FIRST STAGE HYGIENE

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Twelfth Impression (Sixth Edition)
Revised and Enlarged

London: W. B. CLIVE
University Tutorial Press Ld.
High St., New Oxford St., W.C.
1914

PREFACE.

The increased popularity of the study of Hygiene and Public Health is one of the chief reasons that have led to the publication of this work. Small books on the subject are for the most part divided into two parts, viz. Elementary Human Physiology and Elementary Hygiene. This division cannot, however, be followed by the teacher, as the student is likely to regard the two divisions as independent subjects, instead of considering the various parts of the Physiology as essential introductions to certain sections of the Hygiene.

The author believes that this work embodies the first attempt that has been made to treat the successive points in logical order, and to give unity to the subject instead of presenting a medley of facts. The order of the book is practically that which the author has followed in his own classes for the past five years. It has been his endeavour to prevent the student regarding the subject as a number of hard facts, and to invest these facts with the interest derived from an association with the circumstances of every-day life.

At the ends of those chapters where the subject-matter adapts itself to such treatment a list of simple experiments, illustrating the work covered by the chapter, has been added. These should either be performed by the student or gone through by the lecturer. The lists should by no means be taken as exhausting the possibilities in this direction.

The author desires to acknowledge his indebtedness for several useful suggestions to Mr. W. Line, B.A., M.D., and many other friends who are teachers of Hygiene, and especially to his brother, Mr. H. H. Lyster, and to Mr. G. P. Smith, M.R.C.S., L.R.C.P., for their valuable help with the diagrams.

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NOTE TO THE SIXTH EDITION.

In preparing this edition for press the author has revised it throughout in order to ensure that it is quite up to date in all matters of detail.

The separate portions of the Appendix—which contained certain matter added from time to time in earlier editions—have been to a great extent rewritten and have been inserted in suitable positions in the body of the book.

The most important alteration is, however, the insertion of a large amount of experimental work which will serve to explain very thoroughly the first principles of the subject.

R. A. LYSTER.

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FIRST STAGE HYGIENE.

CHAPTER I.

THE GENERAL BUILD OF THE BODY—THE SKELETON.

For the intelligent study of Hygiene or Health-science it is necessary that the student should become acquainted with a certain definite amount of elementary Human Anatomy and Physiology. By Anatomy we mean the study of various parts of the body; and the study of the work which these parts have to do is known as Physiology.

As far as is possible we shall consider such subjects in direct connection with those portions of Hygiene that are concerned with the healthy performance of the work of special organs of the body. In other words we shall first study the structure and the work of some part of the body, and then consider the hygienic conditions under which this part discharges its functions in the best possible way.

Before any special organs can be considered it is necessary to make ourselves acquainted with the general build of the body, the bony framework or skeleton, and the general arrangement of the internal organs.

The simplest division of the body is into hard parts, comprising the cartilage and bones, and soft or fleshy parts.

The Hard Parts.

The Skeleton.

The skeleton serves a double purpose. Primarily it is the support of the soft parts, and serves to give the body a definite shape or build. Secondly, it affords special protection to highly important structures and organs. Thus the skull and vertebral column serve as a protective covering for the brain and spinal cord, and the ribs form a bony framework for the protection of the heart and lungs.

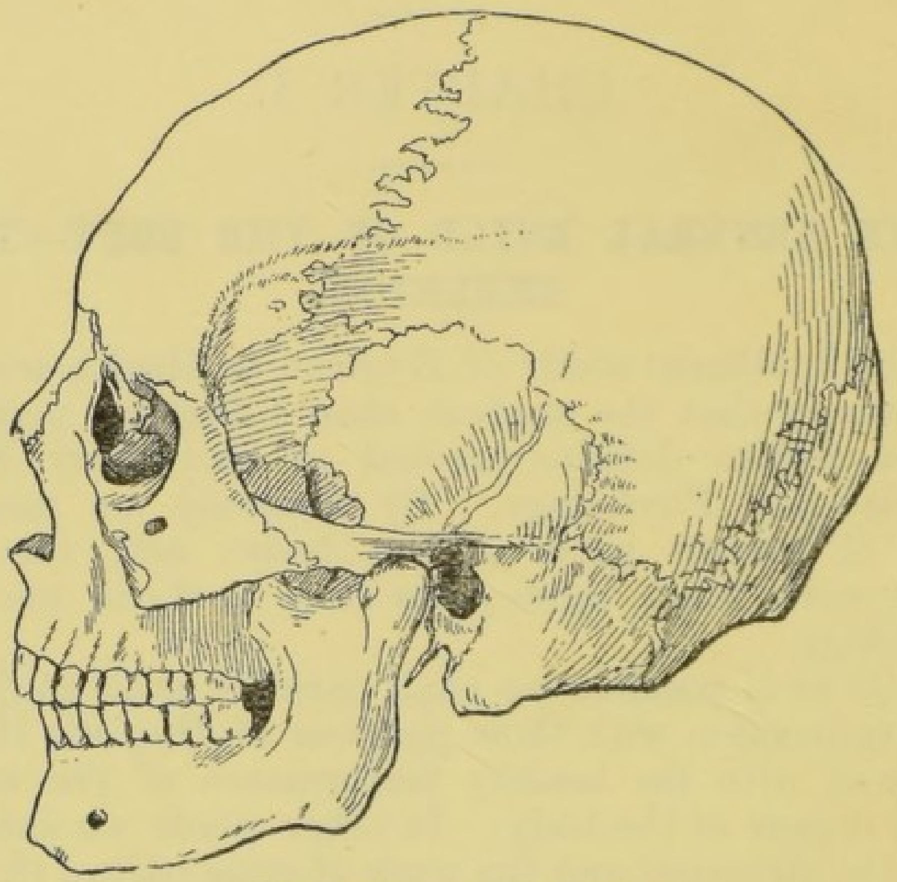


Fig. 1.—SKULL (Side View).

The Skull. Balanced on the top of the vertebral column is the skull. It may be divided into two parts: (1) the **cranium**, which is a bony box for the brain, and (2) the face bones.

The **Cranium**, as we have said, is a box for the brain. It is made up of eight bones very strongly bound together. The bones forming the base are very rough and irregular, while the front, back, roof, and sides are formed of smooth flat bones. Leading into the skull are several openings, one large, and the remainder comparatively small. The large opening—the foramen magnum—serves for the passage of the spinal cord from the brain into the canal provided for it in the vertebral column. Close to this opening, one on each side, are two smooth surfaces or facets which rest upon two similar facets on the first vertebra. In the action of nodding these two pairs of facets glide upon each other. Through the smaller openings in the cranium pass the cranial nerves from the brain to the various parts of the head and face.

The **Face** is made up of fourteen small bones which are closely bound either to each other or to the bones of the cranium. The lower jaw bone is fastened only at each end and can be moved about more or less like a door upon hinges.

The Vertebral Column. The vertebral or spinal column is the chief support of the trunk. It consists of thirty-three bones which are so tightly fastened together that only a very small amount of movement can take place between any vertebra and its neighbour. Taken as a whole, however, the vertebral column can perform very wide movements, and these are capable, by practice when young, of extraordinary development, as shown by the contortions of the so-called "boneless men."

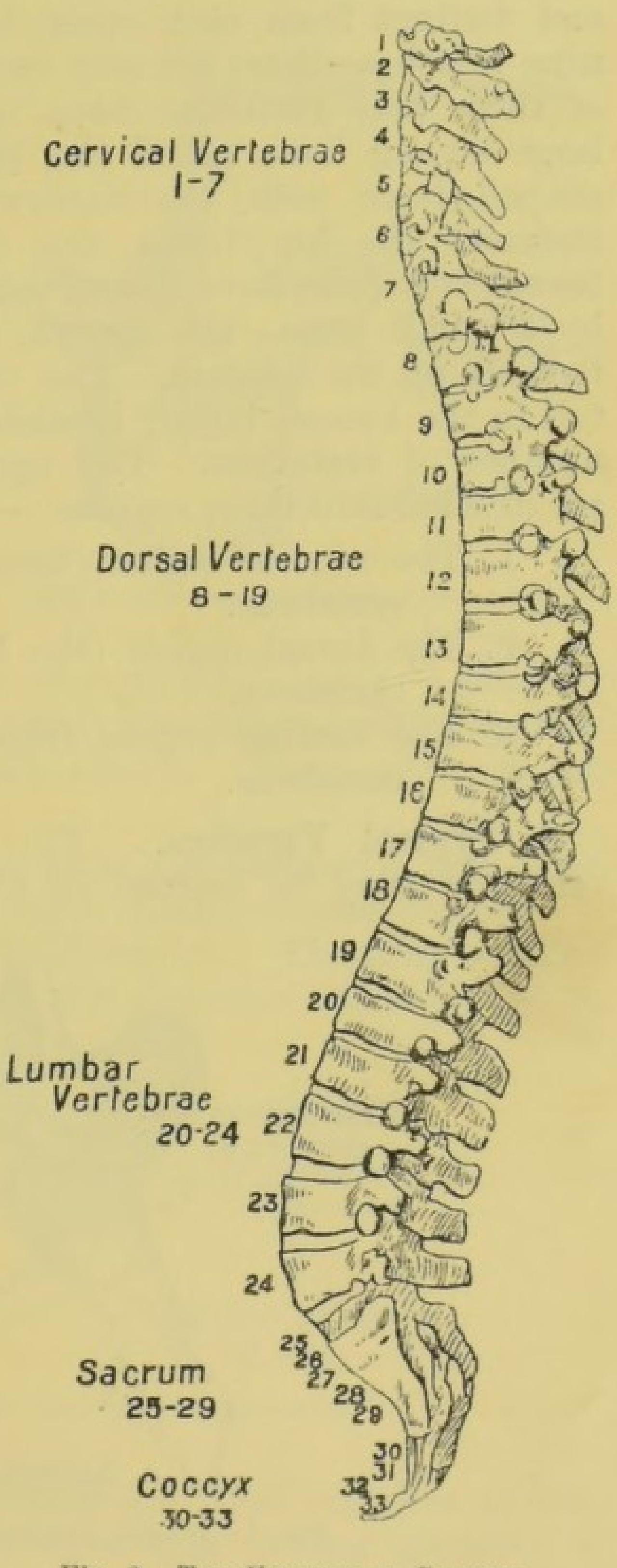


Fig. 2.—The Vertebral Column.

Of these thirty-three bones which make up the vertebral column the upper twenty-four are always quite separate and distinct from each other, but representing the lower nine vertebrae there are only two bones in the adult. Five of these nine vertebrae have united together to form a large strong bone called the **sacrum**. This is a wedge-shaped bone with the narrow end below. To it are fastened the hip bones, one on each side. The four lowest vertebrae have united together, and are represented by a small bone—**the coccyx**, which is attached to the bottom of the sacrum. The coccyx is the rudimentary tail in the human body; in animals it consists of a large number of vertebrae. The upper twenty-four vertebrae are divided into three regions :—

1. The cervical region (the neck), consisting of seven vertebrae.
2. The dorsal region (the back), consisting of twelve vertebrae.
3. The lumbar region (the loins), consisting of five vertebrae.

A Typical Vertebra. The general form of all the vertebrae may be learned by the study of one of them,

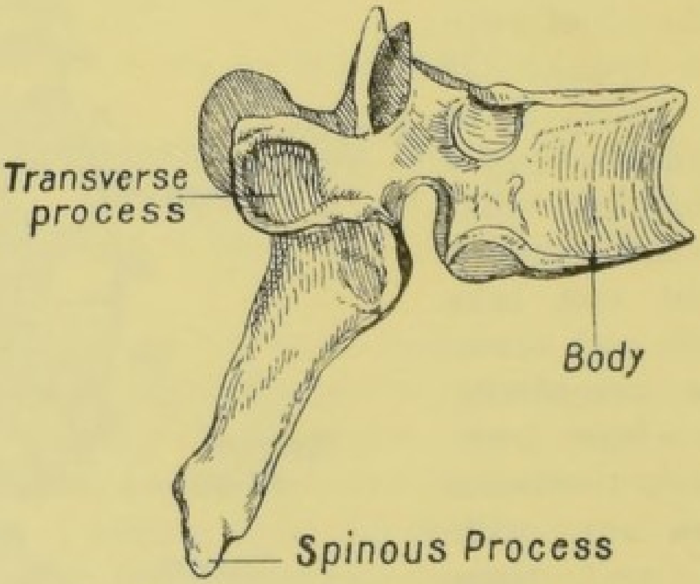


Fig. 3.—Dorsal Vertebra (Side View).

one of the dorsal vertebrae being usually selected for this purpose. In front is a solid rounded mass, flat at the top and the bottom, measuring about an inch and a half across and an inch thick. This is called the **body** of the vertebra. At the back of the body is a bony arch—the **neural arch**—enclosing a central hole, which is the canal for the spinal cord. From this arch spring three processes, one pointing backwards, called the **spinous process**, and one on each side, called the **transverse process**. The spinous processes are felt in the living body as a row of little knobs down the middle of the neck and back.

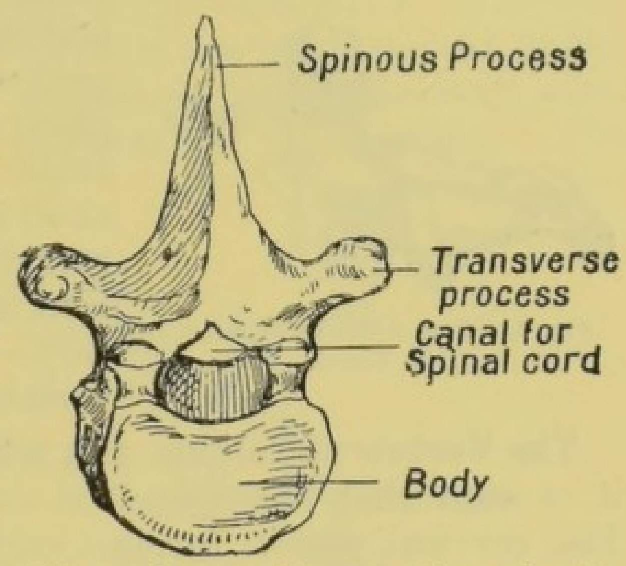


Fig. 4.—Dorsal Vertebra (from above).

On each side of the arch, above and below, is a projecting surface which fits accurately the corresponding surface of the vertebrae below and above. These surfaces are called **articular facets**.

Special Vertebrae. The two first vertebrae have been given special names and have characteristic shapes by means of which they may be identified. The first is called the **atlas**, from the name of the god who was supposed to

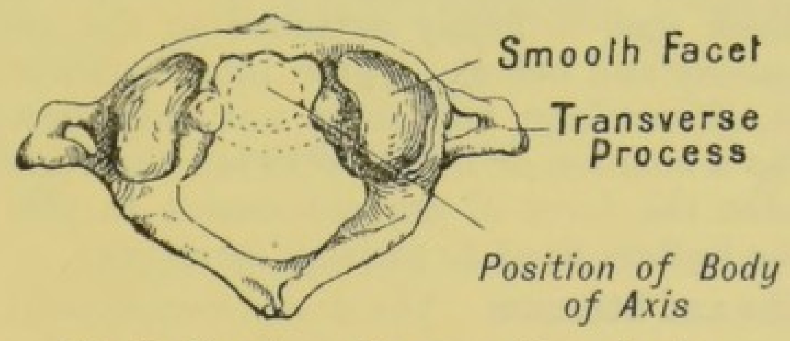


Fig. 5.—The Atlas Vertebra (from above).

bear the earth on his shoulders. This vertebra is distinguished by being ring-shaped and having no body in front. On its upper surface are two hollow, smooth facets which receive the two rounded surfaces near the foramen magnum of the skull. These pairs of surfaces, as we have said above, glide one upon the other in the action of nodding. The second vertebra is called the **axis**. Its peculiarity is that the body is prolonged upwards into the front part of the atlas, and takes the place of the missing body of the atlas. In shaking the head the skull and the atlas move together round this process, which, therefore, serves as the axis of rotation—hence the name of the vertebra.

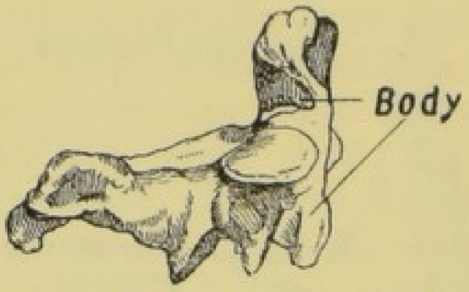


Fig. 6.—The Axis Vertebra (Side View).

The Vertebral Column as a whole. Viewed from the side it is seen that the vertebral column forms four curves. The cervical region forms a curve whose concavity points backwards; the curve formed by the dorsal vertebrae faces the opposite way, while that formed by the lumbar vertebrae again looks backwards, and the sacrum and coccyx unite to form a curve whose concavity faces forwards. The vertebrae are bound firmly together by ligaments at the articular facets, and by numerous other ligaments which pass from process to process and arch to arch. Other sets of ligaments pass from vertebra to vertebra down the front and back of the bodies. Another means of connection between each vertebra and its neighbour are the **intervertebral discs** which are placed between them. Each disc is firmly attached to the body of the vertebra above and below. These intervertebral discs are composed of cartilage, and serve not only as a ligament but also as a cushion or buffer between the vertebrae, and thus deaden the force of any concussion in just the same way as the buffers fixed to railway carriages.

The Ribs and Sternum. The dorsal vertebrae at the back, and the sternum or breast bone in front, together with the curved bones connecting them, **the ribs**, constitute the bony cage called the thorax. There are twelve pairs of ribs. Each pair is attached to a dorsal vertebra, one on each side of it, and the joints by means of which the ribs are attached allow movement to take place up and down. This movement takes place during respiration. The first ten pairs of ribs are attached in front to the sternum by means of cartilages—the **costal cartilages**,—the first five pairs having separate costal cartilages, while the second five are united to a single cartilage—the sixth. The last two pairs, the eleventh and twelfth, are not attached to the sternum at all, and are therefore called floating ribs. These are easily pressed inwards by tight lacing. The

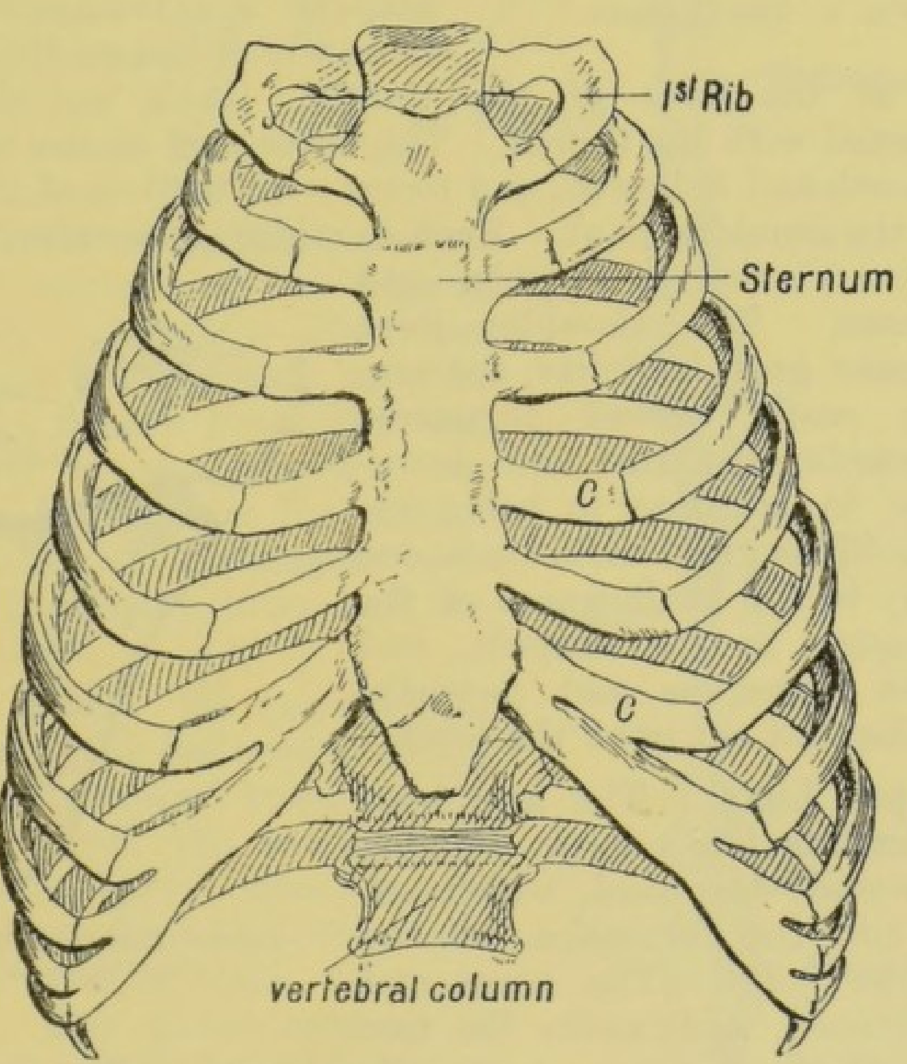


Fig. 7.—The Bony Thorax (*C, C* are two of the costal cartilages).

sternum or breast bone is flat and shaped more or less like a dagger, being broader above than below. Viewed as a whole, the bony thorax is of a conical shape, being broader below than above, when not distorted by corsets. The intervals between the ribs are called **intercostal spaces**, and are filled up by muscles called the intercostal muscles.

Shoulder Bones. Passing from the top of the sternum to the shoulder is the **clavicle** or **collar bone**. This bone is curved like the italic *f*, and extends outwards and backwards to the shoulder, where it is fastened to the outer part of the **scapula** or **shoulder blade**. The outline of the collar bone can be felt distinctly beneath the skin. The scapula is a triangular flat bone which lies on the upper ribs, at the back of the thorax. It is not directly connected with the thorax. The outer part of the scapula is smooth and hollowed, and forms with the top of the arm bone the shoulder joint. Each shoulder is, therefore, made up of a clavicle, a scapula, and humerus. The shoulder joint possesses great mobility, the arm being easily moved forwards, backwards, upwards, and downwards, in addition to being rotated. This great mobility is due mainly to the shallowness of the depression in the scapula, and to the numerous and powerful muscles that act upon the joint.

Fig. 8.—The Clavicle.

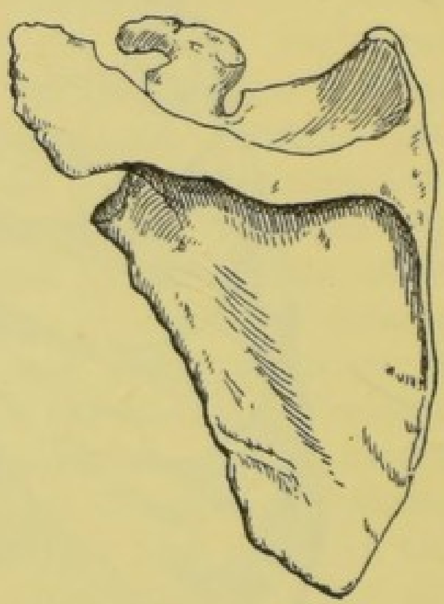


Fig. 9.—The Left Scapula (from the back).

Upper Limb. The arm bone or **humerus** has a large rounded upper end—the head, which enters into the formation of the shoulder joint. The lower end is flattened, and meets the two bones of the forearm at the elbow joint. The bones of the forearm are the **radius** and the **ulna**. The ulna is the inner bone and is on the same side as the little finger. The point of the elbow is formed by the hook-shaped end of the ulna. The upper end of this bone is much broader than the lower, so that, while it forms a great part of the elbow joint, it only has a minor share at the wrist joint. The radius on the contrary is narrow at its upper extremity, and much broader below, where it forms the greater part of the wrist joint. If the hand be laid with its back on a table and then turned over, it will be noticed that the thumb describes a semi-circle round the little finger. In the forearm it is the radius that describes the semi-circle round the end of the ulna — hence the name radius. **The wrist bones** or **carpals** are eight small bones arranged roughly in two rows of four. The **hand bones** or **metacarpals** are the five long narrow bones that can be easily felt at the back of the hand. Attached to the ends of these are the **phalanges**, each finger possessing three and the thumb two.

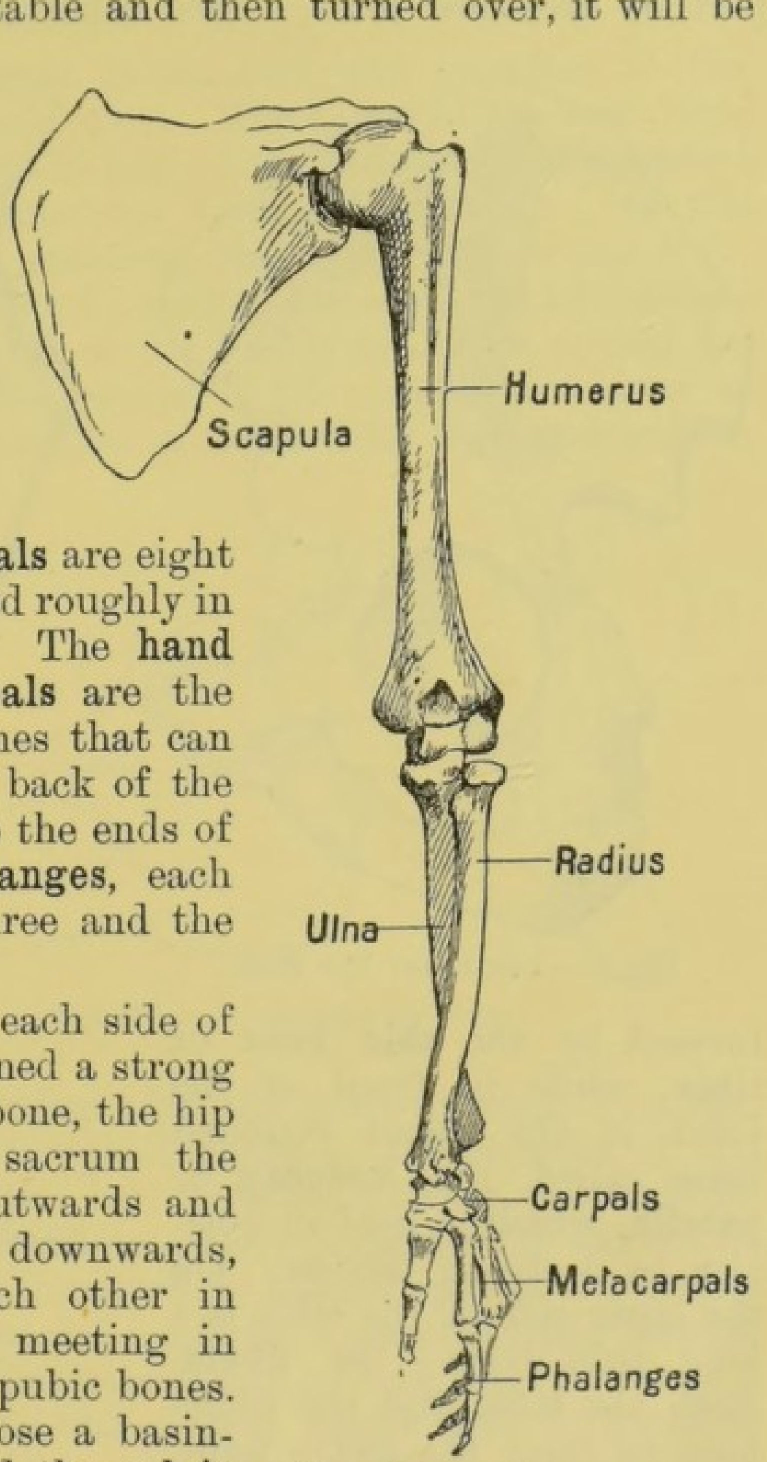


Fig. 10.—The Scapula and Left Arm.

Hip Bones. On each side of the sacrum is fastened a strong irregularly shaped bone, the hip bone. From the sacrum the hip bones curve outwards and then forwards and downwards, finally meeting each other in front. The parts meeting in front are called the pubic bones. The hip bones inclose a basin-shaped cavity called the **pelvic cavity**. The two hip bones, together with the sacrum and coccyx, form a bony girdle called the **pelvis**.

