus. Resting lightly upon the top of the bristles there is a thin delicate membrane named the *membrane of Corti*. This is supposed to act as a damper of sound. The *semicircular canals* also open into the vestibule. They contain fibres of the auditory nerve, and are somehow connected with the balancing of the body. The fibres from the semicircular canals pass through the vestibule and unite with those from the cochlea. They do not, however, pass with the latter to the auditory centre, but have been traced to the cerebellum, which, it will be remembered, is also concerned with the balancing of the body. Disease of the semicircular canals, like disease of the cerebellum, is attended with giddiness.

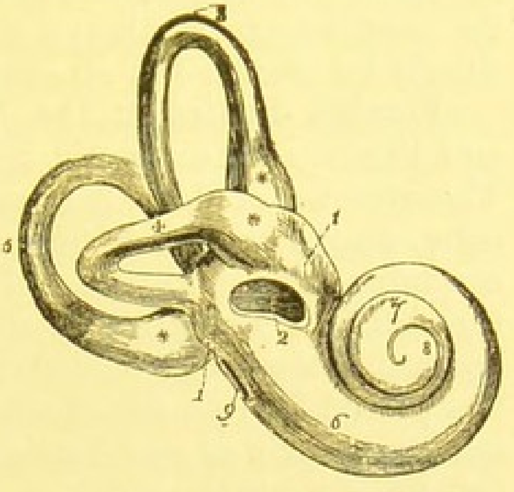


FIG. 88.—The labyrinth (2½ times natural size).

1, the vestibule; 2, fenestra ovalis; 3, 4, 5, the semicircular canals; 6, 7, 8, coils of the cochlea; 9, fenestra rotunda.

(*From Quain's "Anatomy."*)

CONDITIONS AFFECTING THE EAR AND HEARING

The chief conditions affecting the ears, to which it seems necessary to refer, are: (1) earache; (2) foreign bodies in the ears; (3) discharging ears; (4) deafness.

Earache.—Pain in the ear or earache is frequently complained of by children, and though not uncommonly due to conditions affecting the teeth or throat, it is sometimes a sign of more serious trouble, *e.g.* inflammation or abscess of the middle ear. In these cases it is usually more severe than when the pain is referred from the teeth or throat. Since, however, it is frequently impossible to be certain, in children, of the cause of earache, it is advisable always to be suspicious regarding these cases. Inflammation of the middle ear is always a serious matter, and medical advice should be obtained in all cases of severe or prolonged earache.

Foreign Bodies in the Ears.—Foreign bodies, such as peas and beads, are frequently introduced into the ears by children. The removal of these is frequently a matter of considerable difficulty, and is absolutely necessary on account of the risk of their reaching the ear-drum and irritating and possibly ulcerating through it. The attempt at removal should not be made by the teacher, but should be left to a surgeon, especially if the body has passed far into the canal. It is often exceedingly difficult to get a good grip of such foreign bodies, especially if they are round, and there is always a risk of their being pushed further along the auditory canal.

Discharging Ears.—The usual source of a discharge from the ear is an abscess in the middle ear which has burst through the ear-drum. The commonest causes of an abscess in the middle ear are: (1) the infectious diseases, *e.g.* scarlet fever and measles; (2) conditions affecting the throat and nose, *e.g.* adenoids and enlarged tonsils. The infection in the majority of cases has spread along the eustachian tube and has given rise to inflammation and the formation of pus or matter. The view generally accepted by ignorant people with regard to a discharging ear is, that it is a matter of no importance, and that the child will outgrow it. This view is quite wrong. In some cases the discharge does disappear, the abscess dry up, and the opening in the ear-drum close without leaving behind any ill effects. There are other cases, however, in which the discharge continues to flow, the health gets undermined, and the hearing ruined as a result of the destruction of the structures in the middle ear. More important still are those cases in which the infection spreads to the mastoid cells, and thence to the brain and its coverings, and death results. These latter possibilities must never be lost sight of, and because of them a serious view must always be taken regarding any discharge from the ears. In this connection also, it must be borne in mind that spread of infection from the middle ear to the mastoid cells and brain may be determined by a very trivial cause, *e.g.* a blow on the side of the head or a box on the ears. Very commonly children suffering from discharging ears are sent to school with plugs of cotton wool pushed well into the auditory canal. These are objectionable, since they have a tendency to dam back the discharge, and may lead to a spread of the infection in the directions mentioned. Teachers must always be prepared to use all the great influence they possess to induce parents to obtain proper medical advice whenever a discharge from the ear is detected.

Deafness.—Any interference with the structures concerned with the transmission of sound, the receiving of sound waves, or the perceiving of sound, will give rise to deafness. The commonest cause of deafness amongst school-children, is disease of the middle ear. In a considerable number of cases, however, the defect is traceable to affections of the throat and nose, such as enlargement of the tonsils or adenoids, and when these have been attended to the hearing usually improves very greatly. Deafness due to middle-ear trouble and associated with perforation of one or both ear-drums and a discharge from the ear, is less easily remedied. All attempts to get the hole in the drum to heal up may prove unsatisfactory, though sometimes by means of an operation a good result may be obtained. The parents of deaf children should always be recommended to obtain medical advice and treatment regarding the condition. Apart from middle-ear disease, or affections of the internal ear, deafness is sometimes due to neglect to clean the external auditory canal. The earwax becomes dry and hard, and formed into a solid cake containing dust particles, and so on. In such cases a thorough cleansing with soap and water will often lead to a disappearance of the defect in hearing. If the plug of material obstructing the passage of sound happens to be particularly solid, it may be necessary to soften it by instilling hot oil or a warm solution of soda. No attempt should be made to remove these or other obstructions by means of pins and similar instruments, and children especially are to be warned against picking the ears with such dangerous implements.

Tests for Defective Hearing.—The teacher will usually be able to pick out such members of his class as are deaf without resorting to any very special tests. Treatment should always be recommended for children who cannot hear the teacher's voice distinctly unless they are near the front of the class. In some cases information that a child is deaf comes from the parents of the child. Inquiry should always be made in such cases as to the steps that have been taken to remedy the defect. If, as is commonly the case, in elementary schools at least, medical advice and treatment have not been sought, the necessity for doing so might be suggested.

Certain tests are recommended for the detection of deafness, but the testing of hearing is difficult to carry out satisfactorily in a school, and the results are of doubtful value. The *watch test* and the *whispering voice test*, are those usually advised. In carrying out the watch test, a watch with a distinct tick is to be employed. A tape-measure is to be fixed, by one end, to the wall of the room in which the examination is carried out, at a distance of $2\frac{1}{2}$ to $4\frac{1}{2}$ feet from the floor, on a level with the child's ears. The child stands with the back of the head not quite touching the tape, and the watch is moved backwards and forwards along, but not in contact with, the measure, till the point furthest from the ear at which the tick is heard is found. One ear should be tested at a time, the other being kept covered up with a pad of some kind. The distance at which the tick of the watch employed in the test is heard by a person with normal hearing should be known. The results obtainable are difficult to control, and children frequently prevaricate in order either to please the teacher or to elicit sympathy. In the whispering voice test the distance at which the child can hear various whispered words is used as a guide to the acuteness of hearing. The words recommended for use in the test are, ten, thirty, twenty-three, thirty-three, thirty-seven, and twenty-eight. The results are to be compared with those obtained in a person known to have normal hearing. One great objection taken to both of these tests is, that hearing is very much a matter of custom, and most people are in the habit of listening to and for sounds other than whispers and the ticking of a watch.

CHAPTER XIII

THE INFECTIOUS DISEASES

Diseases to be considered—Infection—Disinfection—Signs and symptoms—Law as to infectious diseases.

THE chief diseases to be considered under this heading are: scarlet fever, diphtheria, smallpox, measles, whooping cough, typhoid fever, typhus fever, chicken-pox, mumps, and German measles.

All these belong to the same group, and resemble each other to the extent that each is due to an organism, in some cases known, in others not; that each is infectious; and that in each, "fever" is one of the manifestations of infection. In each case, also, the modes in which infection is spread from an infected person to an uninfected person are much the same. The infected person gives off the infection, *i.e.* the germs of the disease, in the breath and the discharges from the body, and the uninfected person takes such infection into his body, either as a result of coming in contact with the infected person or the discharges, or by inhaling air or swallowing material contaminated with the infection.

Intermediaries.—In some at least, however, infection may be obtained in another way, viz. by contact with an *intermediary*, that is, a person who has been associated, or in contact with, the infected person, and though not himself infected, acts as a vehicle for the transmission of the germs. In diphtheria, the possibility of transmission of infection by intermediaries is frequently easy of demonstration, and persons inhabiting places occupied by diphtheria patients have been found to have harboured the bacilli of diphtheria in their throats, and to have been capable of infecting large numbers of persons, though themselves unaffected.

In the school, the commonest modes in which infection passes are by direct contact with the infected person, and his body discharges, which may be adherent to articles used by him; by contact with intermediaries; and by the inhalation of air contaminated with the germs of infection by the infected person or intermediary. To prevent spread in these ways the infected person, and possible intermediaries, must be excluded from school; articles likely to be contaminated with infective discharges must be freed from infection; and the air of any classroom used by him or intermediaries, and which may contain infection must also be purified.

For the freeing from infection of articles which have been in contact with the infected pupil, nothing equals destruction by fire; but as this is not always possible, some method of purification or of disinfection must be resorted to. The methods of bringing about disinfection commonly employed are mainly two, viz. by means of heat, dry or moist, and by means of chemical substances known as *disinfectants*. For certain purposes and certain articles heat is to be preferred, and the germs are killed by exposing them to a temperature of at least 240° Fahr. For other purposes and articles chemical disinfectants are preferred. These may be employed in the form of a liquid or a gas, and the articles may be soaked in the liquid or washed with it, or be exposed to the gas. The commonest liquid disinfectants are corrosive sublimate, which is a highly poisonous salt of mercury, carbolic acid, formalin, and several patent substances. The commonest gas used for disinfection is sulphurous acid gas, which is formed by burning sulphur in the presence of air. Any of these may be used for disinfecting the walls, seats, desks, slates, pencils, etc., which may have been contaminated as a result of contact with the infected person.

Two very practical and important points in connection with these disinfectants must be mentioned, viz. that they must be left in contact with the material containing the disease germs for a sufficiently long time, and they must not be used too dilute.

Carbolic acid, for example, may take hours to kill a germ, and a dilution of less than one part in twenty of water is practically useless. This is especially to be borne in mind in connection with the disinfection of drains. The small quantities of disinfectant employed in the domestic disinfection of these are quite without effect.

For the purification of the air of an infected classroom there is nothing to equal plenty of light. If the air is kept free from dust particles, and from moisture and organic matter by cleanliness and good ventilation, the light should not find many germs to kill. This point has already been dealt with, and need not again be further referred to here.

With regard to the exclusion of the infected pupil and the intermediaries, this should begin the moment the fact of infection becomes apparent, and should continue till he and they are quite free from infection. For the detection of the infection the teacher may have to depend upon himself. Associated with each of the diseases to be considered, there are certain signs with which the teacher is almost expected to be acquainted. As to how long the infection may persist in an infected person, and how long he may continue to give it off, the time varies in the different diseases, and in different cases of each. The average period of duration will be mentioned in connection with each disease.

Signs of the Infectious Diseases

Broadly speaking, in all infectious diseases there are three stages. Each stage has symptoms of its own, from which it is possible to diagnose the disease.

The first stage is that immediately following the entrance of the disease germs into the body. This is called the *incubation period* or *stage*. While it lasts the germs are developing and growing, and producing the poison which is to give rise to the actual disease. There is a fight during this stage between the cells of the body and the organisms. If the cells win, distinct symptoms of disease do not appear. If the organism wins, symptoms do appear, their intensity varying with the extent of the victory. The duration of this stage varies in different diseases: sometimes it is short, as in scarlet fever; sometimes long, as in typhoid fever. The symptoms of incubation also vary to a slight extent in the different diseases, though they may not be at all distinct or distinctive.

In the *second stage* the disease declares itself. The symptoms may come on suddenly, or they may appear gradually. In a fever which has a rash for one of its signs this may not appear for some hours or days after the onset. This stage is frequently divided into two parts, named the *period of onset*, and the *period of eruption* or *acme*.

The third stage is the *stage of decline*, or of *convalescence*, during which the symptoms disappear.

Scarlet Fever.—In scarlet fever, or, as it is sometimes called, *scarlatina*, though this is a bad name, the *incubation period* is short, rarely lasting more than three days. During this time the patient, if a child, may attend school and be apparently quite well. He may, however, be out of sorts, and complain of headache, or sore throat or sickness. The face may be pale, and there may be fits of shivering. There is nothing very distinctive in any of these symptoms; but *shivering* and *sore throat*, especially if scarlet fever is at all prevalent, are suggestive, and the child should be sent home.

The *onset* of scarlet fever is usually sudden, and the disease may be ushered in by a severe shivering and vomiting, and a complaint of headache and sore throat. Shortly afterwards the face becomes flushed, the skin hot and dry, and the rash appears. This never affects the face, but begins usually about the side of the neck and on the chest. Later it spreads all over the body, omitting always, however, the face, the palms of the hands, and the soles of the feet. The backs of the hands and the wrists commonly show the rash, and it may be looked for in these situations. Possibly the best places to examine are the bends of the elbows and the sides of the neck. Even in mild cases, in which there have been few or no symptoms, and the child has either not been off school at all, or only for a day or two without being suspected of having scarlet fever, a careful search, if suspicion does arise later, may reveal the presence of the rash in the places mentioned.

The eruption of scarlet fever is characteristic; where the rash is the skin is of a red colour, and on this red background there are small points slightly raised and of a deeper red tint. This redness disappears on pressure, to reappear when the pressure is removed. Though the face does not show the rash, not infrequently the cheeks become very much flushed, while the skin in the neighbourhood of the mouth becomes abnormally pale. It is often possible with practice to diagnose a case of scarlet fever from this appearance of pallor around the mouth alone. Other symptoms of this stage are *sore throat*, with difficulty in swallowing, and *enlargement of the glands* at the angles of the jaw. In children the throat symptoms are frequently never complained of at all; but if, during an epidemic of scarlet fever, a child is found complaining of sore throat, and stiffness and pain at the angles of the jaw, and presenting in addition a face which is flushed as to the cheeks and pale around the lips, it should be sent home. Indeed, in the presence of an epidemic, it is safer always to send home every child who complains of sore throat.

The rash begins to fade about the seventh day after the onset, and with its disappearance begins the third stage, or *stage of decline*. From many points of view this is perhaps the most important stage of all. In it, it is possible often to detect a case which, on account of its mildness, has escaped detection in the two earlier stages. Its most characteristic feature is skinning, or peeling, or *desquamation*. In an ordinary case this process begins about the end of the first week. It first shows itself about the ears, the sides of the neck, and the upper part of the chest and arms. If the rash has been very marked the skin comes off in flakes; but in cases in which the eruption has been slight the skin may merely powder off. In one form, perhaps the commonest of all, the first sign of skinning is the formation of minute holes in the superficial layer of the skin, as if the tips of numerous small projections had been rubbed off. These holes gradually increase in size, larger and larger areas appearing to be denuded, till eventually the whole of the superficial layer over the entire body has been cast off.

The skinning usually follows a definite course. The ears, neck, and upper part of the chest begin to peel at the end of the first week; the trunk and arms during the second week; the fingers during the third week; the palms of the hands and the toes in the fourth week; the soles of the feet in the fifth week; and the heels in the sixth week. Possibly the fingers and hands are the most important from the teachers' point of view. In a severe case the skin may come off like a glove, but the nails are never shed. In a moderately severe case the skin of the fingers appears somewhat ragged, with patches of semi-detached skin hanging about the tips and between the fingers. The skin under the separating layer is usually of a pinkish colour, but is not inflamed. In mild cases, the desquamation of the hands and fingers is sometimes quite distinct.

Apart from the desquamated skin, regarding which there is some doubt, the conditions in the third stage, which are supposed to give rise mostly to infection, are *discharges from the nose and ears*. These may occur in cases which have escaped detection. A child with a discharging nose or ear, and at the same time signs of peeling, should be sent home as soon as detected. He is a distinct menace to the other children. Another condition occasionally associated with desquamation, in an unrecognized case, is inflammation of the kidney. The outward and visible signs of this are marked pallor of the face, with puffiness of the eyelids. A child with a pale, puffy, somewhat pasty face, with signs of peeling on the neck or hands, or elsewhere, should, for its own sake, be sent home, with a strong hint to the parents to call a medical man at once.

To sum up with regard to scarlet fever, the stages in which cases are most likely to be met with are the first and the last. The first stage has for symptoms occasionally headache, sore throat, shivering, and sickness; in the last stage the principal feature is the skinning, additional evidence of scarlet fever being found in a discharge from the nose or from the ear. A child recovering from scarlet fever is usually always pale, but if the face is pale, puffy, and pasty, and there is also desquamation, the child should be sent home at once. In an ordinary uncomplicated case of scarlet fever the child may be regarded as free from infection in six to eight weeks from the commencement of the fever, though with regard to this opinions vary considerably. In a case in which there is discharge from the nose or ears, infection is likely to be given off until this has ceased. In the case of an outbreak of scarlet fever in a class or school, the teacher might call the attention of the medical officer to cases of discharging ears.

Epidemics of scarlet fever may occur at any time of the year. In ordinary years most cases occur in October and November.

Diphtheria.—Diphtheria was formerly much more common in rural than in urban districts, but within the last twenty years or so this has changed completely, and the disease is more commonly now found in towns. Public elementary schools are blamed for this alteration, and the aggregation of large numbers in such schools is generally supposed to be the chief means by which the disease is disseminated. Like scarlet fever, diphtheria most commonly attacks children under ten years of age. It is not unknown amongst adults, but is much less common than in children. The parts of the body most frequently affected are the upper air passages, the nose, the throat, and the larynx.

The *incubation period* is short, varying from one to five days. There are no symptoms specially characteristic of this stage; but if the throat be the seat of the disease there may be a complaint of sore throat, and if the windpipe there may be hoarseness, and a somewhat hard, brassy cough. In this stage the disease is difficult of recognition.

In the *second stage*, in *diphtheria of the throat*, a child may complain of sore throat and difficulty of swallowing, and the glands at the sides of the neck may be enlarged and painful. Very frequently there are absolutely no symptoms at all, and a child suffering from the disease, and a menace to others, may to all intents and purposes be quite well. The chief sign of diphtheria of the throat is the formation of a *membrane* or coating over the tonsils, and frequently also the soft palate, but this even may be absent. Sickness and vomiting, and indeed symptoms of acute illness, are usually absent. A child suffering from diphtheria, however, even mild diphtheria, is usually rather pale and weak.

In *diphtheria of the windpipe* the early symptoms are hoarseness and cough, which may readily be mistaken for similar symptoms produced by an ordinary cold. For the first day or two these may be the only indication; later the marked difficulty of breathing, so common in what is known popularly as *croup*, comes on, and immediate treatment with diphtheria anti-toxin is indicated. A child showing any difficulty of, or marked interference with, breathing should, of course, be sent home. Quite commonly diphtheria of the larynx is associated with a similar affection of the throat or nose, and sore throat, swollen glands, hoarseness, and cough usually mean only diphtheria.

Diphtheria of the nose is most important from the teachers' point of view. Of all the three types it is by far the most likely to be overlooked by mothers, and is moreover the type most likely to be chronic, and to give rise to other cases. The number of school epidemics of diphtheria that have been traced to unrecognized cases of nasal diphtheria is very high. The main sign of infection of the nose is a discharge from the nostrils. The discharge varies in thickness: sometimes it is thick and mattery, sometimes clear and watery. It is usually irritating, and the nostrils and the upper lip show signs of irritation and may even be ulcerated. Especially if many cases of diphtheria have occurred in the school, the teacher should regard discharging noses with suspicion, and call the attention of the school medical officer or the medical officer of health to any child so suffering.

Reference has already been made to the fact (see p. 225) that school outbreaks of diphtheria are sometimes traceable to the so-called "carrier cases," *i.e.* to children who, though themselves quite healthy, yet harbour diphtheria bacilli in the throat or nose, and are capable of infecting others, through pencils, slate pencils, books, etc. Such cases are only to be detected by the discovery of the germs in rubbings or swabs taken from the tonsils and nostrils of the child. Very commonly, in order to prevent the spread of diphtheria, in a school in which a few cases have occurred, a systematic examination is made of all the children attending the school, swabs being taken from the nose and throat of each child and submitted to a bacteriological examination for the bacilli. Children found to be carriers are excluded. The rubbings are generally taken at the school, and the teachers are expected to assist in bringing forward the children and in the clerical work.

Diphtheria is most common during October, November, and December. It may occur at other times as well. Not uncommonly outbreaks occur when a very wet period is followed by two or three days of bright warm sunshine. The infected child is not free from infection till all diphtheria germs have disappeared from the part which has been the seat of the disease. In the majority of cases, in six weeks from the commencement of the attack all germs have gone; but cases have been recorded in which even after twelve months bacilli could still be found.

Small-pox.—Fortunately small-pox is not very common, and, thanks to vaccination, is decidedly rarer in children at school ages than in adults. In the presence of an epidemic, however, cases may occur in a school, affecting almost certainly the unvaccinated. The teacher will therefore be well advised to be on the look-out for it, and with the object of assisting him to detect it the leading features of the three stages are given here.

The *incubation period* of small-pox is usually twelve or fourteen days. During this period there are practically no symptoms till the very end, when the disease is about to declare itself. The first symptoms of *onset* are usually marked fever, with shivering, headache, and intense *pain in the back.* This last is the most characteristic of all the early symptoms. In children, especially unvaccinated children, these symptoms are usually very severe, and the affected child will usually be kept at home. If, however, during an epidemic a child should show the symptoms mentioned, and in addition vomiting, stomach pains, and diarrhœa, suspicion should be aroused, and the child sent home. If a vaccinated child is attacked the symptoms may be absent, or so mild as to pass unnoticed, and nothing definite may be distinguishable till the rash comes out. This usually appears on the third day after the onset of illness. It comes out first on the face about the forehead, the scalp, and the lips. Soon afterwards it appears on the wrists, and then spreads all over the trunk and limbs.

The rash at first consists of small, raised, firm, rounded bodies, which in a couple of days change into blebs full of a somewhat clear fluid. In another two or three days the blebs have changed in shape, the top being somewhat depressed. The fluid also becomes thicker and more opaque. In small-pox the spots all over the body are much of a size, differing in this respect from chicken-pox, where there is considerable variation in size. In chicken-pox, also, the sinking in of the top of the spot is not usually seen. Moreover, whereas the spots in chicken-pox are surrounded by areas of quite normal-looking skin, in small-pox the skin for some distance around the spots is frequently darker red in colour. In a well-marked case of small-pox it is exceedingly unlikely that all, if indeed any, of these stages in the eruption will be seen by the teacher. In a mild case, however, in a vaccinated child, there may be opportunities of seeing the spots in any of the stages. In such a case they will be few in number, and during an epidemic it is advisable for the teacher to carefully scrutinize the face and wrists of the children from any district which is known to be infected. If any spots are found, the child should be sent home, or, if the teacher is in doubt and there is any place in which it can be isolated for a time, it might be kept apart till the medical officer of health can see it.

In the third stage of small-pox the chief sign is still the rash. About the eighth day after the eruption, the spots begin to dry and form scabs, and finally drop off. The duration of this stage is variable, and may be as long as five or six weeks. Small-pox is most common during the school months, viz. from October to May. A person who has had the disease is not free from infection until all the scabs have disappeared.

Measles.—Measles is a disease which is highly infectious, and which is commonest in children. In schools it is most commonly found in infant departments. Despite the popular idea that measles is a simple complaint, and one which everybody more or less is bound to suffer from, it is, nevertheless, an exceedingly dangerous disease.

The *incubation period* is long, anything up to about eighteen days. During this stage there may be a certain amount of feverishness, with sometimes shivering, and sometimes signs of a cold in the head. In the *second stage* these signs become more marked. There are usually all the signs of a bad cold: sneezing, stopping up of the nose, running at and redness of the eyes, and very often also a tendency to avoid the light. Sometimes there is shivering, usually there is feverishness and cough. A child with blood-shot eyes, and coughing, and sneezing should at once be sent home. These three signs are absolutely characteristic of measles, and a child in this stage of the disease is highly infectious.