Lower Limb. The outer side of the hip bone contains a rounded cavity for the reception of the ball-shaped head of the **femur** or **thigh bone**. The thigh bone is the longest and strongest bone in the body. The lower end forms part of the knee joint. The other part of the knee is

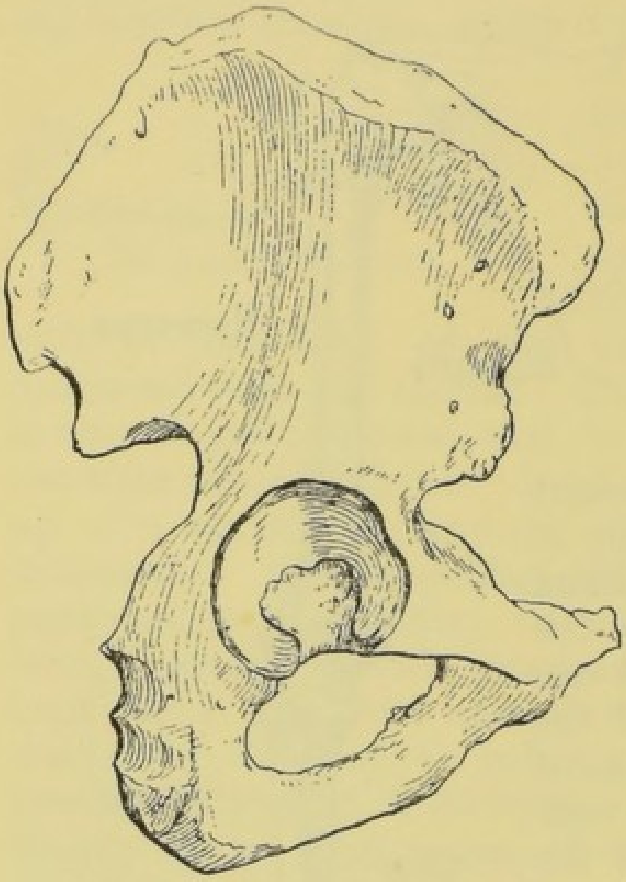


Fig. 11.—The Right Hip Bone.

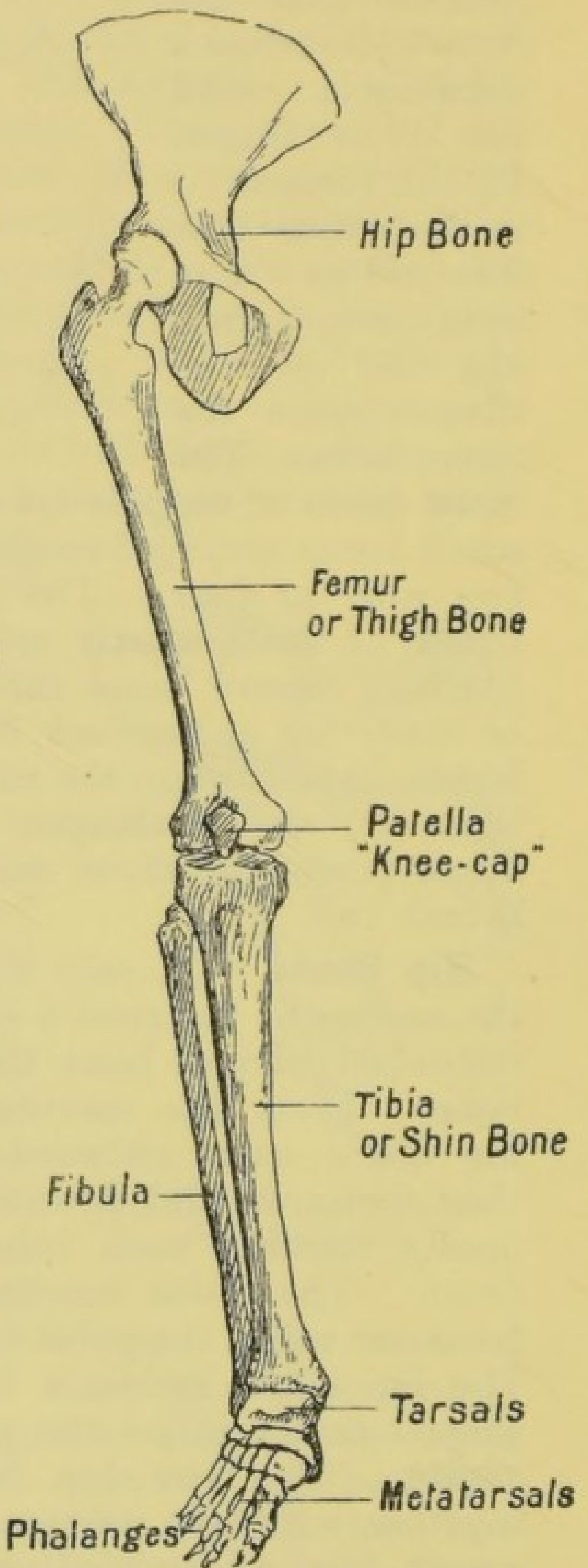


Fig. 12.—Hip Bone and Right Leg.

formed by the **shin bone** or **tibia**, while in front of the joint is the small rounded bone called the **kneecap** or **patella**, which is held in position by a strong tendon. On the outer side of the tibia is a long thin bone—the **fibula**. Both the tibia and the fibula help to form the ankle joint. Forming the ankle and the heel are seven bones, the **tarsal bones**. The bones in the middle of the foot are long and narrow, and are called **metatarsals**. There are five of them, one corresponding to each toe. The **phalanges** or toe bones correspond exactly with the finger bones, there being two in the big toe and three in each of the others.

The foot is narrowest at the heel and broadest at the ends of the metatarsal bones. The bones of the foot form two arches, one from the heel to the ends of the metatarsal bones, the other transverse from side to side. In the ordinary position of standing the foot rests on the heel, the outer edge of the foot, and the ends of the metatarsal bones. The inner side of the foot is too much arched for it to touch the ground, except in the condition known as "flat foot." These arches give elasticity and strength to

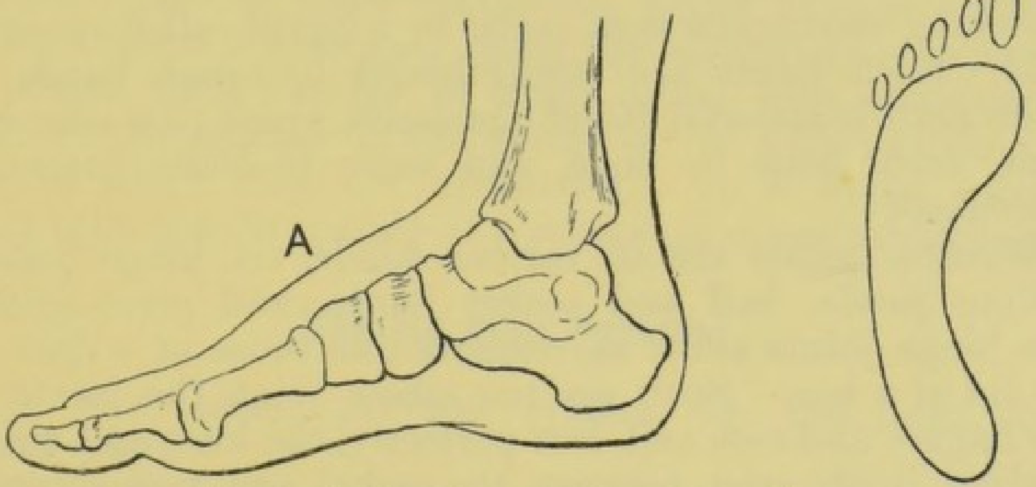


Fig. 13.—A, The Foot; B, Imprint of Foot.

the foot. This, together with the great number of joints, and the excellent leverage obtained by the muscles of the calf which pull on the heel bone in raising the body on tip-toe, renders the foot peculiarly adaptable to the act of walking. Flat foot is caused by the collapse of the arches of the foot, and is a painful condition common among persons whose occupations involve continuous standing. It is best treated by improving the general health and by a course of exercises which give special play to the muscles and tendons of the feet, such as skipping, standing on tip-toe, etc.

Joints.

Joints are formed where bones meet. If the joint admits of movement it is called a **moveable joint**, but a joint where the bones are immovable is said to be **fixed.**

The bones of the skull are locked immovably together by their serrated edges. Some joints, such as those between each vertebra and its neighbours, and the joint between the two pubic bones, consist only of a thick disc of cartilage between the adjacent bones. The amount of movement in such joints is very small.

Other joints, such as the hip, knee, and shoulder, allow great freedom of movement, and are formed by the contact of smooth polished surfaces of the adjacent bones. These surfaces are covered with a thin layer of softer material called gristle or cartilage, and the joint is shut in by a loose bag called the capsule. The capsule is lined by a smooth glistening membrane kept moist by a liquid called synovial fluid. Such joints are strengthened by tough bands of white flexible material called ligaments, which pass over the joint, from bone to bone, and serve to limit excessive movement.

Movable joints are of various kinds, viz. hinge joints, gliding joints, ball and socket joints, and pivot joints. The hinge joints allow movements like those of a door or the lid of a box. Such are the elbow joint, the joints of the fingers and toes and, less perfectly, the knee and wrist. Gliding joints exist between the carpal and tarsal bones. Ball and socket joints are illustrated by those at the hip and shoulder. Pivot joints, allowing of rotation only, exist between the radius and ulna, and between the atlas and axis.

The Soft Parts.

The soft parts of the body are divided into different **organs** and **systems**. Each system is devoted to some special work which is called its **function**. The chief systems are :—

(1) **The nervous system**, which includes the brain, spinal cord, and all the nerves. This system controls all the movements of the body.

(2) **The muscular system**, which effects the movements.

(3) **The alimentary system**, which includes the stomach, intestines, etc. ; its function is to digest the food and hand over the nourishment to the blood.

(4) **The circulatory system,** which is concerned with the conveyance of this nourishment in the blood to every part of the body. This is done by the heart and blood vessels.

(5) **The excretory system,** which includes the lungs, skin, and kidneys. These organs get rid of impurities from the blood. The lungs have an additional function; they bring oxygen into the blood.

The various systems are composed of several different materials or **tissues.** Amongst these we have the epithelial, the connective, the muscular, the fatty, and the nervous tissues. Most of these tissues are found in each system. When a tissue is examined under the microscope it is found to consist of a number of units called **cells**; one tissue differs from another in the nature of its cells, and in the way in which they are connected. In a living animal these cells consist mainly of a substance called **protoplasm.**

The Nervous System.

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

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

(3) The sympathetic nervous system.

The nervous system is the most important of all the parts of the body, and is the most complicated and highly organised. By means of it we think, exercise our will and our various senses (sight, touch, smell, etc.), control the movements of the body, and carry on automatically various acts and processes such as the beating of the heart and the passing of the food along the intestines.

The brain and the spinal cord constitute the **central nervous system,** while the nerves connected with them are collectively called the peripheral portion. The whole system is made up of nerve cells and nerve fibres. Each nerve fibre is connected with a nerve cell. The nerves are bundles of nerve fibres lying side by side and bound firmly together. Masses of nerve cells have a grey appearance and are described as "**grey matter,**" while the bundles of nerve fibres being much paler are called "**white matter.**"

The Brain. The brain is a large light-grey organ weighing about 50 ounces and almost entirely filling the cavity of the skull. It commonly measures 7 inches in length and 5 inches in width. It is covered with 3 membranes which, together with the skull, afford it great protection. The surface is much folded. From the under side of the brain 12 white bands issue. These are the cranial nerves.

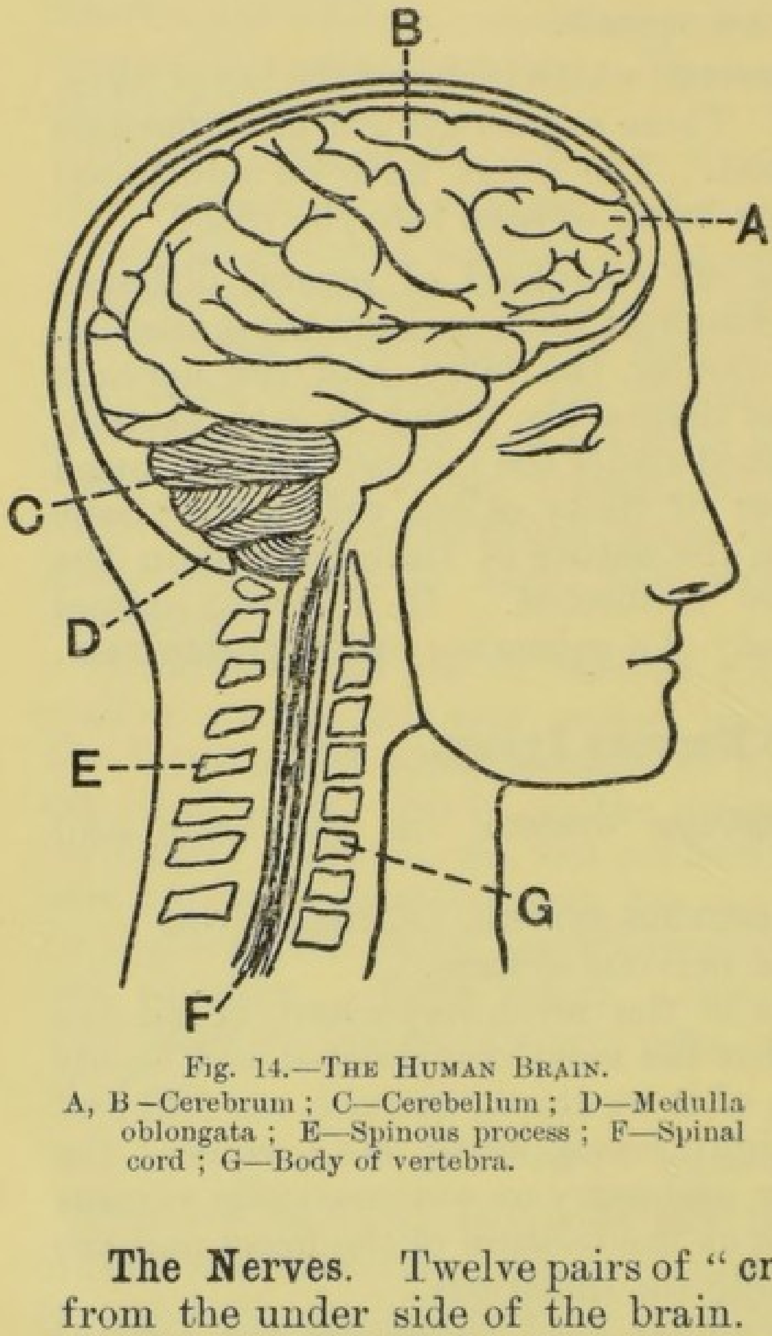


Fig. 14.—The Human Brain.
A, B—Cerebrum; C—Cerebellum; D—Medulla oblongata; E—Spinous process; F—Spinal cord; G—Body of vertebra.

The Spinal Cord. The brain is continuous downwards with the soft whitish mass which passes through the foramen magnum and fills the cavity of the vertebral column as far as the second lumbar vertebra, where it ends in a bundle of white cords or nerves.

The Nerves. Twelve pairs of "**cranial nerves**" emerge from the under side of the brain. These find their way through various holes in the base of the skull and are distributed to various parts of the head, neck, and upper part of the body. The spinal cord gives off white strands in pairs, one on each side, called "**spinal nerves,**" 31 pairs in all. Each nerve leaves the cord by two roots which join together while still in the spinal canal. Each nerve then leaves the spinal canal by a small hole between the vertebrae. Outside the vertebral column they join together in a complicated fashion, and from the networks so formed various large nerves arise. These are distributed to all parts of the body.

In addition to the above nerves a thin grey cord runs from the neck to the pelvis on each side of the bodies of the vertebrae at the back of the abdomen and thorax. Small enlargements or ganglia at intervals occur in its course, making it resemble a string of beads. These are called the **sympathetic ganglia**. Nerve fibres from the spinal cord join the chain of ganglia. The double chain of ganglia and the nerves joining them form the **sympathetic system**. From the chain very fine nerves go to the blood vessels, heart, and intestines.

A nerve is often described as a telegraph wire. Messages or **impulses** are transmitted along nerves to or from the brain, or to or from the spinal cord. Nerve fibres that bring impulses *to* the brain or spinal cord are called **afferent** or **sensory nerves**, because it is by means of such fibres that we acquire our knowledge of the world by means of sight, touch, hearing, smell, etc. On the other hand the nerves conveying impulses *from* the brain or spinal cord are called **efferent** or **motor nerves**, because the impulses result in the contraction of a muscle and so cause movement.

The Muscles.

The various joints allow the bones of the body to be bent in many directions. Of themselves, however, the bones cannot perform any movement, but all movements are accomplished by the contraction of muscles. The muscles of animals constitute the chief part of the flesh of the body, and are the lean part of the meat. Muscles are usually divided into two classes: (1) the voluntary muscles, (2) the involuntary muscles.

Passing to each muscle is a nerve which conveys to it the messages from the brain or spinal cord. This is called a **motor nerve**, because we find that if it is divided the muscle becomes paralysed and incapable of producing any movement.

The voluntary muscles are those muscles whose movements are under the control of the will. The two ends of a muscle are usually attached to two bones with a joint between. When the muscle contracts it bends the joint, and when the joint is bent it may be straightened out again by the contraction of another muscle, which tends to bend the joint in the opposite direction.

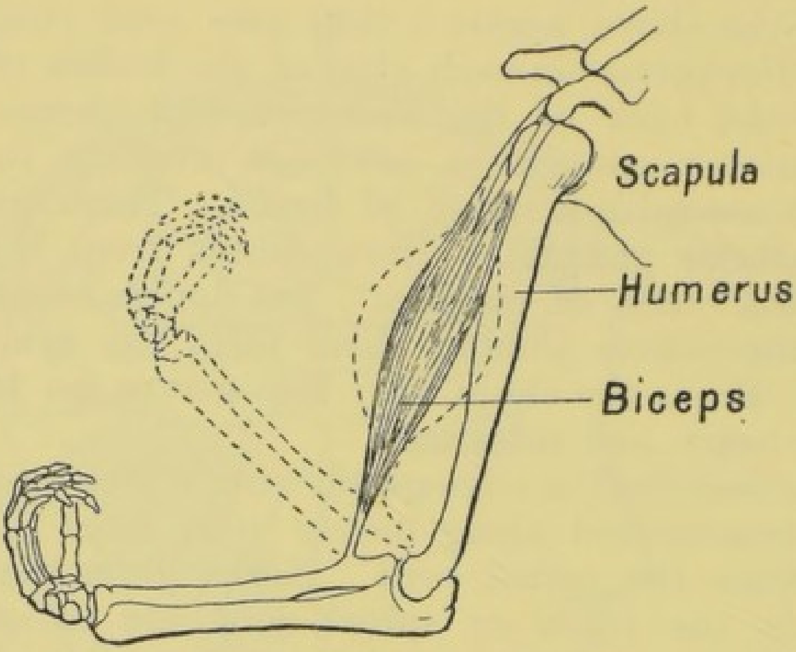


Fig. 15.—The Action of the Biceps Muscle.

For instance, the biceps muscle of the arm is attached to the scapula at the shoulder, and to the radius just below the elbow. When it contracts it pulls up the forearm and so bends the elbow.

The involuntary muscles are those which act independently of the will. They form the muscular walls of the stomach, intestines, bladder, heart, and blood vessels.

Levers. Our voluntary movements are usually produced by a muscle or a set of muscles using a bone as a lever.

A lever is a rigid bar which is capable of being moved about a fixed point.

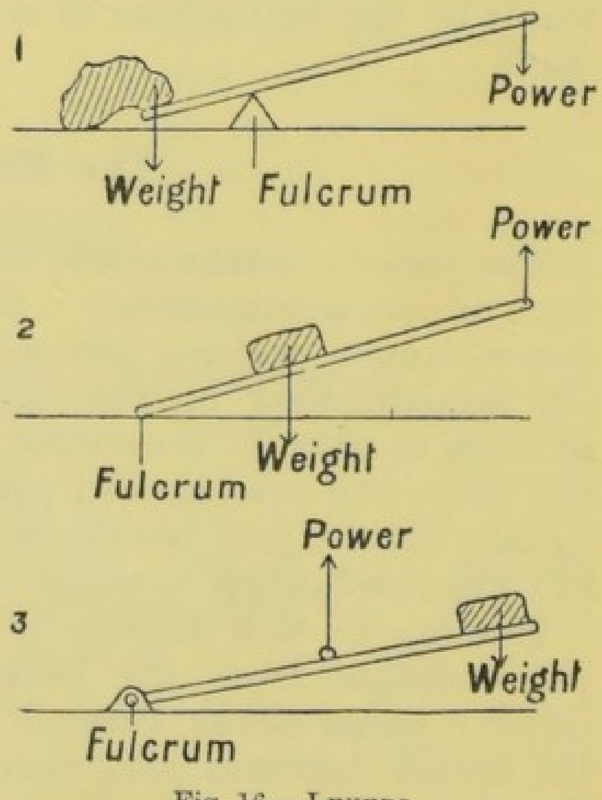


Fig. 16.—Levers.

This fixed point is called the **fulcrum**. The force producing the motion is generally called the **power**, and the body which is being moved by the lever is referred to as the **weight**. These three, the fulcrum, the power, and the weight, may be arranged along the bar in three different relative positions, giving three orders of levers.

A lever of the **first order** is where the power and the weight act with the fulcrum between them, as in a pair of scissors or an ordinary lever. This form of lever is used when we nod our head. A set of muscles pull down the head in front, and another set pull down at the back, the fulcrum being the point at which the skull rests on the atlas.

The **second order** of lever is where the fulcrum is at one end of the lever and the power at the other end, with the weight between them, as in a pair of nutcrackers or a wheelbarrow. This is the position when the body is raised on tip-toe. The force here is represented by the muscles at the back of the leg, which are pulling up the heel. The weight of the body acts in the middle, and the toes form the fulcrum.

The contraction of the biceps producing movement of the forearm illustrates a lever of the **third order**. The fulcrum is the elbow joint. The power is the contracting biceps, and is applied about an inch away from the elbow. The weight acts further down and is represented by the arm which is lifted. A pair of sugar tongs is a common example of this kind of lever.

THE BODY TRUNK.

The limbs are practically solid structures, composed of the above tissues. The trunk, on the other hand, is hollow. This space inside the trunk is called the **body cavity**. At about the level of the three lowest ribs is an arched muscular partition, which divides the body cavity into two distinct parts, an upper part called the **thorax** or chest, and a lower part called the **abdomen**.

The Thorax and its contents. This cavity is bounded **in front** by the sternum and the cartilages of the ribs; **laterally** by the ribs and the intercostal muscles between them; **behind** by the ribs, vertebral column, and the great muscles of the back; **above** by the first rib, the collar bone, and the neck; **below** by the arched muscular partition called the **diaphragm**.

It is convenient to divide the thorax into three parts. At each side it is filled with the lungs (right and left). In the middle portion there are the heart and great blood vessels, the trachea and its branches, the oesophagus, the thoracic duct, and lymphatic glands. Surrounding each lung is a double bag called the **pleura**, the inner layer of which is attached to the lung itself, while the outer layer is fastened to the chest wall. In health these two layers are in close contact and can move smoothly over each other, the surfaces being lubricated by a small quantity of fluid. In the disease known as pleurisy these smooth surfaces become roughened, and pain is felt every time the one surface rubs against the other. The heart is contained in a similar double bag called the **pericardium**. Inflammation of this part is called pericarditis. The inner layer of pericardium covers the heart closely, and the outer layer forms a loose bag in which the heart moves. A small amount of fluid lubricates the two surfaces.

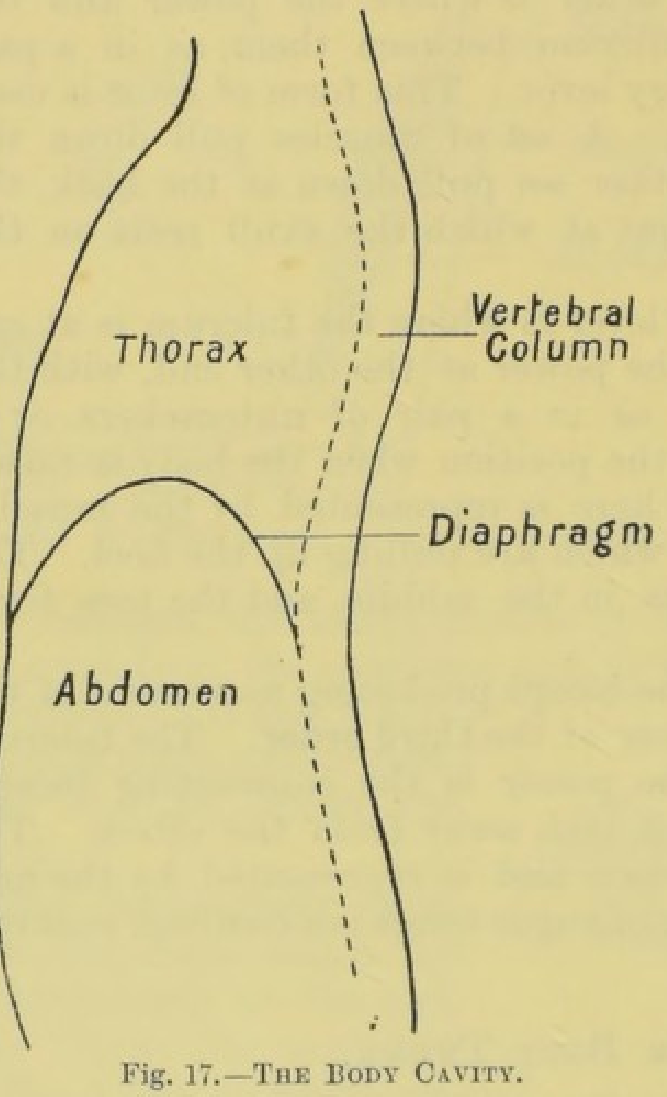


Fig. 17.—The Body Cavity.

The Abdomen and its contents. The abdomen is bounded **in front** by the abdominal muscles, passing from the ribs to the pelvis; **laterally** by the same muscles; **behind** by the lumbar vertebrae, sacrum, coccyx, and muscles of the back; **above** by the diaphragm; **below** by the pelvic bones and muscles.

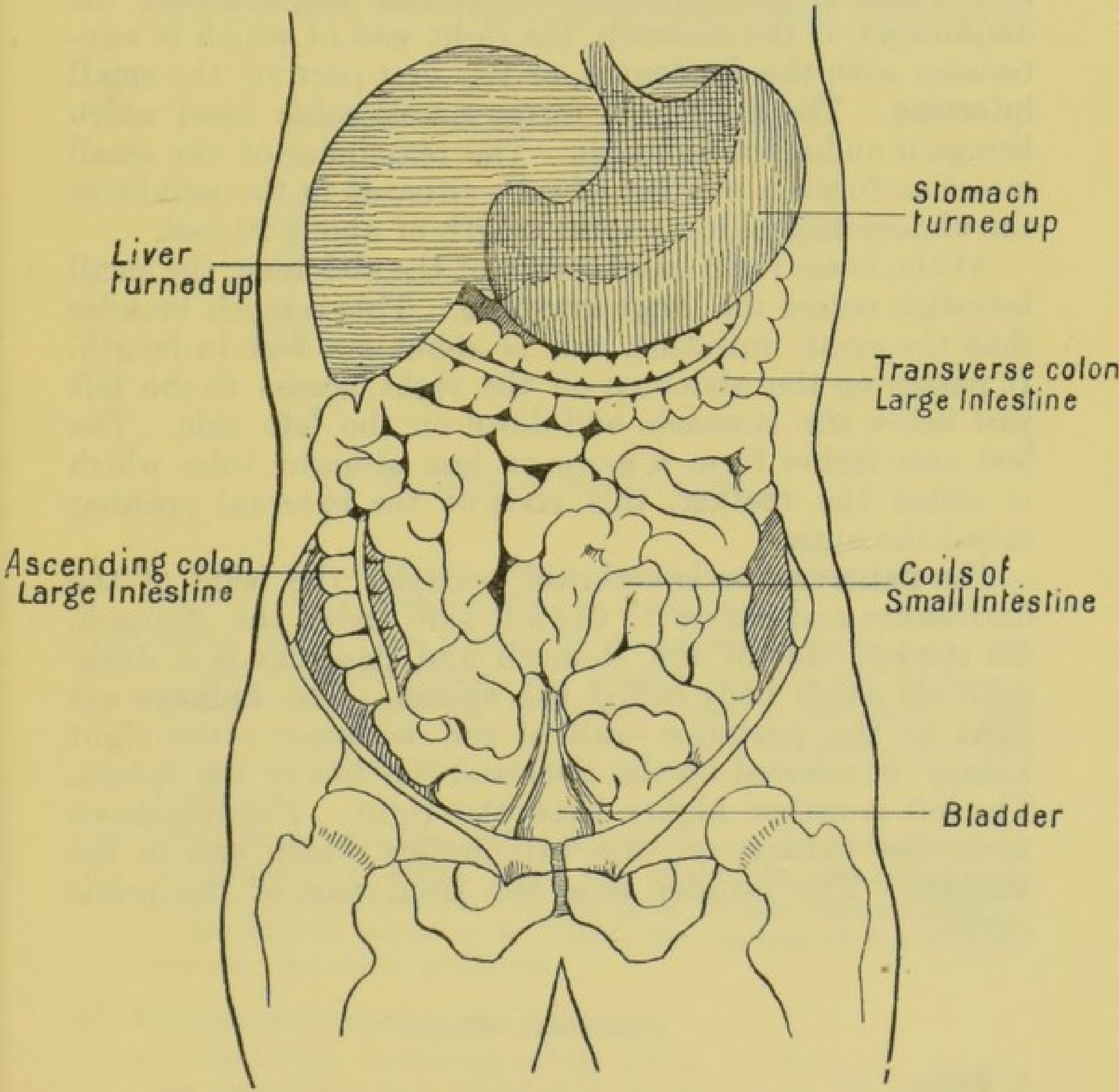


Fig. 18.—Contents of Abdomen.

It is lined by a thin glistening membrane—the **peritoneum**—which also covers all the organs contained in the abdomen. Inflammation of this membrane is called peritonitis. This smooth membrane is kept continually moist by a small amount of fluid which it secretes. In the abdomen are the stomach and intestines, the liver and pancreas, the spleen, the kidneys, ureters, and bladder. Immediately under the diaphragm and chiefly on the right is the **liver**, a large organ with a curved upper surface to fit the arch of the diaphragm. On the left, touching the diaphragm, is the stomach, the right end of which is continuous with the **duodenum**, or the first part of the **small intestine**. The duodenum forms a noticeable bend which brings it under the stomach. The remainder of the small intestine forms a number of coils situated in the middle of the abdomen, making a total length of about 20 feet.

At the lower right hand corner of the abdomen, the small intestine enters the **large intestine**. This is much broader than the small intestine, and is about six feet in length. It passes up the abdomen on the right, across to the left just below the stomach, and down on the left side. The last nine inches form a more or less straight tube which is called the **rectum**; this ends at the external opening called the anus.

The **pancreas**, or sweetbread, occupies the bend of the duodenum and passes to the left side under the stomach. On the left side of the stomach and pancreas is a dark-coloured small body called the **spleen**. The **kidneys** are fixed to the posterior wall of the abdomen; the right kidney is covered by the liver and the left by the spleen. The left is rather higher than the right. Passing down from the kidneys are the two ureters which end in the **bladder**. The bladder is in the front part of the pelvic cavity.

Practical Work.

I. **Bones.**

Each student should handle and draw the bones of the body separately.

II. **Levers.**

(*a*) *First kind.*—Place a hooked stick over the back of a chair, as shown in diagram, so that one-third of its length (the hooked end) projects one way and two-thirds the other way. Place a bag containing a weight (say 6 lb.) on the hook. Place the hook of a spring balance round the end of the stick and hold the stick horizontally by this means. The spring balance will register a pull of 3 lb.

On moving the fulcrum (the chair) nearer the weighted end the reading of the spring balance decreases, showing that large weights can be lifted by means of levers with a small

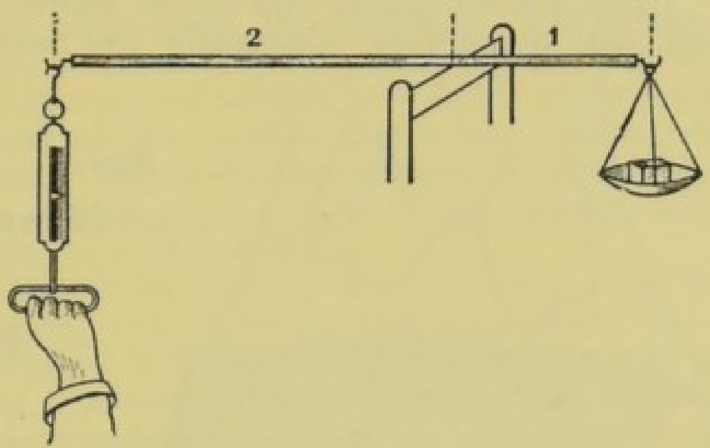


Fig. 19.—LEVER OF THE FIRST ORDER.

expenditure of effort. Note the indications of the spring balance for various positions of the fulcrum.

(*b*) *Second kind.*—Place the end of the stick on a table, hang the weight from the middle, and support the free end by means of the hook of the spring balance held in the hand. The balance registers a pull of 3 lb. Alter the position of the weight and note the reading of the balance for various positions.

(*c*) *Third kind.*—Fix one end of the stick, *e.g.* by insertion into a keyhole of a door. Hang the weight on the other end, and support it by means of the hook of the balance applied to the middle of the stick. Note the reading of the balance for this and other positions.

III. The Simple Dissection of a Rabbit.

A recently killed, unskinned rabbit should be obtained. Fasten the four limbs to a board with strong pins. The parts of the limbs, the bony thorax, and the soft abdomen should be identified by external examination, and their resemblance to the human parts should be noted. The ribs, the sternum, and the vertebrae can easily be felt.

Pick up the skin in the middle of the abdomen between your fingers and push the sharp point of one blade of the scissors through. Then cut upwards and downwards, taking care to cut skin only. Reflect the skin outwards from the thorax and abdomen, and pin it out at the side. You will find a large muscle passing from the sternum to the forelimb ; cut through this close to the ribs. Note appearance of the sternum, the ribs and their method of attachment to the sternum, and the intercostal muscles.

Now cut along the middle line of the abdominal wall from the end of the sternum downwards, and reflect the wall outwards. The liver is noticeable at once and is easily identitified. Draw it down gently and notice above it the arched partition, the diaphragm, separating the thorax from the

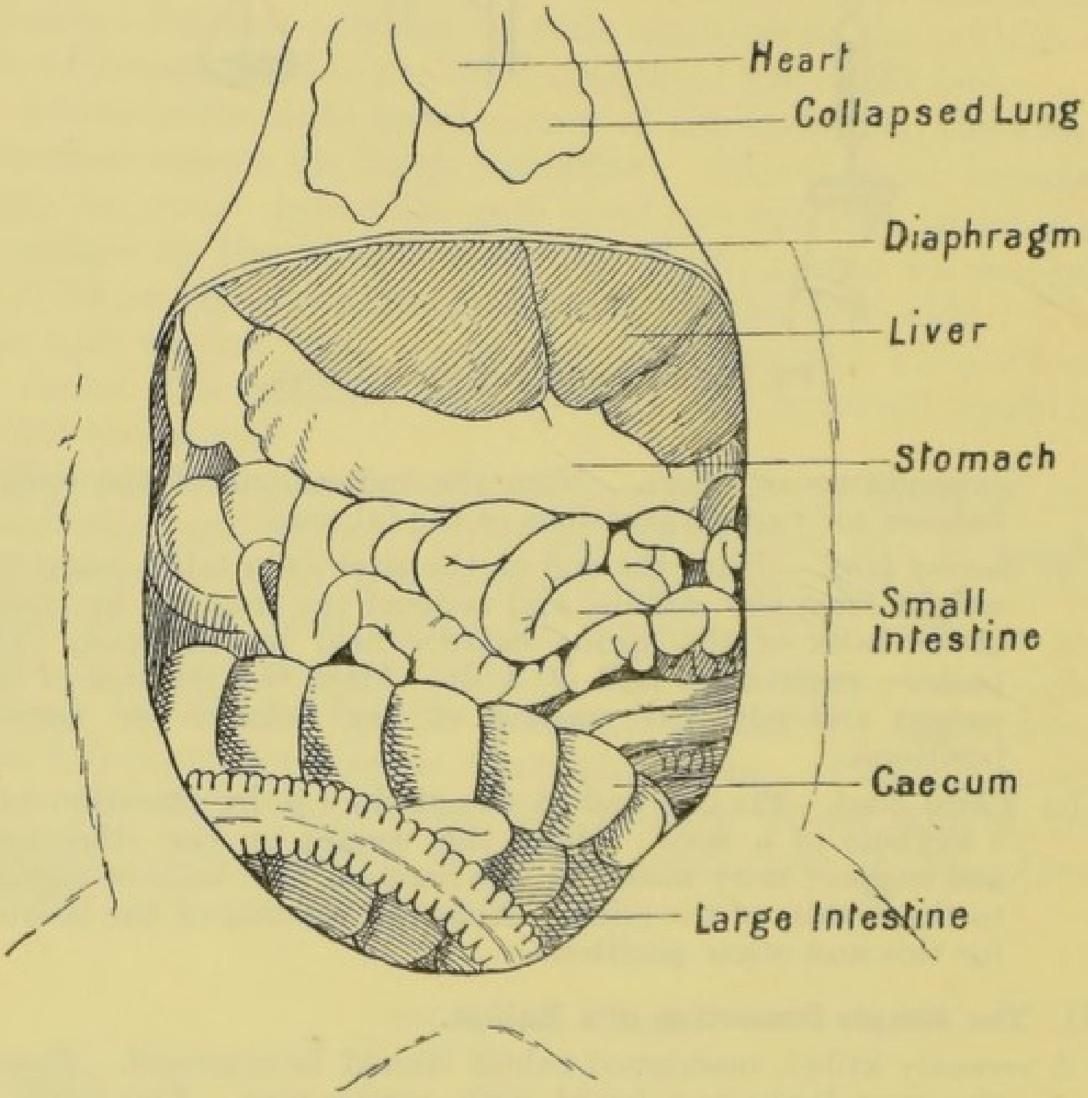


Fig. 20.—Viscera of Rabbit.

abdomen. The stomach under the diaphragm towards the left, and the duodenum passing from it on the right are easily found. The small intestine lies in many coils in the middle of the abdomen. The large intestine is represented by a light-coloured puckered tube lying across the lower right hand side, and also by a large sacculated tube of a dark colour which occupies the lower part of the abdomen. This dark tube is the caecum, and is much larger in the rabbit than in the human being. The bladder is found at the bottom of the abdomen.

Pick up a coil of small intestine: it is attached to the abdominal wall by a thin transparent membrane, the mesentery. Cut through this and travel up and down along the intestine until you have unravelled the whole from the duodenum to the rectum. In the bend of the duodenum is an irregular greyish white body, the pancreas. The spleen will be found as a dark-coloured body just below the left of the stomach. The kidneys and ureters are found at the back. Cut open the stomach, and notice that a tube enters it from above on the left. This is the oesophagus, a tube which passes from the mouth down the back of the thorax, and through the diaphragm to the stomach.

Open the thorax by cutting the ribs away from the sternum on each side, and removing the piece from the middle. The pericardium is in the middle and on the left, a thin bag enclosing the heart. Cut this open, and notice the shape of the heart and the blood vessels passing from its upper part. One of these vessels is light-coloured, and firmer than the others. This is the great artery of the body, the aorta. Coming up to the heart from below is a dark purple vessel, the inferior vena cava, and from above a similar one, the superior vena cava.

The lungs fill the greater part of the thorax. They are pink, spongy bodies. Cut off a piece and put it in water. It floats. Passing upwards from the upper part of the lungs is a hard tube—the trachea or windpipe. This ends above in the mouth, and below it divides into two branches, the bronchi, one for each lung.

Nervous system.—On separating the muscles of the rabbit white threads will appear which branch and disappear in the substance of the muscle. These are nerves. Among the muscles at the back of the thigh will be found one of the largest nerves, the sciatic. Trace this upwards (cut through the hip bone to do this) to the vertebral column. Here it divides into branches which disappear into the vertebral column.

Remove the skin from back and dissect away the muscles from the vertebral column. Cut away the spinous processes of the vertebrae with a pair of strong scissors, and then remove the arches to expose the spinal cord. This has to be done with great care in order to avoid injury to the spinal cord by the cutting scissors.

Trace the spinal cord upwards to the foramen magnum, where it joins the brain, and downwards to the lumbar vertebrae, where it tapers down to a filament and is surrounded by a bunch of white strings (called the cauda equina or horse's tail).

CHAPTER II.

THE BLOOD.

To the naked eye the blood appears to be a red liquid, but under the microscope we see that it really consists of a clear colourless fluid in which are suspended a great number of small solid bodies. Most of these small bodies are red, and they give the red colour to the blood. The clear liquid part of the blood is called the **plasma**, and the small solid bodies floating about in it are called the **corpuscles**.

There are two kinds of corpuscles, red and white, the proportion being about 500 red corpuscles to one white.

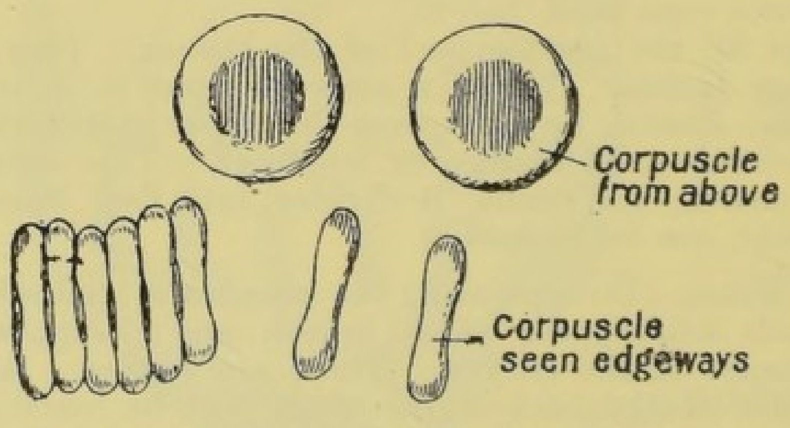


Fig. 21.—Red Corpuscles (Magnified 1600 times).

Red Corpuscles. These are usually described as minute bi-concave discs. This means that they are round and flat like a penny, but are thinner in the middle than at the edge. The diameter of the disc is $\frac{1}{3200}$th of an inch, and it is about a quarter of that in thickness. When viewed under the microscope, they are seen to have a tendency to run together in rows like a pile of pennies. Their colour is not a bright red like the colour of blood, but much paler and yellower. A red corpuscle is made of a soft elastic and spongy material called **stroma**. Owing to their flexibility they can be forced through a small blood-vessel which has a less diameter than their own. This spongy network or stroma is colourless, but contains in its meshes a red colouring matter called **haemoglobin.**

Haemoglobin is a chemical substance capable of combining loosely with oxygen and forming **oxyhaemoglobin,** which has a bright scarlet colour. This can give up its oxygen and return again to haemoglobin. The haemoglobin therefore acts as the oxygen carrier of the body. In the lungs it absorbs oxygen and becomes oxyhaemoglobin, and then this oxygen is carried all over the body to burn up the waste products of the various parts.

The haemoglobin of the blood is capable of forming a more stable compound with a gas called carbon monoxide (CO) which is present in coal gas. The power of combining with the haemoglobin causes the gas to act as a powerful poison, because it deprives the body of oxygen.

The White Corpuscles (Leucocytes). These vary very greatly in form and in size. They average $\frac{1}{2500}$th of an inch in diameter. The red corpuscles have no power of movement of themselves, but the white ones are constantly moving and changing their shape. Each white corpuscle is a complete cell, made of a clear jelly-like substance called protoplasm. In the protoplasm are seen a number of black dots called granules, and, if the cell is treated in a certain way, a rounded body can be distinguished which appears darker than the rest of the cell. This body is called the nucleus. The red corpuscles have no nucleus.

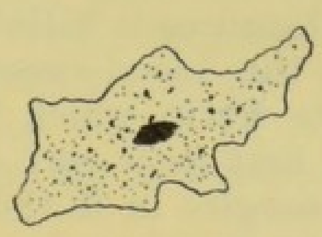
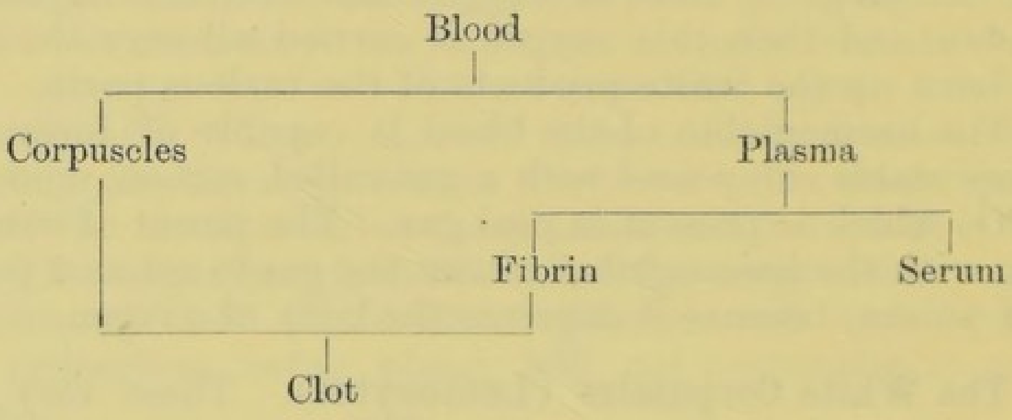


Fig. 22.—White Corpuscle (Magnified 1600 times).

Clotting of Blood. A few minutes after its withdrawal from the body the blood sets to a kind of jelly. In fact it looks very much like red jelly. About an hour afterwards a few drops of a pale yellow liquid appear on the top of the clot, and the surface of the clot becomes concave. The clot is shrinking and is squeezing out the pale yellow liquid—**the serum.** The clot continues to contract, and more serum appears until finally there is a red clot floating in serum. If examined under the microscope this serum will be found to contain no red or white corpuscles. The outside of a clot appears redder than the interior, because the oxygen in the air combines with the haemoglobin of the red corpuscles and forms oxyhaemoglobin on the outside.

The above facts about the blood may be diagrammatically represented thus :—

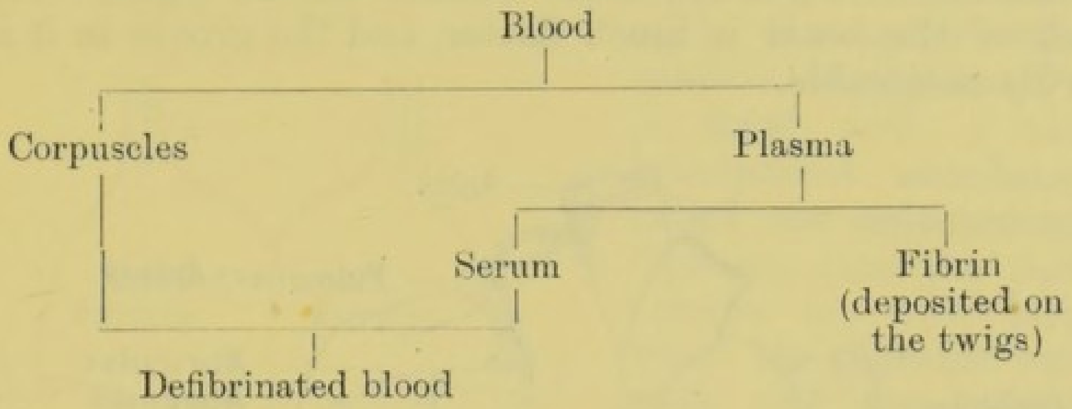


Explanation of Clotting. Blood plasma consists of water with a number of substances in solution. One of these substances is called **fibrinogen**. When the blood is not in the blood-vessels this fibrinogen is rapidly converted into **fibrin** which forms the clot. This fibrin is formed at first as a sort of network throughout the liquid, and entangles in it the red and white corpuscles. The fibres then shrink and squeeze out the remainder of the plasma, *i.e.* the serum. Putting it in a slightly different way, we may say that plasma consists of fibrinogen and serum, and a clot is made up of fibrin with the corpuscles entangled in it.

When coagulation is delayed, the corpuscles have time to sink to the bottom so that the top of the clot is lighter coloured than the bottom. This layer is called " the buffy coat."

If fresh blood is stirred quickly with twigs the fibrin is formed rapidly, and collects on the twigs instead of forming a solid clot. The liquid left behind will consist of serum and corpuscles only, and will not clot. It is called " defibrinated blood."

The following diagram shows the composition of "whipped" or "defibrinated" blood :—



Serum is a yellowish liquid consisting of water, salts (chiefly the chlorides, phosphates, and carbonates of potassium and sodium), and two complex nitrogenous bodies called albumin and globulin. The blood plasma contains all these and, in addition, the substance called fibrinogen.

Uses of Blood. (1) The haemoglobin in the red corpuscles acts as the oxygen carrier from the lungs to all parts of the body. (2) The impurities of the body are carried by the blood to the lungs, kidneys, liver, and skin, where they can be got rid of. (3) When the food is digested it passes into the blood, which conveys the nourishment to the various parts of the body. (4) The flow of the blood through all parts keeps the temperature of the body uniform.

The Heart.

The heart lies in the thorax between the two lungs, and is partly covered by the lungs, but part of it is in contact with the chest wall. The walls are made chiefly of muscle, and the heart weighs nine or ten ounces. It hangs freely in a closed membranous sac called the pericardium. The inner surface of the membrane is smooth and shiny, as is also the outer surface of the heart. The heart is conical in shape, the base being uppermost and directed upwards and to the right, while the apex points downwards and to the left. The **front** of the heart differs from the **back** by being more rounded and convex, and by having a groove filled with fat running from the top on the left across towards the bottom on the right. The back of the heart is much flatter, and the groove in it is hardly noticeable.

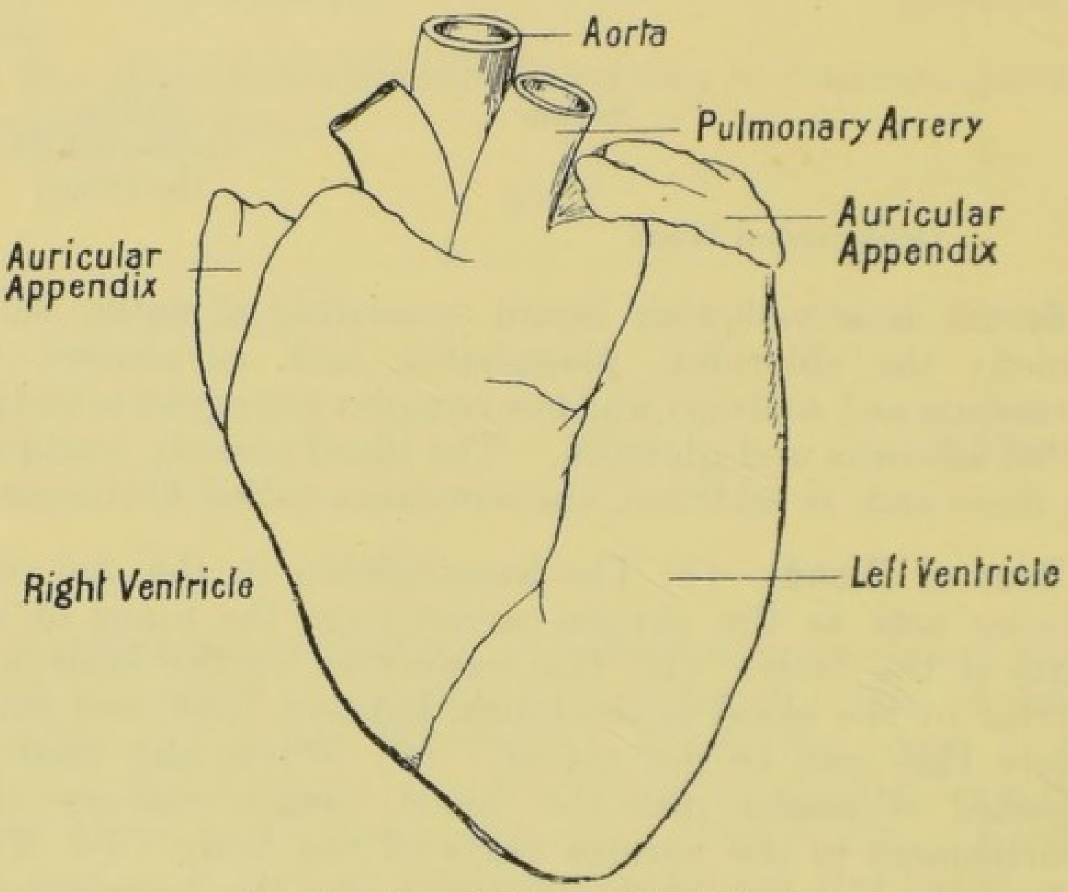


Fig. 23.—Sheep's Heart (Front View).

The **left** side of the heart differs from the **right** side by feeling firm and solid when pinched between the fingers: the right side feels soft and flabby.

Structure of the Heart. The heart is divided into a right and a left half by a partition, and there is no communication through this partition from one half to the other. Each half is again subdivided into an upper and a lower compartment called respectively **auricle** and **ventricle**. Each auricle communicates with the ventricle of the same side by an opening which is guarded by valves. The object of these valves is to prevent any blood flowing from the ventricle to the auricle. They allow blood to flow freely from the auricle to the ventricle. In describing the heart it is best to consider separately its four cavities, the right and left auricles and the right and left ventricles. **The Right Auricle** is a thin walled cavity. In common with the other three cavities of the heart it is lined with a thin transparent membrane, called the **endocardium.** Opening into the right auricle are two large veins, the **superior vena cava** and the **inferior vena cava.** These veins bring blood from the whole of the body except the lungs.

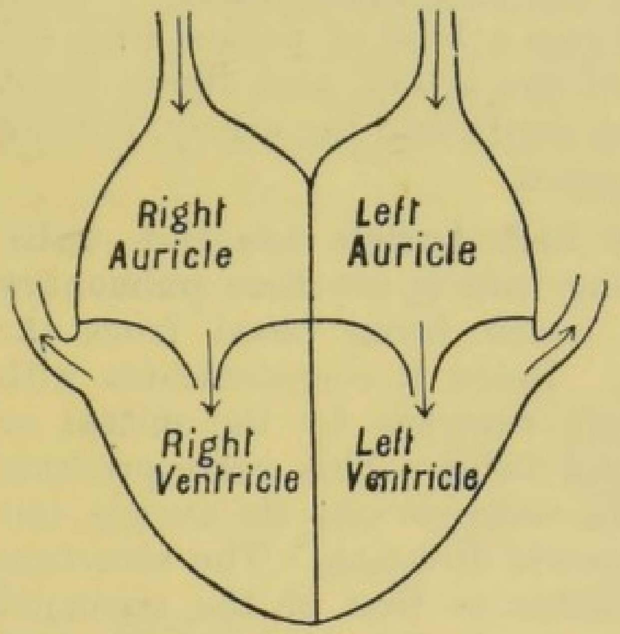


Fig. 24.—Diagrammatic Heart.

The Right Ventricle is separated from the right auricle by a valve which is composed of three triangular flaps or cusps, and is called the **tricuspid valve.** The apices of the flaps can meet together in the middle of the opening between the auricle and the ventricle and prevent blood passing from the ventricle to the auricle. The apices and margins of the flaps are connected by fibrous cords—**chordae tendineae**—with muscular projections on the inner surface of the ventricle. These cords allow the flaps to meet, but prevent them from being forced up into the auricle by the pressure of the blood in the ventricle.

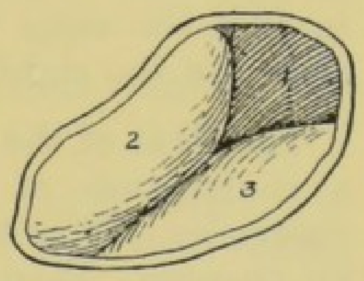


Fig. 25.—The Tricuspid Valve (closed), from above.
1, 2, 3, The Three Flaps of the Valve.

All the valves of the heart are formed of fibrous tissue and are covered by the endocardium, so that there is a layer of endocardium on both sides of the flap.

The right ventricle has much thicker walls than the auricle. Leading from it is a large blood-vessel called the **pulmonary artery,** because it carries blood to the lungs.

The opening from the right ventricle into the pulmonary artery is guarded by a valve to prevent blood flowing back into the ventricle after it has been forced into the artery. The valve consists of three semi-circular flaps which are called the **semi-lunar valves**. Each flap forms a kind of pocket with the wall of the artery, and allows blood to pass easily into the artery, but not back again.

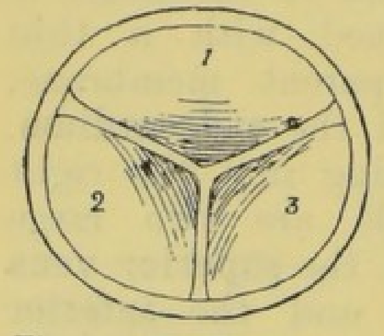


Fig. 26.—The Pulmonary Valve.
1, 2, 3, Flaps of the Valve.