After three, four, or five days of these symptoms the rash appears. At first it occurs as a uniform blush, not unlike scarlet fever, but the redness soon gives place to the true measles rash. This is raised, blotchy, and pink in colour, and affects first the face, especially the forehead about the roots of the hair. Later it spreads to the rest of the body. In the presence of an epidemic it is well to be on the outlook for these early signs.

In the stage of eruption detection is fairly easy; but children in this stage are rarely sent to school.

Measles is said to be infectious from the moment the first symptoms appear till the rash fades. The child may be regarded as free from infection at the end of four weeks. Epidemics are most common from the beginning of November till the end of January, but the disease may also occur in May and June. It is one of the most infectious of diseases, but experience has shown that second attacks are exceedingly uncommon.

Whooping-cough.—This disease, from the teachers' point of view, is of considerable importance. Whooping-cough is a disease which affects mainly children. It is highly infectious. It causes twice as many deaths as scarlet fever. As a rule, it is disregarded by parents, as it is only whooping-cough. For all these reasons it is important that the teacher should send home the child with whooping-cough as soon as suspicion that it is suffering from that disease has been aroused.

The *incubation period* varies from five to fourteen days, and during this stage the signs, if there are any, will be those of an ordinary cold, viz. sneezing, watering of the eyes, and possibly a cough. In the *second stage* the signs of cold become more marked. The child may be feverish and may be troubled with a cough which tends to come on in spasms. Especially in epidemic periods any child showing such symptoms should be sent home. The characteristic whoop of whooping-cough does not appear until about twelve days after the onset of the disease. An attack of coughing seems to be brought on by conditions which disturb the child. Before the cough occurs the patient seems frightened, and often begins to cry. After the attack he becomes quite cheerful. The fit of coughing may be followed by vomiting. When the whoop has fully developed, infected children are hardly likely to attend school. Just at the very beginning, when the whoop is only making its appearance, or late in the disease, when recovery is practically complete, they may, however, be found attending. Not uncommonly a child who has had whooping-cough has a recurrence of the whoop with every fresh attack of cold. In such a case the whoop rarely lasts any time, and is not important. If, however, there is vomiting with the cough, the child should be at home.

Whooping-cough is a winter disease, and is most common from November till March. A child may be supposed to be free from infection at the end of eight weeks, though there are many who hold that the period of greatest infectivity is that stage preceding the appearance of the whoop.

Typhoid Fever.—Typhoid fever in children is exceedingly difficult of detection, and there are in reality no symptoms specially characteristic of it. Attention may be attracted to a child sickening with the disease, on account of its being out of sorts generally. Headache at an early stage is not uncommon, and this may be accompanied by bleeding from the nose. Vomiting sometimes occurs. During an epidemic, a suspicious combination is headache, vomiting, and bleeding at the nose. Typhoid fever is commonest in the autumn months, and for this reason is sometimes named "Fall fever." Epidemics may, however, occur in spring or at other times. A child who has had the disease may return to school when strength has been regained. There is little chance of its bringing infection with it.

Typhus Fever.—*Typhus fever* as an epidemic disease is not now common, though cases occasionally appear in some of the larger cities, such as London, Liverpool, Glasgow, and Edinburgh. Like typhoid fever the *incubation period* is long, usually about a fortnight. Severe headache is sometimes one of the earliest symptoms, and this may or may not be accompanied by severe pain in the back or stomach, and shivering. If an epidemic did occur, teachers in all probability would be warned, and might then be on the look-out for the symptoms mentioned. The disease occurs mainly during the winter months; in the spring and summer, when the poor do not have to huddle together for warmth inside their houses, it is rare. It is highly infectious, but it does not tend to spread in a place where there is plenty of fresh air, and the ventilation is good. The infected child is fit to return to school when convalescence is complete.

Chicken-pox.—Chicken-pox is important mainly because it, to a certain extent, resembles small-pox. It is mainly a disease of childhood, and is highly infectious. It is practically not at all dangerous. The *incubation period* varies from about twelve to nineteen days. During this stage there are no symptoms, and almost always the rash itself is the only sign to be noticed. This rash appears generally on the first day the disease declares itself. It occurs first as red spots which rapidly change into blisters or blebs, round or oval in shape, and resembling very often drops of water on the skin. In a few days the contents of the blebs become opaque, and milky, and finally they dry up and form scabs, which ultimately fall off.

Chicken-pox differs from small-pox in that the rash appears first on the trunk, and spreads later to the face and limbs, and for this reason it may be the second or third day of the disease before it is detected. The rash comes out in crops at intervals of a few days, and not uniformly as does the small-pox rash. The depression in the centre of the spot, which is so characteristic of small-pox, is very commonly wanting in chicken-pox. A child showing an eruption such as has been described, should be sent home with instructions, especially when small-pox is epidemic, that a doctor is to be called in.

Chicken-pox is more common in October and November than at other periods. The child is free from infection when all the scabs have disappeared. The usual period is four or five weeks from the commencement of the disease.

Mumps.—Mumps is most commonly seen amongst boys. It is highly infectious, and is most prevalent during the cold, wet seasons of the year. The *incubation period* is long, generally two or three weeks elapsing between the exposure to infection, and the occurrence of symptoms. The disease is sudden in its onset, the child first complaining of pain and stiffness, in front of one or the other, generally the left, ear, and down the side of the neck. In a few days a swelling begins to appear in front of the ear and down to the angle of the jaw. The swelling is painful and very tender; the skin over it may, or may not, be reddened. On account of the pain and swelling there is great difficulty in opening the mouth. This is especially the case if both sides of the face are affected, as they frequently are, though there is generally an interval of a day, or, more occasionally, even a week or two before spread occurs. The disease does not often last longer than a week, but the child must be regarded as infectious for at least three weeks after the onset of the disease. The symptoms to note are the pain and stiffness in front of the ear and at the side of the neck, and later the swelling, and pain, and tenderness, in the same region. A child with signs of mumps should of course be sent home. Occasionally the swelling of the neck, which so often accompanies a bad attack of diphtheria, is mistaken for mumps. This is a point worth remembering.

German Measles.—German measles is mainly interesting, because it may be mistaken, sometimes for measles, and sometimes for scarlet fever. It is the mildest of all the infectious diseases. The *incubation period* is somewhere between twelve and sixteen days. The onset closely resembles that of measles in that there are signs of a cold in the head, viz. sneezing, red eyes, running at the eyes, and occasionally a slight cough. These symptoms are, however, often absent, and the first sign of the disease is the rash which comes out first on the face. In this it resembles measles, and differs from scarlet fever.

The rash is commonly measliform, *i.e.* it is patchy and slightly elevated and smooth. The colour is pink or rose red. On the body the eruption is often like scarlet fever, but is somewhat more patchy. A sign to which medical men attach importance is swelling of the glands at the back of the neck and elsewhere. A child affected with German measles is not often very much out of sorts, and is usually quite fit to attend school. Opportunities of seeing the rash may present themselves. The symptoms upon which stress may be laid are the sneezing, coughing, and redness of the eyes, the rash on the face, and the glands in the neck. The child may be regarded as free from infection at the end of three or four weeks. The disease is commonest in the spring of the year, from March to June.

Law as to the Infectious Diseases

In connection with the infectious diseases certain responsibilities are laid by law upon the citizen. To these it seems advisable to refer at this point. Apart from local Acts, dealing with special points in relation to these diseases, which may be in force in certain districts, the chief general Acts, a plicable throughout the country, and containing provisions for t.e prevention of the spread of infection, are the "Public Health Act" of 1875, the "Infectious Diseases Notification Act," 1889, and the "Infectious Diseases Prevention Act." By these Acts it is provided amongst other things, that—

(1) The head of any household in which there is a case of infectious disease, must, as soon as he becomes aware of the existence of the case, notify the medical officer of health of the district. If the head of the house fails to do so, the liability falls upon the nearest relative of the patient or those relatives or other persons present in the building or in attendance on the patient. If they fail, notification must then be made by the occupier of the building. (The duty of notifying the case is also laid upon the medical man attending the patient and, as he always does so, notification by any one else is rarely if ever called for.)

(2) The occupier of a house in which there has been a case of an infectious disease must see that the house, and all articles in it, which have been exposed to infection, are properly disinfected. (This duty is usually carried out by officials acting under the medical officer of health.)

(3) No person, in trying to let a house, is permitted to conceal the fact that there is, or has been, within six weeks, a person suffering from an infectious disease in the house.

(4) Information of the death of any person from an infectious disease must be given to the medical officer of health within twenty-four hours by the occupier of the house in which the death has occurred.

(5) Any person who is suffering from an infectious disease must not enter any public conveyance, or go into any public place or street.

(6) Any person who is in charge of any one suffering from infectious disease must not allow the sufferer to enter any public conveyance, or go into any public place or street.

(7) Any person who gives, lends, sells, transmits, or exposes, without previous disinfection, any bedding, clothing, or other things which have been exposed to infection will be liable to a penalty.

(8) No person shall knowingly cast, or cause or permit to be cast, into any ashpit, ashtub, or other receptacle for the deposit of refuse matter, any infectious rubbish.

Table of the Infectious Diseases

In the following table an attempt has been made to bring together some of the more important points in connection with the infectious diseases. Though the periods of exclusion and the quarantine periods are determined rather by the medical officer of health of the district than by the teacher, the contacts being admitted on a certificate that the house has been disinfected and the infected pupil on a certificate that he is now free from infection, it has been thought advisable to introduce in the table columns showing the duration of those periods.

In connection with school closure the quarantine period is of some importance, though this again is determined, not by the teacher, but by the sanitary and education authorities. The question of school closure is an exceedingly difficult one, and its value as a means of preventing the spread of infectious diseases very much doubted. In towns especially, it frequently fails to lead to any great diminution in the number of cases.

Measles and diphtheria are the diseases in which school closure is most commonly called for. When the percentage of children affected in any class reaches to about ten, in the case of measles, the question of closing the school usually arises. In diphtheria, which is much more dreaded, a smaller percentage than this leads to the adoption of this procedure. If swabs are taken from the throats of the children in the class in which most cases have occurred, and those showing the diphtheria germs are isolated and kept under observation, spread of the disease is generally prevented.

Quite recently, in the case of measles, the procedure has been modified. This disease, it has been noted, spreads most rapidly in the infants' department of a school, and children who have once had the disease rarely develop it again. The suggestion has therefore been made that when an epidemic occurs it is necessary only to close the *infants' school* completely, and in the other departments to exclude those children who have never had measles. By doing so the number of children absent on account of measles is diminished, and the attendance is not so much reduced as to make closure necessary. In Brighton this plan was adopted some time ago and works well. In Sheffield it is now on trial, and, though regarded with suspicion in some quarters, is likely to become permanent.

Disease.	Chief signs.	Quarantine period.	Period of exclusion.
Scarlet fever .	Shivering, sore throat, sickness, enlarged glands, scarlet rash, cheeks flushed, lips pale ; desquamation, pale face in late stages	14 days	Six to eight weeks; till discharge from nostrils or ears has ceased.
Small-pox .	Shivering, headache, sickness, backache; eruption of spots on forehead, face, and hands; top of spots depressed	18 days	Till all scabs have disappeared.
Diphtheria .	Sore throat, weakness, pallor, enlarged glands. In *nasal diphtheria:* discharge from nostrils. In *diphtheria of larynx:* cough and croup	14 days	Six weeks, or till all germs have disappeared from the affected part.
Typhoid and typhus fevers	Indefinite	3 weeks	Till strength is recovered.
Whooping-cough	In early stages : sneezing, running at the eyes, more or less paroxysmal cough. In later stages: whooping, vomiting, or bleeding at the nose, with cough.	3 weeks	Two months; till paroxysmal cough and vomiting cease.
Measles . .	Shivering, headache, signs of cold in the head, sneezing, redness and watering of the eyes, coughing, blotchy rash on the face and wrists	3 weeks	Four or five weeks.
Chicken-pox .	In early stages none ; eruption of blebs on face on second or third day	3 weeks	Till all scabs have disappeared.
Mumps . .	Pain and stiffness and swelling in front of the ears	3 weeks	About four weeks.
German measles	Sneezing, running at the nose and eyes, patchy rash on face, enlarged glands at back of neck	3 weeks	Three weeks.

PART II

THE SCHOOL BUILDING

CHAPTER XIV

REGULATIONS OF THE BOARD OF EDUCATION, 1905

THOUGH the teacher is apparently only rarely consulted regarding the construction and planning of new schools, it is important for him to have a certain acquaintance with these and kindred subjects. In this connection the following regulations laid down by the Board of Education in 1905 are of interest, and this part of the book will be devoted to a consideration of these rules, and to an amplification of some of the points contained in them.

PART I

PRINCIPLES TO BE OBSERVED IN PLANNING AND FITTING NEW BUILDINGS FOR PUBLIC ELEMENTARY SCHOOLS

SECT. I.—GENERAL

Before an architect is instructed to prepare plans for a new building for use as a public elementary school, careful consideration should have been given to various points which have an important bearing on the character of the building which is required in the particular case.

The principal factors to be considered are the respective numbers of boys and girls for whom it has been determined that provision is necessary. The distribution of these scholars in respect of age is also very important in its bearing on organization, and consequently on planning; the type of building required will probably depend, to some extent, on the manner in which the local education authority have exercised their discretion as to the exclusion of children who are under five years of age; and the nature of the accommodation required in the upper departments of ordinary public elementary schools will be affected if higher elementary schools are provided in the locality.

It must be remembered that a head-teacher can seldom undertake effectively the responsibility for more than four to five hundred scholars, including the supervision of the teaching staff required for that number. This, therefore, is the greatest number of scholars for whom provision can wisely be made in one and the same department, remembering that each department must have its own head-teacher, who is responsible for the general control and supervision of the instruction and discipline of that department (Article 8 of the Code).

The number of departments on any one site will depend upon the total number of scholars for whom provision is required, but it will be very seldom that more than three departments (or four, if one of them is for boys and girls of seven to nine or ten years of age) could properly occupy parts of one and the same building. When a school comprising departments for boys, girls, and infants is attended by all the children of the area for which it is available, it is not unusual to find that the average attendance in each department is much the same; and this fact will be a guide in planning a building for these conditions. But it is desirable to have a certain margin of places in the infants' department in order to meet the great variability of the attendance at different seasons.

All these considerations should be kept in mind in deciding how many places should be provided in the several departments of a large school. But in every case the local circumstances must be carefully considered, and if children under five years of age are excluded, or if many of those who reach the age of twelve years are transferred to schools of a higher grade, or if other special circumstances exist, the proportions above suggested must be considerably modified.

The number and circumstances of the scholars who will attend in each department (if more than one be contemplated), and the number and qualifications of the teaching staff to be employed in each, will determine approximately the grouping of the scholars for teaching, the number of rooms which should be provided in the building, and the number of places in the several rooms. The rooms must be grouped compactly and conveniently so as to secure proper organization and supervision; every building intended for use as a public elementary school must be planned so that the children who will attend can be seated in the best manner for being taught. It is important to remember that the number of places provided in any room depends not merely on its area, but also on the lighting, the shape of the room (especially in relation to the kind of desk proposed), and the position of the doors and fireplaces, which should be arranged so as to allow the whole of one side of any room to be left free for the groups of desks.

For large departments containing from 350 to 500 places the most suitable plan is that of a central hall with the classrooms grouped round it; as a rule such a department would require from seven to ten classrooms. Such departments may be planned conveniently with the classrooms opening from a corridor, and a similar plan may be adopted even for larger departments. For small rooms a schoolroom with one or more classrooms will be sufficient. There should always be at least one classroom, except in special cases.

Where the site is sufficiently large, open, and fairly level, the most economical plan is that in which all the rooms are on the ground floor, and this arrangement is preferable on educational grounds. It is desirable that a building for use as a public elementary school should be on not more than two floors. A building on three floors is open to many objections, though it may be necessary in special circumstances, as, for example, on a site where land is very costly, or where it is otherwise impossible to get adequate area for playgrounds.

SECT. 2.—CENTRAL HALLS

When there is a central hall it should have a floor-space of not more than 4 square feet for each scholar for whom the school is recognized; about $3\frac{1}{2}$ square feet for each scholar will be sufficient. The hall must be fully lighted, warmed, and ventilated.

(*a*) A single central hall may be provided for the joint use, at separate times, of two departments, provided that it is so placed as to be readily accessible from the classrooms of each department.

(*b*) Where outdoor space is not available, physical training should be given in the central hall (or corridor). This purpose should be taken into consideration at the time when the building is planned. Since fixed gymnastic apparatus is unsuitable for children under fourteen years of age, a separate gymnasium is not required, and cannot be approved.

SECT. 3.—CORRIDORS

Large schools not built with a central hall must be provided with a wide corridor giving access to the rooms; and two or three of the rooms ought to be divided from one another by movable partitions only, so that on occasions one large room may be available.

A corridor should be fully and directly lighted and ventilated, and from 8 to 12 feet wide, according to the size of the school.

SECT. 4.—SCHOOL-ROOMS

Where a schoolroom is the principal room in a school which has neither central hall nor corridor it should never be designed for more than a hundred children, and a room of even smaller size is desirable. The width should vary according to the kind and arrangement of the desks (sect. 6).

No schoolroom lighted from one side only can be approved. The gable ends should be fully utilized for windows, and there should be no superfluous windows opposite the teacher.

When a school consists of a single room, that room should not contain more than 600 square feet of floor-space.

SECT. 5.—CLASSROOMS

The number of classrooms should be sufficient for the size and circumstances of the school.

(*a*) The classrooms should not be passage-rooms from one part of the building to another, nor from the schoolrooms to the playground or yard. Both schoolrooms and classrooms must have independent entrances. The rooms should be arranged so that each can be easily cleared without disturbing the work proceeding in any other room.

(*b*) A classroom should not be planned to accommodate more than from fifty to sixty children; but in special cases somewhat larger rooms may be approved. In the absence of supplementary light the measurement from the window-wall in a room 14 feet high should not exceed 24 feet 8 inches. Except in very small schools classrooms should not be planned for less than twenty-four scholars.

(*c*) The proportions of classrooms should vary with the kind and arrangement of the desks; but a long and narrow room should always be avoided, and a room approximating to a square is most satisfactory.

SECT. 6—DESKS

Seats and desks should be provided for all the children, graduated according to their ages, and placed at right angles to the window-wall. (*See* also sect. 4 and Rule 6, Part II.) The seats should be fitted with backs.

An allowance of 18 inches per scholar at each desk and seat will suffice (except in the case of the dual desk), and the length of each group should therefore be some multiple of 18 inches, with gangways of 18 inches between the groups and at the walls. In the case of the dual desk the usual length is 3 feet 4 inches, and the gangways 1 foot 4 inches.

(*a*) In an ordinary classroom five rows of long desks or six rows of dual desks are best; but in a schoolroom or room providing for more than sixty children, there should not be more than four rows of long desks or five rows of dual desks.

If a schoolroom is 18 feet wide, three rows of long desks or four of dual desks may be used; if the width is 22 feet, the rows may be four and five respectively.

Long desks should be so arranged that the teacher can pass between the rows. Where dual desks are used this is not necessary, as the gangways give sufficient access; but the teacher should be able to pass behind the back row.

(*b*) The desks should be very slightly inclined. An angle of 15° is sufficient. The objection to the flat desk is that it has a tendency to make the children stoop. A raised ledge in front of a desk interferes with the arm in writing. The edge of the desk when used for writing should be vertically over the edge of the seat.

(*c*) Single desks are not necessary in an ordinary public elementary school.

SECT. 7.—ACCOMMODATION

The accommodation of the school, *i.e.* the number of places for which the school is finally recognized, will depend in part on the arrangement of the desks, which must be approved by the board. (*See* sect. 6, Part I. of these Regulations and Article 17 (*c*) of the Code.)

No central hall or corridor, and no classroom for cookery, laundry, handicraft, drawing or science, will be counted towards the accommodation.

When the building to be erected is for the use of older scholars, the plans of the schoolroom (if any) and classrooms must show an average of not less than 10 square feet of floor-space for each place proposed to be provided.

SECT. 8.—INFANTS' SCHOOLS

Infants should not, except in very small schools, be taught in the same room with older children, as the methods of instruction suitable for infants necessarily disturb the discipline and instruction of the older scholars. Access to the infants' room should never be through the older children's schoolroom.

(*a*) It is desirable that the partition between an infants' room and any other schoolroom or classroom should be impervious to sound, and there should be no habitual means of direct communication other than an ordinary door.

(*b*) An infants' school and playground should always be on the ground floor.

(*c*) No infants' classroom should accommodate, as a rule, more than sixty infants.

(*d*) A space in which the children can march and exercise should be provided. A corridor intended for this purpose should not be less than 12 feet wide.

(*e*) The babies' room should always have an open fire, and should be maintained at a temperature of not less than 60°.

(*f*) In infants' schools an allowance of 16 inches per child at long desks will be sufficient. Dual desks should be 3 feet long.

(*g*) The accommodation of the school, *i.e.* the number of places for which the school is finally recognized, will depend in part on the arrangement of the desks which must be approved by the board. (*See* sect. 6 and Article 17 (*c*) of the Code.)

No central hall or corridor will be counted towards the accommodation.

When the building to be erected is wholly for the use of infants the plans of the schoolroom (if any) and classrooms must show an average of not less than 9 square feet for each place proposed to be provided.

(*h*) Where an infants' classroom is attached to a school for older children, and there is no corridor or hall available, it is desirable that the classroom should have a larger floor-space than 9 square feet per child, and that provision should be made of sufficient space, free of desks, for exercise. This space should extend across the room, and be not less than 12 feet wide.

[*Sect.* 9 *deals with rooms for cookery, etc., and is omitted.*]

SECT. 10.—HIGHER ELEMENTARY SCHOOLS

A higher elementary school should in general be planned in accordance with the principles applicable to an ordinary public elementary school, but it is important that the curriculum of the school should have been determined, and that it should have been generally approved by the board, before an architect is instructed. Attention is directed to the following points of importance:—

(1) For a higher elementary school accommodating from 300 to 350 scholars, 8 to 10 classrooms will generally be required, since every class should have its own classroom. No classroom should accommodate more than 40 scholars.

(*a*) The classrooms may be furnished with single or dual desks as may be desired. If single desks are adopted, a classroom should have an area of about 15 square feet per scholar. Classrooms fitted with dual desks need not be so large, but a minimum of about 12 square feet per scholar will be requisite.

(2) There must be available for use by the scholars of a higher elementary school special rooms of suitable size and proper equipment, if any such are required for giving the instruction which is provided in the approved curriculum. If special rooms are otherwise available, they need not be provided in the building of the higher elementary school; but if special instruction is to be given elsewhere than in the building occupied by the higher elementary school, full information must be furnished, when the plans are submitted, showing that the needs of the scholars will be properly met.

(*a*) If cookery, laundry-work, or handicraft is to be taught in the school building, the room in which each is to be taught should be specially constructed.

(*b*) If advanced drawing is taught in the school a drawing classroom is desirable. It should provide 30 square feet of floor-space for each scholar who will be taught in it at any one time. If the school has a suitably lighted central hall that would answer for a drawing classroom, but no class other than a drawing class should be taught in a central hall.

(*c*) (i.) A laboratory, if included in the building, should afford 30 square feet of floor-space for each scholar who will be instructed in it at any one time.

(ii.) A laboratory must have suitable tables. These should be well lighted and should be fitted as required for the experimental work included in the approved curriculum. If chemistry is taught the laboratory should have sinks, cupboards, and the necessary fume closets.

(*d*) (i.) If there is a separate lecture-room it should be fitted with a suitably furnished demonstration table. If chemistry is to be taught the lecture-room, if any, should have a fume closet.

(ii.) If chemistry or physics is taught and there is no separate lecture-room, one or more of the classrooms may have a suitable demonstration table, and a fume closet if chemistry be taught.

(iii.) A small preparation room may be provided near the lecture-room, or other room used for the purpose, in schools where science is taught.