The Left Auricle has thin walls. Opening into it are four **pulmonary** veins which bring blood from the lungs. Below it communicates with the left ventricle by the **mitral** or **bicuspid** valve. This valve prevents blood from passing from the ventricle into the auricle, but allows it to pass in the opposite direction. The structure of the valve is exactly similar to that of the tricuspid valve, except that it is composed of two flaps instead of three, and that the flaps are thicker and stronger.

The Left Ventricle is the thickest-walled cavity of the heart. It is longer and narrower than the right ventricle. The largest artery in the body—the **aorta**—goes from the left ventricle. Its opening is guarded by semi-lunar valves in just the same way as the opening of the pulmonary artery in the right ventricle.

The Beat of the Heart. A beat of the heart consists of a contraction of the walls of both auricles and both ventricles. This takes place about 75 times in a minute on an average First the two auricles contract at the same time, and this is immediately followed by a contraction of both ventricles. Then there is a pause during which the auricles and the ventricles are relaxed; then the auricles again contract, and immediately afterwards the ventricles contract, then follows a pause, and so on. In a new-born baby the heart beats one hundred and sixty times a minute, while in old people it only beats sixty times a minute or even less. Exercise increases the rapidity of the heart beat. It is generally quicker in women than in men.

The Blood-vessels.

The blood-vessels are branched tubes which convey the blood to and from the different parts of the body. There are three kinds—arteries, veins, and capillaries. An artery is a vessel that brings blood from the heart to any part of the body, and the vessel carrying the blood back again to the heart is called a vein. When an artery reaches the organ which it supplies it breaks up into smaller branches, and then each branch subdivides again and again until very small vessels are arrived at. These

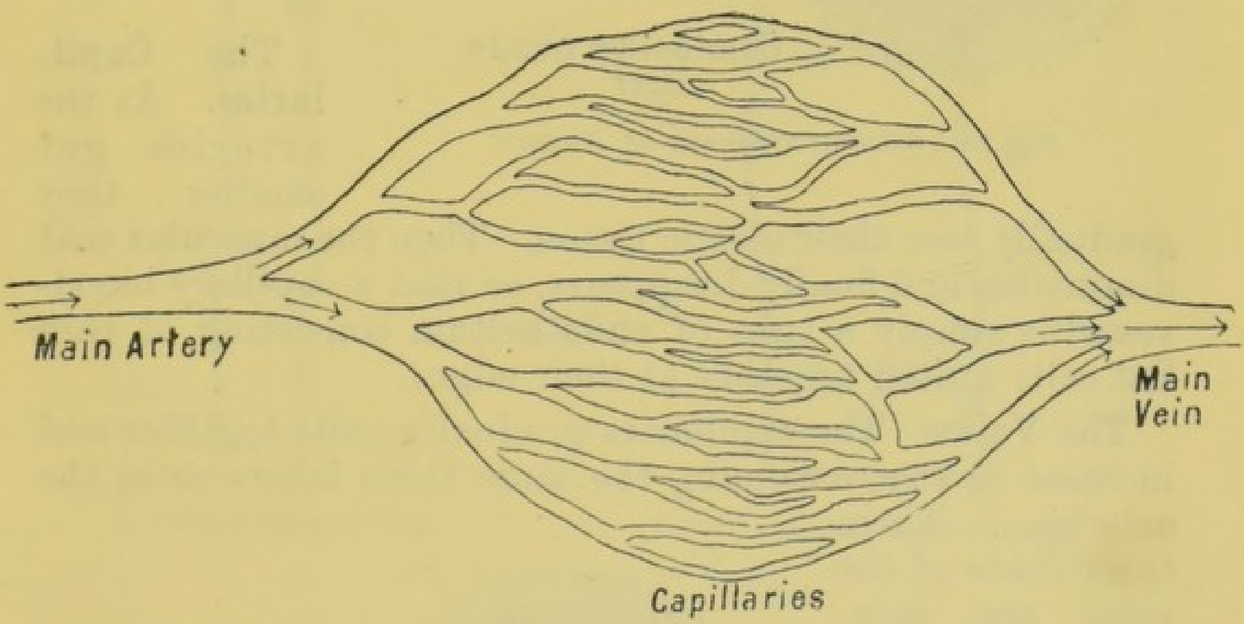


Fig. 27.—Diagrammatic Representation of Artery, Capillaries, and Vein.

are called capillaries because they are as fine as hairs. The capillaries eventually reunite and form the vein taking the blood back to the heart.

The Arteries are thick-walled vessels which do not collapse when empty. Their walls are strong and elastic, and consist of three layers—an inner, middle, and outer coat. The inner coat of an artery is a transparent colourless membrane called **endothelium**. This is continuous with the endocardium lining the heart. The middle coat is made up of layers of muscle and elastic tissue. In the large arteries this coat is chiefly elastic, and in the smaller ones it is mainly muscular. The outer coat is made of connective tissue. When an artery has an extra quantity of blood suddenly forced into it, its elastic coat enables it to dilate, and afterwards to recover its normal size. By means of its muscular coat the size of an artery can be regulated independently of the pressure of blood within it.

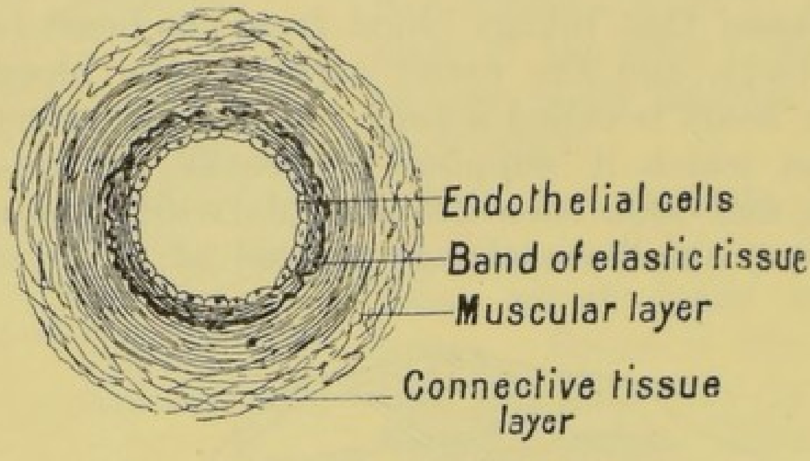


Fig. 28.—Section through an Artery.

The Capillaries. As the arteries get smaller they gradually lose their elastic tissue. Then the muscular coat diminishes and finally disappears, so that a capillary blood-vessel is simply a tube of **endothelium** consisting of thin flat cells united together at their edges.

The Veins. The capillaries gradually unite together and increase in size, assuming the same three layers as in the arteries. These three coats of the veins are, however, much thinner than the coats of the arteries and contain much less elastic and muscular tissue. A vein collapses when it is empty. Another difference between an artery and a vein is that many veins, especially those in the arms and legs, have valves which allow the blood to flow only towards the heart. These valves are semi-lunar folds of endothelium with a small amount of connective tissue.

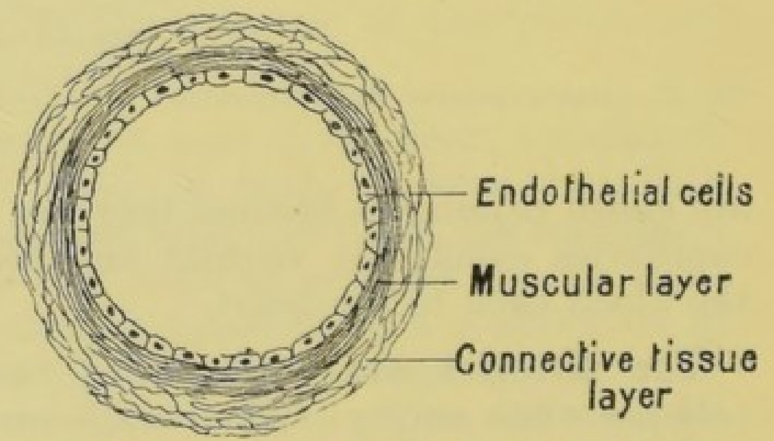
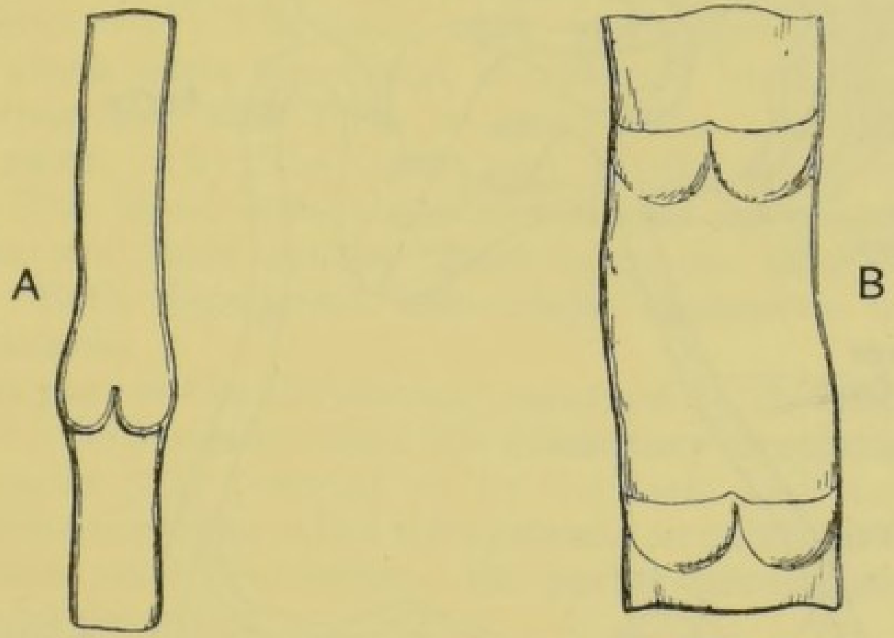


Fig. 29.—Section through a Vein.

Circulation of the Blood.

When describing the heart, mention was made of the fact that the blood-vessels opening into the ventricles are arteries, while those opening into auricles are veins. The forcing power producing the circulation of the blood is the heart, which by its contraction squeezes the blood into the



A, Section along a Vein. B, Vein opened longitudinally.

Fig. 30.—Valves in Veins.

arteries and receives a supply from the veins during its dilation.

When the auricles contract they close the openings of the veins, and force the blood into the ventricles through the mitral and the tricuspid valves. Then the ventricles contract. This closes the mitral and tricuspid valves and forces the blood into the arteries.

In any description of the circulation, it is best to begin with the blood that is contained in any one of the four chambers of the heart and to trace its journey over the body until it again reaches the chamber from which it started. We will begin with the blood in the right auricle.

When the right auricle contracts it forces the blood through the tricuspid valve into the right ventricle. Then the right ventricle contracts, closes the tricuspid valve by the blood pressure, and forces the blood into the **pulmonary**

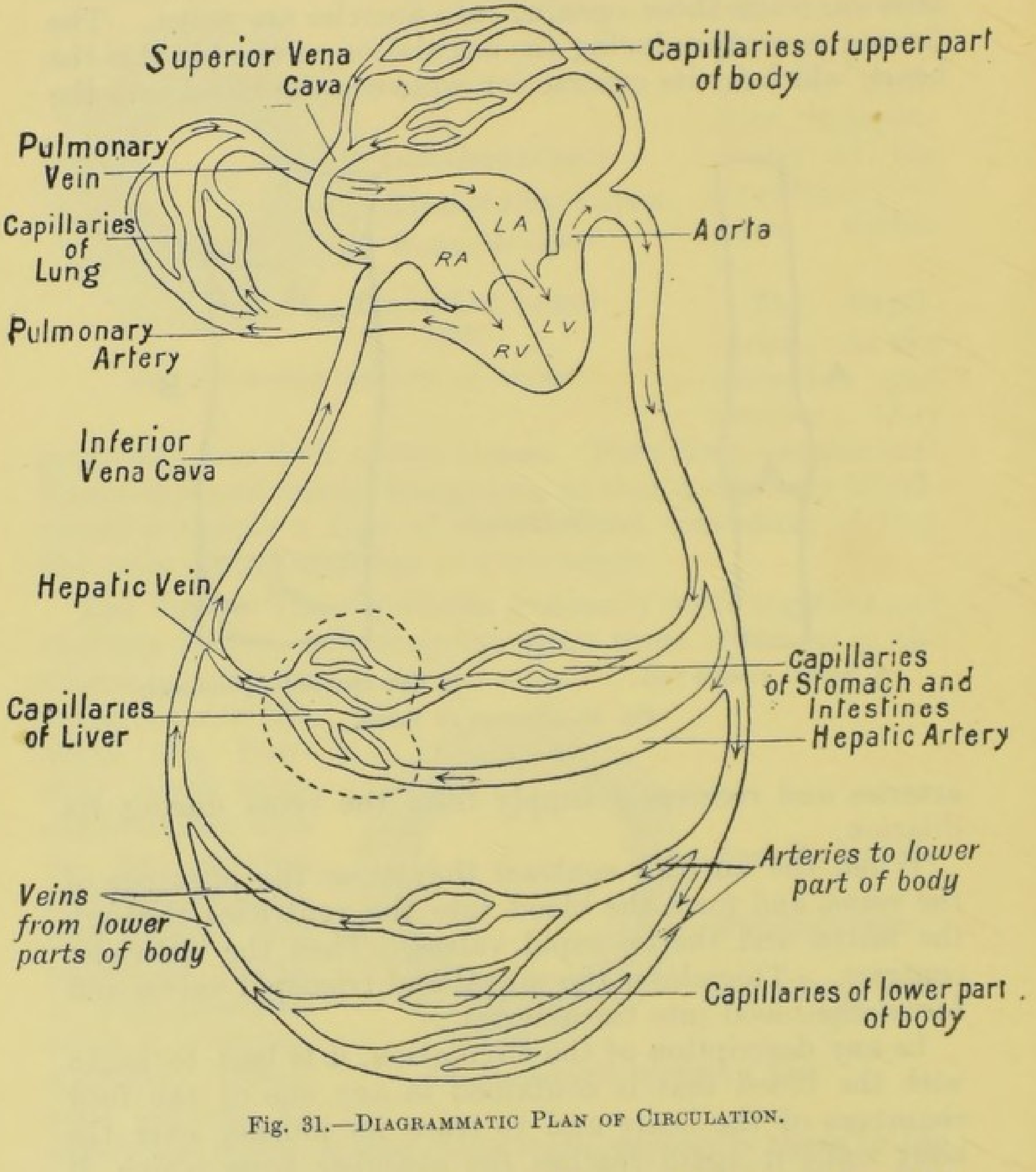


Fig. 31.—Diagrammatic Plan of Circulation.

artery through the semi-lunar valves. It passes along this artery and reaches the capillaries of the lungs, where it receives oxygen from the air in the lungs and gives up some of its impurities to the air. The **pulmonary veins** bring the blood back from the lungs to the **left auricle**, which, by its contraction, forces the blood into the **left ventricle** through the mitral valve.

By the contraction of the left ventricle the mitral valve is closed, and the blood is forced through the semi-lunar valves and along the great artery of the body—the **aorta**. This artery distributes the blood over the whole body except the lungs. Its distribution may be divided into two parts:—(1) The head, neck, and upper extremities, from which parts the blood is collected by veins which unite together and form a great vein—the **superior vena cava**. (2) The lower part of the body and the legs. The blood from these is collected by veins which coalesce and form another great vein—the **inferior vena cava**. Both these great veins empty themselves into the right auricle.

That part of the circulation concerned in the supply of blood to the lungs is called the **pulmonary circulation**, and the greater part (carried on by the aorta and the venae cavae) is sometimes called the **systemic circulation**. There is another small circulation—**the portal circulation**—that has to be described.

The aorta supplies blood to the stomach, intestines, spleen, and pancreas. This blood is collected by veins which unite together to form the **portal vein**. The portal vein goes to the liver and there breaks up into capillaries. An artery—the **hepatic artery**—also passes direct from the aorta to the liver and breaks up into capillaries there. The liver therefore has two blood supplies, one from the portal vein and one from the hepatic artery. The blood from the liver is collected by a single vein—the **hepatic vein**—which joins the inferior vena cava.

The cause of the circulation. The capillaries offer a very great resistance to the flow of blood through them because of their very small diameter. Now the arteries have a definite quantity of blood forced into them at each beat of the heart. They will obviously therefore become overfilled with blood. Their elastic coat enables them to distend in order to accommodate much more blood than would fill them in their ordinary condition. The elasticity of the walls tries always to decrease the diameter of the distended arteries, and so there is set up a pressure in the blood—**blood pressure**—that tends to force the blood out of the arteries, *i.e.* into the capillaries. When the contents of the ventricles are suddenly pushed into the artery an extra distention takes place in order to accommodate this extra amount of blood, and therefore the blood pressure will certainly increase in the arteries at each contraction of the ventricles. This causes the pulsation of the arteries, *i.e.* the **pulse**.

Between any contraction and the following one the pressure in the arteries decreases because the pressure in them is forcing blood into the capillaries, *i.e.* the arteries are emptying themselves. In this way the elasticity of the arterial walls acts as a reservoir of the heart's force, "just as the distended air-bag of a piper acts as a reservoir of his expiratory efforts." Its effect on the circulation is to convert the pulsating force of the heart into a continuous force, the energy of each heart-beat being mainly absorbed in keeping the arteries distended, by which means a constant flow is kept up in the interval between the beats. On this principle, fire-engines, garden watering-engines, etc., are made.

The blood-pressure steadily decreases in passing from the larger to the smaller arteries, because of the friction which opposes the flow in the small arteries and the capillaries. In overcoming this friction, the energy of the heart-beat is turned into heat, and thus the pressure produced by the heart is changed into heat in the small arteries. When the blood has been driven through the capillaries and has reached the veins the force is almost entirely expended, and so the blood-pressure in the veins is very small indeed.

Minor forces assisting the circulation of the blood are the respiratory movements of the chest, and the muscular movements of the body.

Practical Work.

I. Blood.

(*a*) Tie a string tightly round the last joint of the forefinger. The end of the finger becomes congested with blood. Hold a clean sharp needle for a second in a flame, and when cool prick the finger sharply just behind the finger nail. A drop of blood collects. Just touch the blood with the middle of a clean microscope slide, and quickly cover the blood on the slide with a cover slip. Examine the film thus produced under the microscope, and note the red and white corpuscles and the almost colourless plasma.

(*b*) In about ten minutes the formation of minute fibres of fibrin may be observed.

(*c*) Examine a film of frog's blood under the microscope and note the large egg-shaped red corpuscles with large nuclei.

(*d*) From a butcher obtain a jar filled with fresh blood and a jar filled with blood that has been whipped with some twigs immediately it has been collected from the animal.

The fresh blood quickly sets to a jelly or clot and the subsequent events should be observed and noted. When the clot is floating in a bath of exuded serum it should be cut open and the difference in colour between its inner and outer parts should be observed. Note the characters of the serum.

The whipped blood and the twigs used for the whipping should be examined. The blood is bright scarlet and remains fluid without any clotting. The twigs after washing under a tap will be found to be covered with a whitish fibrous material.

(*e*) Place a minute fragment of clot on a microscope slide, spread out, and examine. Note network of fibrin and the corpuscles. Make a film of serum and examine this also. Note absence of corpuscles.

(*f*) Pour some defibrinated blood into a test-tube—note that it is opaque to light. Add twice its bulk of water and hold up to the light again. It has now become transparent owing to the fact that the water has broken up the red corpuscles and dissolved the haemoglobin.

(*g*) Half fill a jar with strong solution of common salt and ask a butcher to collect blood into it. The salt will prevent the process of clotting and so the corpuscles sink slowly to the bottom of the jar. The clear liquid on top is a mixture of plasma and the salt water. If this is diluted with water and warmed it clots.

II. The Circulation.

(*a*) Stroke one arm downwards from the elbow. Notice the little swellings that stand out in the course of the veins. These show the situation of the valves which close up when the blood is forced in the wrong direction.

(*b*) Lightly tie a tape round the arm. Notice how the part below the ligature becomes swollen and blue. This is the result of the compression and closure of the veins, while the arteries, which lie deeper and have stronger walls, remain open. The result is that the blood continues to flow through the arteries, but cannot return because the veins are stopped.

Next hold the other hand above the head for a few minutes, and while in this position tightly ligature the arm. The part beyond the ligature remains pale and soon feels numb. The arteries are now compressed and no blood can flow.

(*c*) Note the "pulse" by pressing the first two fingers of the right hand on the lower end of the left radius. Count the number of beats per minute. Count again after active exercise.

(*d*) Wrap a piece of wet blotting-paper round the body of a tadpole, leaving the transparent tail exposed. Lay it on a microscope slide and examine the transparent tail under the microscope. The blood will be seen in the process of circulation through the capillaries. The tadpole is not injured in any way.

III. Directions for Dissecting a Sheep's Heart.

Obtain a sheep's heart with "the bag" (the pericardium) and as much of the vessels as possible still attached.

Open the pericardium, note its fluid, and its attachment to the heart and the roots of the great vessels. Then cut it away.

The Heart.—First decide which is the front of the heart and which the right and the left side. Note relative thicknesses in the walls of the right side and the left (felt by pinching the wall); also the thin walls of the auricles at the upper part. The flat ear-like flap on each side of the base of the heart, one lying on each auricle, is called the auricular appendix. Observe grooves showing line of separation between the two ventricles, and also the transverse groove between the auricles above and the ventricles below.

At the back of the heart, just above the transverse groove, will be found the openings of the superior and inferior venae cavae, both opening into the right auricle. Pass the finger through one of these openings (enlarged with the scissors if necessary) into the right auricle, and pass it downwards into the right ventricle through the tricuspid valve.

To the left of the opening of the inferior vena cava are the two pulmonary vein openings into the left auricle (sometimes there is only one to be found). Pass the finger into the left auricle and through the mitral valve into the left ventricle. Open both the auricles by two vertical slits, starting from the superior vena cava and the pulmonary vein. Note the appearance of the inside.

Pour water into each ventricle until quite full and then gently press the ventricular wall. On the left side you will see two flaps of membrane (the mitral valve) spring from the sides and meet in the middle of the entrance into the ventricle, completely shutting off the auricle from the ventricle. On the right side three flaps will be seen.

Cut open the left ventricle by an incision right round the apex, keeping just to the left of the inter-ventricular groove. Note thickness of the walls, appearance of the flaps of the mitral valve, chordae tendineae, etc. At the top of the ventricle is the opening of the aorta, the walls of which will be seen to be very thick. Pour water down the aorta towards the ventricle ; the three pockets of the aortic valve at once swell out and meet in the middle, completely blocking the way. Cut open the aorta and examine the valve.

Open the right ventricle by a similar incision, keeping to the right of the interventricular groove. Examine the tricuspid valve and the pulmonary valve, and follow the same directions as have been given for the left ventricle.

CHAPTER III.

AIR—RESPIRATION.

AIR.

THE relative importance of air to the body is easily understood when we consider that there are cases on record of human beings living for five or six weeks without food, whereas deprivation of air causes death in four or five minutes.

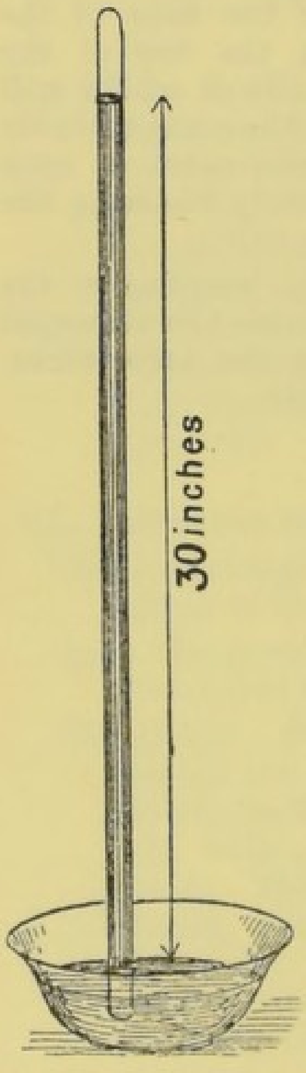


Fig. 32.—BAROMETER.

It may be easily proved (see experiments at the end of the chapter) that the air has weight. This being the case it at once follows that it must exert a pressure upon us, as we live at the bottom of a sea of air many miles deep.

The actual pressure of the atmosphere varies slightly, but it is usually about 15 lb. per square inch, or about 14 or 15 tons on the body of the average adult. The pressure is equal in all directions and evenly distributed, the air in the lungs pressing outwards with almost the same force as the outside air is pressing inwards, and so, under ordinary circumstances, we are not aware of its existence.

The atmospheric pressure is measured by the **barometer**. This is a tube about a yard long and closed at one end. It is first filled with mercury, and then the thumb being placed over the open end, the tube is inverted in a vessel containing mercury. The mercury in the tube does not sink to the level of the mercury in the vessel, but remains about 30 inches higher, being kept up by the pressure of the air on the surface of the mercury in the vessel. The pressure of the air will obviously be less on the top of a hill than at a lower level, and so the level of the mercury in the barometer gets lower the higher we climb. Also, cold air is heavier than warm air, and dry air is heavier than moist air. The barometer will therefore stand higher on a dry cold day than when it is moist and warm.

Composition of Air.

The average composition of the atmosphere may be taken as

Nitrogen	79
Oxygen	20·96
Carbon Dioxide	·04
	100·00

There are also variable quantities of :—Water vapour, ozone, ammonia, acid gases, excess of carbon dioxide, and suspended impurities.

Nitrogen is a clear colourless gas without any taste or smell. It is very inert, being incapable of supporting combustion or respiration, and it is incombustible. Its use in the air is to modify the activity of the oxygen. One out of the 79 per cent. that we put down for nitrogen really consists of a gas called **Argon**. This, as far as we know, is of no hygienic importance, as it behaves in the same way as nitrogen.

Oxygen is the most important constituent of the air. It is a clear colourless gas without any taste or smell, and its presence is essential for all cases of combustion and respiration. Any substance that will burn in air burns with increased brilliance when dipped into a jar filled with oxygen. When a candle is lighted and placed in a limited volume of air, it can only burn as long as there is oxygen around it. But when a candle (or any combustible substance) burns in air it gradually combines with the oxygen, and so the amount of oxygen in the air round the candle will get less and less, until at last there is too little oxygen present to support the combustion of the candle, and the candle goes out. In exactly the same way an animal uses up the oxygen and, unless fresh air is supplied, will die.

Carbon Dioxide (carbonic acid gas) exists in pure air to the extent of four volumes in 10,000 of air. Sometimes as little as three volumes per 10,000 is found. It is a clear colourless gas with a very faint pleasant taste and smell. It is very heavy, being about one and a half times as heavy as air. The property by means of which this gas is recognised is its action on lime water, which it turns milky. Carbon dioxide is incombustible and will not support combustion or respiration.

Carbon dioxide is poured into the air in enormous quantities, being produced by the following processes:—

(*a*) By all ordinary cases of combustion, *i.e.* by the burning of coal gas, candles, fires, etc.

(*b*) By the breathing of animals. All animals absorb oxygen from the air and give out carbon dioxide in their breath. Plants also behave in the same way, but only on a small scale.

(*c*) During the numerous cases of fermentation and decay that are continually going on.

As the supply is so abundant it would seem reasonable to expect that the amount of carbon dioxide in the air would rapidly increase. It is found, however, that the amount in pure air remains stationary. This is owing to the action of the plants upon the carbon dioxide. When the sun is shining, their green parts are capable of absorbing carbon dioxide from the air. They keep the carbon for growing purposes, *i.e.* to make wood, and give back oxygen to the air. Obviously, therefore, the chief effect of plants upon air is exactly the opposite to that of animals, and tends to decrease the amount of carbon dioxide in the air. As a matter of fact, plants are continually taking in small amounts of oxygen and giving out carbon dioxide, just like animals, but during the day this action is masked by the opposite one. During the night, however, plants act in a very small way like animals and give off carbon dioxide. For this reason some people urge that it must be injurious to have plants in a bedroom. If the bedroom is well ventilated there cannot possibly be any ill effects.

In large towns and in inhabited rooms the amount of carbon dioxide in the air is often above ·04 per cent. Any excess over this is considered to be an impurity. Thus if a sample of air were found to contain ·07 per cent. of carbon dioxide we should say that this air contained an impurity of ·03 per cent. carbon dioxide. An impurity of ·02 per cent. is found to produce no ill effects, but air containing any more carbon dioxide than this is injurious. This amount is, therefore, called the "maximum permissible impurity," and the maximum total percentage of carbon dioxide that may be allowed in air is ·06 per cent.

Carbon dioxide is also present in **ground air** in large quantities. By ground air is meant the air occupying the interstices of the soil above the level of the ground water. Since this air is impure it is obviously unhealthy to live in underground rooms.

The air in wells consists mainly of ground air and is often very impure. A common method of testing this air, before sending down workmen, is to lower a lighted candle down the well. If the candle goes out the air is too impure to breathe, and means must be taken to purify it.

Ozone is a gas that is found in very small quantities in the air of country places and at the seaside. It is a condensed form of oxygen, and is very active, attacking decomposing matter and rendering it harmless.

Water Vapour is always present in the air, but the quantity is very variable. It is produced in many ways:—(*a*) by evaporation from the surface of water; (*b*) by the respiration of animals; (*c*) by many cases of combustion, *e.g.* of coal gas, candles, etc.

The warmer the air the greater the amount of water vapour that it can take up. When the air at any given temperature contains as much water vapour as it can hold it is said to be **saturated**, and when it is capable of holding more it is **unsaturated**. Obviously, if the temperature of a certain quantity of saturated air is raised it ceases to be saturated and becomes unsaturated, because it is now capable of taking up more water vapour. On the other hand, if the temperature of a given volume of saturated air is lowered it becomes incapable of holding so much water, and so some of it appears in the form of rain, mist, or dew. This is easily illustrated by placing a flask filled with cold water in a hot room. It soon becomes covered with a deposit of dew.

When the air is close to its saturation point it is said to be moist, and when it is far from saturated it is called dry air. As a rule the atmosphere contains from 1 to $1\frac{1}{2}$ per cent. of water vapour.

Suspended Impurities. The presence of these impurities in air is shown when a ray of sunshine enters a darkened room. The tiny solid particles are of the most varied composition, some of the commonest being common salt, sand, coal dust, minute seeds of plants, particles of wood, straw, cotton, etc., also scales of skin, hair, and germs of disease, especially the germs of tuberculosis (consumption), smallpox, and scarlet fever, as well as an enormous number of practically harmless organisms. Suspended impurities are also produced by various trades. These irritate the lungs, and often set up disease. For this reason lung troubles are especially common among tin miners, needle-makers, cutlers, cement workers, etc. In white-lead works the dust gives rise to lead colic and lead poisoning.

Special Local Gaseous Impurities.

Carbonic Oxide, or carbon monoxide. This gas is given off from imperfectly burning charcoal stoves, and in other cases of partial combustion. For this reason such stoves should never be used without proper flues. Carbon monoxide is extremely poisonous, and fatal consequences have followed when the air contained only $\frac{1}{2}$ per cent. of the gas. The symptoms are dizziness, headache, and a sense of oppression and constriction. "Water gas," which is now extensively added to coal gas, contains carbon monoxide. An escape of coal gas into a room is a common cause of death by carbon monoxide poisoning.

Coal Gas is a mixture of gases obtained by the distillation of coal. It should never be present in the air, as it is very dangerous for two reasons:—

(*a*) When mixed with air it is explosive and will explode violently when a light is applied. Coal gas not mixed with air is not explosive in any way.

(*b*) It contains poisonous gases, especially carbon monoxide. Even in very small quantities it produces headache and sore throat. In larger quantities it produces a sense of suffocation, and many people have been poisoned by it in their sleep.

The commonest cause of an escape of coal gas is neglect to turn off the gas completely. Sometimes it may get turned on by accident, while other causes are leaky pipes and the evaporation of the water from chandeliers, or coal gas may enter a house from an escape into the soil below. When an escape of coal gas is noticed, it is, of course, the height of folly to light a candle or match, and yet nearly all the fatal explosions have been caused by people going with a light to find where the gas is escaping. The proper course under these circumstances is to—

(*a*) Put out all the lights in the house.
(*b*) Turn off the gas at the meter.
(*c*) Open the windows to get rid of the poisonous and explosive gas.

The products of the combustion of coal gas are chiefly carbon dioxide and water vapour. One cubic foot of coal gas when burned produces about one cubic foot of carbon dioxide and one cubic foot of water vapour, and removes from the air about two cubic feet of oxygen. Now the average gas burner consumes about 4 cubic feet of gas per hour and, therefore, will produce 4 cubic feet of carbon dioxide, which is more than six times the amount that an ordinary adult would give off in his breath in the same time. Oxides of sulphur are also produced in small quantities when coal gas is burned. For this reason plants do not flourish as a rule in rooms lighted by coal gas. The paint of pictures and other materials are also injuriously affected.

Sewer Gas occasionally finds its way into the air in houses owing to a defective condition of the traps to the drains, or by unsanitary arrangements connected with the water-closet and its cistern. It may cause vomiting, diarrhœa, and colic. Sore throat and probably diphtheria are other results, while erysipelas and puerperal fever have often been traced to this pollution.

Vapours from injurious trades. The most important is the impurity arising from phosphorus in match-making. The fumes of the phosphorus give rise to a serious disease of the jaw (phossy jaw). In artificial-flower-making injurious effects are often produced by the arsenical vapours. Workers in copper and brass foundries are often affected by the fumes.

The Respiratory System.

On its way to the lungs the air passes through (*a*) the mouth or nose, (*b*) the pharynx, (*c*) the larynx, (*d*) the trachea, (*e*) the bronchi and their branches.

The **pharynx** is a wide funnel-shaped cavity, four inches long, at the back of the nose and mouth. It divides below into two tubes, one behind the other. The posterior tube is usually collapsed, as it has only soft flabby walls: this is the oesophagus, or the tube to convey the food from the pharynx to the stomach. The front tube has hard cartilaginous walls and so is always kept open: this is the beginning of the windpipe and is called the **larynx** or voice-box. It is continued below as the **trachea**. Within the larynx are the vocal cords. The air passes through a narrow chink between them and can set them in motion like the reed in a whistle. This chink is the glottis.

The trachea is a round open tube, about $4\frac{1}{2}$ inches long, and 1 inch wide. It is kept open by C-shaped rings of cartilage—the open part of the C being directed backwards so as to present a continuous cartilaginous ring in front. There are from 16 to 20 of these rings.

It is lined inside with columnar epithelium, on the surface of which are numerous hair-like processes called cilia. These, during life, are constantly in motion and tend to drive any fluid that is on them outwards towards the

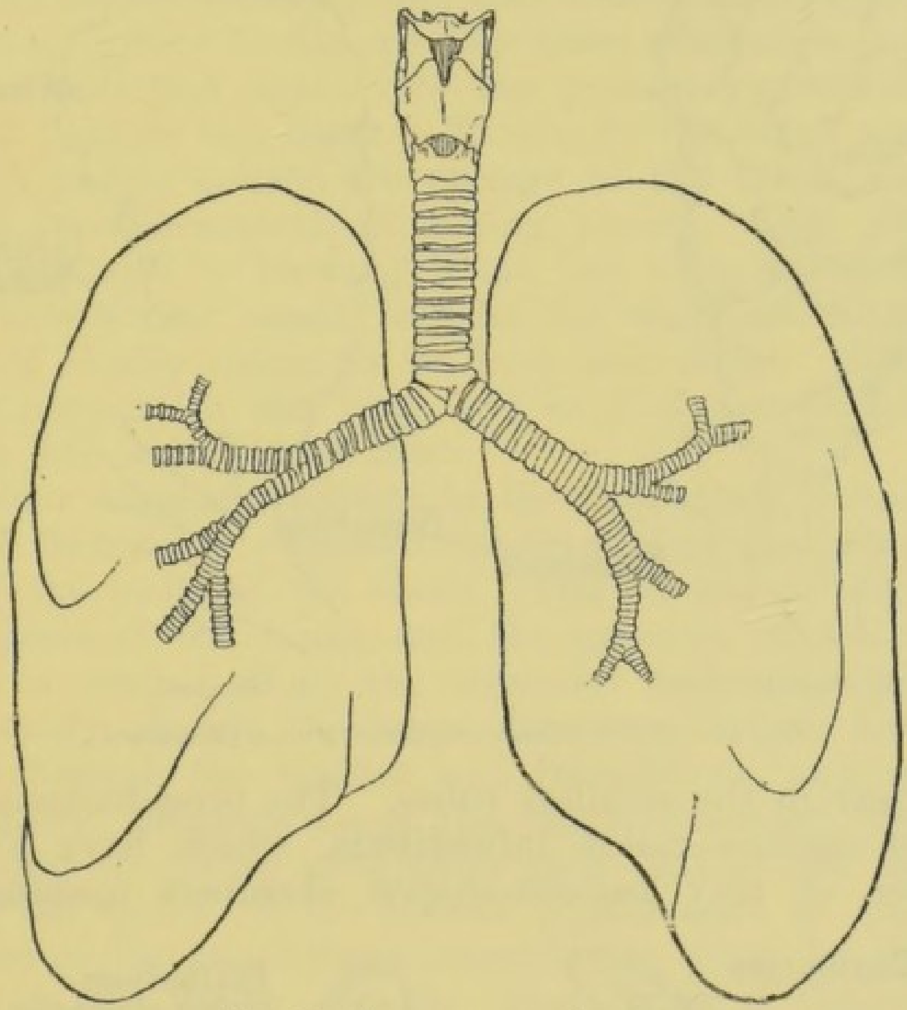
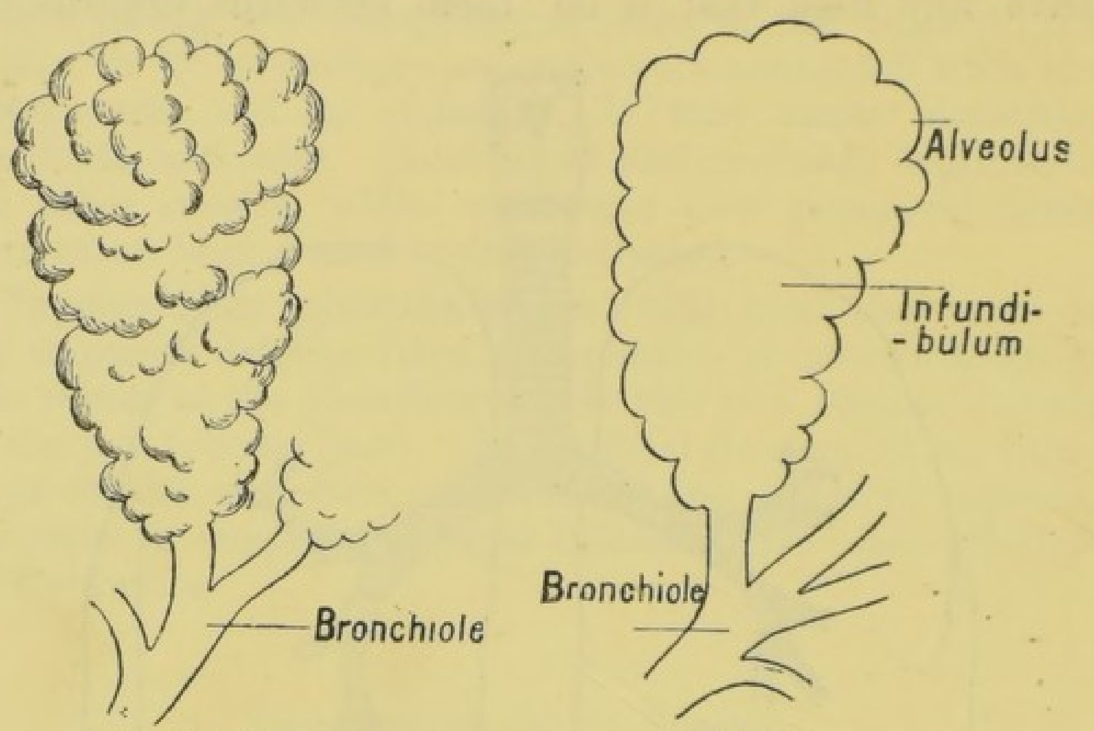


Fig. 33.--Trachea and Bronchi.

mouth. These cilia also line the larynx and all the branches of the trachea. The middle coat of the trachea consists of muscle, cartilage, and fibrous tissue. The external coat consists of connective tissue containing a little fat. Close to the lungs the trachea divides into two tubes called the **bronchi**, the right bronchus going to the right lung and the left bronchus to the left lung. These bronchi again divide and subdivide until finally the branches are so small that they can only be distinguished by the microscope. The smallest tubes are called **bronchioles** or bronchial tubes.

The branches of the trachea have a similar structure to the trachea itself, but the bands of cartilage become less and less complete as the branches get smaller, until they are merely scattered pieces of cartilage; they altogether



A, Outside View. B, Section.

Fig. 34.—Termimation of Bronchiole (Magnified).

disappear in the smallest tubes. The bronchioles end in dilated cavities called **infundibula**, which have a large number of tiny balloon-shaped chambers opening into

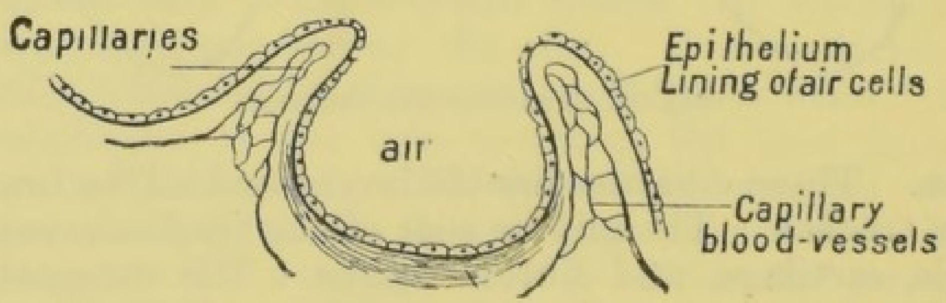


Fig. 35.—Section of Alveolus (Diagrammatic).
(Very highly magnified.)

them. Each of these chambers is called an **alveolus** (see Figs. 34, 35).

The lungs are therefore made up of an enormous number of infundibula or dilated ends of the bronchioles. These are connected together by fine connective tissue and the whole is covered by a transparent elastic membrane, the pleura. The alveoli are lined internally by a layer of flattened cells joined edge to edge. Beneath this is a layer of elastic tissue, and a close network of capillary blood-vessels. The blood in the capillaries is only separated from the air in the alveolus by a very thin delicate partition. The pulmonary artery breaks up into these capillaries and the blood is collected again into the pulmonary vein, which takes it back to the heart. Externally the lungs are of a mottled purple colour, are spongy to the touch, and are covered by the smooth glistening pleura. They may be easily expanded by blowing in air, but when left to themselves they shrink again because the walls are composed partly of elastic tissue, as we have said above. Some air always remains in the lung, and so if a piece of lung is thrown into water it will float.

In their natural condition in the thorax, the outer surface of each lung is pressed closely against the inner surface of the walls of the chest. The air has no access to the outside of the lungs, and the pressure of the atmosphere is warded off by the muscular and bony walls of the thorax. Inside the lungs, however, the air has free access through the trachea and bronchioles, and so the atmospheric pressure keeps the lungs distended, causing each lung to fill up completely each half of the thorax. When the cavity of the thorax is increased in size the pressure of the atmosphere expands the lungs by forcing more air into them. On the other hand, if the size of the thorax is decreased some of the air is forced out. It is important to understand and to remember that the atmospheric pressure can only expand the lungs when, by some means or other, the cavity of the thorax is increased in size.

Respiration.

Respiration consists of two acts—(*a*) **inspiration** or the drawing of air into the lungs, and (*b*) **expiration** or the act of forcing air out of the lungs. Respiration is effected by the alternate enlargement and contraction of the thorax, and the double act takes place in the ordinary adult about 16 to 20 times per minute.

Inspiration is effected chiefly by (*a*) the contraction and descent of the diaphragm, and (*b*) the contraction of the intercostal and other muscles, causing the ribs and sternum to be elevated.

Reference to the figure of the diaphragm will cause the

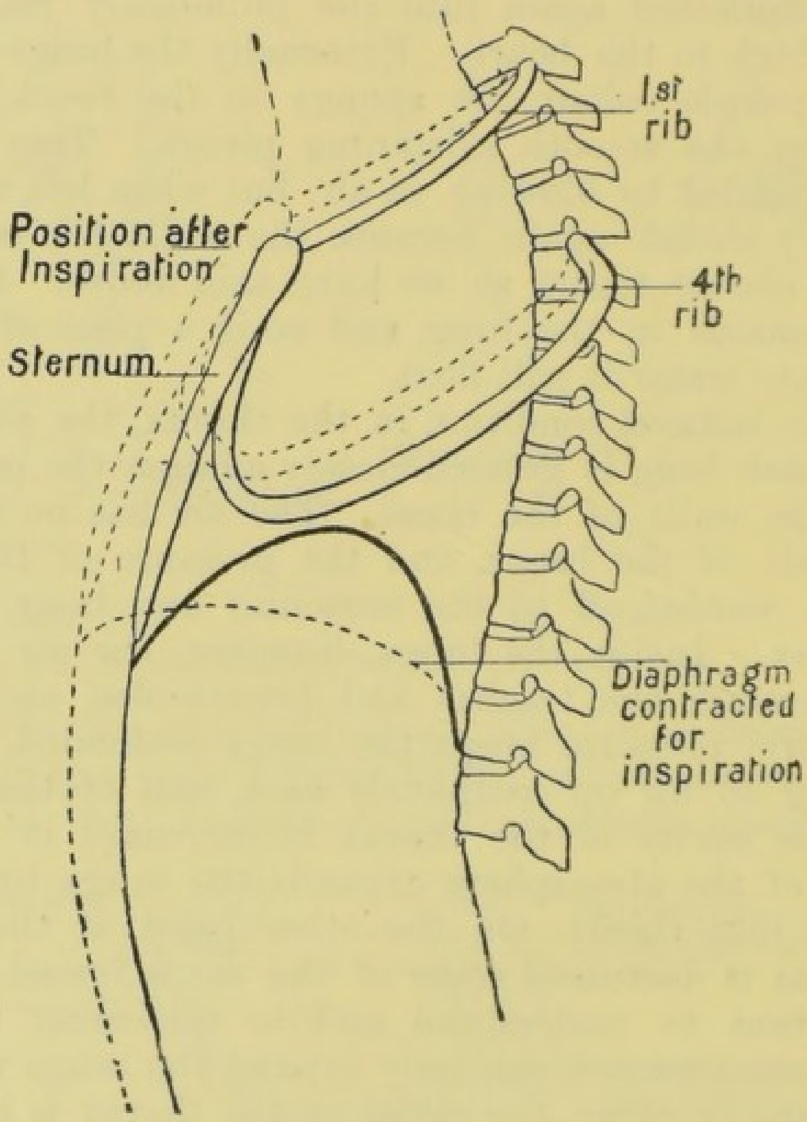


Fig. 36.—Movement of Ribs, Sternum, and Diaphragm.

The dotted lines show the position occupied by the Sternum, Ribs, Diaphragm, and Abdominal Walls at the end of a full inspiration.

first to be easily understood. If the diaphragm contracts it will become straighter, and so enlarge the cavity of the thorax. This, as explained above, will cause air to rush into the lungs. The other method of increasing the size of the thorax is by elevating the ribs and pushing out the sternum. Each rib describes a greater arch than the one above, and evidently, therefore, if each is suddenly raised into the position previously occupied by the one above, the size of the thorax will be increased.

In men the diaphragm is the more important factor in causing inspiration, while in women the movement of the ribs and sternum is more conspicuous.

Expiration is effected mainly by the natural elasticity of the lungs and the weight of the ribs. The elasticity of the lung tissue tends to force out the air, while the weight of the ribs causes them to fall, and so reduce the size of the chest. In forced expiration, as in coughing or sneezing, the abdominal muscles are used in order to press up the diaphragm, thereby decreasing the capacity of the thorax and forcing out the air.

Quantity of Air. At each inspiration an adult takes in about 30 cubic inches of air, and breathes out the same quantity during the succeeding expiration. This is called the **tidal** air. At the end of ordinary expiration an extra 100 cubic inches can be driven out by forced expiration, and this is called the **supplemental** air. Similarly the extra 100 cubic inches that may be forced into the chest at the end of ordinary inspiration is called the **complemental** air. The air left in the lungs at the end of forced expiration is called **residual** air, and measures another 100 cubic inches. Obviously, therefore, at the end of ordinary expiration there are about 200 cubic inches of air in the lungs, and this air, which is called the **stationary** air, is only renewed by being mixed with the tidal air in the bronchial tubes. This mixing of the stationary air with the tidal air prevents too sudden changes of temperature in the lungs.

Changes in the Air. The composition of the air going into the lungs is, as we have seen—

Nitrogen	79	per cent.
Oxygen	20·96	,,
Carbon dioxide	·04	,,

together with a variable quantity of water vapour.

Expired air consists of—

Nitrogen	79	per cent.
Oxygen	15·96	,,
Carbon dioxide	4·04	,,

Expired air is always saturated with water vapour, and also contains small quantities of other gases and organic impurities. Expired air therefore differs from inspired air:

(*a*) It contains more carbon dioxide.

(*b*) It also contains more water vapour.

(*c*) The oxygen is decreased.

(*d*) The temperature is raised to about 96° Fahr.

(*e*) It contains organic impurities. These are the most injurious of the impurities produced by respiration.

Changes in the Blood. The blood that reaches the capillaries of the lung is impure, containing an excess of carbon dioxide and a deficiency of oxygen. It is purple in colour, and is derived from the veins of all parts of the body. When passing through the lung capillaries the blood is only separated from the air in the lungs by a very thin membrane. Oxygen and carbon dioxide can pass readily through this membrane, and, as the result of this, the blood going away from the lungs is "arterial" in character, has a bright red colour, and contains about twice as much oxygen as, but less carbon dioxide than, the blood coming to the lungs.

One hundred volumes of venous blood (*i.e.* blood coming to the lungs) contain

10 volumes of oxygen,
46 ,, ,, carbon dioxide;

while 100 volumes of arterial blood (*i.e.* blood going away from the lungs) contain

20 volumes of oxygen,
39 ,, ,, carbon dioxide.

This extra oxygen is carried to the heart along the pulmonary vein, and from the heart all over the body by the arteries, and is used up in oxidising the waste matters of the body, thereby producing heat. Part of it returns to the lungs in the form of carbon dioxide and water, and is expired.

Loss from the Lungs. An adult breathes out about ·6 cubic feet of carbon dioxide per hour. This in twenty-four hours amounts to about 14½ cubic feet. The oxygen in this is derived from the air, but the carbon is derived from the tissues of the body. There are about eight ounces of carbon in this volume of carbon dioxide. The above amount of carbon dioxide is given off when the body is at rest. During work this quantity is greatly increased, being ·9 cubic feet per hour during light work, and 1·9 cubic feet during hard work.

The water lost from the lungs as water vapour during the twenty-four hours may be taken as half a pint.

Suppose, for instance, a concert room contains about 2,000 people and that the concert lasts for two hours. During this time there would be poured into the air in the breath of the people about 11 gallons of water and as much carbon as there is in a hundredweight of coal!

Practical Work.

I. The Atmosphere and Combustion.

(*a*) *The Weight of Air.* Take a round-bottomed glass flask fitted with a bung through which a short glass tube passes. At the end of the glass tube is fastened a short piece of india-

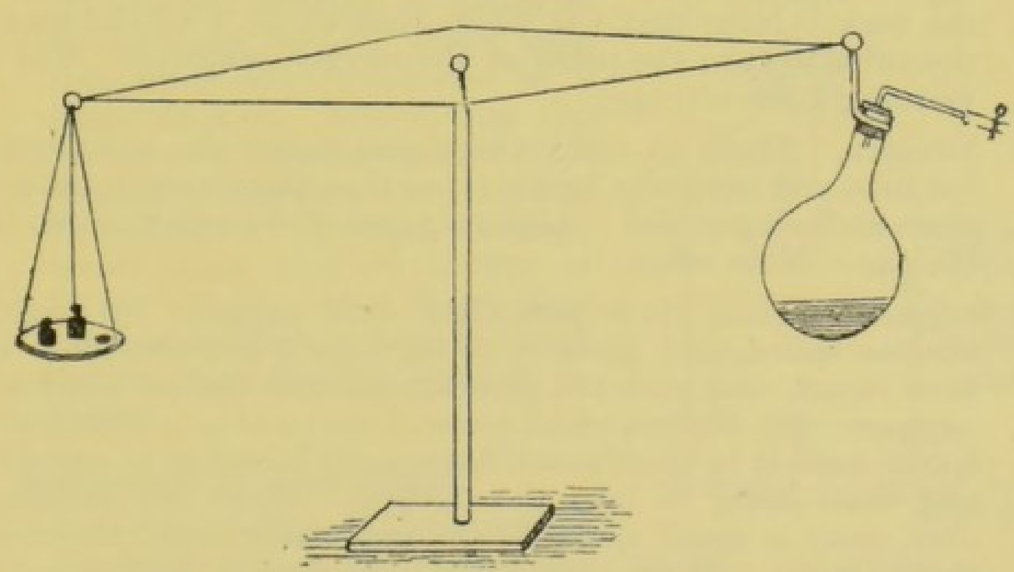


Fig. 37.—Apparatus for proving that Air has Weight.

rubber tubing. Place a small quantity of water in the flask, boil the water over a Bunsen burner, take away the burner and quickly place a clip on the rubber tubing. Next carefully balance the flask as in Fig. 37. The steam produced when the water was boiling has driven the air out of the flask and has taken its place. As the flask cools, however, this steam condenses and produces a partial vacuum in the flask. On opening the clip therefore, the air rushes in and increases the weight of the flask.

(*b*) *The Pressure of Air.* The great pressure of the air is simply illustrated by the following experiments. A flimsy tin vessel is taken, and a small quantity of water poured into it. This is boiled for a few minutes over a Bunsen flame and then a cork is quickly inserted into the vessel. If cold water is now poured over the vessel it collapses owing to the pressure of the air on the outside. The atmospheric pressure is measured by the **barometer**. The student should make the simple barometer described on page 40.

(*c*) *The Composition of Air.* The relative proportions of nitrogen and oxygen in air are roughly estimated as follows :—Take a glass tube about one inch wide and eighteen inches long, closed at one end and provided with a well-fitting cork for the open end. Put into the tube a piece of phosphorus about as large as a pea, press in the cork, and gently warm the tube near the phosphorus. Great care should be taken when using phosphorus, and it must always be cut under water. The phosphorus takes fire and melts. Turn the tube so as to cause the melted phosphorus to run along the sides of the tube. The phosphorus, in burning, combines with and removes all the oxygen from the air. When all signs of burning are over, hold the corked end under water and remove the cork. Note that the water rises about $\frac{1}{5}$ of the way up the tube to take the place of the oxygen removed. The remaining $\frac{4}{5}$ are nitrogen.

(*d*) *Nitrogen.* Place an indiarubber pad under the open end of the tube and carefully invert it, so that the nitrogen takes its place at the open end. Light a taper and push it down into the gas. Note effect.

(*e*) *Oxygen.* Obtain three jars filled with oxygen. (i) Light a wooden splint, and allow it to burn for a few seconds ; then blow it out, and push the glowing end into the jar filled with oxygen. (ii) Place a small piece of charcoal in a deflagrating spoon, hold it in the Bunsen flame until it begins to smoulder, and then lower it into the oxygen. When all burning is over, pour a small quantity of lime-water into the jar and shake it up. Note that the lime-water is turned milky, showing that the gas formed by burning charcoal is carbon dioxide. (iii) Lower a lighted candle into the third jar. When the burning is over, remove the candle, and with lime-water test the gas formed.

(*f*) *Combustion of Candle.* Hold a cold dry tumbler over a burning candle. Notice that a mist forms on the inside of the tumbler and that after a short time this resolves itself into small drops of water which run down the sides of the glass.

(*g*) *Combustion of Coal Gas.* Hold a flask filled with cold water over a Bunsen flame. Note the mist formed on the glass and, subsequently, the formation of drops of water.

(*h*) *Combustion of Oil.* Hold a gas jar over a small oil lamp flame for a few moments. Close the jar by a plate and allow to cool. Pour into the jar a little lime-water and shake up after replacing the plate. The lime-water is turned milky, showing that carbon dioxide has been produced by the combustion of the oil.

(*i*) *Combustion.* Repeat the above experiment, using a small gas flame instead of the oil lamp. The same result is obtained, showing that carbon dioxide is also produced by the combustion of coal gas. Similar results may be obtained with a candle flame.

II. The Respiratory Organs.

Examine the lungs and wind-pipe of a sheep, and identify epiglottis, larynx, glottis, trachea, and bronchi, following one of the latter to its small sub-divisions.