SECT. 11.—TEACHERS' ROOMS

In large schools there should be provided for the use of the teachers a small room or rooms with suitable lavatory accommodation. A store-room for books and other school material should adjoin the teachers' room.

[*Sect.* 12 *deals with the teachers' house, and is omitted.*]

PART II

RULES AS TO THE HYGIENIC AND SANITARY CONDITIONS OF THE PREMISES, THE CONSTRUCTION OF THE FABRIC, AND THE SAFETY OF THE SCHOLARS IN CASES OF EMERGENCY

RULE 1.—SITES AND PLAYGROUNDS

In planning a school care must be taken to secure that there shall be an open airy playground proportioned to the size and needs of the school, and the site should, if possible, have a building frontage suitable to its area. A site open to the sun is especially valuable for the children, and important in its effects on ventilation and health. The minimum size of site is, in the absence of exceptional circumstances, a quarter of an acre for every 250 children, irrespective of the space required for a teacher's or caretaker's house, or for a cookery or other centre. If the school is of more than one storey this area may be proportionately reduced; but a minimum unbuilt-on or open space of 30 square feet per child should be preserved.

(*a*) Except in the case of very small schools, playgrounds should be separate for boys and girls, and should, where practicable, have separate entrances from the road or street.

(*b*) All playgrounds should be fairly square, properly levelled, drained, and enclosed. A portion should be covered, having one side against the boundary wall. A covered-way should never connect the offices with the main building; buttresses, corners, and recesses should be avoided.

(*c*) An infants' school should have its playground on the same level as the school, and a sunny aspect is of special importance.

RULE 2.—WALLS, FLOORS, AND ROOFS

The walls of every room used for teaching, if ceiled at the level of the wall plate, must be at least 12 feet high from the level of the floor to the ceiling; if the area of the room exceed 360 square feet the height must be not less than 13 feet, and, if it exceed 600 square feet then the height must be at least 14 feet.

(*a*) The walls of every room used for teaching, if ceiled to the rafters and collar beam, must be at least 11 feet high from the floor to the wall plate, and at least 14 feet to the ceiling across the collar beam.

(*b*) Great care should be taken to render the roofs impervious to cold and heat.

(*c*) Roofs open to the apex are very undesirable. They can be permitted only where the roofs are specially impervious to heat and cold, and where apex-ventilation is provided. Iron tie-rods are least unsightly when placed horizontally.

(*d*) In the case of a school of more than one storey especial care must be taken to render the floors as far as possible sound-proof.

(*e*) The whole of the external walls of the school and residence (if any) should be solid. If of brick, the thickness must be at least one brick and a half; and if of stone, at least 20 inches; where hollow walls are proposed, the external wall must be 9 inches thick, with a $4\frac{1}{2}$-inch lining, and a 2-inch cavity.

(*f*) The board are only prepared to sanction the erection of schools of a lighter construction, *e.g.* in iron and wood, or other suitable material, in very special circumstances, as for example in colliery districts where, owing to mining operations, there is no site available upon which a building of the ordinary solid type can be safely erected; or where the population is not of a stationary character, as, for example, during the progress of a large piece of engineering work, or in the neighbourhood of a mine likely to be soon worked out; or where temporary accommodation is required during the building of a new school, or the reconstruction of an old one.

Where such buildings are proposed special care must be taken to ensure the comfort of the children with regard to warmth and ventilation.

(*g*) All walls, not excepting fence walls, should have a damp-proof course just above the ground line.

(*h*) The vegetable soil within the area of the building should be removed, the whole space covered by a layer of concrete not less than 6 inches thick, and air bricks inserted in *opposite* walls to ensure a through current of air under floors for ventilation to joists.

(*i*) Timber should be protected from the mortar and cement by asphalt or tar.

RULE 3.—ENTRANCES

Entrances should be separate for each department and each sex. In large schools more than one entrance to each department is desirable (*see also* Rule 4). Entrance doors should open outwards as well as inwards. A porch should be external to the schoolroom. An external door, having outside steps, requires a landing between the door and the threshold.

RULE 4.—STAIRCASES

There must be separate staircases for boys and girls, and each department should have its own staircases.

Every staircase must be fire-proof, and external to the halls, corridors, or rooms. Triangular steps or "winders" must not be used. Each step should be about 13 inches broad and not more than $5\frac{1}{2}$ to 6 inches high. The flights should be short, and the landings unbroken by steps. The number of staircases must be sufficient not only for daily use, but also for rapid exit in case of fire or panic. For any upper floor accommodating more than two hundred and fifty a second staircase is essential.

RULE 5.—CLOAKROOMS AND LAVATORIES

Cloakrooms should not be passages, and should be external to the schoolrooms and classrooms. Cloakrooms should be amply lighted from the end, and should not be placed against the gable wall which should be fully utilized for windows giving light to the rooms used for teaching (*see* sect. 4, Part I.). There should be separate ingress and egress so that the children can enter and leave the cloakroom without confusion or crowding. There should be gangways at least 4 feet wide between the hanging-rails. Hat pegs should be 12 inches apart, numbered, and of two tiers. The lineal hanging space necessary to provide a separate peg for each child is thus 6 inches. The hat pegs should not be directly one above the other.

Thorough ventilation and disconnection are essential, so that smells are not carried into the school. Ample space is needed immediately outside a cloakroom.

Lavatory basins are needed (*see* Rule 9 (*g*)). Girls' schools require a larger number than boys' or infants'.

A lock-up slop sink, water-tap, and cupboard are desirable for the caretaker.

RULE 6.—LIGHTING

Every part and corner of a school should be well lighted. The light should, as far as possible, and especially in classrooms, be admitted from the left side of the scholars. (This rule will be found greatly to influence the planning. *See* Rules 6 (*b*) and 7 (*a*) and Section 4, Part I.) All other windows in classrooms should be regarded as supplementary or for ventilation. Where left light is impossible, right light is next best. Windows full in the eyes of scholars cannot be approved. Unless the top of the windows be more than 14 feet above the floor the plan should show no space more than 24 feet from the window-wall in any room used for teaching. (*See* Section 5 (*b*), Part I.)

(*a*) Windows should never be provided for the sake merely of external effect. All kinds of glazing which diminish the light and are troublesome to keep clean and in repair must be avoided. A large portion of each window should be made to open for ventilation and for cleaning.

(*b*) The sills of the main lighting windows should be placed not more than 4 feet above the floor; the tops of the windows should as a rule reach nearly to the ceiling; the upper portion should be made to swing. The ordinary rules respecting hospitals should here be remembered. Large spaces between the window heads and ceiling are productive of foul rooms.

(*c*) Skylights are objectionable. They cannot be approved in schoolrooms or classrooms. They will only be allowed in central halls having ridge or apex ventilation.

(*d*) The colouring of the walls and ceilings and of all fittings in the rooms should be carefully considered as affecting the light. This point and the size and position of the windows are especially important in their bearing on the eyesight of the children.

(*e*) The windows should be properly distributed over the walls of the classrooms so that every desk shall be sufficiently lighted. The glass line of the window furthest from the teacher should be on a line with the back of the last row of desks.

RULE 7.—VENTILATION

The chief point in all ventilation is to prevent stagnant air; particular expedients are only subsidiary to this main principle.

There must be ample provision for the continuous inflow of fresh air, and also for the outflow of foul air. The best way of providing the latter is to build to each room a separate air chimney carried up in the same stack with smoke flues. An outlet should be by a warm flue or exhaust, otherwise it will frequently act as a cold inlet. Inlets are best placed in corners of rooms furthest from doors and fireplaces, and should be arranged to discharge upwards into the room. Gratings in floors should never be provided. Outlets in ceilings must not open into a false roof, but must be properly connected with some form of extract ventilator.

The size of the inlets and outlets must be carefully adapted to the method of ventilation proposed. A much larger area is required when no motive force is provided.

It is as well that the windows should have both the top and bottom panes arranged to open inwards as hoppers.

Besides being continuously ventilated by the means above described, rooms should as often as possible be flushed with fresh air admitted through open windows and doors. Sunshine is of particular importance in its effects on ventilation and also on the health of children.

(*a*) Although lighting from the left hand is considered so important, ventilation demands also the provision of a small swing window as far from the lighting as possible, and near the ceiling.

RULE 8.—WARMING

The heat should be moderate and evenly distributed, so as to maintain a temperature of from 56 degrees to 60 degrees. When a corridor or lobby is warmed, the rooms are more evenly dealt with and are less liable to cold draughts. Where schools are wholly warmed by hot water, the principle of direct radiation is recommended. In such cases open fireplaces in addition are useful for extra warming on occasions, and their flues for ventilation always.

(*a*) A common stove, with a pipe through the wall or roof, can under no circumstances be allowed. Stoves are only approved when—

(i.) provided with proper chimneys (as in the case of open fires);

(ii.) of such a pattern that they cannot become red hot, or otherwise contaminate the air;

(iii.) supplied with fresh air, direct from the outside, by a flue of not less than 72 inches superficial; and

(iv.) not of such a size or shape as to interfere with the floor-space necessary for teaching purposes.

(*b*) A thermometer should always be kept hung up in each room.

(*c*) Fireplaces and stoves should be protected by fireguards.

(*d*) If a room is warmed by an open fire, the fireplace should be placed, if possible, in the corner of the room, in order to leave space for the teacher's desk and black-board.

RULE 9.—SANITARY ARRANGEMENTS

Water-closets within the main school building are not desirable, and are only required for women teachers. All others should be at a short distance and completely disconnected from the school. Privies should be fully 20 feet distant.

(*a*) The latrines and the approaches to them must be wholly separate for boys and girls. In the case of a mixed school, this rule especially affects the planning. Boys and girls should not use the same passages or corridors; where such an arrangement is unavoidable, there must be complete supervision from the class-rooms by sheets of clear glass.

(*b*) Each closet must be not less in the clear than 2 feet 3 inches wide, nor more than 3 feet, fully lighted and ventilated, and supplied with a door. The doors should be at least 3 inches short at the bottom, and at least 6 inches short at the top. More than one seat is not allowed in any closet.

(*c*) The children must not be obliged to pass in front of the teacher's residence in order to reach their latrines.

(*d*) The following table shows approximately the number of closets needed :—

	For Girls.	For Boys.	For Infants.	For Girls and Infants.
Under 30 children	2	1	2	2
,, 50 ,, ...	3	2	3	3
,, 70 ,, ...	4	2	3	4
,, 100 ,, ...	5	3	4	5
,, 150 ,, ...	6	3	5	6
,, 200 ,, ...	8	4	6	7
,, 300 ,, ...	12	5	8	8

There should be urinals in the proportion of 10 feet per 100 boys; urinals are required for infant boys. If the numbers in the school are not very large, offices common to girls and infants can be approved; a proper proportion of the closets must then be made of a suitable height for infants.

(*e*) Earth or ash closets of an approved type may be employed in rural districts, but drains for the disposal of slop and surface water are necessary. Cesspits and privies should only be used where unavoidable, and should be at a distance of at least 20 feet from the school. [Building form "A," which may be obtained on application, gives suggestions as to their construction and arrangement.]

(*f*) Soil-drains must always be laid outside the building (on a hard even bottom of concrete) in straight lines with glazed stoneware pipes, carefully joined in cement and made absolutely water-tight. A diameter of 4 inches is sufficient except for drains receiving the discharge of more than 10 closets, when the diameter should be 6 inches. The fall should never be less than 1 in 30 for 4-inch, and 1 in 40 for 6-inch drains. An inspection opening or chamber should be provided at each change of direction, so as to facilitate cleansing the drain without opening the ground. Every soil-drain must be disconnected from the main sewer by a properly constructed trap placed on the line of drain between the latrines and the public sewer. This trap must be thoroughly ventilated by at least two untrapped openings; one being the 4-inch soil pipe carried up full size above the roof, and the other an inlet pipe connected with the side of the trap furthest from the public sewer. Automatic flushing tanks are desirable where trough closets are used.

(*g*) Waste pipes from sinks or lavatories should be first trapped inside and then made to discharge direct through an outer wall over a trapped gully.

RULE 10.—WATER SUPPLY

In all schools adequate and wholesome drinking water must be available for the scholars.

In cases where it is not taken from the mains of an authority or company authorized to supply water, care must be taken to ascertain that the water proposed to be used is adequate in quantity, is of suitable character, and is not liable to pollution in any way, as, *e.g.* by surface drainage, or by leakage from sewers, drains, cesspools, or other receptacles.

Where water pipes are used, they should be so laid or fixed as to be properly protected from frost, and so that in the event of their becoming unsound the water conveyed in such pipes will not be liable to become fouled, or to escape without observation.

There should be no direct communication between any pipe or cistern from which water is drawn for domestic purposes, and any water-closet or urinal.

All water-closets and urinals should be provided with proper service cisterns, which, together with the outlet therefrom, should be capable of providing a sufficient flush.

Any cistern to be used for the storage of water should be watertight and be properly covered and ventilated, and should be placed in such a position that the interior thereof may be readily inspected and cleansed.

[*Part III. refers to Plans, and is omitted.*]

CHAPTER XV

THE SCHOOL SITE

The size of the site—The soil of the site—Ground water—Ground air.

THOUGH little is said in the foregoing rules regarding the selection of a site for the school, there are certain points which must be borne in mind in this connection, and which must influence the choice—

(1) The location of the site. It must be as near as possible to the centre of the area it is to serve.

(2) The size of the site. It must be airy and open, of sufficient size, and sufficiently elevated.

(3) The amenities of the site. It must not be too near manufactories, busy streets, mean streets, or railways.

(4) The soil of the site. It must be clean.

Location of the Site.—This needs no very special consideration here, since the importance of placing the school in such a position that the children will not have too far to travel is obvious.

The Size of the Site.—The necessity for choosing a site which is open, airy, and of sufficient size is also clear. By placing the school on a site which will bring it, when completed, in close proximity to houses or other buildings, or even to trees in country districts, lighting and ventilation will both be interfered with, and the amount of space which can be given for playgrounds will be diminished. According to the regulations, the school buildings should be at least 60 feet from surrounding buildings, and this may be taken as the minimum distance. If the distance is less than this, light will be shut out from the classrooms, and the free circulation of air round the building prevented.

The Area of the Site.—The minimum is said to be one quarter of an acre for every 250 children, *i.e.* 42 square feet per child, but twice this amount would not be too much. An *elevated site* is to be preferred, partly in order to secure purer air and better light, but mainly to allow of easy draining of the soil under the building when it is erected. For these reasons the higher up the slope the site is the better, the nearer the foot the worse. The worst site is one in a valley.

The Amenities of the Site.—The neighbourhood of manufactories, busy streets, mean streets, and railways is to be avoided. One reason for keeping the school far from these is, the noises which are produced, and which tend to distract the attention of the children, cause unnecessary nervous strain and prevent the opening of windows, though, by the use of wood pavements, these objections might be overcome. The risk of pollution of the air by smoke and effluvia; the effect which may be produced on the children by the degrading sights they may see, especially in mean streets; and the risks of accidents occurring to the children, on their way to and from school, through busy thoroughfares, are other reasons for objecting to a site so placed.

The Soil of the Site.—This should be clean and dry. If it is to be clean, it must be as free as possible from organic matter, animal and vegetable, which may undergo decomposition. Practically all soils contain organic matter to a greater or less extent, but this is destroyed by various living organisms in the soil itself. If the organic matter is large in amount, or if the soil is very damp, the action of the organisms is interfered with, and putrefaction and bad smells, or even disease, may be caused. Natural soil is the product of the breaking down of various rocks, and so on, the result of what is called *weathering*. Sometimes, in towns, what is known as *made soil* is met with. This consists of refuse, road-sweepings, and so on, which has been tipped into hollows with the object of filling them up; it is very rich in organic matters of all kinds, and no school should be erected on it.

The dryness of the soil will depend upon the porosity of the sub-soil, the natural drainage of the sub-soil, and the depth of what is called the *first impermeable stratum*. The porosity of the sub-soil is of great importance. The sub-soil is that layer of the earth's crust which lies immediately below the soil, and its porosity depends upon the size of the particles of which it is made up. It may consist of large particles, like gravel, when it will be very porous; or of small particles, like sand, or sandstone, when it will also be porous; or it may consist of fine particles, such as are found in clay or slate, when it is very little porous.

When rain falls upon the surface of the earth, part of it runs into rivers or streams, part of it evaporates, and part of it passes through the soil and sub-soil. If the soil and sub-soil are porous, the water sinks rapidly; if they are very little porous, the water remains in their interstices, and keeps them always damp. A clay soil and sub-soil are always damp, because they retain the water which falls upon them and prevent it from passing downwards. The water which passes down through the soil and sub-soil continues to sink till it reaches the first impermeable stratum, which may be a layer of rock or clay. This stratum may absorb some of the water, but the great bulk finds a bed on it. If there be any slope at all the water follows it till it finds an outlet into a river, a lake, a spring, or the sea. If there be no slope the water remains, and as it is from time to time being sucked up by the action of the sun, and so on, it tends to keep the sub-soil and the soil wet. In the case of valleys, where the impermeable stratum may be more or less cup-shaped, the chances of the water ever getting away are very small. Dampness is therefore more marked, even though the sub-soil may consist of gravel or sand, and be very permeable. For this reason a site in a valley is to be avoided.

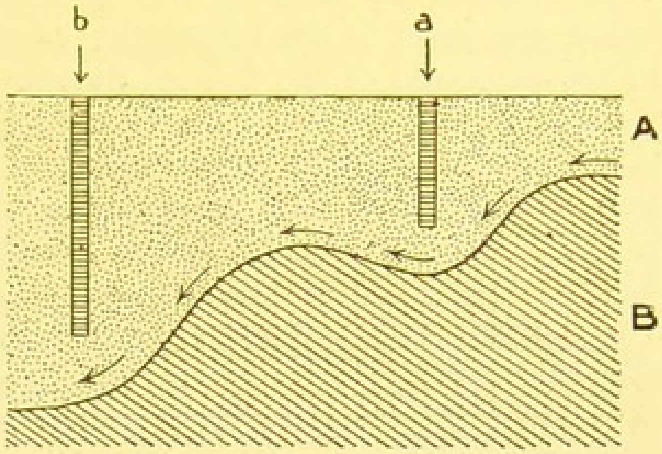


FIG. 89.—Diagram showing direction of flow of ground water.

A, permeable ; B, impermeable stratum.

(*From Notter and Firth's "Hygiene."*)

Ground Water.—The water which has passed down to find a resting-place on the impermeable stratum is known as the *sub-soil* or *ground water*. Its depth below the surface varies with the depth of the impermeable stratum. It forms a large sheet of water underground, which is more or less continuously flowing towards rivers, etc. The level of the sub-soil water varies from time to time, depending, mainly, on the temperature above ground as determined by the heat of the sun. In warm weather it is high, because the heat aspirates it up through the interstices of the sub-soil. In cold dry weather it is low. The level, naturally, also varies with the rainfall. If there is a heavy rainfall, the level rises, and, in some instances, the flooding of house-cellars, which sometimes occurs in towns, is due to the rise of the ground water under the houses. In choosing the site for a school it is well to find one where the level of the ground water is low, say from 12 to 15 feet below the surface of the soil. It is important also to see that it does not vary much in its level. A soil where the ground water is liable to sudden and great variations in level is bad. The depth may be determined by sinking a hole in the ground, and the variations in level may be watched in this hole also.

To overcome the tendency to dampness of a site, the result of variations in the level of the ground water, it is usual to drain it. This is done by digging trenches, the bottom of which must be below the level of the foundation of the building, and which slope in the direction of the flow of the ground water. In these trenches porous drain-pipes are laid, which collect the water and carry it off. Sometimes the pipes are connected with sewers, into which the water discharges. To prevent the back flow of sewage along the pipes they must not be carried directly to the sewer, but through what is called a disconnection chamber (see Fig. 115).

Ground Air.—Besides ground water the existence of ground air must also be borne in mind. Like the water, this occupies the interstices of the sub-soil, and there is a continual interchange going on between the air above ground and the underground air. The latter differs from the former in containing less oxygen and more carbonic acid gas, and also other gases, the product of decomposition of organic matter underground. Like the ground water the ground air is drawn upwards by heat, and the heat of a house or a school is sufficient to bring this about. When there is much rain the escape of the ground air is interfered with, and it spreads out till it finds a place where it can make its escape. A ready exit is found at the site of a house or school, and it pours into these unless steps are taken to exclude it. The methods usually adopted are, to cover the whole foundation with an impervious substance like concrete, to make the ground-floor as impervious as possible, and to provide for what is called *sub-floor ventilation* by placing gratings or air bricks in the walls below the level of the first floor.

CHAPTER XVI

THE SCHOOL BUILDINGS

Orientation—Size—Building materials—Floors, etc—Classrooms—Cloak-rooms—Lavatories, etc.

Orientation.—The site for the school having been selected, the school building has next to be planned. First, however, it is necessary to determine how the building shall be set upon the site. As the object is to ensure that the sun shall have access to every room at some part of the day, provided there is no obstruction, that is best done by placing the building so that the corners look towards the four points of the compass. This placing of the building is called *orientation*, and it is a matter which in the past has been very much neglected.

School Construction.—In connection with construction the following points have to be considered, viz.: the size and height of the building; the style of architecture; the building materials to be used; the foundations; the floors; the ceilings; and the roof.

The *size* of the building will depend upon the number of children to be accommodated, and the number of classrooms required for the teaching of separate classes and subjects. These points will be further considered in dealing with the school plan, and need not be referred to at present.

The *height* of the building will depend to a certain extent upon the factors just mentioned. Very largely, however, they depend upon the size of the site. The fewer the storeys in the school the better, and an attempt should be made to avoid the necessity of having more than two, by having a site of sufficient size. The climbing of stairs is a strain on children, and especially on girls. In the case of fire, also, stairs constitute a great difficulty.

The *style of architecture* to be chosen has a certain amount of importance. It is best to avoid anything florid, and to aim at something simple yet dignified, and free from contrivances likely to interfere with lighting and ventilation. Architects are occasionally tempted to sacrifice too much to effect.

As *building materials*, brick or stone will of course be employed for the walls. To prevent rain from being driven between the bricks and through the walls, care will have to be taken that the walls are well pointed with cement. As many of the internal walls as possible should be constructed of brick, in order to minimize the risks of fire. The inner surface of the walls should be cemented smooth.

Foundations.—The foundation of the school building should be solid. In the absence of rock or clay, trenches must be dug and filled in with concrete, upon which the walls must be erected. The point to which the concrete must reach will depend upon whether or not there is to be a basement to the building. If there be no basement, the upper level should come to within two or three feet of the ground surface. With a basement the level may be lower. A basement is an advantage in a school, and many authorities recommend it, as it tends to prevent the entrance of ground air into the rooms. It also protects the upper floors from dampness. In the basement the heating apparatus may be placed, and if its walls rise, as they should, sufficiently above the ground to ensure lighting, the space may even be used for other purposes, such as a recreation-room in wet weather.