Pass a tube down the other bronchus and inflate the lung like a balloon, noticing the elasticity of the wall.

III. The Breath.

(*a*) To prove the presence of moisture, breathe upon a cold surface such as a piece of glass or slate.

(*b*) Carbon dioxide is detected by blowing down a glass tube into lime-water contained in a small beaker. Notice that the lime-water becomes turbid. (*c*) Organic impurities are proved to be present by blowing through water made pink by a drop of Condy's fluid. In a short time the bright pink colour becomes duller, and finally changes to brown.

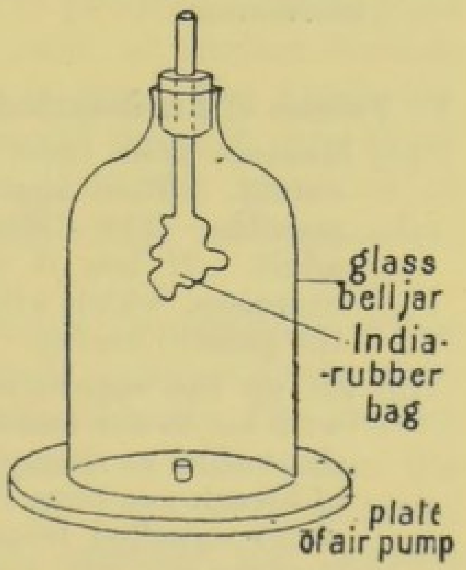


Fig. 38.—Apparatus for Illustrating Mechanism of Respiration.

IV. Mechanism of Respiration.

The bell jar in Fig. 38 is placed on the plate of an air pump and the air is extracted. The tube at the top has attached to it the half-filled indiarubber bag which represents the lungs. When the air is extracted the effect is the same as is produced in the chest by depressing the diaphragm and raising the ribs, *i.e.* the pressure inside the bag (or lungs) becomes greater than the pressure outside, and the bag expands.

Another method of illustration is obtained by using the apparatus shown in Fig. 39, which is similar to that used in Fig. 38 except that the bottom of the jar is formed by a sheet of indiarubber, which represents the diaphragm. When the sheet is pulled downwards the capacity of the jar is increased and the rubber bag is expanded by the air rushing in through the tube at the top.

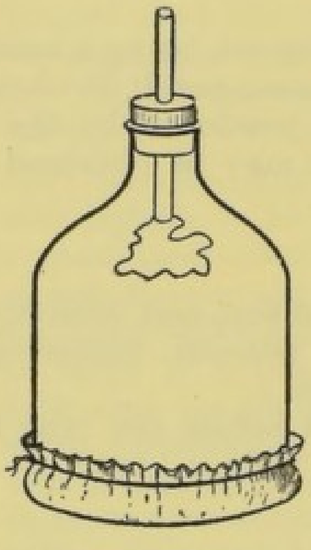


Fig. 39.—Apparatus for illustrating the Mechanism of Respiration.

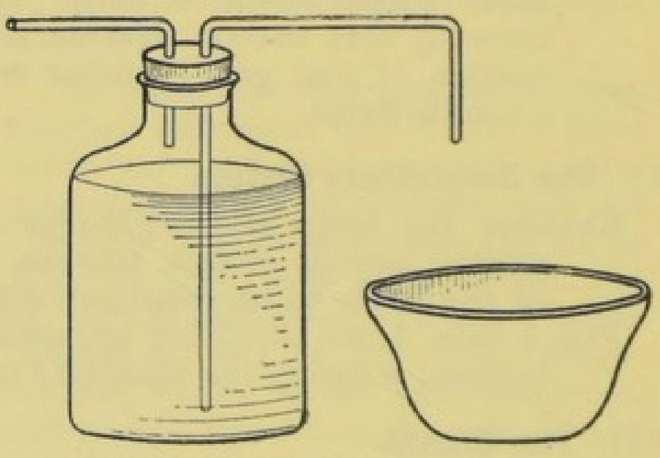


Fig. 40.—Apparatus to measure volume of Air Breathed.

V. **Volume of Air Breathed.**

(*a*) Measure your chest when it is expanded to its maximum extent. Then again when it is emptied of air as far as possible. The difference should be about 3 inches in an adult. If less it can be increased by careful breathing exercises, which will probably have an astonishing effect on the general health.

(*b*) Fit up the apparatus shown in Fig. 40. Fill up your chest with air to the maximum extent and then blow through the short tube as strongly and as long as you can. The amount of breath you blow into the jar is measured by the volume of water expelled from the jar. By pouring this water into a measure you will know its volume. This volume, representing the amount of air that can be breathed out after the deepest possible inspiration, is called the **vital capacity.** It is usually about 230 cubic inches.

CHAPTER IV.

VENTILATION.

VENTILATION may be defined as the dilution or removal of the products of respiration and combustion in dwellings by supplying fresh air. We have seen that the injurious products of respiration are carbon dioxide and organic impurities, while the injurious product of combustion is chiefly carbon dioxide. There are evidently, therefore, two sources of carbon dioxide in a room: (1) the breath of the occupants, and (2) lamps, candles, gases, etc. The first of these two sources is by far the more injurious because, as we have said, the carbon dioxide in this case is always accompanied by organic impurities which are more injurious than the carbon dioxide itself. It is owing to the presence of these organic impurities that such a small percentage of carbon dioxide seems to produce such a great effect. A room containing ·06 per cent. of carbon dioxide smells close to a person entering it from the fresh air, while a percentage of ·1 per cent. would make it very close. It must be remembered, however, that the presence or absence of currents of air in a room affect very considerably the sensations produced.

The organic impurity is very difficult to estimate, while the estimation of the carbon dioxide is comparatively easy. For this reason it is usual to estimate only the carbon dioxide in a given sample of air, and to infer from the amount of this gas the quantity of organic impurities present. This is generally reliable, because the organic matter is an invariable accompaniment of the carbon dioxide produced by respiration, and so the quantity of carbon dioxide in the air of a room may be taken as a fair index of its purity.

Effects of bad ventilation. (1) Living in a badly ventilated room for a few hours produces drowsiness and headache, but these ill effects soon wear off on regaining the fresh air.

(2) If this exposure to foul air is prolonged from day to day, *i.e.* if the individual lives in badly ventilated rooms, the general health becomes impaired, and the tendency to take cold is increased. Consumption very often occurs under such circumstances, and infectious diseases, when once started, spread very rapidly. A striking illustration of the relationship between foul air and consumption is given by the following statistics contained in the report of the Army Sanitary Commission. The Foot Guards had been allowed 331 cubic feet of space per man in their barracks, and the death rate from consumption among them amounted to 13·8 per 1,000; while the Horse Guards, with a cubic space of 572 feet per man, showed a mortality of only 7·3 per 1,000. On increasing the cubic space per man there was a very marked diminution of the mortality from all causes.

(3) In extreme cases, when the products of respiration are breathed in a concentrated condition, rapid poisoning results. This is well illustrated by the incident of the Black Hole of Calcutta, where 146 persons were imprisoned in a room about 18 feet square and with only two small windows. In the morning there were 123 dead, and, of the 23 who were living, several afterwards died of putrid fever—the effects of the organic poison they had inhaled.

Agents purifying the air. (1) The rain as it falls washes the air free from most of the suspended impurities. It also removes much of the organic impurities that may be present, as well as any acid gases such as oxides of sulphur, oxides of nitrogen, etc.

(2) The wind tends to produce a uniformity of composition and aid the removal of the impurities by distributing them. Diffusion also produces a similar result.

(3) The plants, as we have already explained, remove the carbon dioxide from the air during the day.

(4) The oxygen in the air—especially when in the form

of ozone—gradually oxidises and renders harmless the organic impurities.

As the result of all these purifying agents the composition of ordinary air remains constant.

Amount of air required per head. We have seen that (1) an average adult produces ·6 cubic foot of carbon dioxide per hour by respiration, and (2) the amount in the air may be increased by ·02 per cent. without producing any injurious results. From (2) we may say that—

·02 cubic foot of carbon dioxide may be added to 100 cubic feet of pure air,

∴ ·2 cubic foot of carbon dioxide may be added to 1,000 cubic feet of pure air,

∴ ·6 cubic foot of carbon dioxide may be added to 3,000 cubic feet of pure air,

i.e. an average adult produces sufficient carbon dioxide to render impure 3,000 cubic feet of pure air in one hour. Therefore 3,000 cubic feet of fresh air must be supplied for each person in a room.

It is found that the air in a room can be changed three times per hour without causing any draught, and so if 1,000 cubic feet of space is provided for each person, and we change the air three times per hour by proper ventilation, the necessary 3,000 cubic feet of fresh air is supplied. For example, suppose it is desirable to know how many people may be allowed to sleep in a room 12 feet long, 8 feet broad, and 10 feet high: here the cubic contents are $12 \times 8 \times 10$, *i.e.* 960 cubic feet. Evidently from the above, only one person should sleep in such a room unless special methods of ventilation were adopted so as to change the air more than three times per hour. In calculating the contents of a room more than 12 feet high it is best to reckon 12 feet only for the height, because cubic space is of no value when it is principally obtained by means of lofty ceilings.

For sick people the supply of fresh air should be at least half as much more than that allowed in health, *i.e.* 4,500 cubic feet per hour. Soldiers in barracks are allowed 600 cubic feet of space; children in board schools 100 cubic feet; in prisons 800 cubic feet; in hospitals 1,500 cubic feet. Five hundred cubic feet of space for each person should be taken as the absolute minimum permissible.

Methods of Ventilation.

The methods of ventilation may be divided into two kinds—the natural and the artificial. By **natural ventilation** we mean any method that depends upon the natural forces which set air in motion, and does not involve the use of any mechanical means for the renewal of the air. **Artificial ventilation**, on the other hand, depends upon the use of pumps, fans, bellows, etc.

Two properties of gases play a very important part in the theory of ventilation; these are (1) diffusion, and (2) changes in the density of air produced by heat.

Diffusion is the property of gases to mix thoroughly and completely even against gravity, *i.e.* a heavy gas will diffuse upwards and completely mix with a lighter gas, and a light gas will diffuse downwards and mix with a heavier one. For instance, if in Fig. 41 the upper jar is filled with coal gas, which is a light gas, and the lower jar with air, which is a comparatively heavy one, then, on removing the plates between them and allowing them to diffuse for about half an hour, the lower jar will be found to contain just as much coal gas as the upper jar, and both may be lighted. The same result would be obtained, after a longer time, if a partition of some porous substance, such as unglazed earthenware, were placed between the jars. Another simple experiment illustrating the rapid diffusion of gases is to fill a jar with coal gas, close it with a cork or plate, and remove the plate after standing the jar on a table. In a short time the smell of

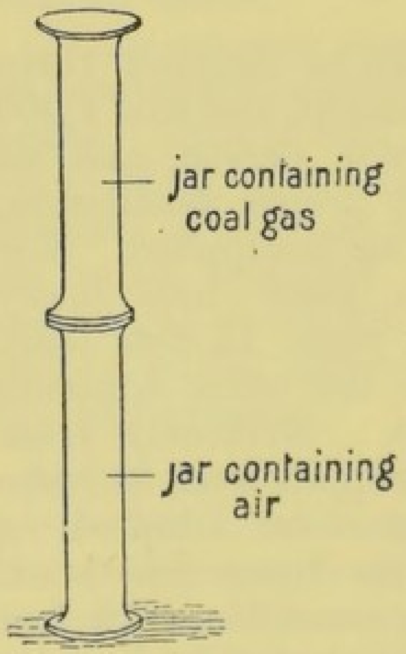


Fig. 41.—Diffusion Experiment.

coal gas can be perceived all over the room, showing that it has diffused to every part.

It is found that the lighter a gas is the faster it diffuses, and that if a light gas is on one side of a porous partition and a heavier gas on the other, then the light gas will diffuse through into the heavy one faster than the heavy gas will diffuse into the light one.

Now in an ordinary room the air is warmer and, as we shall see, lighter than the cold air outside. Diffusion outwards, therefore, will take place at a greater rate than diffusion inwards, and fresh air will enter the room not only as the result of this process of diffusion but also in order to equalise the pressure inside and outside the room. Diffusion through the walls of a room is greatly interfered with by the paper, plaster, and paint with which the walls are covered. As an example of the power of diffusion as a ventilating force it is said that in the case of a cubical room with brick walls, contents 3,000 cubic feet, and difference of temperature between the inside and outside air being 35° Fahr., the air would be completely changed in one hour by diffusion alone.

Changes in Density of Air. When air is heated it expands. For this reason a pint of cold air will weigh heavier than a pint of hot air. Hot air therefore rises and cold air will takes its place. This is exactly how **winds** are produced. The surface of part of the earth becomes heated by the sun; this warms the air in contact with it and causes it to expand and rise; the colder surrounding air then rushes in to take its place and a wind is produced.

The application of this to ventilation is easy. Foul air —being a product of respiration and combustion—is always hotter than the fresh air, and so it will rise, and if an opening is provided, it will escape. Fresh air will then enter through any opening to take its place. For the same reason the hot air over a fire goes up the chimney, and is replaced by fresh and colder air entering by windows, door, keyholes, and cracks.

Wind, as a ventilating agent, may act in two ways :—

(1) By perflation, *i.e.* by blowing through a room when the doors and windows are open.

(2) By aspiration. This is illustrated by the draught up a chimney when there is no fire below. The wind blowing over the top of the chimney lessens the pressure of air in the chimney, producing an up-draught, while fresh air is drawn in the room to take its place. In crowded courts surrounded by higher building this ventilating action of the wind is greatly interfered with.

Openings for Ventilation. It is most important that an outlet for foul air and an inlet for fresh air should both be provided. It is a common practice to provide only the outlet and to make no provision for the entrance of fresh air. This enevitably leads to bad ventilation.

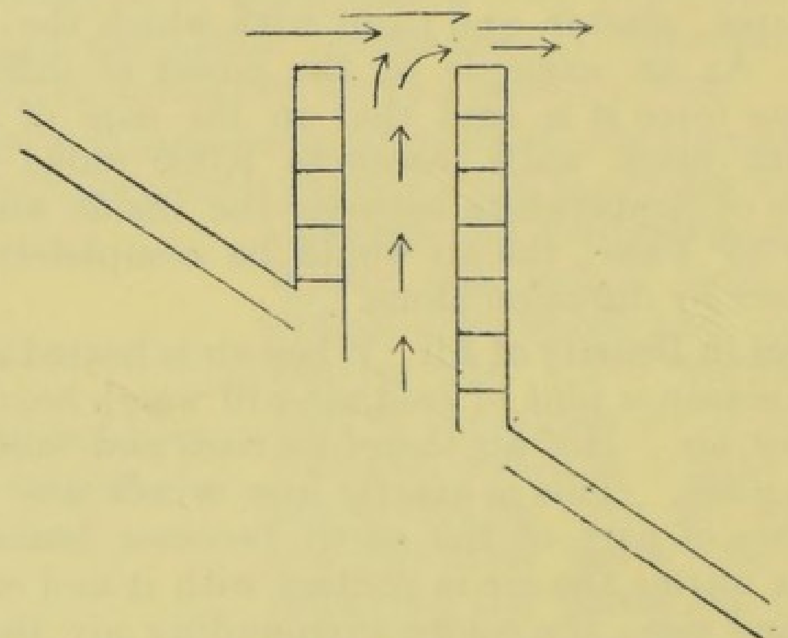


Fig. 42.—Aspirating effect of Wind passing over a Chimney.

In order to provide the necessary 3,000 cubic feet of fresh air per hour an opening of 24 square inches must be provided, assuming the air to enter the room at an average velocity of five feet per second. If the velocity is greater than this it will give the sensation of draught. An outlet of the same size is also necessary, making a total of 48 square inches of openings for each person in the room.

Position of Inlets and Outlets. The foul air is usually much warmer than fresh air, and so it rises to the top of the room. **Outlets**, therefore, should be provided close to the ceiling. The best place for **inlets** is theoretically at the level of the floor, but in practice this is found to produce draughts, giving rise to cold feet and general discomfort. If the incoming air is warmed by passing it over hot pipes, it may be introduced at the floor level, but under ordinary circumstances it is best to arrange inlets at about six feet from the floor and to direct the current of air upwards.

Ventilators for Rooms. In an ordinary room the chimney is the chief ventilator, and should on no account be closed. It acts as an outlet. The only inlets as a rule are the door, the window, and the numerous cracks in the frames and walls. We may divide the **special inlets and outlets** into three groups: (1) Window ventilators; (2) Openings at floor level fitted with vertical tubes or shafts; (3) Openings in the wall or roofs.

In criticising any form of inlet ventilator attention should be devoted to the following points:—

(i) The size of the opening should be adequate.

(ii) The size of the opening should be capable of being altered.

(iii) The current of air admitted should be deflected upwards.

Window Ventilation (Inlets).

(*a*) The simplest and most obvious method of ventilation is that of open windows; and in warm weather it is undoubtedly the best. In cold weather, however, it is very liable to produce draughts.

(*b*) The upper part of the window can be made to work on a hinge so that the top moves into the room. Triangular pieces of glass or wood should be placed at the sides to prevent down draught. The current of fresh air will then be directed upwards, as is the case with all efficient ventilators. An efficient window ventilator is obtained by arranging the lower part also to fall in (hopper

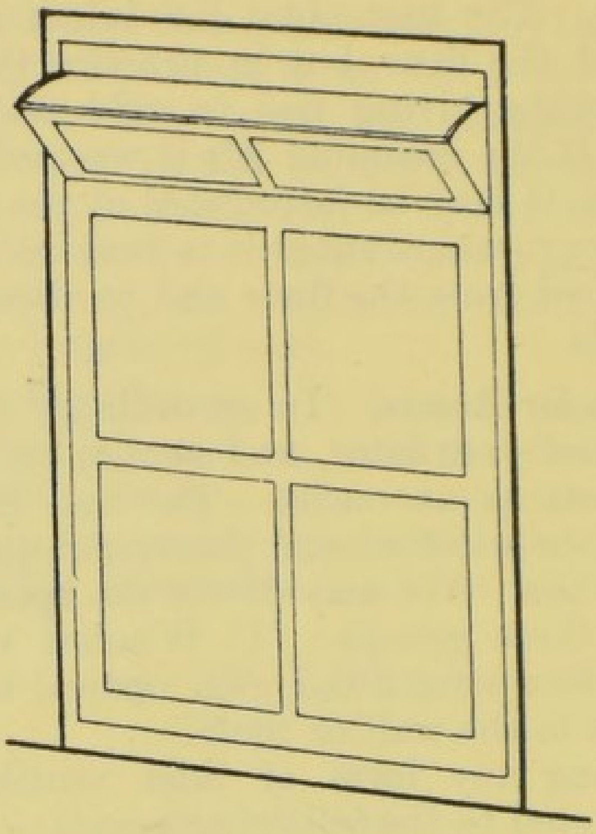


Fig. 43.—Ventilation by hinged top of Window.

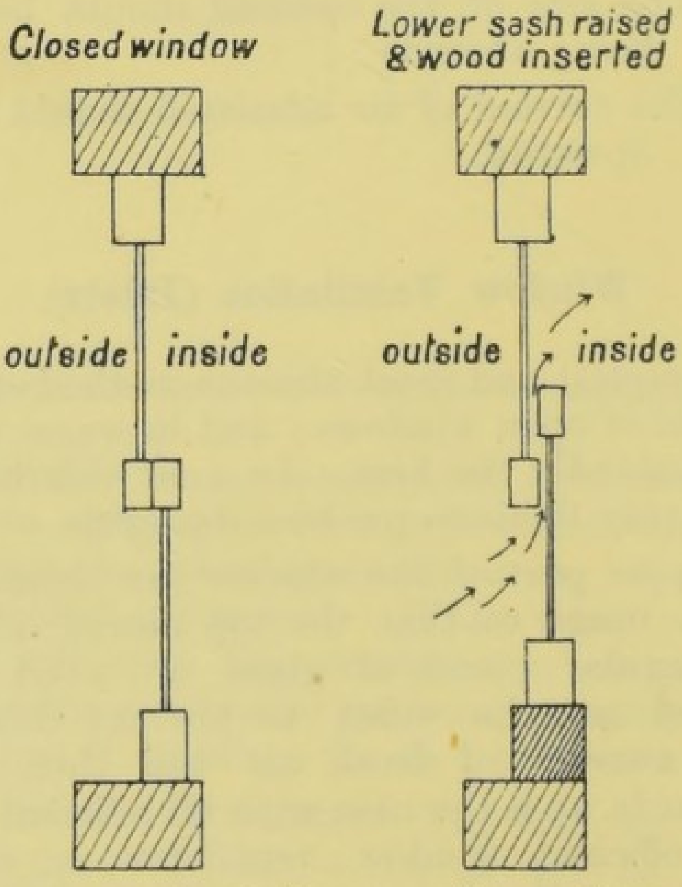


Fig. 44.—Hinkes Bird's Method of Window Ventilation.

fashion) on hinges at the bottom. This will form a satisfactory inlet and is particularly useful for school ventilation.

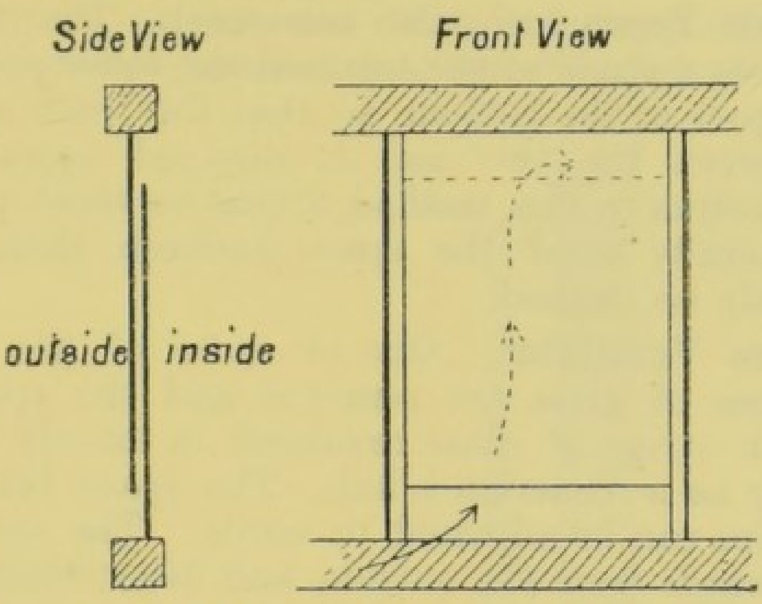


Fig. 45.—Ventilation by Double Panes.

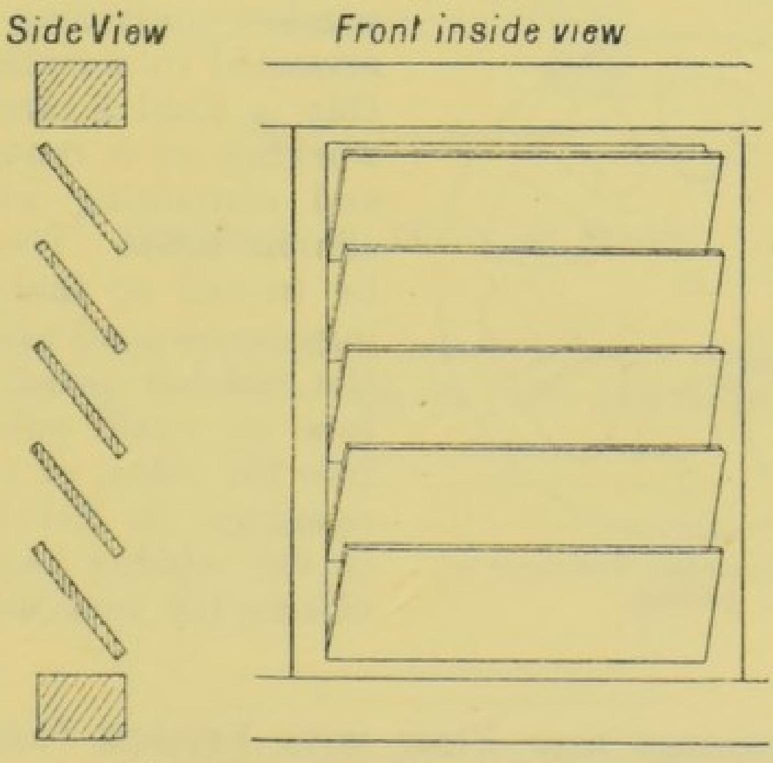


Fig. 46.—The Louvre Ventilator.

(c) A very simple and excellent method of window ventilation is that suggested by **Hinckes Bird**. The lower sash is raised, and a block of wood is accurately fitted in the opening below so as to completely close it. Fresh air enters between the two sashes and is directed upwards.

(*d*) **Double Panes** have also been used. The inner pane leaves a space at the top and the outer pane leaves a space at the bottom, so that the fresh air enters between the two and is directed upwards. An objection to this method is that as these panes are generally fixed the space between them cannot easily be cleaned.

(*e*) **Louvre Ventilator.** One or more of the ordinary panes of glass are removed and the space fitted with strips of glass arranged in exactly the same way as a Venetian blind. The space between the strips can be adjusted by cords. The strips slant upwards from the outside, and direct the current of air upwards.

(*f*) **Cooper's Ventilator.** A special pane is fitted in the window containing five holes arranged in a circle. Inside this is fixed a circular disc, working on a central pivot, and containing five exactly similar holes. The disc can be turned so that its openings correspond with those in the window pane, in which case air could pass through into the room, or so that its openings lie between those in the window pane, thereby closing the ventilator.

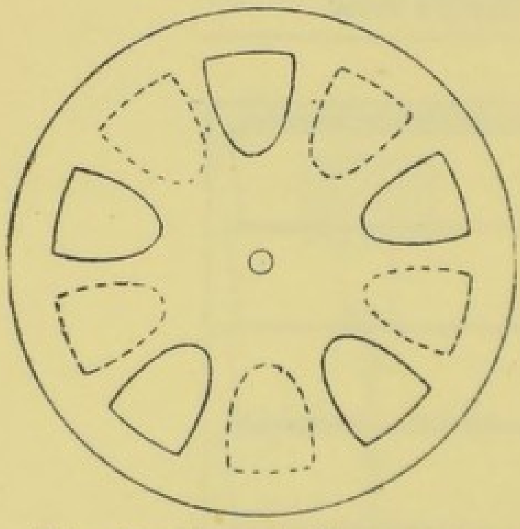


Fig. 47.—Cooper's Ventilator (closed).

Openings near Floor with Vertical Shafts.

Tobin's Tubes. The air enters from the outside through an opening in the wall at the floor level; it is then directed upwards by the vertical shaft or tube about six feet high. At the top the tube is fitted with a valve by means of which the amount of air coming in may be regulated. These ventilators are more suitable for large public rooms than for private houses, as they are difficult to keep clean and are liable to become choked up with dirt, etc.

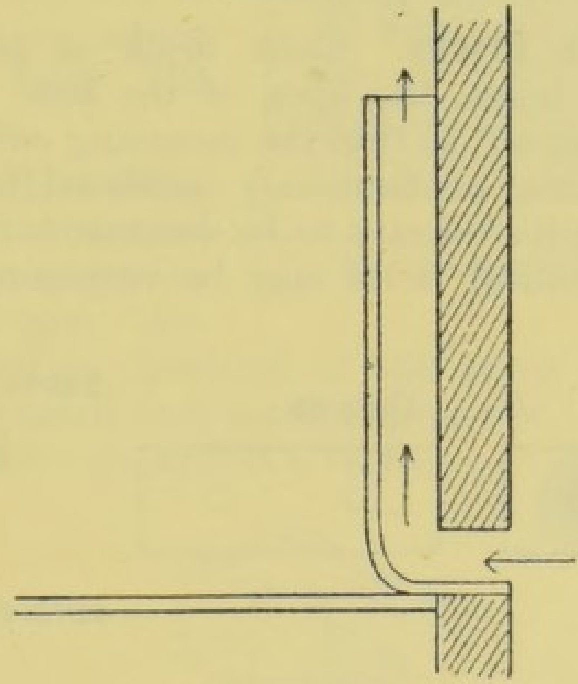


Fig. 48.—Tobin's Tube.

Openings in Walls or Roofs.

I. **Inlets** :—

Common inlet ventilators inserted in the walls of buildings are the Sherringham valve and Ellison's bricks.

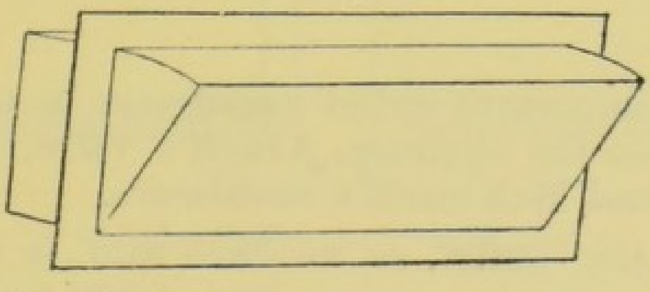


Fig. 49.—Sherringham Valve (from inside).

(*a*) **The Sherringham Valve.** This is a simple and a very good inlet ventilator. A hole is made in the wall about seven or eight feet from the floor. Into this is fitted an iron box, with a grating on the outside and a hopper valve on the inside. The air passes from the outside through the grating and into the room through the valve, the size of which may be regulated by a pulley. The inside aperture of the ventilator is larger than the outer, so that draughts are not usually produced.

(*b*) **Ellison's Bricks**. Each brick is perforated with conical holes, the apex of the cone being towards the outer air, so that the incoming current of air has its channel continuously increased in size, thereby causing its velocity to be decreased. The action of these conical holes may be very simply illustrated

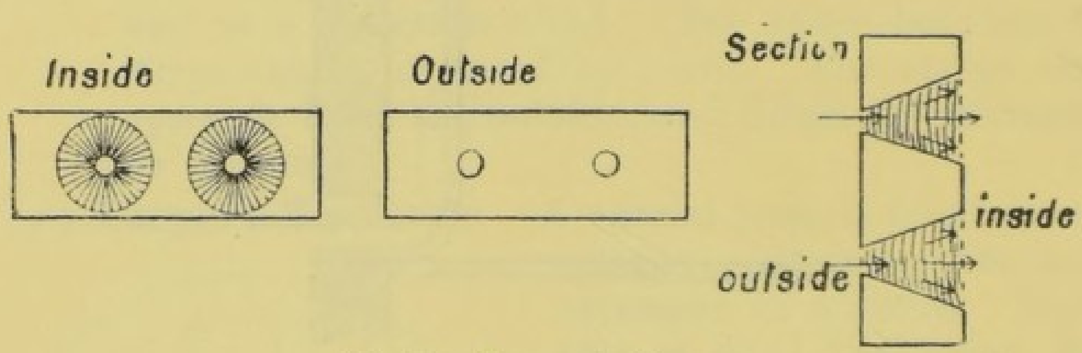


Fig. 50.—Ellison's Bricks.

by a cone of paper. Direct the large opening towards a lighted candle and send a puff of breath down the small opening. The candle is hardly affected. If the cone is now reversed and the experiment repeated the candle will be at once blown out.

II. **Outlets**:—

The more important outlet ventilators in the walls and roof are the chimney, Arnott's valve, Boyle's mica flap, and McKinnell's ventilators.

(*a*) The chief outlet, as we have said, is the **chimney**. When a fire is burning, from 5,000 to 15,000 cubic feet of air pass up the chimney per hour.

(*b*) **Arnott's Valve** is an outlet made to be fixed in the wall so as to open into the chimney. It consists of an iron box with a light metal valve capable of swinging towards the chimney but not into the room. The foul air can therefore pass up the chimney but the smoke cannot pass into the room. An objectionable feature of these ventilators is the clicking noise they make. Also, when in any way out of order, they admit smoke from the chimney.

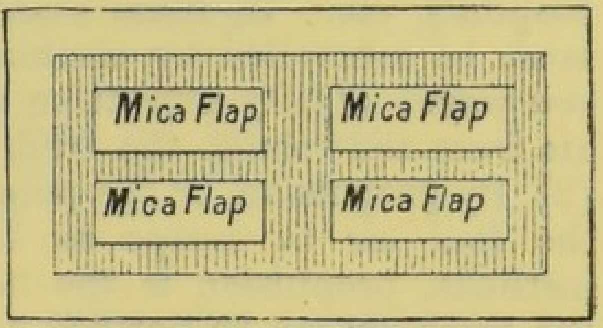


Fig. 51.—BOYLE'S VENTILATOR.

(*c*) **Boyle's Mica Flap Ventilator** is simply an improvement upon Arnott's valve. Instead of one valve there are four or more small ones made of thin talc. The principle is the same as Arnott's valve.

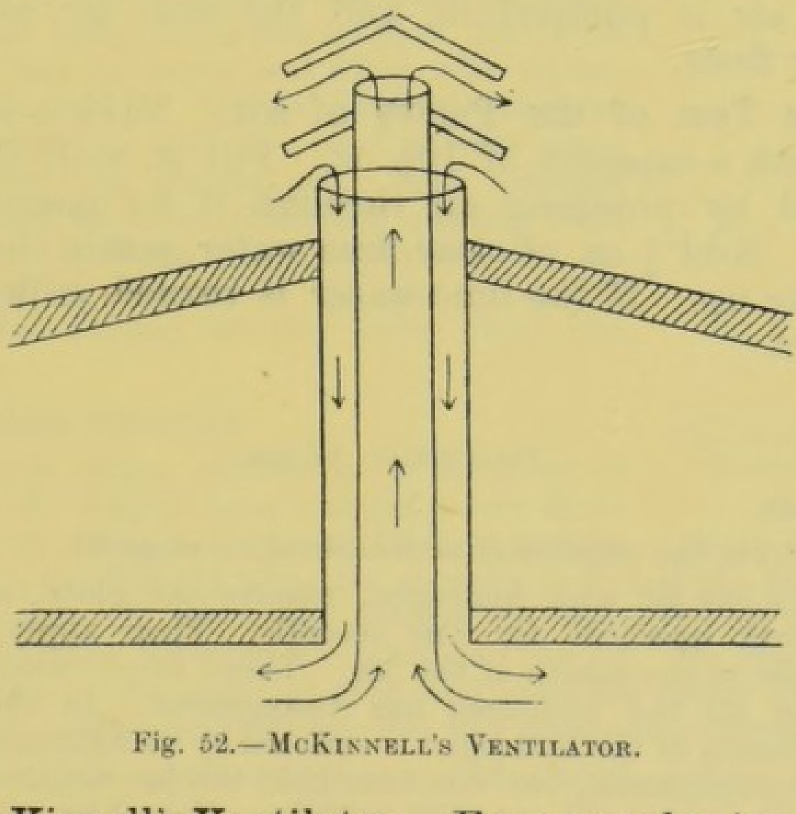


Fig. 52.—MCKINNELL'S VENTILATOR.

(*d*) **McKinnell's Ventilator**. For rooms having no other rooms above them this ventilator is usually very efficient. It acts as an inlet and outlet. There are two concentric tubes as shown in the figure. The inner tube forms an outlet, and the space between the tubes forms the inlet.

Artificial Ventilation.

The above methods of ventilation are found to be inadequate for large buildings such as prisons, barracks, hospitals, etc. In these cases the movements of the air must be controlled by machinery. This may be done in two ways: (1) By **aspiration** or the extraction of the foul air from the rooms, the fresh air entering where it can; (2) By **propulsion**, or the pumping in of fresh air, leaving the foul air to escape as best it may. Of these two methods, propulsion is the better, because in this case the fresh air can be purified and warmed before it enters the rooms, whereas in the aspiration method there is no control over the incoming air, and it may possibly be drawn from some undesirable source.

For complete ventilation it is necessary to combine aspiration with propulsion. In this case the purified and warmed air is pumped in, and the foul air escapes by shafts or flues.

Simple Test of the Purity of Air. Take a stoppered bottle with a capacity of $10\frac{1}{2}$ oz. Fill it with the air to be tested by pumping air through it by means of foot bellows. Add $\frac{1}{2}$ oz. of clear lime water, put in the stopper, and shake up. If the lime water is turned milky the air is impure.

Practical Work.

I. **Diffusion.**

(*a*) Perform the experiments described on page 60.

(*b*) Fill a gas jar with hydrogen, remove the plate, and hold it mouth upwards for ten seconds. Then apply a lighted taper to the mouth of the jar. There is no result, showing that all the hydrogen has disappeared. In this case the diffusion of the hydrogen is assisted by its lightness. Repeat the experiment, but this time hold the jar mouth downwards for ten seconds. Apply a light. There is an explosion, showing that air has diffused into the jar and mixed with the hydrogen and formed an explosive mixture.

(*c*) Take two gas jars. Into one pour a few drops of strong hydrochloric acid and place the plate on the top. Into the other pour a few drops of strong ammonia solution and also close with a plate. Next place the jars one on the other, so that the jar containing ammonia gas (a light gas) is on top and the jar containing hydrochloric acid gas (a heavy gas) is below. Then pull away the two plates that separate the jars. A white cloud immediately fills the two jars. This is ammonium chloride, produced by the combination of the ammonia and the hydrochloric acid gas, and its formation in every part of both jars shows clearly that the light gas has diffused downwards and the heavy gas has diffused upwards very rapidly. Of course if the experiment is repeated but the position of the jars reversed, it will be seen that the diffusion takes place still more rapidly, as in this instance it is helped by gravity.

(*d*) The apparatus shown in Fig. 53 should be supplied, but if it is not, the student can easily make it under the direction of the teacher. It consists simply of a bent glass tube which passes through an india-rubber bung into a porous pot. The bent tube has its lower end filled with water. Fill a bell-jar with a light gas such as hydrogen or coal gas, and quickly place it over the porous pot. The coal gas diffuses into the pot more quickly than the air diffuses out, thereby causing an excess of pressure in the pot, as shown by the forcing of the water from the tube.

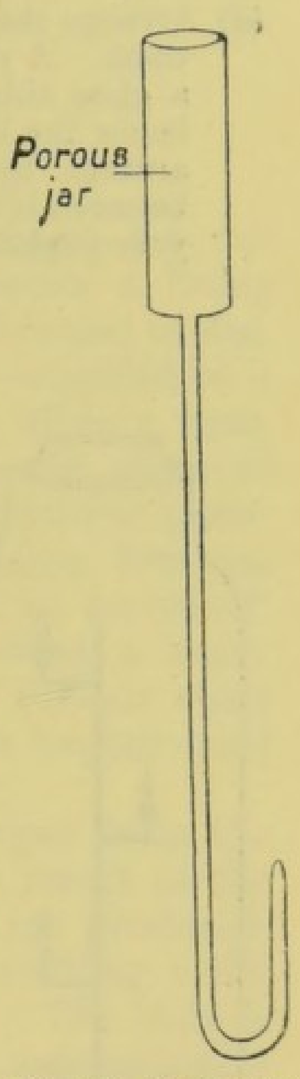


Fig. 53.—DIFFUSION EXPERIMENTS.

II. **Ventilation Openings.**

(*a*) Arrange three candles on a stand as in Fig. 54. Light them and place over them a large stoppered jar without a bottom. Note behaviour of the candles (1) when the stopper is in and the jar rests on the table, (2) when the stopper is removed and there is a small space between the table and the jar. In the first case the top candle goes out first, and then the lower ones, while in the second case the candles will continue to burn brightly.

(*b*) Take a glass cylinder with open ends and place it over a lighted candle, so that the cylinder rests on the table. On the top place a piece of tin or cardboard with a circular hole in it, as in Fig. 55. The candle will die out. Repeat the experiment, but this time allow a small space between the table and the jar.

(*c*) Repeat the experiment (*b*), but when the candle flame is dying down insert a T-shaped piece of cardboard into the hole at the top so as to divide it equally into two parts. One half then acts as an inlet and the other as an outlet, and the candle continues to burn brightly.

(*d*) Arrange the candles as in Fig. 56, with a bottomless jar over them. A piece of cardboard rests on the top of the jar, and a glass tube passes through the centre of this, and reaches below the level of the upper candle. Light the candles and arrange the jar over them so that there is a small space between it and the table. Note the result and write down your explanation of it.

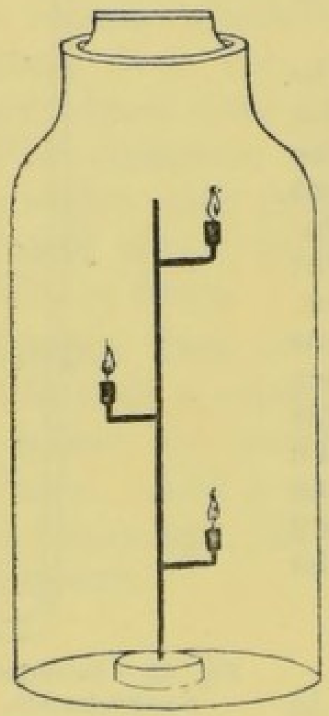


Fig. 54.

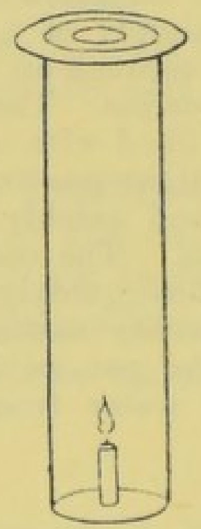


Fig. 55.

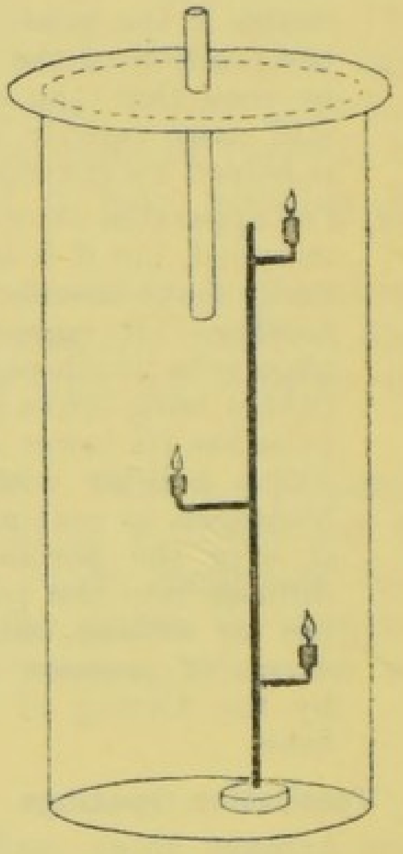


Fig. 56.

(*e*) Perform the experiment described on page 68, illustrating the action of Ellison's bricks.

III. Test the air in the room by the method already described, by using a $10\frac{1}{2}$ oz. bottle and $\frac{1}{2}$ oz. of lime-water.

IV. By means of a lighted taper or candle test the direction of the air currents at a slightly open door communicating between a warm room and a passage or other room at a lower temperature, (*a*) holding the candle near the top of the door, and (*b*) near the floor. It will be seen that at the top of the door the flame is blown outwards showing that the hot air is escaping from the room, while at the floor level there is a stream of cold air entering to take its place.

CHAPTER V.

FOODS.

EXPERIENCE teaches us that food is necessary for our existence. The old comparison drawn between a living body and a steam-engine at work is instructive and useful. The engine will only work as long as food is supplied to it in the shape of fuel, water, and air. Also, after a time, another kind of food is supplied to it in the shape of various metals which have to replace the worn-out parts. Supplied with its food then, the steam-engine becomes hot, works its own internal machinery, and is, moreover, capable of doing work such as dragging along a heavy train. This is not all; there are produced various waste matters in the form of carbon dioxide, water vapour, and cinders from the furnace.

In just the same way the body takes oxygen from the air, and receives a supply of food. As the result of the combination of these two, heat and energy are produced. The food also serves to repair and keep in working order the blood and the various parts of the body. The body is kept warm and the different organs are kept automatically at work.

This is **internal work. External work** is also done, such as walking, running, talking, etc. Various waste matters are at the same time produced: the lungs giving off carbon dioxide and water vapour; the kidneys getting rid of water with waste substances in solution; the skin chiefly eliminating water as sweat; and the undigested remains of the food being thrown out by the rectum.

Uses of Foods. From the above it is obvious that the uses of foods are (1) to keep up the heat of the body; (2) to supply the energy for internal and external work; (3) to make good any loss, and replace decayed tissues. In addition to this, part of the food of young children is used to build up the growing tissues.

Classification of Foods. Perhaps the simplest classification of foods is to divide them into (1) solid foods, and (2) liquid foods such as water, milk, etc. A more useful classification is to divide foods according to their source into—

(1) **Inorganic** foods, which include the various mineral salts.

(2) **Organic** foods, *i.e.* those of animal or vegetable origin.

The organic foods are further subdivided into those which contain nitrogen and those which do not. The foods containing nitrogen are called **nitrogenous** foods or **proteins**, and those containing no nitrogen are called **non-nitrogenous** foods.

Non-nitrogenous foods include three chief classes, the **fats** and **oils**, the **carbohydrates** or **sugars** and **starches**, and the vegetable acids.

We may say, therefore, that all foods can be divided into groups of **food-stuffs** or **proximate principles**. Some foods contain representatives from practically all the divisions, while other foods, we shall find, contain one proximate principle only, or mainly one with very small quantities of one or two others. We may classify all foods under one or more of the following headings,—water, mineral salts, proteins, fats, carbohydrates, and vegetable acids.

The following table clearly shows the division of foods into food-stuffs.

Food.
- Inorganic.
  - Water.
  - Mineral Salts.
- Organic.
  - Proteins or Nitrogenous foods.
  - Non-nitrogenous foods.
    - Fats and Oils.
    - Carbohydrates or Sugars and Starches.
    - Vegetable Acids.

Water stands second only to oxygen among the necessaries of life. About seventy per cent. of the body consists of water. It is not only necessary to the body as a food, but it is also necessary because—

(1) It dissolves the foods when digested, and aids in their absorption.

(2) It maintains the fluidity of the blood, which contains about 80 per cent. of water.

(3) It assists in the removal of waste matters, especially by dissolving the urea so that it may be eliminated by the kidneys.

The average person loses from $3\frac{1}{2}$ to 5 pints of water per day from the skin, lungs, kidneys, and intestines. This must be replaced in the food. Usually one third of this amount is present in the solid food, leaving about 3 pints of water to be drunk per day. In many foods the percentage of water is large, as shown in the following table:—

Green vegetables	90—95	per cent. water.
Lean meat	70—75	,, ,,
Fish	75—80	,, ,,
Bread	35—40	,, ,,
Milk	87	,, ,,
Peas (dried)	13	,, ,,

Mineral Salts (inorganic). These consist of chloride of sodium or common salt, chloride of potassium, phosphates of potassium, calcium, and magnesium, and salts of iron. They are essential constituents of our food. Thus, common salt is the source of the hydrochloric acid that is present in the gastric juice of the stomach, and which is necessary for digestion. It is also the source of the sodium in bile salts, and is found in every fluid and tissue of the body. The calcium or lime salts are necessary to build up the skeleton. They are contained in most foods, especially milk and cheese. Phosphorus is an indispensable constituent of bone and brain, and the salts of iron are necessary to supply the iron present in the haemoglobin of the red corpuscles.

Proteins or nitrogenous food-stuffs are composed of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. They are divided into two groups according to their nutritive value. The more nutritious group is the **true proteins**, which are represented in many foods, both of animal and vegetable origin. Thus there is **albumin** in white of egg, **myosin** in lean meat, **gluten** in flour, **fibrin** in blood, **casein** in milk and cheese, and **legumin** in peas and beans, while in the stomach and small intestines are substances called **peptones**, which are the products of the digestion of proteins. The first three — albumin, myosin, and gluten—are coagulated by heat. The result of cooking any food containing either of these three principles will, therefore, be to coagulate the protein constituent.

The second and less nutritious group of nitrogenous food-stuffs are called **albuminoids**. These include such substances as **gelatin**, **chondrin**, **ossein**, and **keratin**, all of which are obtained from animal tissues by prolonged boiling. Although they are richer in nitrogen than true proteins, yet they are far less valuable as foods. In fact, these substances alone are not sufficient for the nitrogenous part of any diet.

The **use of proteins** is to build up the nitrogenous tissues of the body, and to repair these when worn out. The old idea was that protein foods were converted directly into muscle, and that when the muscles did any work they became worn away and needed more nitrogenous food to repair them. From this it followed of course that protein food-stuffs were the source of energy. This is now considered to be incorrect. In the adult the amount of nitrogenous food necessary is very small, for in all probability the greater part of what is consumed is broken down in the intestine and liver without ever becoming converted into nitrogenous tissue. Nitrogenous foods, if taken in excess, may even be partly converted into fats and sugars. If insufficient nitrogenous food is supplied, death eventually takes place from nitrogen starvation.

The following table illustrates the class of nitrogenous principles :—

PROTEINS.

True Proteins.	Albuminoids.
Albumin.	Gelatin.
Myosin.	Ossein.
Gluten.	Chondrin.
Casein.	Keratin.
Legumin.	
Fibrin.	
Peptones.	

The proportion of proteins present in some common foods is :—

Beef	21 per cent.		Lentils	24 per cent.
Bread	8	,,		Milk	5 ,,
Cheese	28	,,		Mutton	18 ,,
Eggs	13	,,		Oatmeal	13 ,,
Fish	14	,, (average)		Peas	22 ,,

Fats are compounds made up of carbon, hydrogen, and oxygen, the oxygen present being insufficient to combine with all the hydrogen and form water. They are sometimes improperly called hydrocarbons. Chemically they are best considered to be compounds of fatty acids with glycerine. Thus palmitin is the fat composed of palmitic acid and glycerine, olein the compound of oleic acid, and stearin and butyrin the fats containing stearic and butyric acids respectively. The ordinary fats in food contain varying proportions of stearin, palmitin, and olein. The greater the quantity of olein present the less solid the fat is. For this reason bacon fat is less solid than beef fat, and beef fat than mutton fat. Butter is a very digestible form of fat. One of the most digestible of all fats is cod-liver oil, which contains no stearin. Olein and palmitin may be obtained from plants or animals; stearin from animals only.

The **use of fats** is to produce heat and energy by the oxidation of the carbon and hydrogen into carbon dioxide and water. They also repair the fatty tissues, and their presence in the intestine stimulates the flow of bile and pancreatic juice, thereby aiding the digestion of the other foods. As a general rule, the harder the work to be done and the colder the surroundings, the more fat is required in the diet. The following table gives some idea of the proportion of fat present in common foods :—

Bacon	contains	73	per	cent. fat.	
Butter	,,	85	,,	,,	
Cheese (varies)	,,	25	,,	,,	(average)
Cream	,,	27	,,	,,	
Eel	,,	24	,,	,,	
Eggs	,,	12	,,	,,	
Salmon	,,	7	,,	,,	
Sole	,,	$\frac{1}{2}$	,,	,,	
Goose	,,	45	,,	,,	
Milk	,,	4	,,	,,	
Oatmeal	,,	6	,,	,,	
Peas	,,	2	,,	,,	
Pork	,,	34	,,	,,	

Carbohydrates—a group which includes all starches, sugars, and gums—are composed of carbon, hydrogen, and oxygen, the oxygen being present in exactly sufficient quantity to combine with the hydrogen and form water. Hence the name "carbohydrate." As a rule the carbohydrates are of vegetable origin, although there is a sugar called lactose in milk, and the liver contains a starchy substance called glycogen.

The **use of carbohydrates** is similar to that of fats. They are producers of heat and energy, but they are probably inferior to fats in this respect. They also may be converted into fat in the body. It would seem at first sight, therefore, that the carbohydrates may be substituted for fats in a diet, but experiments have shown that a withdrawal of fat from a diet is not balanced by the addition of carbohydrates. For a good diet both fats and carbohydrates should be present. Being much cheaper than fats, the carbohydrates form very important foods for the poorer classes.

Starch consists of tiny granules which have slightly different appearances according to the source, *e.g.* wheat, rice, sago, etc. In its uncooked state a starch granule is very indigestible because it is enclosed in a covering of cellulose. When cooked, however, the cellulose coat bursts and the starch is set free.

The following table shows the percentage of starch in some common foods:—

Rice	79 per cent.	Peas	59 per cent.
Arrowroot	72 ,,	Wheat bread	47 ,,
Barley flour	69 ,,	Potatoes	19 ,,
Wheat flour	66 ,,	Tapioca	nearly pure starch.
Maize meal	65 ,,	Sago	
Oatmeal	63 ,,		

The **sugars** include sucrose, glucose, and lactose.

Sucrose or common sugar is obtained from the sugar cane, beet-root, or maple. Glucose or grape sugar is in grape juice and may be seen crystallised in dried raisins. Lactose is the sugar contained in milk.

Vegetable Acids are not foods in the strictest sense of the word, but they are essential to the well-being of the body. If they are withheld from the diet for any length of time, the disease known as scurvy is produced from the general lowering of the vitality. This disease used to be very common among sailors on long voyages, but is rarely met with now, as it is customary to provide each sailor with a daily allowance of **lime juice**. Most fresh fruits and vegetables contain vegetable acids, either free or combined. The chief among them are:—

Malic acid	contained in	apples.
Citric acid	,, ,,	lemons and limes.
Tartaric acid	,, ,,	grapes.
Oxalic acid	,, ,,	rhubarb.
Acetic acid	,, ,,	vinegar.

A modified form of scurvy is occasionally met with among infants who are reared solely on condensed milk—this food being deficient in salts.

Accessory Foods. In the above classification of foods we have omitted to include many substances which enter largely into an ordinary diet, such as tea, coffee, cocoa, alcohol, as well as mustard and other condiments. Experience has proved that many of these substances are useful as stimulants, or in exciting appetite and stimulating digestion. We shall consider tea, coffee, cocoa and alcoholic drinks in a later chapter under the head of "beverages."

The **condiments** are substances which are added to the food with the object of making it more tasty and palatable, thereby stimulating the digestive apparatus. This class includes mustard, pepper, salt, ginger, nutmeg, horseradish, cloves, mint, vinegar, parsley, lemon juice, lime juice. Vinegar should be dilute acetic acid, obtained by the oxidation of alcoholic liquors by a process of fermentation. It is often adulterated with dilute oil of vitriol. If taken in excess vinegar is very injurious, but in moderate quantities it may serve to help digestion. Lemon juice and lime juice are valuable in preventing scurvy, as well as providing very pleasant drinks. As they are acid they are useful as antidotes in cases of poisoning by alkalies.

The Value of the Food-stuffs. It is usual to compare the relative values of the food-stuffs by comparing the amounts of heat (or energy) each will produce when burned (or oxidised). That this is a fair method of comparison is obvious when we consider that the products of burning foods outside the body are precisely the same as those produced inside the body and excreted from it—namely, carbon dioxide and water. The nitrogen in the proteins is, however, excreted in the form of urea in the urine. This urea is not a fully oxidised substance, and so an allowance must be made for this when comparing proteins with other food-stuffs. The following numbers represent the relative value of various foods with reference to their power of producing heat and energy when burned to the same products as are manufactured from them by the body:—

Proteins	145	Potatoes	164
Lean Beef	169	Bread	169
Fat	378	Cane Sugar	131
Milk	188	Starch	138

PRACTICAL WORK.

I. **Albumin.**

(*a*) The white of egg is almost pure albumin plus water. Separate the white from the yolk, note the appearance and stickiness of the white, and test its effect upon a piece of litmus paper. The litmus is turned blue, showing that the albumin is alkaline.

(*b*) Put some of the white of egg into a test-tube and add about ten times its bulk of water. Shake up. The albumin dissolves.

(*c*) Place the solution of albumin in a small beaker and heat over a Bunsen flame, carefully noting the temperature of the liquid by means of a thermometer, which should be used to stir the liquid. No change is noticed until the thermometer stands nearly at 60°. Then the liquid becomes milky and the albumin coagulates or precipitates as a white solid. If the heating is continued the liquid boils but the albumin does not dissolve, showing that the coagulated albumin is insoluble in water.

(*d*) Pour a small quantity of the cold solution of white of egg into a test-tube (about $\frac{3}{4}$ inch depth of liquid). Hold the tube slanting and pour down the side an equal quantity of strong nitric acid. The acid being heavier slips under the albumin solution and forms a separate layer, and where the liquids meet there is formed a white cloud of coagulated albumin.

(*e*) To a small quantity of solution of white of egg in water add one drop of copper sulphate solution and a few drops of potassium hydrate. A violet colour is produced.

II. **Proteins.**

(*a*) Place a fragment of cheese in a test-tube, add a little strong nitric acid, and boil. The cheese is stained a deep yellow. Pour away the nitric acid and add a little ammonia solution. The yellow colour deepens to orange. This is a good test for proteins either in solids or liquids. If a liquid is being tested the nitric acid cannot be poured away, and the addition of ammonia must be made with great care. It is best carried out by pouring the liquid from the test-tube into a beaker, and then adding the ammonia solution cautiously until the liquid, after mixing, turns litmus paper blue.

(*b*) Test for proteins in the above way in the following foods: meat, bread, milk, white of egg, oatmeal, rice, peas.