The tendency of the bricks or stones, more especially the bricks, of the walls to absorb moisture from the soil must be borne in mind. This absorption is brought about by capillary attraction, and if not prevented, the water may rise to a great height in the wall. The preventive measures adopted are : (*a*) the introduction of *damp-proof courses* ; (*b*) the keeping away of the soil from the walls. *Damp-proof courses* are layers of impermeable material introduced into the wall. They may consist of lead, or asphalte, or glazed bricks. If there be no basement, the damp-proof course is usually placed above the level of the ground, but

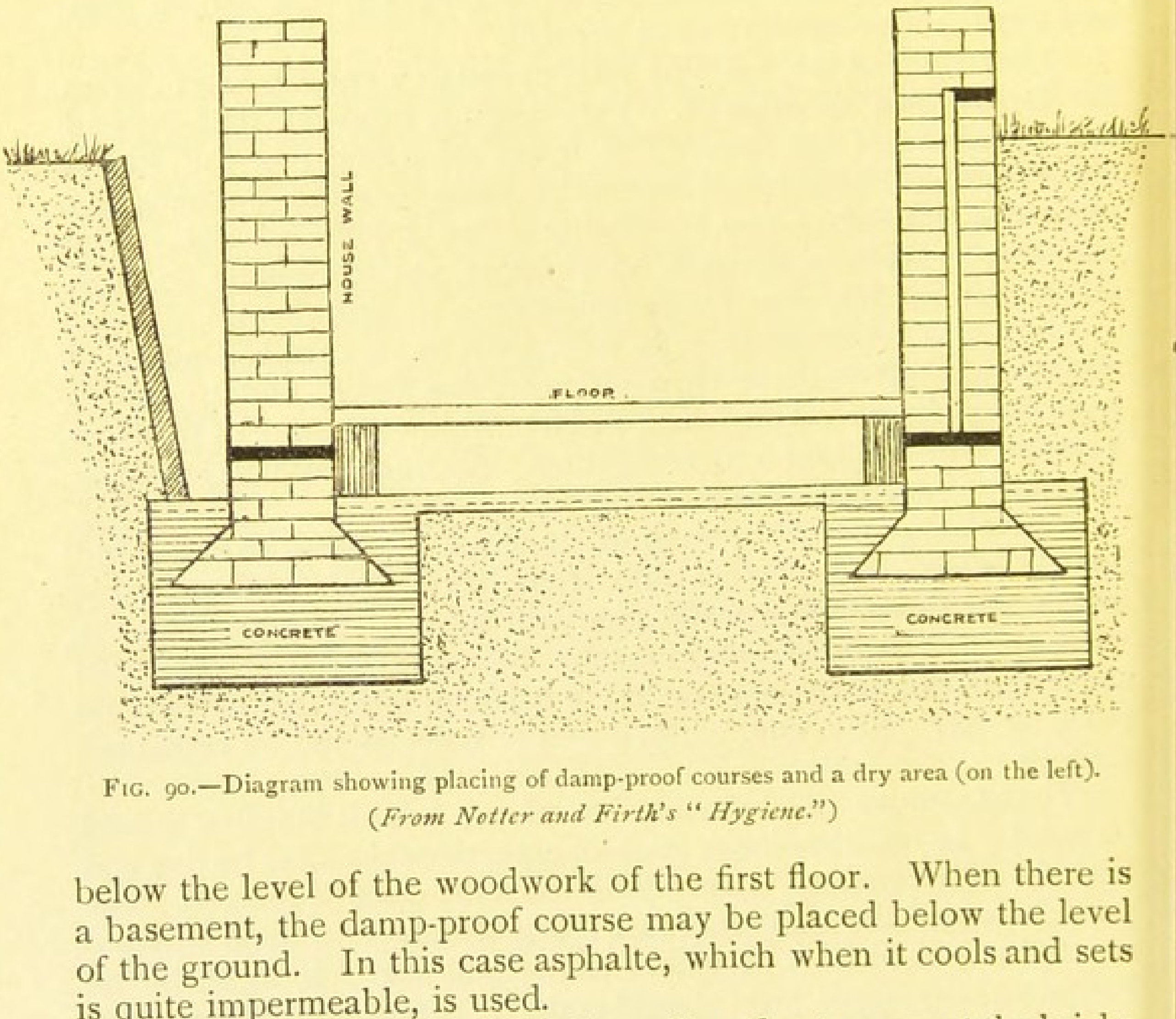


FIG. 90.—Diagram showing placing of damp-proof courses and a dry area (on the left). (*From Notter and Firth's "Hygiene."*)

below the level of the woodwork of the first floor. When there is a basement, the damp-proof course may be placed below the level of the ground. In this case asphalte, which when it cools and sets is quite impermeable, is used.

To keep the soil away from the walls and so to prevent the bricks from absorbing water from it, a dry area is constructed by digging out the soil for some distance down at the side of the wall and lining the space so formed with concrete or asphalte. The whole surface of the site inside the foundation must be levelled and covered with a layer of cement 6 inches thick. This prevents the rise of ground air.

The Floors.—The floor of the basement may consist either of asphalte or of some hard, well-seasoned wood. If there is no basement the first floor should consist of wood planks, either oak or pine, laid on beams, and placed about 6 inches above the cement which covers the site. The space between the cement and the flooring should be ventilated by means of iron gratings let into the wall on each side. Instead of providing such a floor it is now common to do away with the space and to cover the cement with tar, laying the wood flooring, planks or blocks, in this. Planks are to be preferred to blocks, because the aim must be to have as few cracks as possible in the floor, which may retain dust and dirt. With the blocks the numerous spaces between the adjacent pieces give lodgment for much dust. With the planks the spaces are fewer. Each plank must be firmly clamped to its neighbour on each side, and any space left must be carefully packed with oakum or filled up with glue.

Fireproof floors are recommended for buildings of more than one storey, and especially for the upper storeys. In these the planks are laid on concrete, and iron, instead of wood, beams are used, fire-clay tiles being placed between each pair. Where the floor meets the walls it is advisable, for the sake of cleanliness, to have a concavity instead of a rightangle. The floors of corridors and lavatories should be of cement, asphalte, or that kind of mosaic work known as "terazzo," so that they may be easily washed down. In the cloakrooms either wood or asphalte, preferably wood as being warmer, may be used.

Ceilings.—The ceilings are usually made of lath and plaster. When fireproof flooring of the type described above is employed, wire netting takes the place of the laths. The meeting of the ceiling and walls should form a concavity. Angles, indeed, should be avoided in a school, whether it be in corridor, lavatory, or classroom. If there is an attic to the school it should be provided with a floor and a ceiling in order to save heat.

Roofs.—The roof of the school must be water-tight. It has been suggested that in towns where sufficient ground cannot be obtained for playing purposes the roof should be made flat and utilized in this way. In some places this plan has been adopted and works well.

Windows, doors, and entrances to the school will be considered later.

The School Plan

In drawing up the school plan the classrooms should receive the greatest amount of attention. The points of importance in connection with these are the size, the number, and the general arrangement, care being taken that they are so placed that the hygienic conditions, the lighting, and so on, shall be the best obtainable. According to an American writer on this subject, the golden rule for any one preparing a school plan should be "the classroom shall be the unit first to be considered in planning a school building. The building shall be a number of classrooms properly disposed, and not a whole cut up into schoolrooms, whose size and arrangement are dependent upon the size and shape of the building." Halls, corridors, stairways, cloakrooms, lavatories, the sanitation, the ventilation, and the warming, though all of great importance, are secondary to the schoolrooms, and can be arranged according to the disposition of these. With regard to the rooms the following points must be considered: (*a*) the number required; (*b*) the size; (*c*) the shape.

The *number* of classrooms required will depend upon the number of pupils, the number of subjects taught, and whether the classes are to be mixed or not. These points seem fairly obvious, and it is not necessary to say anything regarding them. It may be said, however, that of the custom of having one large schoolroom in which several classes are taught simultaneously it is impossible to approve. The attention of children is readily distracted, and the hum arising from one class cannot fail to interfere with the work of another. The strain thrown both upon teacher and taught must of necessity be considerable. The plan sometimes adopted of introducing curtains or partitions between the classes is highly objectionable. The great objections urged against separate classrooms seem to be that they interfere with the unity of the school, and it is difficult for one head to supervise properly. A larger staff is also required to carry out the teaching. The unity of the school can be maintained, if necessary, by the provision of a central hall, and the supervision by the head can be carried out without the necessity for his presence at all times.

The *size*, *shape*, and *height* of the classrooms are all important. The size depends upon the number to be accommodated, and the accommodation to be provided for each pupil. The number to be accommodated must be no larger than the teacher can control, and the accommodation provided must be in accordance with certain standards.

The Number to be Accommodated.—Though there seems to be an idea in some places that a teacher can instruct, at one time, any number of children, and classes of 70 or even 80 are not unknown, it cannot be doubted but that, for the teacher's sake no less than for that of the pupils, there is a necessity for limiting the size of classes. In order that the teacher may not have to strain his voice, and that each child may have a certain amount of personal supervision, no class should exceed, according to some, 40, and to others, 48 members. In the regulations it is stated, it will be remembered, that a classroom should not be planned to accommodate more than from 50 to 60 pupils. In the case of infant classes the number of pupils should be 30, though the Board put it at 50 for certificated, and 30 for other approved teachers, permitting accommodation to be provided for not more than 60 infants in one room. The plan adopted in certain places of suspending in each classroom a notice showing the cubic capacity of the room, and the number of pupils to be accommodated is worthy of imitation.

The Accommodation to be Provided.—As in the case of the number to be accommodated, so in the case of the accommodation to be provided the standards laid down in the regulations do not correspond with those suggested by authorities on education and hygiene. According to the regulations the minimum amount of floor space per child is 10 square feet; according to experts it should be 15 square feet. According to the regulations a classroom for from 50 to 60 pupils should be about 24 feet 8 inches square; according to experts, to accommodate 48 pupils, it should be at least 30 feet long and 25 feet broad. As regards the height of the classroom the regulations and the experts are agreed that it should be at least 12 feet high, and should not exceed 14 feet. The reason for this agreement is, that it is now well known that any height above 14 feet cannot be taken into account in calculating air space, the additional height merely acting as space for vitiated air.

Besides standards as to the number of square feet required per child, others as to the cubic space have been laid down. By the Board each child is allowed 120 cubic feet of air space, since each has 10 square feet of floor space, and the room is at least 12 feet high. To the expert this amount appears too small. The general opinion is that each child should be allowed at least 200 cubic feet. With a room 30 by 25 feet and 13 feet high, accommodating 48 pupils, each pupil would have rather over 15 square feet of floor space, and a little more that 200 cubic feet of air space. If the number of pupils were limited to 40, as many contend it should be, each child would have $18\frac{3}{4}$ square feet of floor, and $243\frac{3}{4}$ cubic feet of air space. When it is borne in mind that in a common lodging-house each person is allowed a minimum of 300 cubic feet of air space this $243\frac{3}{4}$ does not appear excessive.

In the case of infant classrooms the Board of Education consider that it is sufficient to give each child 9 instead of 10 square feet. This is not wise, since not only is the air space diminished, but the space in which the exercises necessary in the training of infants can be carried out is reduced also. The main object of providing a larger air space is, of course, to make the ventilation of the classroom easier, and to permit of the air in the room being changed without causing a draught.

The Shape of the Classroom.—The classroom should be oblong in shape, the desks being placed across the room, the intervals between them running the long way of the room. The advantages of such a shape are, that the lighting can be more satisfactorily carried out, and the pupils can more readily and with less effort see any apparatus which the teacher may wish to demonstrate behind the desk, there being very little foreshortening for the pupils on the extreme left or right.

The Distribution of the Rooms.—The chief point to be considered here is as to whether or not it is an advantage to have a central hall. It has also to be decided how the classrooms shall be arranged in relation to the central hall. In many cases where a central hall is erected it is customary to have the classrooms arranged round it and opening from it. The chief objections to such an arrangement are the absence of through ventilation in the classrooms, and the ventilation of the classrooms into the large hall. Moreover, when the hall is used for drilling some of the pupils the din is bound to upset those working in the classrooms, who are only shut off from it by thin partitions of glass and wood. There are not so many objections to having a large assembly hall with classrooms on one side only, because it is then possible to have windows on the other side of the hall, and so more or less to secure through ventilation. According to the regulations no central hall shall contain a floor space of more than 4 square feet for each scholar, and classes are not to be held in it except under exceptional circumstances. In grouping classrooms in relation to the hall, care must be taken that their windows are so placed that they shall get the best light, and that that light shall come in on the left of the pupils. If there be no hall the arrangement must also be such as to obtain the very best light, and that from the left hand. The doors of each classroom should be made to open both inwards and outwards, and if the person who makes the doors can be prevailed upon to make them smooth and without ornamentation, it will be found cleaner and better. If the doors are made to open only in one direction they should open outwards. This, it will be understood, is an advantage in the case of a sudden outbreak of fire. Doors connecting classrooms with corridors should be at least 3 feet 6 inches wide.

Cloakrooms.—The best arrangement with regard to cloakrooms is undoubtedly to supply one for each classroom of the size already described, *i.e.* holding 48 pupils. In any case, if accommodation is to be provided for more than 100 or 120 scholars more than one cloakroom is required. They must be rooms distinct and separate from the classrooms. The hanging of coats, etc., in corridors or classrooms is to be discouraged as unsightly and insanitary. The cloakrooms should open from the corridor, and should be so placed that they shall be well lighted. Each must be well ventilated, air inlets and outlets being provided. The cloakroom must not be so placed that the classroom is entered through it, since the tendency will be for it to ventilate into the classroom, and for the odours and emanations from damp clothing to do harm to those compelled to inhale them. It should be of a fair size; 150 square feet of floor space for every 50 pupils has been suggested. There should be two doors, one for ingress and one for egress, and they should not be too narrow. The gangways between the rows of pegs should be at least 4 feet wide. The pegs themselves should be at least 12, preferably 15, inches apart, in order to prevent possible infection or the wetting by one garment of others. The pegs may be arranged in two rows, but should not be too high, 5 feet at the outside. Each should be numbered, and each child should know his own number and peg.

Umbrella racks provided with small channels opening on the outside of the building, to carry off the drippings from the umbrellas, are to be recommended. To assist in the drying of the garments, hot-water pipes should be provided and so arranged that a current of hot air passes upwards among the articles of clothing. In many of the best schools in America, each pupil is provided with a small compartment or locker 10 inches wide, in which are a couple of pegs and two shelves, on one of which the hat may be placed, and on the other the overshoes or dry shoes for wearing in school. In the elementary schools in this country, since few or none of the children possess overshoes, and very few parents can afford to supply a dry pair for school wear, the locker may be omitted.

Teachers' Rooms.—Teachers' rooms should be provided, of course.

Accident Room.—An accident room is, unfortunately, practically always omitted in schools in this country, though provided in many of the American city schools. Such a room need not be large, but should be removed from the classrooms. To it may be sent children who have been hurt or who are sick and are waiting for some one to call for them, or for inspection by the medical officer. The room should be provided with a heating apparatus and a fire, and should preferably have smooth walls, and little furniture. A small cupboard to contain some simple surgical dressings may be introduced.

Corridors.—These should not be too narrow. Ten to twelve feet is a good width for the main corridors. To have them wider is to waste space. They should be well lighted by means of a large window at each end, and, if necessary, light may be borrowed from adjacent classrooms, but no classroom should receive its main light from a corridor. Ground glass should not be used for such windows, preference being given to a transparent or ribbed glass. The sills of such windows should be between 7 and 8 feet from the floor. The floors of corridors may be made of terazzo or of wood. The walls of corridors may be made of glazed bricks, if expense is no object, otherwise wooden wainscotting or smooth painted cement must be employed.

Staircases and Entrances.—There should not be less than two entrances to the school buildings, and if possible there should be a number sufficient to permit of the whole building being emptied in less than five minutes in case of fire. In the case of a mixed school, there should be separate entrances for boys and girls. Each entrance should be provided with a porch so that the doors may open outwards. Moreover, the entrance should be wider than the corridor, or hall, to which it admits.

There should be at least two staircases to every storey, one of which, in the case of a mixed school, may be used by boys, and the other by girls. Staircases must never be placed in the centre of the building, but to prevent risks in the case of fire, should be at the ends or sides. They should be easily accessible from the contiguous classrooms, and they should be well lighted. Spiral staircases are to be avoided, the "box," which has a wall on each side, or the "balustrade" being preferred, the former, according to some authorities being the better, and accountable for fewer accidents than the latter. The staircase should be at least 5 feet wide, and should be somewhat wider at the foot.

The steps should be straight, no triangular steps or winders being introduced, and they should be fireproof. Steps with an iron upright and a slate or steel and lead *tread* are recommended. The step should not be higher than $5\frac{1}{2}$ to 6 inches, and should be from $11\frac{1}{2}$ to 13 inches wide. The "nosing" or projecting edge should be short. The flights should be short, with landings at every eight or ten steps. The staircase should not open directly at the door of a classroom, but there should be a short landing. Handrails for the use of the children should be provided on each side of the staircase. It may be advisable, indeed, to have two, one low for the small children, the other at a higher level for the bigger pupils.

The **Playground** has already been referred to, but there are one or two points in connection with it to be mentioned. It should be as large as possible, and the 30 square feet per child allowed by the Board should be exceeded if possible. It should be placed on the sunny side of the building south, south-east, or south-west, and should be protected from cold winds by the building itself. If there is sufficient space, some ornamentation may be introduced, but in the smoky districts of large cities it is probably better to refrain from introducing trees and plants. For play in wet weather, covered sheds should be provided; these are best placed against the wall bounding the grounds on the north or east side. In order to admit light and air, the front should be quite open, the sloping roof being supported by iron pillars.

The surface of the playground should be as level as possible, and should be efficiently drained. If there is a slope this should be away from the building. As a covering, asphalte or gravel may be used. Asphalte is easily kept clean and level, but it is hard and apt to be slippery. Gravel is dusty, but is fairly clean, and the dust may be kept down by watering the surface. It is probable that the children themselves prefer asphalte, as it is admirably adapted for many of the games which they play. It is held, however, that, being slippery, it interferes with their movements, prevents perfect co-ordination of their muscles and more exact and perfect development of the physical powers. Despite these objections, asphalte must be regarded as the best covering. It is clean, and though hard, yet more or less elastic. Though at the outset more costly than a gravel playground, it is cheaper in the end, as it lasts much longer without requiring patching and levelling. There should, of course, be separate playgrounds for boys and girls. The use of the basement and of the roof as playgrounds has been mentioned. The objection to the former is the difficulty of obtaining sufficient light and sunshine. The playground should be surrounded by a low wall, surmounted by high railings, in order that the sun's rays may not be interfered with.

The **Entrances** to the school grounds should be ample and from the quietest thoroughfares possible. The entrances for the boys should be separate from those for the girls.

CHAPTER XVII

SCHOOL VENTILATION

Appliances used in natural ventilation—Forms of artificial ventilation—Ventilation and warming.

In dealing with the respiratory system, the principles underlying ventilation were considered, and in this section it is only necessary to refer to the appliances that may be adopted in carrying out either natural or artificial methods of ventilation. In ordinary rooms, naturally ventilated, it may be possible to depend entirely on the natural openings, and upon the natural physical forces. In larger rooms and classrooms it is generally necessary to supplement these, and to introduce additional inlets and outlets, at least.

Inlets.—Instead of permitting the air to enter indiscriminately under doors and so on, special *inlets*, which should be placed as low as possible, may be introduced. The lower part of the woodwork of the doors, for instance, may be replaced by an iron grating through which the air outside may freely enter the room. This, however, should not be done with doors which open from corridors, or which form communications between one room and another. Around the lower part of the walls of the room, especially the outside walls, other gratings may be placed, through which the outside air may enter. The lower halves of the windows may be made to lift up, and the air will find an inlet there. The chief objection to low inlets is that the cold air tends to chill the feet of persons compelled to sit or stand in the room. This difficulty may be partially overcome by erecting screens in front of the openings, or by using what are known as *Tobin's tubes*. The air which comes in may be heated by making it pass over hot pipes, a device which will be mentioned again when dealing with school warming.

When the lower half of a window is made to act as an inlet, one very great objection is, that the pupils who sit under it have cold air continually pouring down upon their heads. Draughts, too, are likely to be caused, which are all the more marked the less the window is raised. To overcome these difficulties, a board 6 to 12 inches high may be placed along the lower part of the window. If the window is not raised above it, this will tend to give the air entering an upward direction, and ensure its getting slightly heated before it falls. Again, the lower panes may be shielded by a projecting glass structure, resembling a Tobin's

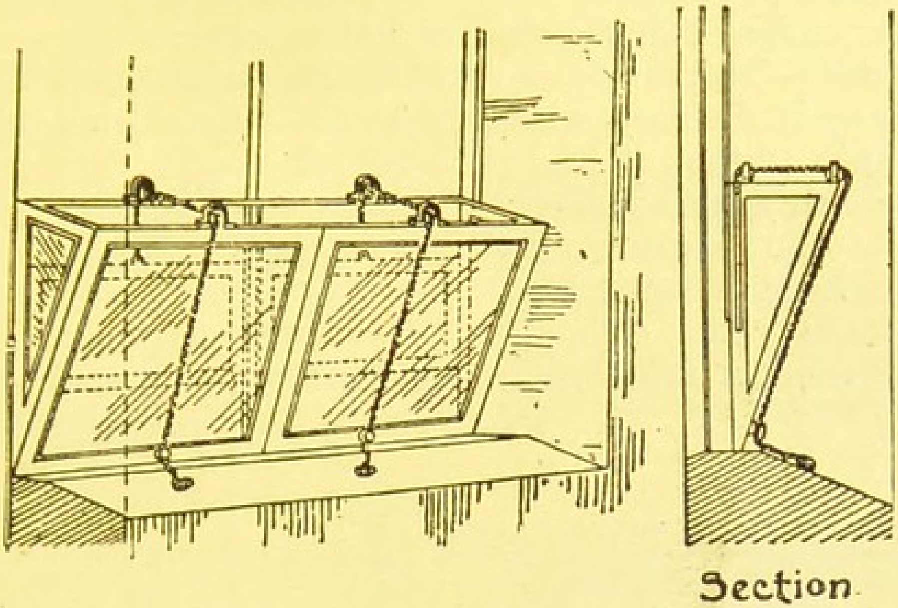


FIG. 91.—Boyle's air-hopper fixed to lower part of window.

tube, the upper part of which is hinged, and may be raised; or such a window hopper as is shown in Fig. 91, may be used. Or, again, *Hinckes-Bird's method* may be adopted, in which the lower sash is permanently raised and supported upon a horizontal block of wood running the whole breadth of the window. In this way an interval is left between the upper and lower sashes through which air can enter.

Louvred panes, which resemble a venetian blind in their arrangement, or some of the

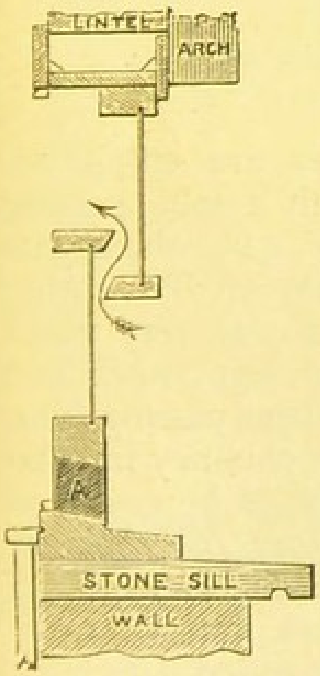


FIG. 92.—Hinckes-Bird's method of ventilation.

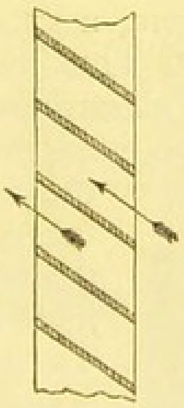


FIG. 93.—Louvre ventilator.

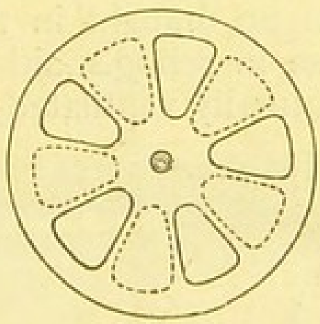


FIG. 94.—Cooper's ventilator.

(*From Corfield's "Law of Health."*)

so-called *hit and miss* mechanisms, such as Cooper's ventilator, may be introduced.

Ventilating bricks may be introduced into the walls to act as inlets. These are ordinary bricks perforated to permit air to enter. The perforations are usually conical in shape, wider at the inner end, so that the air may diffuse better.

Outlets.—To provide an *outlet* for the air, the indication is to go high up in the room where the heated vitiated air tends to go. The upper sashes of the windows may be pulled down for the purpose, or special openings may be made through the ceiling and the roof in the form of tubes. For this purpose *McKinnell's tubes* are employed. *Ventilating gas globes*, which are connected with a tube passing through the ceiling, may be introduced. The gas, which acts as an illuminant for the room, assists in ventilation by causing an up draught in the tube. This method is not of very much use in schools, although in classrooms used for night work and naturally ventilated, it may be employed. The heat passing from the fire up the chimney may be taken advantage of by means of grated *openings in the chimney*, high up in the chimney breast. To prevent back draught, these openings are provided with mica flaps, which are very light, and are hinged to open only in the direction of the interior of the chimney. When the current is away from the room, up the chimney, the flaps remain open. When there is any back draught

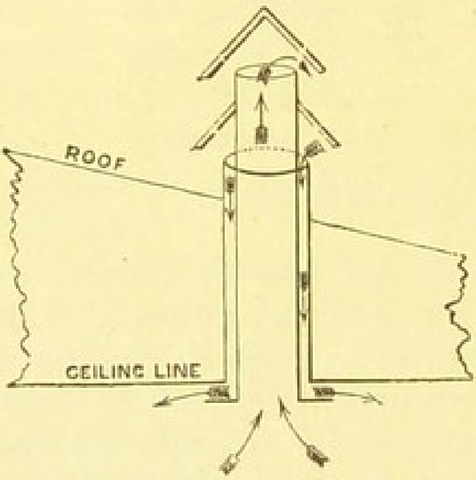


FIG. 95.—McKinnell's tube.
(*From Corfield's "Law of Health."*)

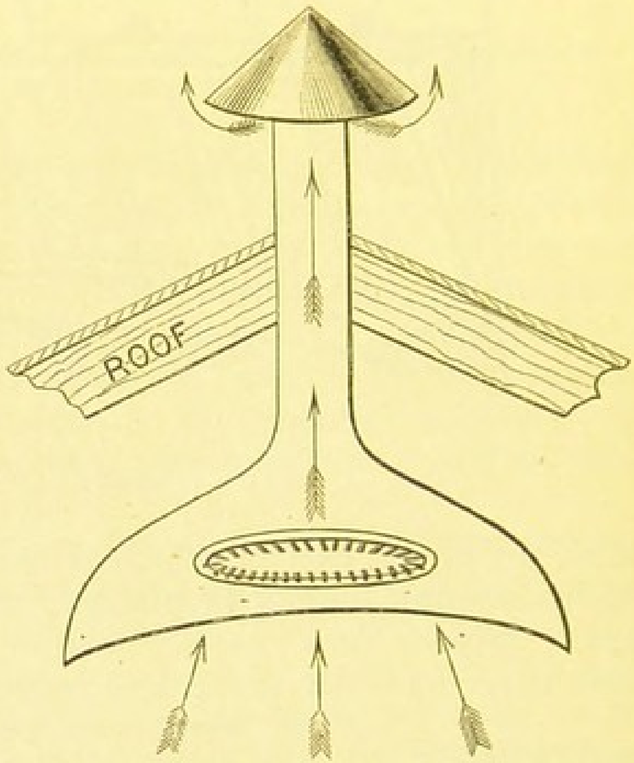


FIG. 96.—Ventilating gas-burner.
(*From Notter and Firth's "Hygiene."*)

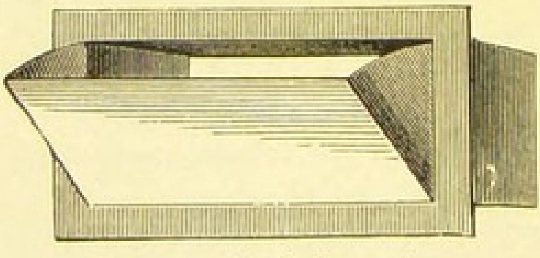
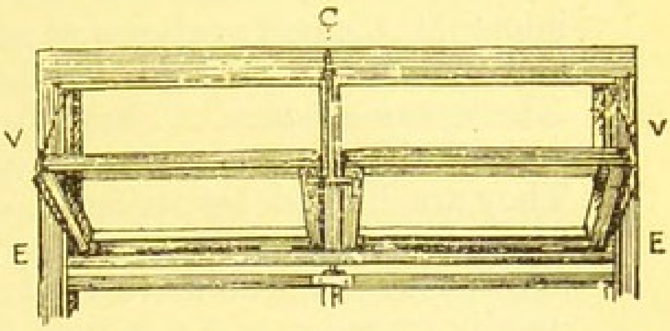


FIG. 97.—Sheringham valve.
(*From Corfield's "Law of Health."*)

they close and prevent the return of smoke into the room. These flaps are apt to be noisy in gusty weather.

Instead of depending upon the chimney, *a special ventilating or foul-air flue* may be provided for the whole building. Usually this runs alongside the smoke flue of the furnace or fire in the basement, which serves the heating apparatus. Into it the foul air from each of the rooms may be conducted by tubes leading from the upper part of each room, the heat borrowed from the smoke flue providing the motive power.



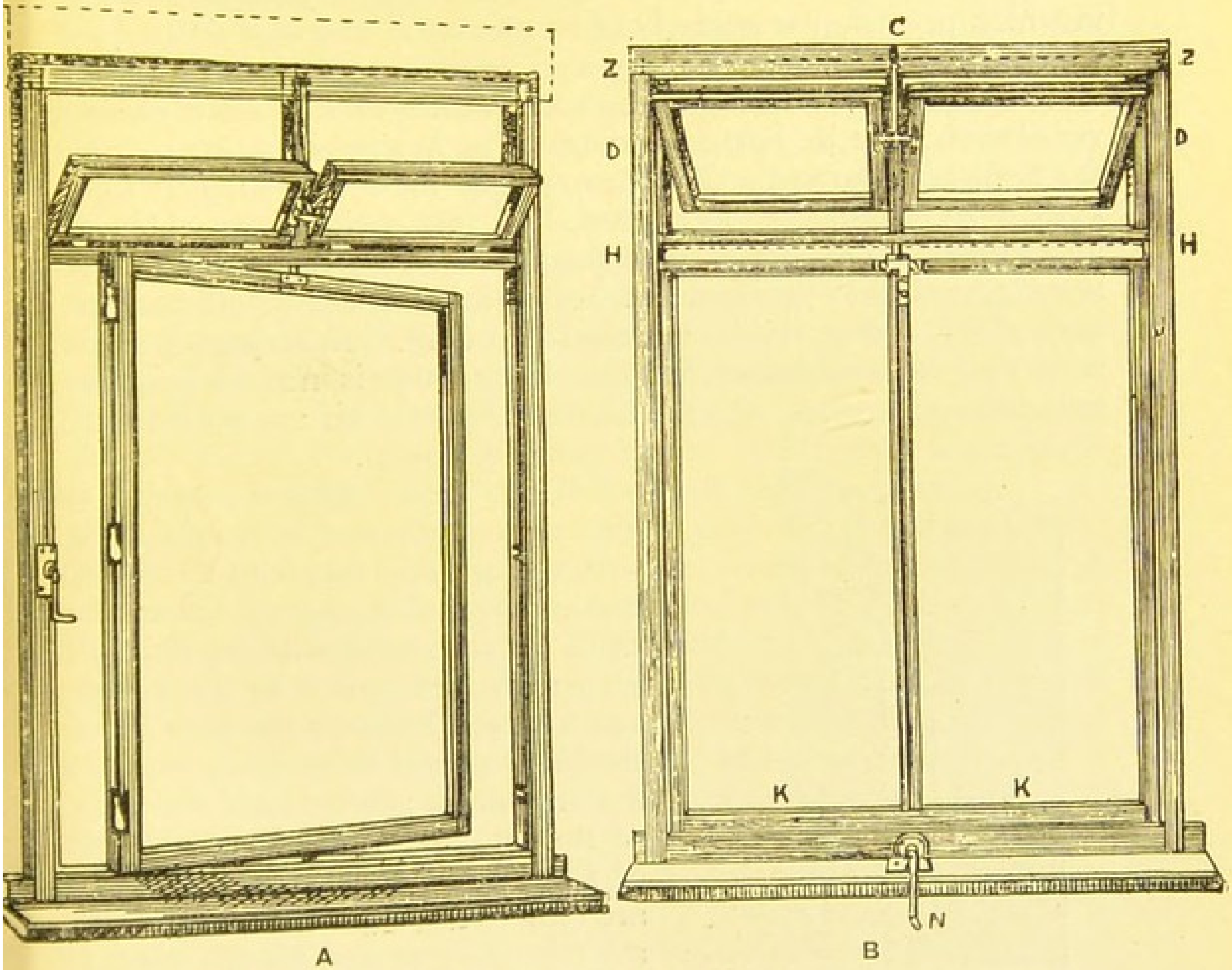


Fig. 98.—The Chaddock window.

N is the key which controls both parts, upper and lower. In A the rotation of the lower part round the central pivot is shown. Air enters the room on one side and passes out on the other, depending upon the direction of the wind.

The Wind and Ventilation.—Some of the contrivances introduced to assist natural ventilation aim at taking advantage of the wind. Instead of having on the window, sashes which pull up or down, it is common to find that the upper half of the upper sash is hinged so that it opens inwards, the windows on one side acting as inlets, those on the other as outlets, by turns, according to the direction of the wind.

If there are windows on one side only, they may be used as air inlets, McKinnell's tubes, and so on, being used as outlets. Inlets and outlets for the wind may be provided in what are known as *Sheringham's valves.* These are fixed on each side of the room, and are the inner coverings of grated openings through the walls. They are hinged below, and are provided with side flaps. They can be opened to different extents, and so the amount of air allowed to enter or leave the room can be regulated. They are usually placed 5 or 6 feet from the floor. The *Chaddock window*, in which provision is made both for the entry and exit of air, and which is shown in Fig. 98, may also be used.

One or two points regarding contrivances used to assist natural ventilation must be borne in mind. The height of the inlets from the floor is important. The best height for the opening is from 5 to 6 feet from the floor level. In this position draughts will be avoided. The *size* of the openings is also of importance. It is calculated that 72 square inches of inlet should be allowed for each child, and a similar amount of outlet. In arranging inlets it is well to remember that one large inlet is not so good as several smaller ones, which will distribute the air more uniformly if properly placed.

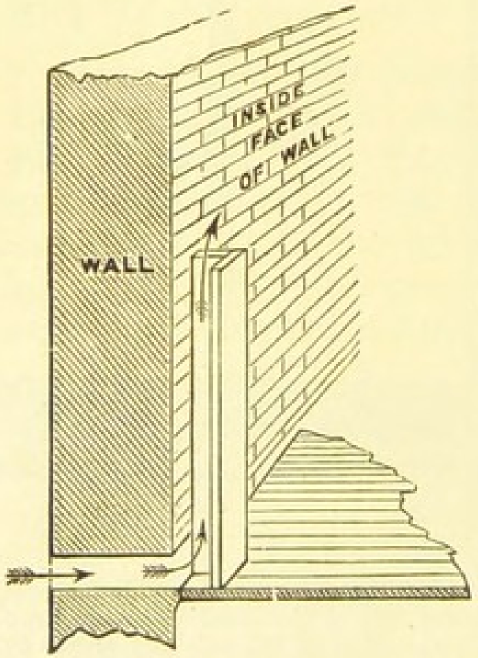


FIG. 99.—Tobin's tube.
(*From Corfield's "Law of Health."*)

When *Tobin's tubes* are used, it is well to have the end communicating with the air, and that with the room, rather larger than the calibre of the tube. The tube should be circular, with a diameter of 6 to 12 inches, and where it bends at the floor level, the bend should be a curve, and not a sharp angle; otherwise, the flow of the air is diminished as a result of friction. If Sheringham's valves are employed, the same precautions are necessary as regards the placing of them.

Systems of Artificial Ventilation.—Some of the appliances and systems mentioned in connection with natural ventilation might almost be considered as systems of artificial ventilation, but they are in reality merely artificial aids to natural ventilation. The term artificial ventilation includes two things: artificial ventilation proper, and mechanical ventilation.

Under the head of *artificial ventilation proper* should be considered those systems in which the heating or lighting appliances are made use of to draw the vitiated air out of the room, or, especially in the case of the heating appliances, to draw it in and prepare it for breathing purposes.

Under *mechanical ventilation* fall to be considered those systems in which special machinery is employed to force the air into the rooms of a building or to draw it out. The former method is known as the *propulsion* or *plenum method*, the latter is called the *exhaust* or *vacuum method.* Not infrequently the two methods are combined.

Ventilation and Warming.—In dealing with natural ventilation, a few of the methods by which the heating and lighting apparatus could be made use of to assist natural ventilation were given. As a matter of fact, the connection between warming and ventilation, in the case of schools, is so close that it is almost impossible to deal with them separately, and it may be laid down as a dictum that *no system of warming that does not to some extent assist ventilation should be considered.* Various methods of combined heating and ventilation are in vogue. If fires are used in the classrooms, the so-called *ventilating fireplaces*, of which Galton's is the type, may be employed. If stoves are preferred and permitted, one or other of the many ventilating stoves, such as *George's Calorigen* or *Bond's Euthermic*, may be installed.

When, as will be necessary in the case of large classrooms, hot water or steam-heating systems are resorted to, heating and ventilation may be made to go hand in hand. The connection between the two may be very slight, and the steam or hot-water pipes may be arranged as radiators in the rooms opposite the air inlets, and merely warm the air as it comes in. Such a method of heating is known as the *direct-indirect*, or *semi-direct.*

When the pipes are in the room, but play no part in ventilation, the method of heating is called *direct.*

When the hot pipes are placed elsewhere in the school buildings than in the classrooms, and the heating is brought about, and the ventilation at the same time, by driving into the rooms air which has been warmed by contact with these pipes, the method of heating adopted is called the *indirect method.* This is one of the forms of mechanical ventilation. A few words may be said regarding each of the above appliances.

Open Fireplaces.—These, though each can remove about 14,000 cubic feet of air per hour from a room, do not really assist to any great extent in the ventilation of the room. This is mainly because they draw away the lower, and therefore the purer air.

One of the best methods of using an open fireplace as an aid to ventilation, is by introducing a Galton or other ventilating fireplace. In the Galton the space behind the fireplace proper is made to act as a heating chamber for air which comes into it from outside through an opening communicating with the outer air. The chamber also communicates with the room through openings made in the wall above the fireplace. When the fire is lighted the entering air gets heated in passing over the back of the fireplace, and rises to escape at any opening which it may find. This opening is usually placed at some point between the mantelpiece and the ceiling, the lower the better. The air mixes with the ordinary foul air of the room, and falls, to be breathed by the occupants. Where this method is in use less air enters under doors and windows, and there are fewer cold draughts.

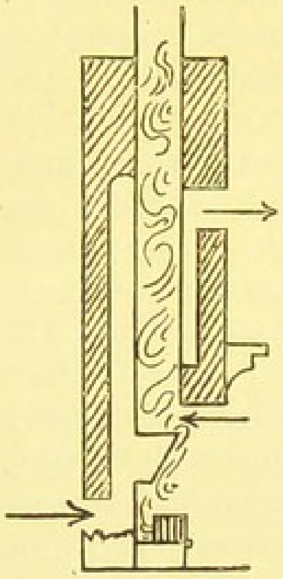


FIG. 100.—Diagram of Galton's fireplace.
(*From Notter and Firth's "Practical Domestic Hygiene."*)

Stoves.—Stoves are only allowed under certain conditions, but if introduced may be made to assist the ventilation. The air coming from the outside is carried into pipes inside the stove as in the

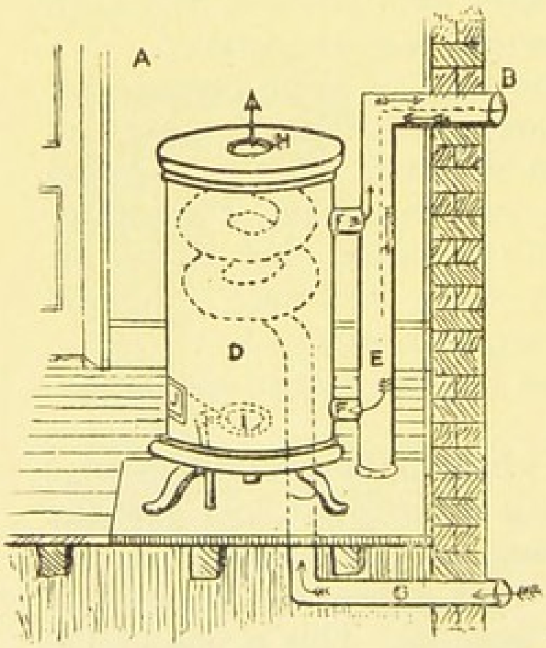


FIG. 101.—George's Calorigen stove.

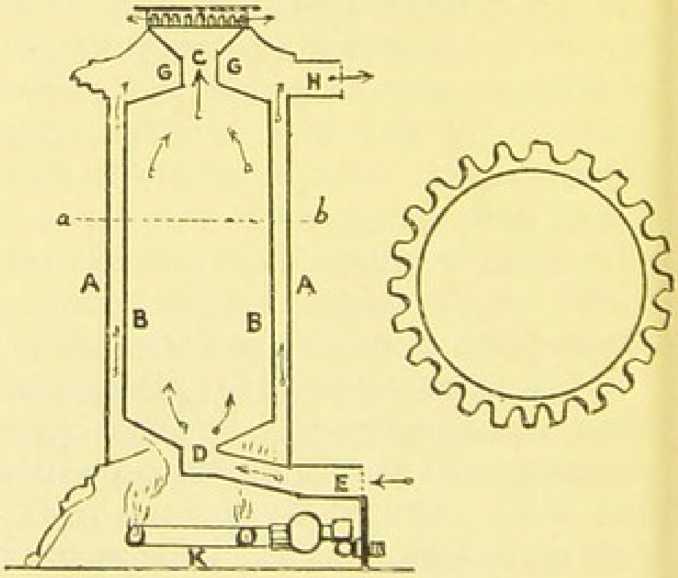


FIG. 102.—Bond's Euthermic stove.

(*From Notter and Firth's "Hygiene."*)

Calorigen, or into a chamber, also inside the stove, as in the

Euthermic, and is heated by the burning gas or coal. The products of combustion are carried away to be discharged outside the room, the heated air being discharged in the room. The air in the pipes or the chamber does not, of course, meet the products of combustion.

Hot Water or Steam Heating and Ventilation

The Direct-Indirect Method.—When the heating of the school is brought about by means of hot water or steam radiators placed in each of the classrooms, these may be erected opposite the air inlets, and the *direct-indirect method* of heating used. When this system is adopted it is better to provide several small radiators in front of several inlets, than one large one in front of one inlet. To ensure that the air coming in through the inlet shall be heated by the pipes, several devices are recommended.

(*a*) In one the air inlet is placed on a level with the middle of the radiator, and the air being heated takes an upward direction.

(*b*) In another the inlet is in the floor below the radiator, and communicates with an air-box below the floor, which in turn communicates with the outer air. The air in the box tends to pass upwards among the pipes, and so gets heated.

(*c*) The inlet may be made in the wall opposite the lower part of the radiator which is encased, so that the air, prevented by the casing from passing straight through, tends to take an upward direction. In all these systems it is well to increase the radiating surface by employing more or less fluted instead of circular pipes.

Air Inlets and Outlets.—The *air inlets* should in all cases be provided with gratings, and be fitted with wire gauze. This gauze tends to collect dust and other particles from the air, and should be easily removable, so that it can be taken out and cleaned. When an *air-box* is used, this also must be cleaned out regularly. Care should be taken, in fixing the radiators, that they are not made harbours for dust. It should always be possible to get all round and under them with a brush.

In this direct-indirect method the necessity for providing *air outlets* must not be overlooked. As in natural ventilation, they should be as high up as possible. Tubes passing through the ceiling and opening at the roof may be used. In some cases the outlet pipes from the various rooms are carried to a common shaft which runs alongside the chimney from the furnace in connection with the boiler which supplies the hot water, etc., to the radiators.

As it is well, no matter what type of heating is used, to introduce a fireplace into each room, the chimney from this will, to a certain extent, act as an outlet. So also will the windows.

All these are usually insufficient, and it is practically necessary to supply some motive power to remove the impure air, and to induce a current of fresh air to enter. This may be done by running the outlet pipe alongside the boiler flue as mentioned, or a fan driven by steam or electricity may be introduced. The number of revolutions to be made by the fan per minute will depend upon its size, and the amount of air to be passed through the opening per minute. This method of extraction by fan is a good one. It must be remembered, however, that the fan may prove a distraction for the children, and it must be, as far as possible, concealed.

One great objection to the direct-indirect method of ventilation is one that can be taken to all forms of ventilation, except ventilation by propulsion, viz. that it is impossible to answer for the purity of the air supplied, since the air enters the room at several points. By attending to the air inlets, however, and having them cleaned at regular intervals, this can be overcome to a certain extent.

Effect of Breathing Hot, Dry Air.—Another objection is that though the air can be kept at a suitable temperature by regulating the temperature at which the boiler is kept, if the system is a hot-water one; or by having means of cutting off a part of each radiator if steam is used, the air is apt to be deprived of its moisture. The objections to breathing hot, dry air are many, and drying must be prevented if possible. The capacity of the air for moisture is very much increased by warming it. In the classroom this moisture will be absorbed from anything that will give it up, *e.g.* the furnishings; and the skin, and the respiratory passages, of the persons in the room. As a result the air passages become dry and irritated, sore throat and catarrh are apt to be produced, and injury to the health on account of the changes from the hot, dry air of the classroom to the cold, moist outside air. To prevent this drying of the air it is necessary to provide for the evaporation of water in the room. This is done by placing dishes containing water upon the radiators. Vessels of flower-pot clay, running the whole length of the radiator, and of a depth of 4–6 inches, may be used for the purpose, and will diminish to a certain extent the dryness of the air. This tendency to drying of the air both by hot-water radiators and stoves is generally recognized, but the usual method of trying to overcome it, by placing a small dish of water on or near the heating apparatus, is futile.

Humidity.—The amount of moisture present in the air can always be learned from the difference between the readings of the dry and wet bulb thermometers. The lower the reading of the wet in comparison with the dry bulb thermometer, the smaller the amount of moisture present, and the lower is what is called the *relative humidity* of the air.

From the readings of the dry and wet bulb thermometers it is possible to work out the relative humidity, but as for most temperatures it has already been calculated, it is generally only necessary to refer to certain tables for the figure when the temperatures have been found. Broadly speaking, it may be said that the relative humidity should never be allowed to fall below 55. This result can be obtained by keeping the dry bulb thermometer at from 56° to 60° Fahr., and ensuring, by the artificial addition of moisture, that the wet bulb reading is never allowed to be more than 9° lower.

If the temperature of the room is carefully regulated the evaporation from the water vessels on the radiators will, to a certain extent, prevent excessive drying. That they will completely prevent it is doubtful, and it is probable that of the many methods suggested for the purpose there is not one really satisfactory.

Mechanical Ventilation

The Indirect Method and Ventilation by Propulsion.—The best method of combining heating and ventilation is the *indirect* method, in which hot air is propelled into each room in the school, all the warming being brought about by this means. This is one of the methods of mechanical ventilation, viz. the *propulsion* method, the other being the *vacuum* or *exhaust* method, in which the foul air is drawn from the room by means of a revolving fan, inlets being provided for the entry of fresh air. In the propulsion method the air drawn from outside is forced by means of fans into the rooms, escape of the foul air being brought about by the greater pressure in the room, which drives the air out through special openings. Very commonly the propulsion and exhaust methods are combined in order to overcome the difficulty of getting rid of the air after it has been breathed.

It cannot be doubted that this indirect method is by far the most satisfactory method of heating and ventilating a building like a school. It is an expensive method, since a skilled person is required to look after the apparatus, but the results are good. Usually it is a success, but sometimes it fails, but it is noticeable that it only fails in those schools where prejudice exists against it, and when no trouble is taken to understand it. Its great advantage is that the heating and ventilating apparatus are centrally placed in the building, and are completely under control. The temperature can be regulated, the source of the air can be carefully chosen, and the air can be treated in any way, filtered, moistened, and so on, before it is sent into the classrooms.

The point or points from which the air in the plenum or propulsion method is to be drawn should be carefully chosen. They should be as high above the ground as possible. The side of the school furthest from houses, streets, and so on, is the best. From this point the air is driven by means of a fan, which is propelled by electricity or water, into a specially built chamber situated usually in the basement. In order to deprive the air of dust particles, and to clean it, it is usually passed through screens of jute or cheese-cloth, stretched on a wooden frame. Instead of using cheese-cloth, which is apt to become clogged, a matting of hemp may be substituted, the strands of which are kept moist by means of a fine stream of water. Such a device, in addition to filtering the air, also washes it. Having been washed and filtered, the air next passes over a series of radiators where it is heated, and from the basement chamber it is distributed by special ducts which open into the various classrooms. To provide against drying of the air, as before, evaporating dishes are placed upon the radiators, and from these the air collects moisture.

Air Inlets and Outlets.—The position of the air inlets in each room must be carefully chosen. Instead of having one large inlet, it is better to have several small ones, and to place them about 8 feet from the floor. The openings should be covered with a wire screen in order to prevent the introduction of foreign bodies into the duct, which may interfere with the flow of the air. The velocity of the incoming air should not exceed 6 feet per second.

The foul air may be permitted to find its own way out through windows, chimneys, etc., or special extract tubes may be provided. In the latter case the outlets should be equal in number to the inlets, and should be situated about 6 inches from the floor, preferably on the same side of the room as the inlets. The pressure of the air in the room may be left to drive the air through the outlets when the plenum system alone is used.

Exhaust or Vacuum Method.—In the *exhaust system* the air is drawn from the room, the motive power being either a fan placed at the outer end of the shaft with which the outlets from all the rooms communicate, or heat, provided by a furnace at the foot of the common outlet shaft, or by the boiler stack in connection with which the outlet shaft is constructed. When the plenum and exhaust systems are combined, power in the shape of a fan is used to drive the air in, and power, either heat or a fan, is used to draw the air out of the rooms also.

The Methods compared.—The main difference between the plenum and exhaust systems is in the relation which the room to be warmed and ventilated bears to the heating apparatus, and the mechanism causing the air to flow through the room. In the *plenum system* the room is at the end of the system, the heating apparatus being placed between the room and the propelling apparatus. Sometimes the relative positions of the two latter are changed, in which case the propelling apparatus will occupy the middle position. In the *exhaust system* the room to be ventilated and warmed is always placed midway between the heating and the exhaust apparatus.

As to which of the methods is the best, opinions vary. The combined method is probably the most satisfactory. Next to it comes the plenum, the exhaust occupying the third place. They all labour under the disadvantage of being costly, and they all require to be watched. The extra expense is worth incurring if by it a uniformly good air can be supplied to the children, and if the person or persons at the head of the school take the trouble to study the system, and see that the individual looking after the mechanism does his duty, it will work satisfactorily.

In the earlier part of the book (p. 87) the objections urged against the artificial methods of ventilation were mentioned. It was shown that one of the chief of these was that difficulties were likely to arise in connection with the windows in the classrooms. These, it is usual to state, should be kept hermetically sealed, since, if they are opened, the system gets upset, cold air being sucked through them in the exhaust system, and warm air being driven out through them before it has circulated through the room in the plenum system.

In the plenum system, at least, it is not, however, absolutely essential to permanently seal the windows. When the full pressure is on, it is better to keep them closed, but at other times they may be opened. In the exhaust system there is a greater tendency for open windows, and also open doors, to upset the system, since cold air will be drawn through the windows, and foul air from the corridors and adjoining rooms through the doors.

The great disadvantage of the exhaust system is that it is not possible always to answer for the source of the air supplied to the rooms. This difficulty is insuperable, and for schools the exhaust cannot be considered a good system. On the ground that they are apt to upset the system, fireplaces are usually omitted from classrooms heated and ventilated by these methods. This idea is quite wrong, and a fireplace should be provided in each room—not in the infants' room only, as the regulations provide—though it may be rarely, if ever, used.

The tendency for the air to be cooled by contact with the glass of the windows, and to lead to the production of draughts in their neighbourhood, must not be forgotten. The thicker the glass, the less the cooling of the air, so that plate-glass is to be recommended. Double windows may be used. In cities, especially, it must be remembered that the air is dirty, and that the dirt tends to collect in the air-ducts. To ensure that the system shall work well, the ducts should be examined and cleaned at regular intervals.

Tests for Impurities in Air.—Though the necessity for the teacher knowing how to test for impurities in air is not particularly obvious, it is usual, in works on school hygiene, to touch upon these, and they may be mentioned here.

The *tests for carbon dioxide* are chemical, and are based upon the fact that it will, when shaken up with lime-water or baryta, produce a white cloud. If the amount of any air that will produce cloudiness in a given quantity of lime-water be known, it is possible to say how much carbon dioxide is present. In one test, bottles of different known sizes are taken, and are filled with water and stoppered. In the room the air of which is to be examined, the water is poured out. The air of the room at once rushes in to take its place, and the bottles are re-stoppered. Half an ounce of lime-water is then quickly added to each bottle, and the stoppers are rapidly replaced. The bottles are shaken, and a note taken of any showing cloudiness. The bottles vary in capacity from $15\frac{1}{2}$ to $2\frac{1}{2}$ ounces. If cloudiness appears only in the former, the air contains 0·4 per thousand carbon dioxide. In a bottle of $10\frac{1}{2}$ ounces capacity, 0·6 per thousand produces cloudiness. The smaller the bottle in which cloudiness appears, the larger the quantity of carbon dioxide present in the air tested.

In a method of estimating carbon dioxide suggested by Dr. Scurfield, medical officer of health for Sheffield, advantage is taken of the fact that baryta is alkaline, and carbon dioxide acid. In an alkaline fluid a substance known as *phenol-phthalein* is pink, and in acid solution it is colourless. If a small quantity of this substance be added to an alkaline fluid like baryta it becomes pink, but if afterwards an acid like carbon dioxide be introduced the pink colour disappears. In Dr. Scurfield's method, tubes containing a mixture of baryta and phenol-phthalein are fixed to a pan containing water, and provided with a tap through which the water can escape. As the water runs out, air enters the pan to take its place, but the arrangement is such that the only way for the air to do so is through the baryta. If the quantity of water that has escaped from the pan be known, the amount of air that has passed through the baryta to take its place will also be known. If the exact moment when the pink colour disappears from the baryta be noted, the quantity of carbon dioxide that

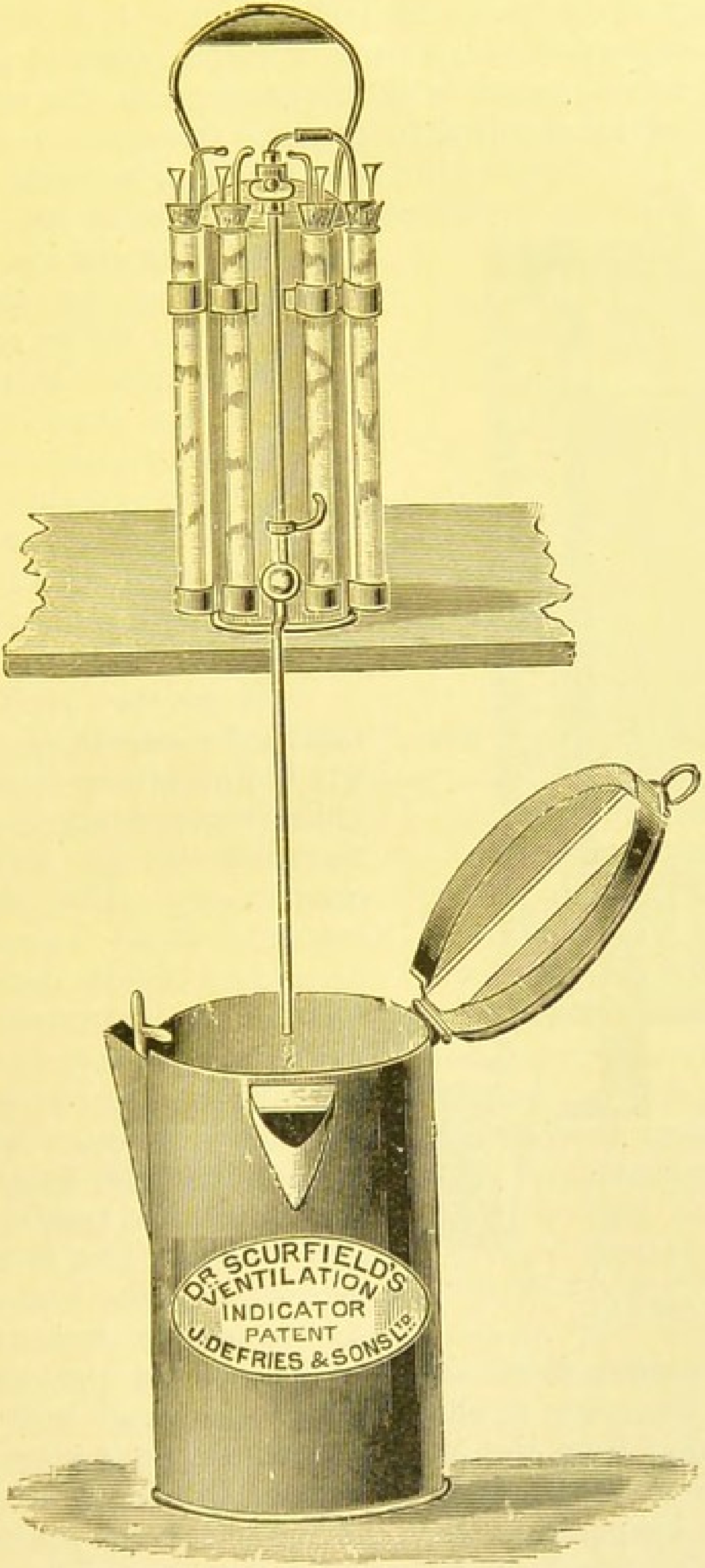


FIG. 103.—Dr. Scurfield's apparatus in use. The outer tube on the right is connected with the water-tank, from which the water is escaping and drawing the air of the room through the baryta in the tube.

must have been present in order to bring about a discharge of the colour can easily be estimated.

The method is a comparative one. The amount of outside air necessary to discharge the pink colour is first found. This is taken as being equal to 0·4 parts of carbon dioxide per thousand. The air in the classroom is then examined in the same way, and the amount of air required to produce the same result noted. If the amounts be equal in each case, then the air of the room is as good as that outside. Any quantity less than an equal amount indicates that the air contains more carbon dioxide. If 10 ounces be required for outside and 5 for inside, the air inside contains twice as much carbon dioxide, and so on. In testing the air of several of the Sheffield schools this method has been employed, and has given very accurate results.

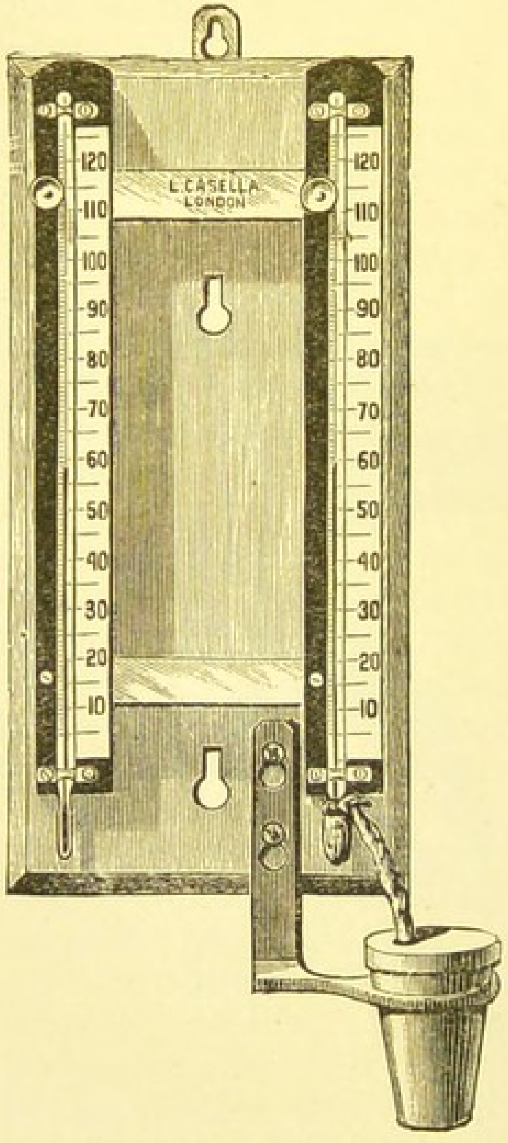


FIG. 104.—Wet and dry bulb thermometer.

The *moisture in the air* is estimated by means of the dry and wet bulb thermometers. The dry bulb thermometer is an ordinary thermometer for registering the temperature. The wet bulb thermometer is an ordinary thermometer in which the bulb containing the mercury is covered with muslin. To this is attached a thread of wool, which dips into a small vessel containing water. The material dipping into the water absorbs it, and keeps the muslin around the bulb moist. The moisture in this evaporates in the heat of the room. As a result the mercury is cooled, and is prevented from rising so high as in the ordinary thermometer. The point to which it will rise depends upon the amount of evaporation from the muslin, which depends upon the amount of moisture in the room. The dryer the room atmosphere the greater the evaporation, and the lower the temperature as indicated on the wet bulb thermometer scale. The moister the atmosphere the less the evaporation that takes place, and therefore the less is the cooling of the mercury, so that the reading will be high. In reading the thermometers, the difference between that of the wet and that of the dry bulb is noted. If they are almost the same, the air is saturated with moisture, and the ventilation of the room is bad. The greater the difference between them, the dryer the atmosphere. The ventilation should be such that there is a difference of at least three or four degrees. In a properly heated and well ventilated classroom the dry bulb reading should be 60° Fahr., the wet bulb 56° or a little lower. To prevent the relative humidity falling below 55, the difference between the two should never exceed 9°.

CHAPTER XVIII

SCHOOL WARMING

Fires—Hot pipes—Hot air.

On the subject of school warming it will not be necessary to say very much, as it has been already touched upon in dealing with artificial ventilation. The heating of the various classrooms may be brought about in one of three ways—

(1) By fires; (2) by hot pipes; (3) by hot air.

Fires.—In the smaller classrooms it is possible that sufficient heat may be obtained from a fire to warm the room. In the larger classrooms the method is inapplicable, since large quantities of coal would have to be burned, and the distribution of the heat would be very irregular, those children near the fire getting too much, those further off too little. It is, moreover, an exceedingly wasteful method, only about one-eighth to one-tenth of the heat produced by the burning coal passing into the room. The remainder is lost in unconsumed smoke and cinders, and in hot gases which disappear up the chimney.

The heat from a fire is transmitted in two ways, viz. by *convection* and by *radiation*. By *convection* is meant the conveyance of heat by heated particles, such as particles of air, from one part of the room to another. In *radiation* the heat rays pass from the substance giving them off, through any intervening medium, for example, air, to be transformed into heat when they reach some solid object. The amount of heat brought about by convection in the case of a fire is small. It is produced as a result of the air coming in contact with furniture, etc., which has been heated by radiation. The molecules of air which come in contact with the hot furniture ascend, other, colder molecules descend, and in this way currents known as *convection currents* are induced.

Most of the heat from a fire is distributed by radiation. The amount any object gets from it varies inversely as the square of its distance from the fire. One important point in connection with radiation is that the air through which the rays of heat pass is not itself heated, and is not therefore deprived of its moisture. In convection, the particles of air themselves, being warmed by contact with the heated surface, undergo at the same time a considerable amount of drying.

The absence of drying of the air in radiation constitutes one of the chief arguments in favour of the use of fires for heating. Other advantages of open fires are, that they add no products of combustion to the room, and they assist in ventilation. It is chiefly because of the part it plays in ventilation that it is advisable to introduce a fireplace into every classroom, whether it is to be used or not.

Stoves.—Instead of using fireplaces, closed stoves may be resorted to. These burn much less coal than fireplaces and are less wasteful of heat. Part of the heating is done by convection, as a result of the air of the room coming in contact with the sides of the stove. Part is also brought about by radiation from the sides of the stove. Stoves are cleaner than open fires, but the air of the room is apt to be dried by contact with them, and *carbon monoxide* gas may be produced if the stove be over-heated and the iron be allowed to get red-hot. The dryness of the air may be to a certain extent mitigated by placing a vessel containing water on the top of the stove. The risk of the production of carbon monoxide by over-heating may almost completely be prevented by seeing that the stove is properly constructed and lined with fire-clay. The assistance obtained from stoves in ventilation is small. In this country there is rather a prejudice against them, and in schools they are only approved by the Board under certain conditions.

Hot Pipes.—Heating may be accomplished by means of pipes carrying either hot water or steam. The value of hot water or steam depends upon the fact that a small quantity of either contains a large amount of heat and can warm a large quantity of air. There are two hot-water systems, viz. *low pressure* and *high pressure.*

In the *low-pressure system* the boiler in which the water is heated and the furnace which heats it are placed, generally, in the lowest part of the building, the hot water circulating through the school and back to the boiler in cast-iron pipes 2 to 4 inches in diameter. The water in this system is kept at or about boiling point, *i.e.* 212° Fahr.

In the *high-pressure system* there is no boiler, the pipes carrying the water passing in the form of a coil through the furnace. The pipes are of wrought iron, and not more than an inch and a half in diameter. One-tenth part of the piping is in the furnace, the remainder is distributed throughout the rooms. The temperature obtained in this system is higher than in the other, and the heat can be much more rapidly obtained. It is more complex than the low pressure system, and whereas it is possible in the former to have valves cutting off certain parts of the system, in the latter this cannot be done.

Steam may be used for heating purposes on account of the fact that when it condenses it gives off a large amount of heat. It is generated in a boiler in the basement of the building. It is then carried by small pipes, cased in felt to prevent condensation, to pipes of a greater diameter in the rooms. These act as condensers, and from them the condensed water is returned to the boiler by another set of pipes.

The distribution of the hot pipes is a matter of great importance. The usual amount of piping allowed is twelve feet of a four-inch pipe for every thousand cubic feet of air space to be heated. The pipes should not, as was formerly the case, be laid alongside the walls. They should be arranged as radiators opposite the air inlets, and so be taken advantage of in connection with the ventilation of the room. Heating is brought about partly by convection partly by radiation, but mainly by convection. The air is therefore dried to a certain extent, and moisture will have to be added in one or other of the ways already mentioned.

Hot Air.—Heating by means of hot air has already been considered in connection with artificial ventilation. The air should be distributed through several openings.

The best working temperature for a classroom is between 60° and 65° Fahr. It should be the aim of the teacher to keep the temperature even. If there is, as there should be, a thermometer in every classroom, it should be placed away from the heating apparatus and the door. It should be consulted at intervals during a class session, and variations in the readings prevented by attention to the heating.

CHAPTER XIX

SCHOOL LIGHTING

Natural and artificial illuminants—Points to be attended to—Tests for illumination.

Methods of Illumination.—In dealing with the question of lighting two kinds have to be considered, viz. natural and artificial. The advantages of the natural over the artificial methods of illumination are many. The stimulating effect of bright daylight on the vital functions is well known, and is, of course, most marked in the case of children. The effect of good daylight in diminishing the strain on the eyesight in any work in which the eyes are largely employed need hardly be mentioned, although it does not seem to have come home yet to many people connected with teaching.

The schoolroom, it is needless to say, cannot be too well supplied with daylight. No effort should be spared to obtain all the natural light possible, and to diminish the necessity for having recourse to artificial illuminants, which are less satisfactory, even absolutely harmful, in that they tend to vitiate the air of the room.

In aiming at the best light possible, it must not be forgotten that many of the schooldays are dull days, and the following points have to be specially considered—

(1) The window area in relation to the size of the classroom.

(2) The placing of the windows so that the light shall come in the proper direction, and the space between the windows be the smallest possible.

(3) The assistance which is to be obtained in lighting by choosing carefully the colours for the walls.

In the section on eyesight, in the first part of the book, reference was made to the majority of these points, and it is hardly necessary to say very much regarding them at present.

The Window Area.—The window area, according to the majority of authorities, should be one-fourth to one-sixth of the floor space of the room according as the school is, or is not, in close proximity to other buildings. Preferably the window area should be one-fourth of the floor space, except in the case of rooms having a northern exposure, when it should rather exceed one-fourth. In the basement the one-fourth limit is certainly not too high, though it may be possible to do with a limit of one-fifth or one-sixth in the upper storeys. It is impossible to have too much light. If it is necessary to diminish it at any time window blinds may be used. The chief objection to large windows is the cooling of the air of the room, and the production of draughts immediately under the window.

The Placing of the Windows.—The importance of having the main light windows on the left of the pupils is generally recognized. The supplementary light windows are best placed on the right of the pupils. The objections to front, and rear, and top lights, have already been sufficiently detailed. The following points are of importance in connection with the placing of the windows, and must be attended to :—

(1) The windows admitting the light must not come too near the floor nor must they be placed too far off it.

(2) The windows must go as close to the ceiling and to the back wall of the room as possible.

(3) They must be as broad as possible, and be as close to one another as is consistent with the safety of the walls.

The reasons for these desiderata may be summarized as follows :—

(*a*) If the windows come too near the floor, the light, instead of falling from above downwards on to the work, passes in more horizontally and tends to produce a glare. If on the other hand they are placed too far above the pupils' heads, those sitting close under them are working in a shadow. The best level for the window-sill is 4 feet from the floor. The sills of the windows supplying the supplementary light may be 5 feet from the floor, but in order not to interfere with cross ventilation, the tendency to make such windows too small must be avoided.

(*b*) The windows should be carried up as close to the ceiling as possible, mainly because the best light is that entering from the upper part. They should be carried as close up to the rear wall of the room as possible, because the children forced to sit near that wall must not be deprived of light.

(*c*) With regard to the breadth of the windows, the practice of having narrow windows with broad spaces between is essentially bad. The windows should be as broad as possible, and the spaces between narrow, in order that the shadows produced by the latter shall also be narrow, and the light supplied to the children seated in a line with them as little interfered with as possible. The use of iron instead of stonework pillars in order to avoid weakening of the wall has already been mentioned. With regard to the best kind of glass to be employed, enough has already been said. The importance of bevelling all woodwork in connection with the windows in order to avoid cutting off any rays of light should be borne in mind.

Tests for Lighting.—The test for effective lighting is made by estimating the amount of illumination in the most *unfavourable* part of the room. The normal eye should be able to read with ease in any corner print of this size, *i.e.* diamond print, at from 16 to 12 inches distance. For a second test a special instrument known as the *photometer* is used. In a third test the light is regarded as effective if it is possible to distinguish as separate dots at a distance of 10 feet a line of dots 1 millimetre square with an interval of 1 millimetre between each pair. According to the regulations, in rooms 14 feet high any space beyond 24 feet from the window wall is insufficiently lighted. Briefly the plan should be to make the lighting such that it shall be effective on the *dullest* day, and so that children unfavourably placed in relation to the windows, that is to say, too near or too far from them, behind the rearmost window, or in front of the foremost window, shall have a sufficiency of light.

Something has already been said regarding blinds for the windows. Many recommend outside blinds of white or drab canvas, which are attached to iron rods hinged at the middle of the window and are controlled from within. By falling outwards these cover only the upper part of the window, and cut off the heat rays without interfering too much with the light rays. Another plan which has been suggested is to have inside blinds which are made of some opaque material, greenish gray in colour, and rolling up from below, so that if light is to be cut off the least valuable, namely, that from the lower half, shall be the part removed. To exclude direct rays of sunlight, blinds from the top may be used. The first suggestion, viz. the outside shade seems to be the more satisfactory. That the effective lighting may be increased by regular and frequent cleaning of the windows is to be remembered.

The lighting of the classroom is greatly affected by the colouring of the walls and ceilings. The colours to be employed are given in the chapter on eyesight.

Artificial Lighting.—Artificial means of lighting should be introduced into schools for the use of evening classes, and for the day classes in very dull and foggy weather. If care has been taken to regulate the window area for lighting on ordinary dull days the necessity for using artificial light will only arise on the occasions mentioned. The best kind of artificial light is undoubtedly electric light, since it is clean, and cool, and steady, and adds no products of combustion to the air of the room. Moreover, it can be easily shaded, and more can be got out of it.

Gas is not nearly so good, but if it has to be used it should be in conjunction with incandescent mantles. Unprotected flames are apt to flicker. They are dirty and wasteful of oxygen. The ordinary gas burner fouls as much air in an hour as five or six adults. If an incandescent light is used the fouling is distinctly less.

Oil may have to be used as an illuminant in country places, and one oil lamp can foul as much air as a single gas-burner. For this reason the ventilation must be very efficient if gas or oil be used. The necessity for distributing the lights properly must not be overlooked, and has already been touched upon.

CHAPTER XX

SANITATION AND CLEANSING

Water supply—Lavatories—Sanitary conveniences—Sewage disposal—Removal of refuse—School cleansing.

Water Supply.—In schools water is required for drinking and washing, for cleansing, and for flushing the various sanitary appliances. For these purposes the water must be pure and plentiful. In large cities there is usually little difficulty in obtaining such a supply. The authorities, by collecting the water from rivers and lakes in upland districts, where the risk of pollution by human beings is slight, and by filtering or otherwise treating it, if necessary, ensure that the water in the mains, from which the supply for domestic uses is drawn, shall be pure and plentiful. In rural districts there is less certainty with regard either to the purity or the amount. In such places springs and wells have to be depended upon, and these are not always satisfactory sources of supply. Wells especially are exceedingly liable to be polluted by noxious matters, knocked in from the surface of the soil, or carried by the ground water which discharges into the well.

Wells.—Wells are of two kinds—*shallow* and *deep*, and are named from their relationship to the first impermeable stratum and not from their actual depth. A deep well is one which passes through the stratum; a shallow well is one which may or may not reach it, but does not pass through it. The water obtained from a shallow well is mainly water which has percolated through the soil, and which forms the ground water. Deep well water is derived from springs or collections of water lying beneath the first impermeable stratum. It is likely to be much more pure than shallow well water, since the impermeable layer forms a barrier against possibly contaminated surface and ground waters. Wherever possible the supply for country schools should be

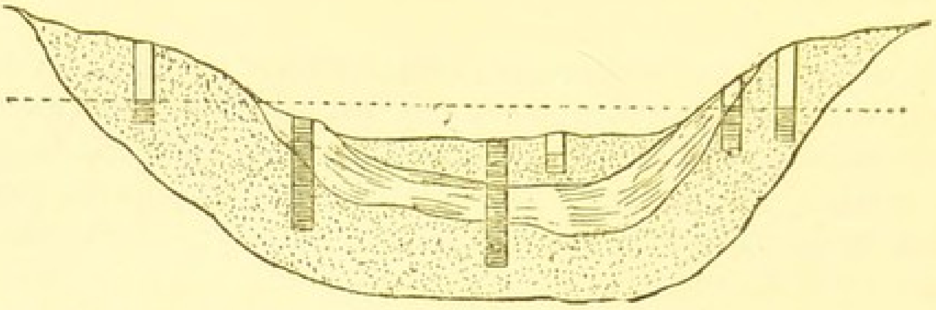


FIG. 105.—Shallow and deep wells, the former marked only at the lower part and not passing through the impermeable stratum.

(*From Notter and Firth's "Hygiene."*)

drawn from deep wells, but since they are less expensive to sink, preference is usually given to shallow wells.

Prevention of Pollution.—To protect the water in the well from pollution the sides must be built round, down to the level of the bottom of the well, in the case of the shallow well; and to the level of the impermeable stratum, in the case of the deep well. Bricks set in good cement are the best materials for the purpose. From both of these wells the water is best obtained by means of a pump, a much stronger one being required in the case of the deep well.

The most likely sources of pollution of wells are manure heaps, leaking cesspools, and drainpipes, and before sinking a well it is necessary to look out for, and to avoid, such sources. Before being drunk the water from wells may be filtered, and for filtration on a small scale, a large crock, resembling a flower-pot in shape and structure, may be employed. The perforation in the bottom of the pot is fitted with a cork, through which a tube passes, and into the pot itself the filtering material is put. This consists of sand and gravel, the gravel being placed at the bottom and the sand on the top. The water is poured upon the sand and is collected from the tube at the bottom of the pot, after filtration.

In city schools there is less likelihood of the water being polluted, and connections may generally be made with perfect safety with the mains, and the water brought into the school. If the supply be what is called "constant," the pressure in the mains will be sufficient to carry the water through the pipes to all the water-taps. If the supply be "intermittent," a cistern will have to be introduced into the school. To this cistern the water is brought by pipes from the main, and from it, by another set of pipes, it is carried to the water-taps.

Cisterns and Pipes.—Such a cistern should consist either of galvanized iron, or slate, or glazed porcelain, never of lead or wood. It should be easily accessible, and should be situated in a place which, while being well lighted, is sheltered from the sun's rays. It should be provided with a cover to exclude dust, but should be well ventilated. An overflow pipe discharging in the open air must be introduced. The water which is to flush water-closets or urinals must not be drawn direct from such a cistern, but should pass first into a smaller cistern placed near the closet.

The pipes to the cistern, and from it to the taps, consist usually of lead, and to prevent the water from acting on the lead, and so possibly setting up an epidemic of lead-poisoning, these pipes may be lined with tin. For drinking purposes fountains will have to be supplied; for washing purposes, the pipes will have to be lead to taps in the lavatory basins, and, if these are provided, also to baths. For flushing purposes the pipes will have to pass to the special flushing cisterns.

Drinking Fountains.—Drinking fountains may be fixed either inside the school, in connection with the lavatories, or outside in the playground. They must be provided with drinking-cups for the use of the children. The possibility of the organisms of diphtheria and other diseases of the throat and mouth being deposited on the edge of the drinking-cups by infected children must be borne in mind, and steps taken to prevent healthy children, using the cups afterwards, from being infected. The most satisfactory method is, of course, to provide each child with a cup for his or her own use. This is, however, a counsel of perfection practically impossible to carry out, and some other method must be adopted. Sterilization of the cups after use would be a satisfactory method also, but is quite impracticable.

Probably the risk of infection can be very much diminished by rinsing the cup, and especially the edges, with water before drinking, and the plan sometimes adopted of hanging the cup under the source of the water supply, so that it is exposed to the running water, forms a fairly good safeguard. If, instead of placing the edge of the cup between the lips, the person drinking puts both lips into the water, the risks are still further diminished. The children should be directed to do this, and, in addition, to rinse the cup well, and to let the water run on its edge for some time before filling it.

A type of fountain sometimes recommended, in which the water bubbles upwards, and from which the children drink directly by placing the mouth over the stream of water, is not generally regarded as satisfactory. There is a tendency for air to be swallowed by the children when drinking. There is the objection also that it is impossible to see any gross impurities which may be present, and which would be noted if the water were in a vessel and could be looked at, as it should always be, before it is drunk.

In some cases, especially if there is any reason for suspecting the pollution of the water, it may be necessary to provide for filtration. The best filters to use are either the *Pasteur-Chamberland*, or the *Berkefeld*, which are so made that they can be fixed to ordinary water-taps. Of the two probably the former is the better, since it more readily removes the polluting micro-organisms, lasts longer, and is less easily broken. It consists of prepared infusorial earth. The Berkefeld consists of kaolin, a kind of china clay. In each case the filter, which is shaped like a hollow candle, fits into a metal chamber, which in turn is screwed on to the water-tap. The water from the tap fills up the metal chamber all round the candle, and is forced through into the hollow centre of the candle, and thence escapes. After about a week's continuous use, the rate of flow of the water becomes slow, and the micro-organisms show a tendency to grow through the filter into the centre. The candle should, before this takes place, be removed, and thoroughly washed and brushed with a clean, hard brush, using hot water containing soda for the purpose. After washing, the candle should be sterilized by boiling, or in the flame of a Bunsen burner.

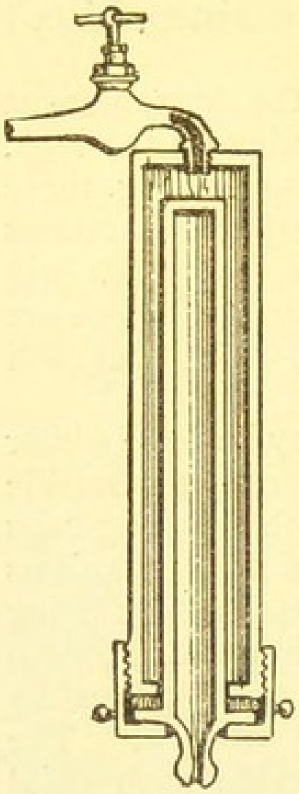


FIG. 106.—Pasteur-Chamberland filter.
(*From Notter and Firth's "Hygiene."*)

Lavatories.—The lavatories should not be placed in the cloakrooms, but should be conveniently near them. They should be well lighted; they should have an asphalt or terazzo floor, and if possible the walls should be of glazed bricks.

The *wash-basins* are best made of glazed earthenware or enamelled iron, though the latter is apt to get chipped, and to become unsightly. To obviate the tendency with children to use water in which some one else has already washed, numerous devices have been suggested. Of these perhaps the best is that which leaves the basin without a plug, the child washing in the water which gushes from the tap. The risk of the spread of skin diseases, and of infectious eye troubles, has prompted the introduction of such a system. The continuous-flow basin shown in Fig. 107 may be recommended.

If the supply of water be limited, and basins which retain a certain quantity are used, then probably the tip-up variety which is suspended on lateral projections is the best. The children must be carefully instructed always to empty the basin after they

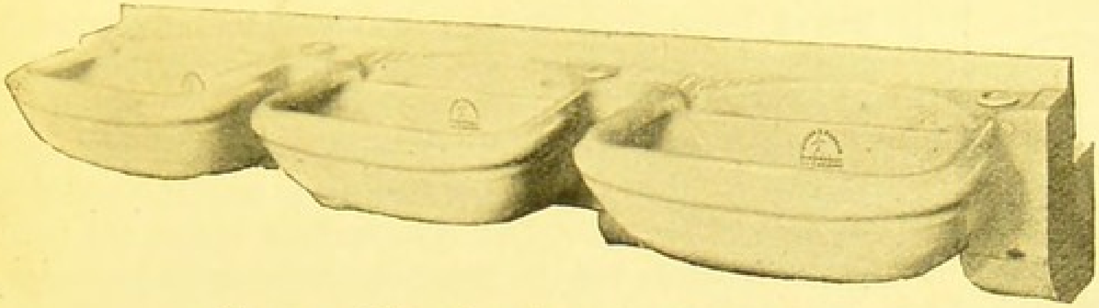


FIG. 107.—Series of continuous-flow lavatory basins.

have washed, and never to use water already fouled by some one else.

In addition to providing lavatories, wash-hand basins contiguous to the closets should be introduced, and the children should be instructed to wash the hands after using the closet. For the use of teachers special lavatories should, of course, be provided.

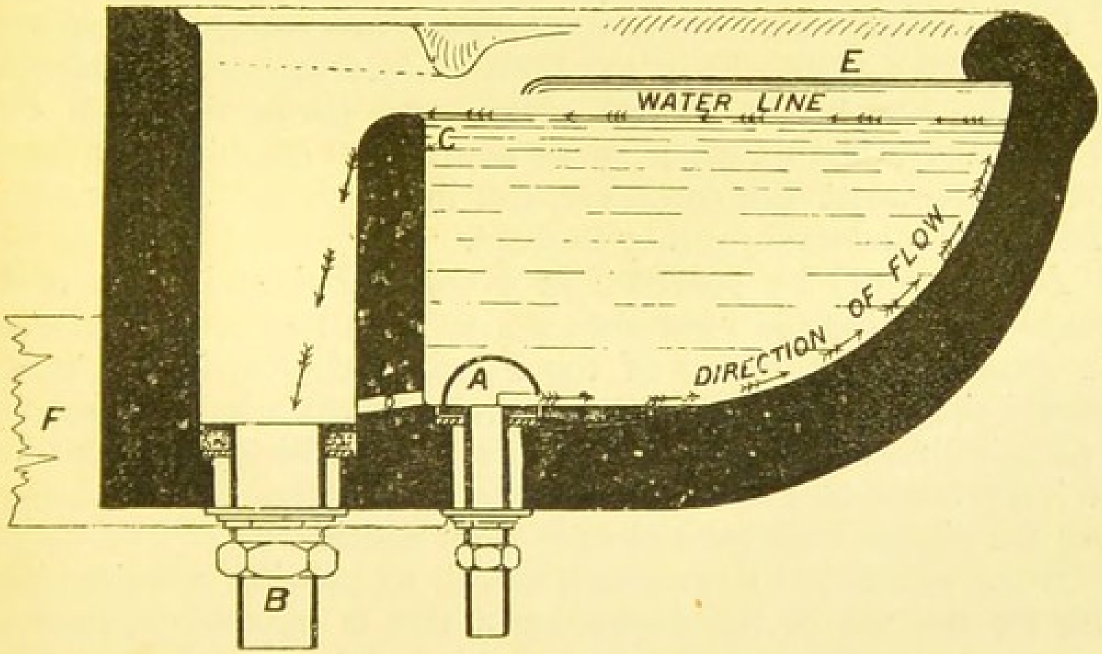


FIG. 108.—Section of one of the basins shown in Fig. 107.
A, supply nozzle; *B*, waste outlet; *C*, overflow weir; *D*, draining hole; *E*, bead line; *F*, lug to build into wall for support.

The pipes carrying away the waste water from the basins should be of lead, and should be trapped, *i.e.* provided with a bend immediately below the outlet from the basin. These pipes, if the lavatory is on the ground floor, should pass through the wall to discharge in the open air, over a gully. If the lavatory be high up, the pipes should pass into an iron or lead pipe fixed against the wall of the building, and carried down to the ground level to discharge over a trapped gully. Such sink or waste-pipes should never open into what is called the *soil-pipe*, i.e. the pipe carrying off the discharges from the closets.

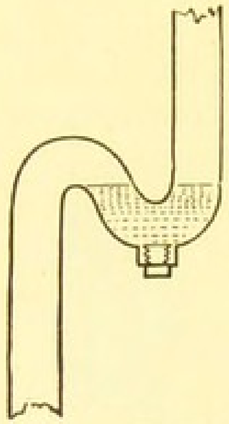


FIG. 109.—Syphon sink trap with movable screw for cleaning. (*From Corfield's "Laws of Health."*)

Soap and Towels.—For all practical purposes probably the best soap is the ordinary yellow variety. The so-called disinfectant soaps are practically useless for disinfecting purposes, and simply give a feeling of false security which is most undesirable.

Fresh towels should be provided every morning, and they should be removed after afternoon school. Any which are quite wet through before that time should be removed and replaced by clean dry ones. Roller towels are bad, and the ideal plan would be to provide each child with a towel for its separate use. As this is impossible, the children should be directed to use only the parts of the towels which are quite dry.

Careful supervision of the lavatories is necessary, and teachers should make a point of visiting them at intervals, to see that the attendants are keeping them clean. In connection with the lavatory there should be a small apartment containing a slop sink for the use of the caretaker, and in which the apparatus for cleansing the classrooms may be kept.

Baths should be provided in every school, and every child should have a bath at least once a week. In this matter many of the American are ahead of the English schools, special bathrooms being provided and special arrangements adopted whereby each child has an opportunity of cleansing its body, and learning the importance of a clean skin. The advantages of the shower over the plunge bath have already been considered.

If the school is a large one it is well to provide a swimming-bath for the use of the pupils, or if this is impossible, then to arrange that those attending the school shall have, on certain days in each week, the use of one of the public swimming baths found in most cities.

SANITARY APPLIANCES AND DRAINAGE

Sanitary Appliances.—Separate sanitary appliances must be provided for boys and for girls, and according to the Board of Education's code the school offices must be disconnected from the school building proper. In districts where water is scarce, and earth-closets or privies are in use, this is probably a wise rule, but where water-closets are used it seems to be rather a disadvantage to have them placed too far off from the main building. If closets of a good type are introduced, if the "plumber" work in connection with them is good, and if they are so placed that they are against an external wall, and are cut off from rooms and corridors by a passage cross ventilated by windows facing one another, there is no reason why they should not be inside the school building. The danger to health of such a situation is non-existent, and if in drawing out the school plan provision can be made to have at least the girls' closets in the school building it would be an advantage.

In the case of a mixed school, unless there are separate corridors for boys and girls it may be impossible to find space inside the building, and provision will have to be made for each sex in the playgrounds. It is not necessary to place the offices too far off from the building, and it is better to have no covered passage between the school and the sanitary annexes.

The building to contain the closets should be well built, well lighted, and well ventilated. The interior, the walls, floors, and ceilings should be smooth and easily washed and kept clean, and every corner should be accessible for cleansing. In the offices the rounding of all corners, in the manner described in dealing with floors, is especially important. The floors may be of asphalt or terazzo. The walls are best covered with glazed tiles or bricks, which have this advantage, that scribbling is made less easy. If glazed tiles or bricks are too expensive the walls must be limewashed, and the process repeated two or three times a year.

A point of importance is the amount of accommodation to be provided. For the girls' and infants' departments a larger number of closets is required, and an average of about one to fifteen as suggested by the Board is probably sufficient. In the boys' department one closet for every twenty-five will be sufficient. Urinal accommodation of at least one place for every twenty boys should be allowed.

The type of apparatus to be supplied is of the greatest importance, and will of course depend on whether the district in which the school is situated possesses sewers, and a water-carriage system of sewage disposal or not. If so, then water-closets will be used, and urinals will be more easily arranged. In rural districts and where there is no water-carriage system, earth, or ash closets, which are preferable to privies or cesspits, will have to be introduced.

Urinals.—As regards urinals, there is no need for much to be said. The best type is the simplest. The material of which they consist should be smooth, impervious, and durable. Slate slabs may be used, one at the back and one at each side, but the type of stall in which the back and sides are in one piece and there are no angles is preferred. The floor should be of asphalt, and should slope towards an impervious channel at the bottom of the back slab. The channel itself should slope towards the point where it discharges into the drain. At this point a trap should be introduced in order to prevent the passage backwards of gases from the drain, and the sewer with which it communicates.

A *flushing cistern* to contain from five to ten gallons, distinct from the ordinary cistern, should be provided, and should flush the urinal by discharging its whole contents automatically at regular intervals. This is better than having a mechanism which provides a continuous trickle of small streams. The water escapes from the cistern through a pipe at its lowest point, which in turn is connected with a pipe running the whole length of the urinal, and placed near the top of the back slab. The latter pipe is perforated and the water escapes through these holes, to wash down the walls and sides of the urinal. The cistern should be at least three feet above the perforated pipe. The whole place should be kept scrupulously clean, and the head teacher should see to it that the caretaker flushes the urinal daily, and scrubs it down with a hard broom.

Water-Closets.—In districts where there is a water-carriage system water-closets will have to be provided. There is only one good form of closet, and that is what is called the "wash-down" closet. This consists of a basin which has at its lower end an "S" shaped bend or trap. This bend always retains part of the water discharged into it when the closet is flushed, and acts as a barrier against the gases in the drains.

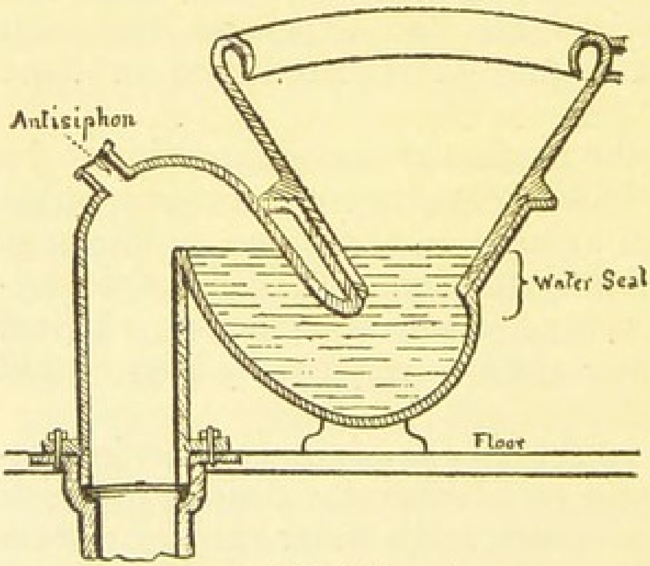


FIG. 110.—Wash-down closet.
(*From Notter and Firth's "Hygiene."*)

The term "water seal" is applied to that portion of water which stands in the trap, and which acts really as the barrier. It is the height of the water above the level of the upper part of the first bend in the "S." It should be at least an inch and a half deep. The closet pan should consist of glazed earthenware. The back wall should go straight down to the trap, the remaining sides sloping downwards and inwards in the same direction. The trap and the pan may be made in one piece, or separately, being clamped together afterwards; preferably the former.

On the side away from the pan the trap is connected with a pipe which passes through the wall of the building, to open into what is called the *soil-pipe*. The pipe passing through the wall should not pass straight into the soil-pipe, but at an acute angle.

The upper border of the pan should be folded over to form a hollow *flushing rim*. The pipe from the flushing cistern opens at the back part of the rim, and the water entering here rushes round the rim to be directed round the whole inner surface of the pan, into the trap. The force of the discharge from the cistern is little interfered with by the rim, and the whole contents of the trap are driven into the soil-pipe and so into the drain. A certain amount of water remains in the trap to await the next discharge.

The cistern should be of such a size as to hold from $2\frac{1}{2}$ to 3 gallons of water, and should be at least 3 feet above the pan. The discharge pipe should be about $1\frac{1}{2}$ inches in diameter. In the case of the closet for the senior pupils the flushing should be left to the children themselves, being brought about by the pulling of a chain connected with the escape valve of the cistern. To prevent its being tampered with the chain may be concealed in a pipe fixed to the wall, the handle only being visible. In the infant school the flush is best brought about automatically. This may be obtained by means of a mechanism which ensures that the cistern shall discharge its contents as soon as the child rises from the seat of the closet.

The closets should never on any account be covered in with woodwork. The only wood necessary is that forming the seat, and this is now being replaced to a certain extent by a wooden pad on each side of the rim. It should always be possible to get all round the closet in order to clean it. The upper edge of the door of each closet should stop about one foot from the top of the doorway, and the lower about one foot from the floor. Closets for teachers should be provided in connection with the lavatories for their use.

Trough-closets are sometimes introduced into schools, and consist of troughs, semi-circular in shape, of stoneware or cast-iron. The bottom of the trough is rounded, and slopes slightly towards the outlet into the drain, from which it is separated by an "S" shaped trap, and a grating to catch stones, etc., mischievously dropped into the trough. In order to provide for the retention of water in the sloping bottom of the trough, a weir is formed at the entrance into the trap. The top of the trough is covered with wood, perforated to form seats, each of which is

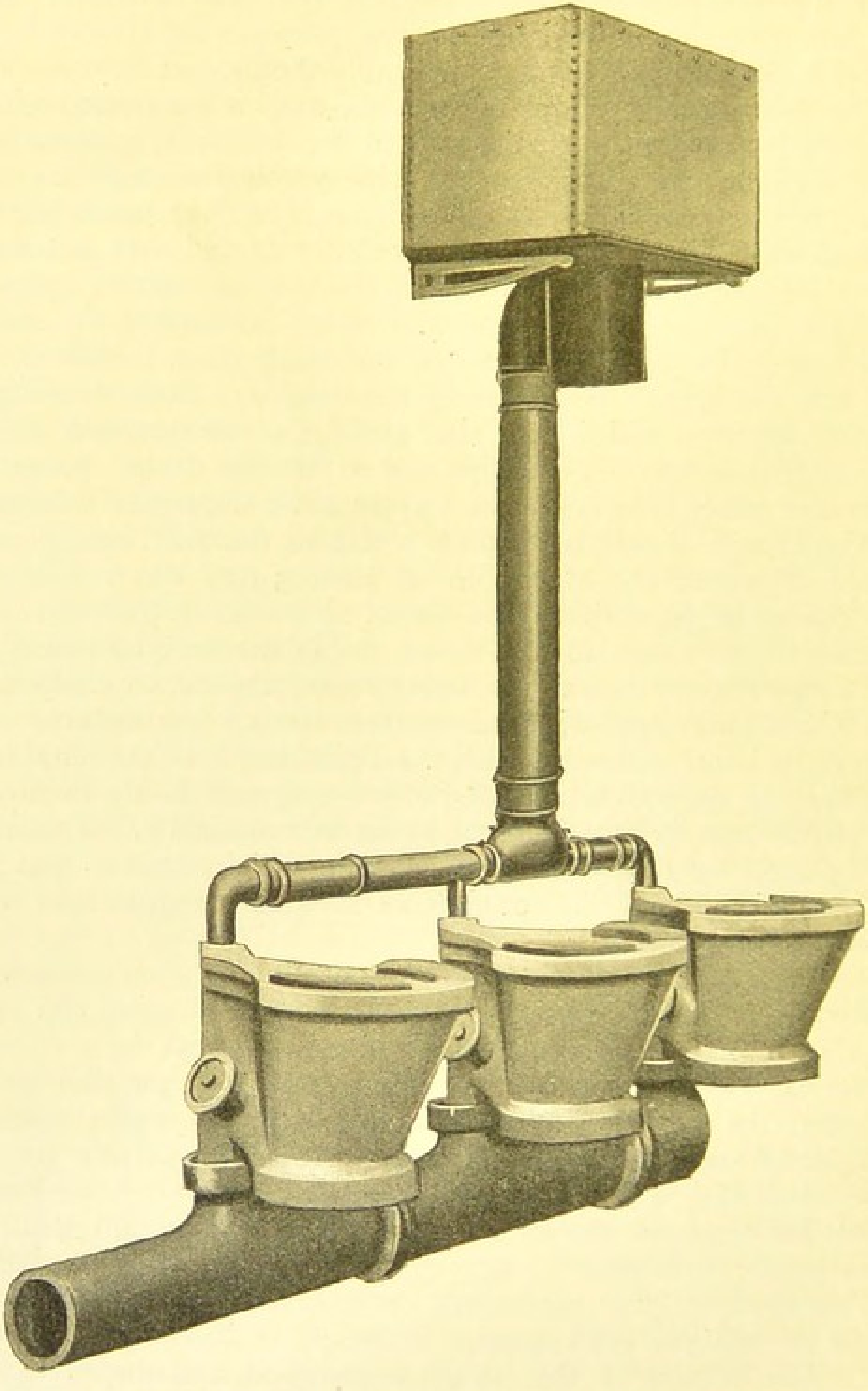


FIG. 111.—Wash-down water-closets arranged in series for school use. Each is provided with a trap, and there are pads instead of a wooden seat. The flush is automatic from the cistern above the closets. When fixed the botttom of the pan rests on the floor, and the pipe is not seen.

contained in a separate compartment. Flushing of the trough is carried out by means of a large flushing cistern, which acts automatically at regular and frequent intervals. A certain amount of water remains after each flushing, the depth depending upon the height of the weir.

The trough-closet has many disadvantages. It is wasteful of water; if the rush of water is not strong the flushing is incomplete

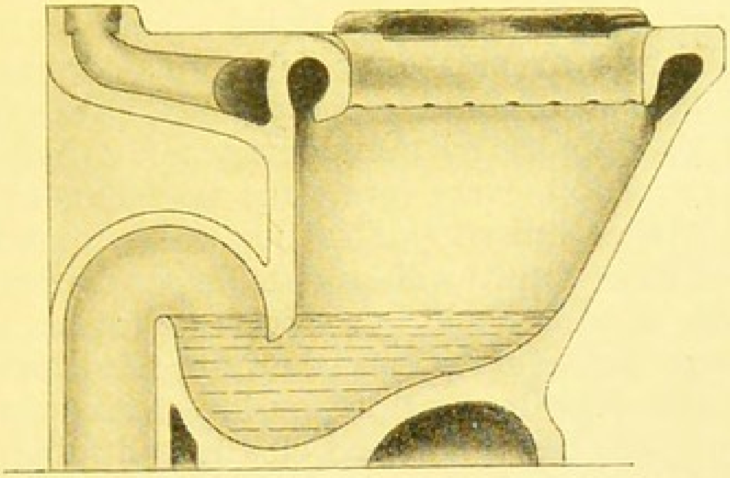


FIG. 112.—Section of one of the closets shown in Fig. 111.

in the intervals between the flushings, offensive odours may be given off from the contents of the trough; the flushing process is noisy and disturbing. An improved form of trough-closet is recommended, in which an iron pipe is used as the container. Along this pipe, earthenware pans are set, each being connected with the pipe from the flush tank. The trap, instead of being at the end, is placed at the middle of the iron pipe. This seems to be a much more satisfactory arrangement than the ordinary trough-closet, but they are neither of them so satisfactory as the single wash-down closets. In Fig. 111, a method of introducing a series of wash-down closets is shown.

Dry Closets.—In rural districts and in districts where the water-supply is limited, the dry, as opposed to the wet system of sewage disposal just described, must be adopted. Earth-closets or ash-closets will have to be used, and must, of course, be placed in offices distinct from the main building. In both, a pail may be used as a container, earth or riddled ashes being applied by some mechanical device or by hand. The pails should be removed every day, preferably before or after school hours, and the material buried. The earth-closet is to be preferred to the ash-closet. To be successful, good dry loamy soil should be used. One and a half pounds of such earth should be applied each time after the closet is used.

Slop and waste waters in earth-closet districts are carried off by drains, and are best disposed of over land. Care must be taken to avoid risk of contaminating drinking-water.

Hints as to Appliances.—No matter what type of convenience is employed, there are certain points in connection with them which should be attended to specially. When the school is to be built, the best and strongest appliances should be provided. They must be so placed that they will cause no nuisance, but be at the same time readily accessible, so that the children will use them. The child should learn at school what good sanitary conveniences are like. The drainage arrangements should be flawless, and capable of standing the severest test that can be applied by the sanitary authority. When the school is in occupation, every care must be taken in order that bad smells and other nuisances shall not arise from the sanitary appliances, and these results will be obtained by enforcing regular cleansing by the caretaker, and by exercising a regular supervision. The teacher must not trust the caretaker, but must visit the places regularly himself. The custom of pouring small quantities of a disinfectant fluid into the drains and closets is a futile one. If it does anything at all it does harm by masking odours, which would otherwise show that something was wrong.

Sewage Removal and Disposal

Drains and Drainage.—In towns where the water-supply is good the wet method of sewage disposal is usually employed. The waste water from sinks and lavatory basins, the drainage from sanitary conveniences, the rainwater from the roof and from the playgrounds all pass into drains which in turn open into the public sewers. The pipes passing from the lavatory-basins pass through the wall of the building, to open, in the case of lavatories on the ground-floor, over a gully, and in the case of lavatories on other floors, into an upright pipe fixed to the school wall, which in turn opens over a gully at the foot of the wall.

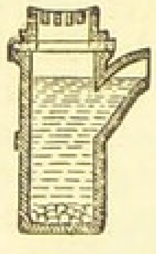


Fig. 113.—Trapped gully. (*From Notter and Firth's "Hygiene."*)

Over this same gully, or similar gullies, discharge "*down spouts*," which carry the water collected from the roof in the eaves'-gutters round the edge of the roof. Such a gully should be trapped, *i.e.* have a bend at its lower end, and should open into the drain or into a disconnection chamber.

If there are baths in the school, the water from these will discharge in the same manner as the rain-water and lavatory wastes, over a trapped gully. The washings from the playground should be provided with an exit into a gully at some point towards which the playground slopes.

The pipes from the urinals and closets do not discharge over a trapped gully, but should be brought directly into the drain. The pipes leading from the closets pass through the wall of the building into an upright iron or lead pipe fixed to the wall and called the "*soil-pipe*." At its lower end this pipe opens into the drain. Its upper end should be carried above the roof and any windows, and should be left open to act as a ventilator for the drain. The soil-pipe must have a diameter equal to that of the drain with which it communicates, *i.e.* 4 to 6 inches, and must be well jointed and watertight.

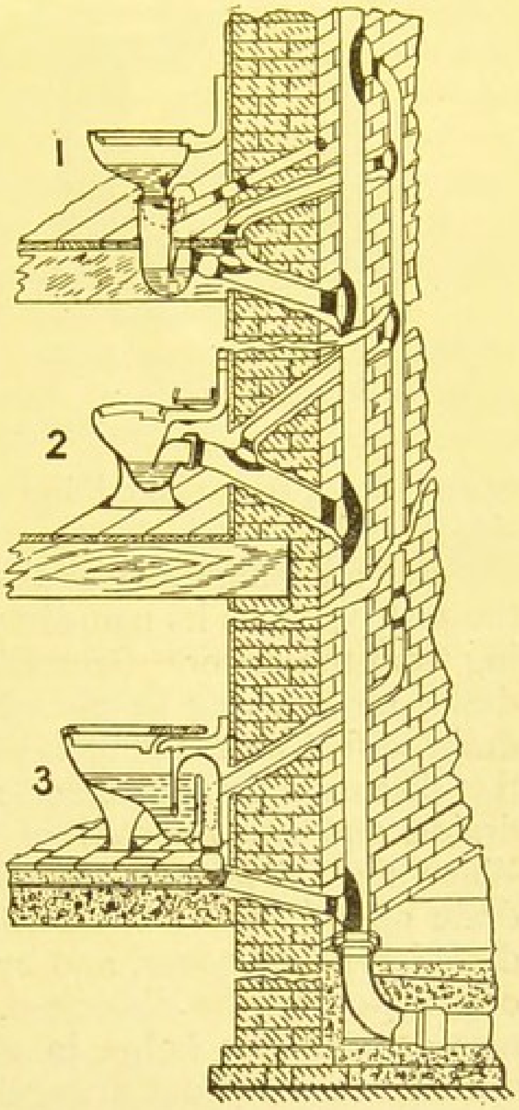


FIG. 114.—Water-closets on different floors opening into a soil-pipe placed against the outside wall of the building.

(*From Notter and Firth's "Hygiene."*)

The drains into which the soil-pipes and trapped gullies collecting the rain and waste waters open, consist of short lengths of earthenware piping, glazed and quite smooth internally. The pieces must be carefully jointed and made perfectly watertight. These pipes are from 4 to 6 inches in diameter, and should be laid in trenches which slope towards the sewer into which the drains are to open. In this way, they are given what is called a "fall," and their contents flow readily towards the sewer. The fall for a 4-inch pipe should be at least 1 in 30, and for a 6-inch pipe 1 in 40.

Instead of having the drains opening directly into the sewer, it is usual to lead each separately into a *disconnection chamber*. This is a small pit in the ground between the sewer and the school building. It is built of brick, and its inner surface is cemented absolutely smooth. As a covering for the chamber an iron lid is used. Into this chamber all the separate drains come, and in its floor smooth channels are made, one for each entering pipe, and all converging to a single channel in the middle of the floor of the chamber which conveys the sewage collected from the separate channels out of the chamber into a single drain. This channel

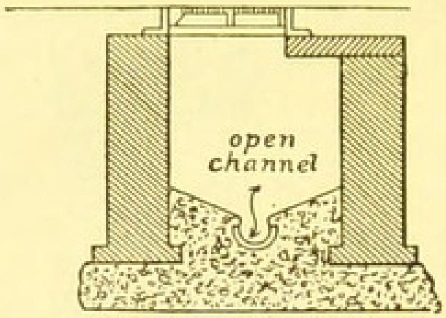


FIG. 115.—Sectional view of a disconnection chamber.

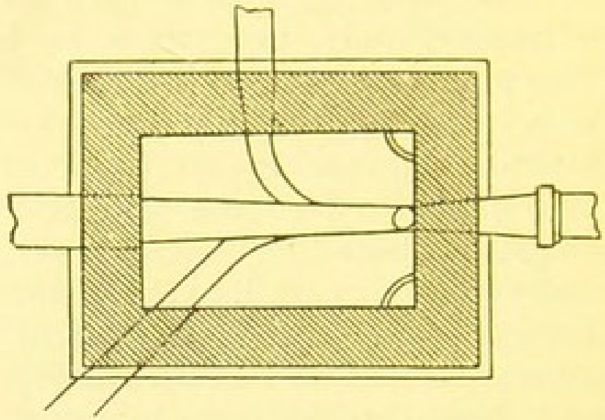


FIG. 116.—Disconnection chamber viewed from above.

(*From Notter and Firth's "Hygiene."*)

opens into a trap placed immediately outside the chamber on the single drainpipe which communicates with the sewer.

The advantages of a disconnection chamber are many. In the first place, as its name implies, it disconnects the school building from the sewer. Secondly, it assists in the ventilation of the drain, air entering at the chamber and passing back along the drain to find an outlet at the open end of the soil-pipe. Thirdly, the disconnection chamber makes the inspection of the school drains, and the removal of any obstruction, very much easier. When the lid is removed, absolute command is obtained of the drain above, in the direction of the building, and below, in the direction of the sewer, and by means of special jointed sticks any obstruction can be dislodged. In testing the drains, the disconnection chamber helps in the locating of leaks. This testing should be carried out at regular intervals, and will be undertaken by the sanitary authority of the district. It has been suggested that the certificate of the medical officer of health or sanitary inspector should be hung up in the school after each inspection. Any flaws or defects found should be remedied at once.

Dry Method of Sewage Disposal.—In districts where the water-supply is limited, and earth or ash closets are in use, the material removed from these will have to be disposed of over the land. Usually shallow pits are dug in the superficial layers of the soil, and the contents of the earth-closets tipped into these. The waste water and slops will have to be carried in drains similar to those already described, and disposed of by spreading over land.

In some places where the water-supply is limited, but sufficient to allow of the use of water-closets, the school drains may be made to discharge into a *cesspool*. Great care has to be taken in the building of this in order that it may be watertight, and that it shall not by leaking contaminate any well or other source of water-supply.

Removal of Dry Refuse.—In the case of a school the dry refuse to be disposed of will consist mainly of ashes, waste-paper, and dust. Part of the dry refuse collected may be of such a nature that it can be burned in the school furnace, and all that can be disposed of in this way should be so treated daily. All matters, vegetable or animal, likely to decompose should also be burned, and the children, especially the girls, should be told that this is the best method of dealing with these. The remainder should be taken from the school each day if possible.

For the collection of the material, movable dustbins should be provided. These are to be preferred to fixed bins or ashpits. It is advisable to have them small rather than large, so that emptying at short intervals is necessary, and the caretaker is not tempted to retain them too long unemptied. The removal will, of course, be carried out in towns by the cleansing department at stated intervals, daily, weekly, or twice a week.

Dustbins are best made of galvanized iron, and should be provided with a lid. In most towns a standard pattern is recommended for use. If ashpits are employed they must be watertight. They are best constructed of brick, lined with cement. The floor should be of cement, and the roof watertight. Openings for discharging refuse into, and for removing it from, the ashpit must be provided, the former near the roof, the latter near the floor. Both openings should have doors.

School Cleansing

Dust.—Under this heading the methods to be adopted to get rid of the dust, etc., which collect so readily, and in such large quantities, must be described. Of the *rôle* of the dust particles in spreading infection by acting as the carriers of germs, mention has already been made. The sources of the dust in the classroom are many. It is brought in on the children's feet; it rises from the floor; it blows in at the windows; it is shaken from the children's clothing; it comes from the fire; and a very large quantity comes from the chalk used for writing on the blackboard. In addition, a certain amount comes from the skin of the occupants of the room, and if any of the children happen to be skinning after scarlet fever, that added by them may be of a kind that is infectious. This may not, however, be the only infectious dust in the classroom, since what is brought in on the boots of the children may include particles containing the germs of consumption or some other disease.

All forms of dust, whether manufactured in the room, or brought in from outside must be dealt with. If not removed it will find a resting-place in the nooks and crannies in the room, and some of it, having a certain odour of its own, may prove objectionable. The chief methods to be adopted are—

(1) To provide as few resting-places for it as possible.

(2) To have the classrooms cleaned at regular and frequent intervals.

Prevention of Deposit.—To prevent the dust from depositing there should be as few right-angled corners as possible in connection with the floors, ceilings, walls, doors, and windows. In addition, there must be no places in the classrooms into or under which the person carrying out the cleaning cannot get. There must be plenty of space about the seats and desks, and about the radiators, so that the difficulty of introducing a broom into their interstices may not serve as an excuse for leaving them dirty. Partly because it is a dust collector, a platform for the teacher's desk is to be avoided.

To prevent large quantities of dust arising from the use of chalk on the blackboard one or other of the *dustless chalks* now on the market may be used. These are rather more expensive than the ordinary chalks, but their dustlessness is undoubtedly a great advantage. A *dust trough* should also be provided at the lower edge of every blackboard. It should be about $2\frac{1}{2}$ inches wide, and be provided with a cover of fine wire netting hinged to the trough. Into this a great part of the chalk dust will fall, and can be easily removed. For cleaning the blackboards probably erasers are better than cloths, but if proper slateboards are used moist cloths or sponges may be substituted. If erasers are in use, it is well to have a double set so that one set at a time may be removed completely from the classroom to be thoroughly beaten and cleaned.

Cleansing of Classrooms.—The cleansing of the school should include a daily cleansing, a weekly cleansing, and a thorough cleansing periodically, for example, before the commencement of each term. In the daily cleansing the floors should be thoroughly swept, particular attention being paid to the corners and the parts about the seats and desks, and radiators. During the cleansing of the classrooms the windows should be kept open, and the floor should be sprinkled with wet sawdust. If troughs are used for chalk these should be dusted, as should also the doors, window-ledges, etc. As dust is likely to settle during the night, all desks and seats should be wiped down each morning before school with a damp cloth. Once a week, on Friday or Saturday, each classroom should be more thoroughly attended to. The black-boards, if of slate, should be thoroughly washed; the chalk trough should be cleaned out; the floors should be thoroughly swept, and all maps and wall-cards dusted down. The walls, especially those parts behind maps, etc., should not be omitted.

In the thorough cleaning which precedes the opening of the school term, after the various holidays, the whole school should be attacked. Everything that can be scrubbed should be scrubbed; everything that can be washed should be washed. Wall-cards and maps should be taken down, and the walls, if painted, washed with water. All ledges, and desks and seats, which are likely to have been soiled by the hands and clothing of the pupils, should be thoroughly washed. As soap or soda and water are likely to spoil the varnish, it is recommended that cloth saturated with paraffin be used. The importance of having clean windows must not be overlooked. They should share in the general cleansing of the school, and should be cleaned at intervals of one or two weeks.

Disinfection.—In addition to cleaning the room as described, it is an excellent plan to provide each school with a *disinfecting*

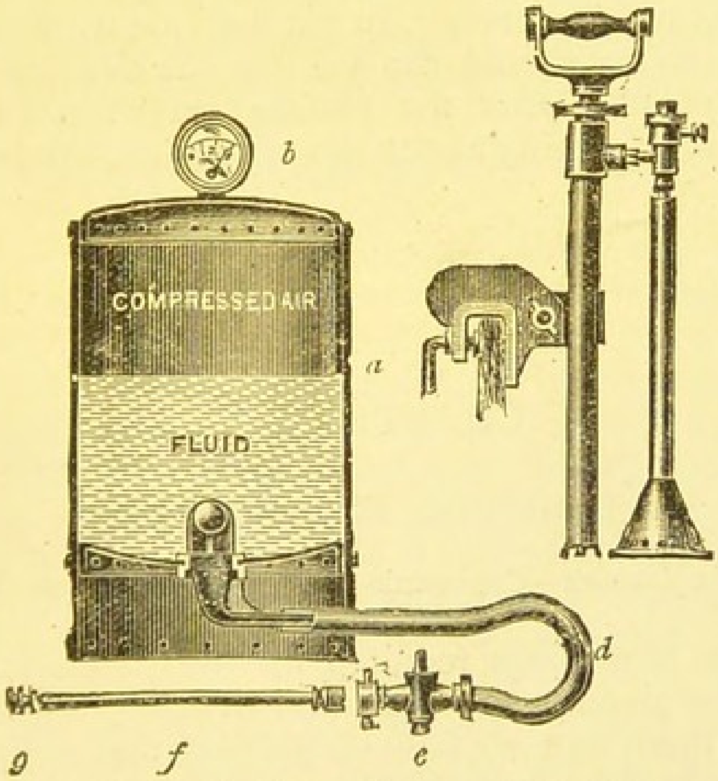


FIG. 117.—Dr. Robertson's "Invicta" portable spray disinfecting apparatus. After the fluid is introduced, the air-chamber is filled by means of the pump shown on the right, and the spray can be maintained for a considerable time.

apparatus, and to spray each room with such a disinfectant as *formalin* at intervals, and so ensure the killing of any disease germs that may be present. A formalin spray apparatus does not cost much, and formalin itself is not particularly expensive. The spray apparatus shown in Fig. 117 is particularly useful and easily worked.

The formalin might also be used for disinfecting pencils. This could be done daily, the pencils being placed on racks in a closed metal box on the floor of which formalin is poured, in the proportion of about 1 cc. to 300 cc. of air-space in the box. It might also be used for disinfecting books, which have a tendency to retain dirt and disease germs. For these a box similar to that used for the pencils may be employed, the books being so placed that they are as open as possible.

Formalin is a substance which very readily gives off its vapour. It is a very powerful disinfectant. The vapour is rather irritating to the eyes, but very rapidly diffuses, and the eyes soon get used to it. A pencil should be thoroughly disinfected by exposure to the vapour for about fifteen minutes. The duty of carrying this out might be entrusted to the person responsible for the daily cleaning of the classrooms.

As the cleansing of the school, besides having a hygienic value, is of importance from the educational point of view, from its effect on the child mind, the teacher should take part in it. The part should be that of a supervisor, to see that the work is thoroughly done. The teacher should also see that the cleaners get to work as soon as possible after the classes are over. To this end keeping in and lingering about the school should be avoided if possible.

CHAPTER XXI

SCHOOL FURNITURE

The teacher's platform—Cupboards—Blackboards—Maps—Wall-cards.

AMONGST the furnishings required for the classrooms the chief place must be given to the seats and desks. In the chapter on "Eyesight" these were so fully considered that nothing need be added to what will be found there.

The Teacher's Platform.—The teacher's platform is a piece of furniture which is now generally objected to. Its chief disadvantages are that it throws a strain upon the eyes of the children, who have to look up too much; it takes up space, and acts as a harbour for dust. A chair and a desk are really all that the teacher requires. The chair, especially by women teachers, should be made use of much more than it generally is.

Cupboards.—Cupboards for books and apparatus should be provided. Preferably they should be placed outside the classrooms, since they take up room and tend to collect dust.

Blackboards.—Plenty of blackboard space should be provided in each classroom. In the infant classrooms especially it should be abundant, for the reasons already given. The points of importance in connection with blackboards are the position, the size, the surface, and the colour.

The Position.—The board primarily intended for the teacher's use should be so placed that it gets plenty of light. It should not be on the same side of the room as the chief lighting windows, otherwise the children's eyes may be injured. The blackboards for the children may be placed all round the room. They may be let into the wall or the wall itself may be specially prepared by covering it with tough paper, which is afterwards painted or slated. Blackboards hinged to the wall, and capable of being fixed at various angles to it, are used in some places, and work well. The lower edge of the blackboards for the children should be at a suitable height from the floor. In the infant classrooms 26 inches is a good height. In the lower standards 30, and in the upper standards 36 inches will be found sufficiently high.

Size.—The teacher's blackboard should be large, and at least 4 feet wide.

Surface.—A shiny surface which will reflect the light is to be avoided, and preference given to a dull " matt " surface.

Colour.—The colour of the blackboard is all-important. The aim must be to select a colour which will be restful to the eye, and which will form a good contrast for the chalks usually employed. Probably black is the best colour, and dark green the next best. Slate, if it can be obtained of the proper shade, is to be preferred to board, since it can more easily be cleaned, and does not become less black with time, if washed frequently, as boards tend to do. A greyish or brownish black slate is to be avoided.

Three great objections to the use of slate are its price, its weight, and the difficulty of getting the proper shade. To meet these objections imitation slate boards or ground glass with a black background may be used.

If it is found that the large amount of blackboard introduced absorbs too much light, or if it is offensive to the eye, it may be covered when not in use. One side may be painted of the same colour as the walls of the classroom, and the board made reversible. To diminish the diffusion of chalk dust, the trough at the lower edge must not be omitted. For the children's boards very small dusters should be issued.

Wall Cards and Maps.—With regard to these little need be said. The point of chief importance in connection with the wall-cards is the size of the lettering. This should be such that no unnecessary strain is thrown upon the eyes. In the case of maps small print for the same reason is to be avoided.

INDEX

THE END

PRINTED BY
WILLIAM CLOWES AND SONS, LIMITED
LONDON AND BECCLES

26-4-28