III. **Starch.**

(*a*) Mix a little starch with water, and add some iodine solution. The particles of starch are coloured dark blue. The production of a blue colour with iodine solution is a good test for the presence of starch.

(*b*) Make another mixture of starch and water so as to form a milky liquid. Filter carefully. A clear liquid passes through the filter and if iodine solution is added to this it produces no blue colour, showing that the starch has not dissolved in cold water.

(*c*) Place some of the milky liquid as used in (*b*) in a test-tube and heat carefully over the Bunsen flame. As the solution gets hot it becomes much clearer. The starch has now dissolved. To a beaker nearly full of water add some of this starch solution and then add a few drops of iodine solution. A beautiful blue colour is produced.

(*d*) Pour a few drops of iodine solution upon a slice of raw potato. Notice the blue colouration showing the presence of starch.

(*e*) Scrape the fresh cut surface of raw potato with a knife. A milky liquid is produced. Mix a drop of this liquid with a drop of water on a microscope slide and cover with a cover glass. Examine with the low power of the microscope. Make drawings of the starch grains seen.

On the microscope slide, close to the side of the cover glass, put a drop of iodine solution, and by means of a glass rod make the iodine solution run to the edge of the cover glass. By means of a piece of blotting-paper suck away the liquid from the opposite edge of the cover glass. This draws the iodine solution under the glass and in contact with the starch grains. Note the blue colour of the starch grains.

(*f*) Using finely powdered wheat, flour, rice, oatmeal, tapioca, arrowroot, and peas, repeat the above experiment. It will be best to use the higher power of the microscope for some of these, as the starch grains are small. Make drawings of the various grains seen.

IV. **Sugar.**

(*a*) Taste a little of the dextrose (glucose) provided. Notice that it is sweet, but not so sweet as ordinary cane sugar. Dissolve a fragment in some hot water in a test-tube, and add an equal quantity of Fehling's solution and boil. A red precipitate of oxide of copper is produced. This is a characteristic test for glucose

(*b*) Repeat the above experiment with a solution of cane sugar. No result is obtained.

(*c*) Repeat also with a solution of starch. No result is obtained.

(*d*) To some starch solution in a beaker add a few drops of dilute sulphuric acid. Boil for about twenty minutes. Now test a small quantity of the liquid with iodine solution. Notice that no blue colour is produced. To another portion add Fehling's solution and boil. The production of the red precipitate shows that the starch has been converted into glucose.

(*e*) Make a dilute solution of cane sugar (about a quarter of a teaspoonful in half a teacupful of water), place in a flask, add five or six drops of strong hydrochloric acid, and heat the flask on a water bath for half an hour. Then pour into a dish and add with stirring carbonate of soda solution until no effervescence occurs. To a portion of the liquid apply the Fehling's solution test and note the production of the red precipitate, showing that glucose has been formed. The process is called the "inversion" of the cane sugar, and the product is called "invert sugar."

CHAPTER VI.

THE DIGESTIVE SYSTEM.

The food we eat is subjected to a great many processes before it is really assimilated by the body. Some of these processes are merely mechanical or physical, and are very simple, while others are complicated chemical actions. The food is first broken up thoroughly by the teeth, and while this is going on it is being acted upon chemically by the saliva. It is then forced through the funnel-shaped pharynx into the oesophagus, down which it passes on its way to the stomach, and in the stomach it is again subjected to chemical changes. From the stomach it passes along the intestines, where it is still further acted upon. Absorption of digested material is going on all the while, from the moment the food enters the stomach.

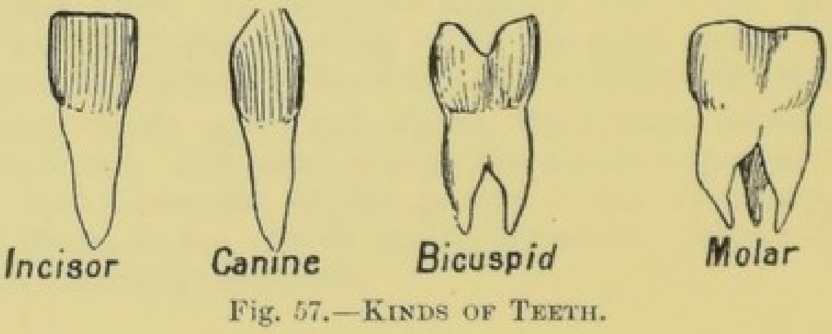


Fig. 57.—Kinds of Teeth.

The Teeth. The teeth are divided into four classes according to their shape. In front are the **incisors**—the flat sharp-edged biting teeth. The long narrow fang-like teeth at each side of the incisors are called **canines**. Still further along the jaw are teeth which seem to be partly split into two at the top—these are the **bicuspids**. The **molars** are the broad-topped grinding teeth which are placed at the back.

There are two sets of teeth, the first set or the temporary teeth, and the second set which are more or less permanent. The first set are called the **milk teeth**. They are twenty in number, and consist of eight incisors, four canines, and eight molars; each half of each jaw being provided with two incisors, one canine, and two molars. This set is usually complete at three years. They begin to drop out about the seventh year, and have all gone at twelve. By the fourteenth year all the permanent set have appeared except the last four molars, called the **wisdom teeth**. These may not be cut until the twenty-fifth year.

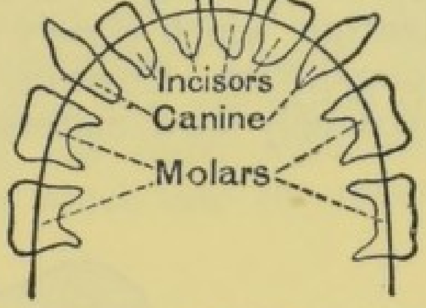


Fig. 58.—MILK TEETH. (Upper or Lower Jaw.)

The **permanent teeth** are thirty-two in number, and are

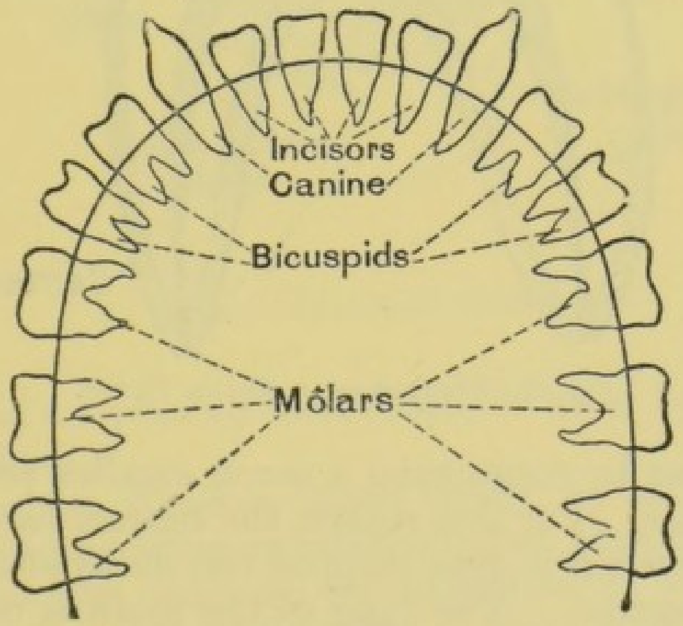


Fig. 59.—PERMANENT TEETH. (Upper or Lower Jaw.)

divided into eight incisors, four canines, eight bicuspids, and twelve molars. At about fourteen years there would be twenty-eight teeth, the last four molars not being cut at this age.

Structure of a Tooth. Each tooth consists of a **crown**, or the part showing above the gum, and the **root**, or the part imbedded in the jawbone. The root consists of one or more fangs. A slight constriction is visible at the line where the crown and the root meet; this is called the **neck**. The main body of a tooth is made of a substance called **dentine**, which closely resembles bone in its structure and composition. Covering the crown of the tooth is a layer of extremely hard material called **enamel**. It differs from

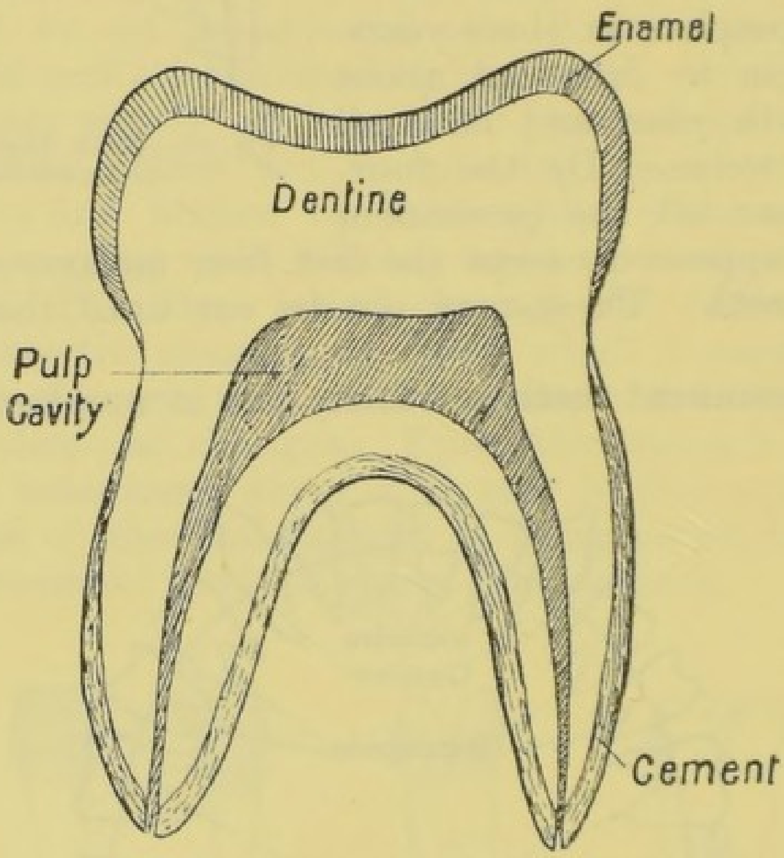


Fig. 60.—Section of a Molar Tooth.

ordinary bone by containing a much smaller percentage of animal matter. For this reason the enamel rarely or never decays; but when it gets chipped off, decay at once attacks the softer dentine. The fang of the tooth is covered by a bony layer called **cement**, which fixes the fang securely in its socket.

In the body of the tooth is a cavity which is filled with a pulpy substance containing nerves and blood-vessels. These enter the tooth at the tip of each fang, and pass into the **pulp cavity**. Ordinary **toothache** is caused by the inflammation of this pulp in the tooth.

The Salivary Glands. There are three pairs of glands which secrete the saliva. Small tubes or ducts lead from each gland, and the saliva trickles along these into the mouth. Each pair of glands has a special name. Those placed in front of and below each ear are called the **parotid** glands; another pair, close to the inner side of the lower jaw on each side, are called the **submaxillary glands**; the third pair are placed under the tongue, and are called the **sublingual** glands. These glands are lined with cells which secrete the saliva, the flow of which into the mouth

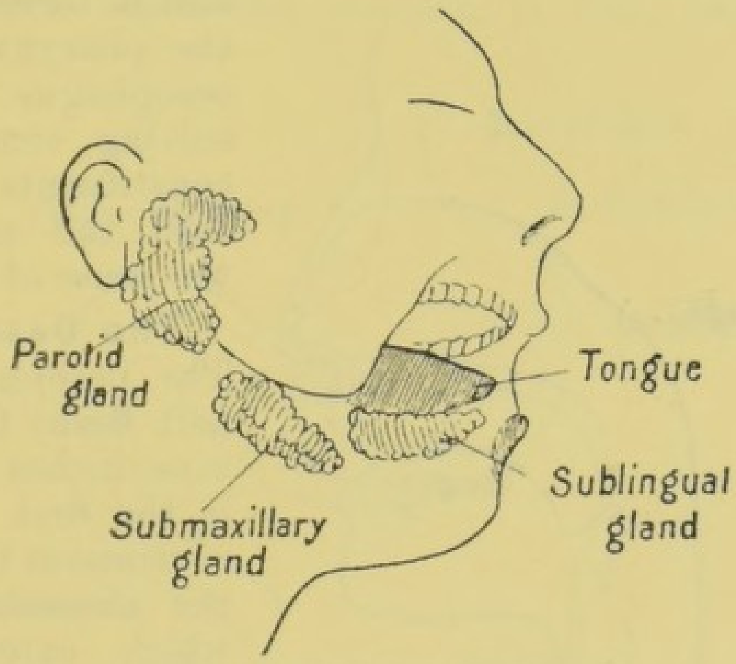


Fig. 61.—Salivary Glands.

is increased by placing food there, or even by the sight or smell of food.

Saliva is an alkaline liquid made up of water, salts, mucus, and a peculiar substance called **ptyalin**—a ferment. This is the first example we have had of this important class of bodies called **ferments.** They have the property of causing remarkable changes to go on in various substances when the conditions are favourable. We divide ferments into two classes—(1) The **organised ferments**, or living ferments like yeast, which is really a tiny plant, and which has the power of converting sugar into alcohol and carbon dioxide; (2) The **unorganised ferments**, which have no life at all, but are simply chemical substances secreted from living cells. They have the power of bringing about certain changes, and do not themselves increase or decrease in quantity during the process. Ptyalin is an unorganised ferment. It causes the starch in our food to unite with water and become changed into sugar.

The saliva also serves to moisten the food and thereby assists mastication. After the food has been thoroughly broken up by the teeth and moistened by the saliva, it is collected into a mass, and is forced through the pharynx into the oesophagus. By dissolving some of the constituents of the food the saliva aids the sense of taste.

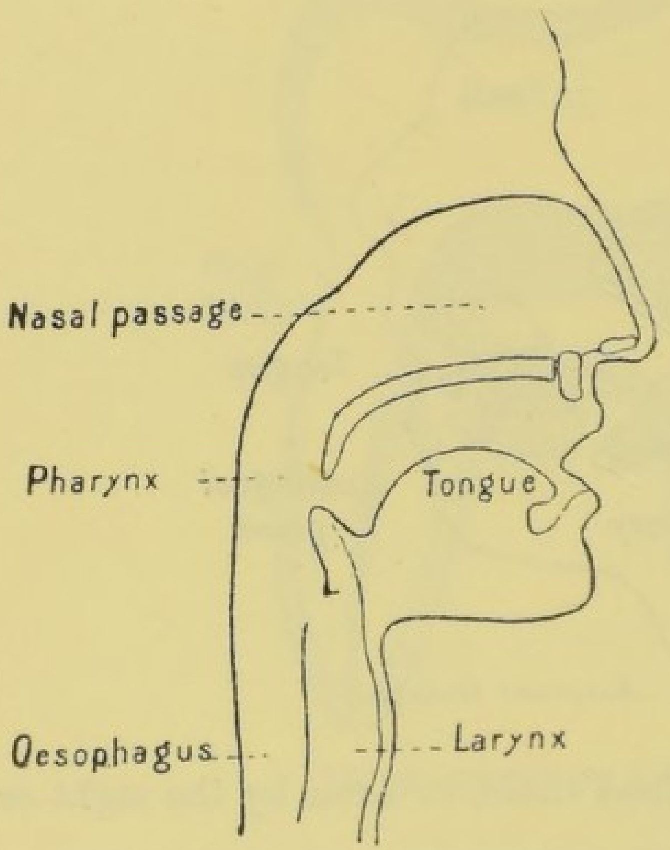


Fig. 62.—Pharynx.

The Oesophagus. The oesophagus is a soft fleshy tube about nine inches long. It is the first part of a continuous tube, called the alimentary canal, which extends from the mouth to the anus. It passes from the pharynx above to the stomach below. Owing to the softness of its walls, it does not remain open when there is no food passing down. Lining the tube is mucous membrane, which is thrown into folds and contains some small glands. Outside the mucous membrane is a double muscular coat, the fibres of the inner part running in a circular direction round the oesophagus; while in the outer layer the fibres run in a longitudinal direction. The oesophagus plays practically no part in the actual work of digestion.

The Stomach may be described as a somewhat irregular dilation of the alimentary canal. It is situated in the abdomen, just below the diaphragm. It measures about ten inches from left to right. The enlargement is greatest on the left or **cardiac** end of the stomach. On the right the **pyloric** end of the stomach becomes continuous with the first part of the small intestine (the duodenum). The upper border of the stomach is concave, and is sometimes called the **lesser curvature**, in comparison with the lower convex border, which is called the **greater curvature.**

The stomach is lined with mucous membrane, which is quite smooth when the stomach is full, but becomes

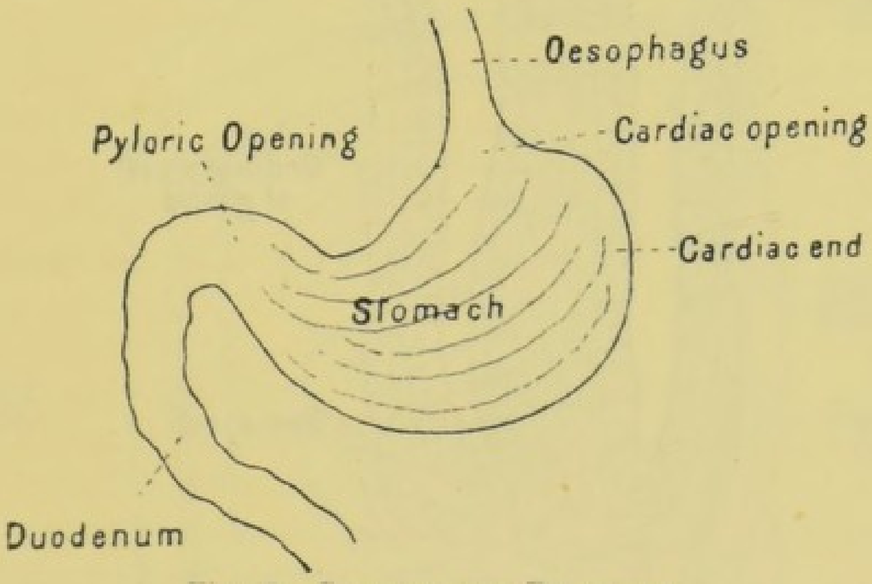


Fig. 63.—Stomach and Duodenum.

thrown into ridges and folds as the stomach gets empty and contracts. This mucous membrane is almost entirely made up of minute simple blind tubes running at right angles to its surface. These are called **tubular glands**. They are lined with cubical cells, amongst which are a few round or ovoid cells in the cardiac region of the stomach. Between the tubules is connective tissue containing blood-vessels and lymphatics. The presence of food in the stomach causes the blood-vessels to dilate and to bring extra blood to the stomach. Then the cells in the tubular glands at once secrete a colourless liquid called the **gastric juice**, which is poured out into the stomach and mixes with the food.

Outside the mucous coat of the stomach is the muscular coat, which is divided into three layers according to the direction in which the muscular fibres run. In the inner layer the fibres run obliquely, in the middle layer they run circularly, and in the outer layer longitudinally. At the pylorus there are a greater number of circular muscular fibres than anywhere else, and here they form a sphincter muscle which prevents the food passing from the stomach until it has been properly churned up with the gastric juice.

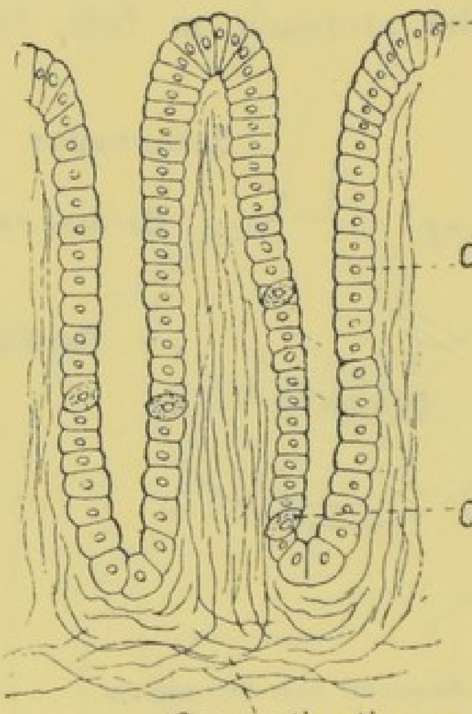


Fig. 64.—Tubular Glands of Stomach. (Very highly magnified.)

The outer layer of the stomach is the covering which is common to all the organs of the abdomen. It consists of a smooth glistening membrane, called **peritoneum**.

Gastric Juice is the liquid secreted by the glands of the stomach. It is a clear, colourless, acid liquid, containing water, salt, hydrochloric acid (0·2 per cent.), and an unorganised ferment called **pepsin**. The pepsin and the hydrochloric acid together act on the food and convert the protein part of it into **peptones**. Some absorption of digested food takes place in the stomach.

The Small Intestine commences at the pyloric opening of the stomach, and ends at the ileocaecal valve, which is situated in the lower right hand corner of the abdomen. The greater part of the small intestine is coiled up in the centre of the abdomen. When uncoiled it measures about 21 feet. It is usual to divide it into three portions, the duodenum, the jejunum, and the ileum, but there is no

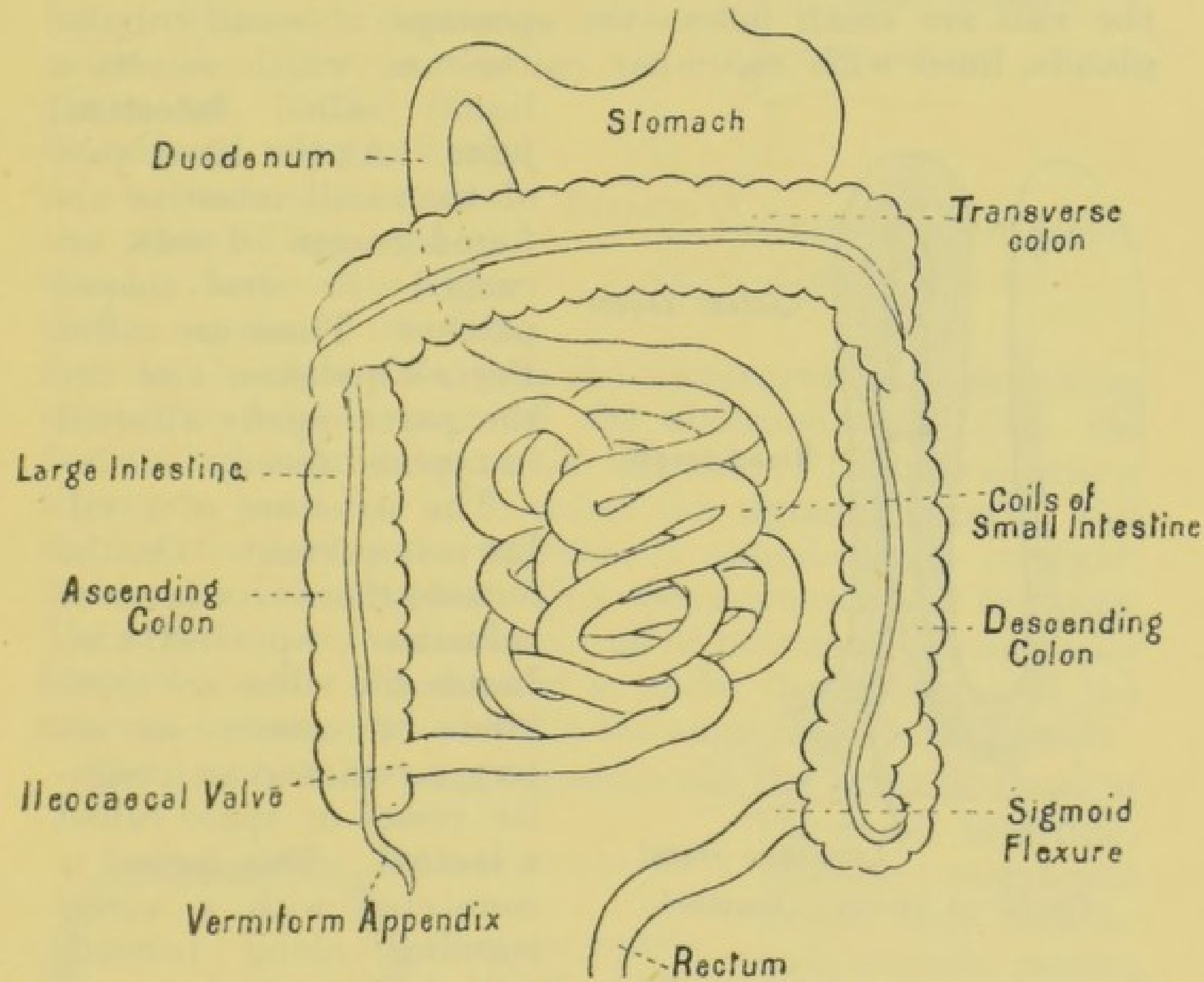


Fig. 65.—Small and Large Intestine.

need to do this in an elementary text-book. The walls are made up of three coats arranged in just the same order as those of the stomach. Inside we have a mucous coat, next a muscular coat in two layers, and outside this the peritoneum. The mucous coat of the small intestine is thrown into large folds, some of them being a quarter of an inch in depth. These folds differ from the folds of mucous membrane in the stomach by *not* disappearing when the intestine is filled with food. By means of these folds—called **valvulae conniventes**—the area of surface of the mucous membrane is very greatly increased.

If a piece of small intestine is opened, put into water, and the inner surface examined with a magnifying glass, it will be seen to be covered with a great number of tiny projections like the fingers of a glove, which give the surface a velvety appearance. These projections are called **villi**. Between the villi are small holes—the openings of small tubular glands, lined with columnar epithelium, which secrete a liquid called **intestinal juice**. At the lower part of the small intestine are found groups of cells arranged in oval-shaped patches. These are called Peyer's patches, and are the parts chiefly affected in typhoid fever.

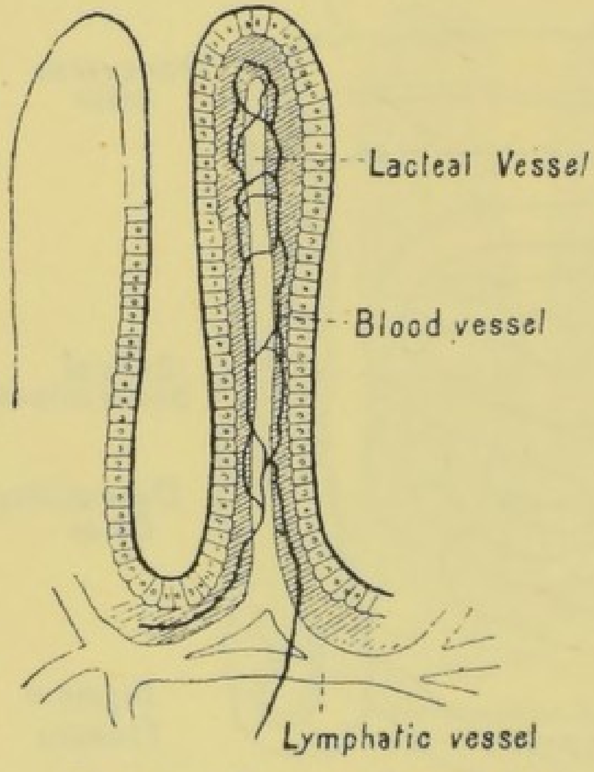


Fig. 66.—A Villus. (Magnified.)

The structure of a **villus** is important. On the outside there is a layer of columnar epithelium. Inside the villus are three kinds of vessels—an artery, a vein, and an irregular vessel or space called a **lacteal**. This lacteal is connected with a vessel running along beneath the mucous membrane. This is called a lymphatic vessel, and is filled with a fluid called lymph. These villi, we shall see, play a very important part in the process of digestion.

The chief function of the small intestine is the absorption of digested foods. This is carried out by the villi. The intestinal juice is not important for digestive purposes.

The Ileocaecal Valve is situated at the part where the small intestine enters the large intestine. It consists of a double fold of mucous membrane which is so arranged that it allows food to pass freely from the small to the large intestine, but not in the reverse direction.

The Large Intestine is about six feet in length. The part below the ileocaecal valve is called the **caecum**, and from this a narrow worm-like process is given off, called the **vermiform appendix**. Above the caecum comes the **ascending colon** which reaches to the under surface of the liver on the right side, then the **transverse colon** stretching across the upper part of the abdomen, and then the **descending colon** down to the left side of the pelvis, where there is a bend like an S called the **sigmoid flexure**. For the last few inches the intestine is comparatively straight, and is called the **rectum**. This opens externally at the **anus**. The anus is surrounded by a ring of muscle which normally keeps it closed. The muscle is under the influence of the nervous system, and controls the emptying of the bowels.

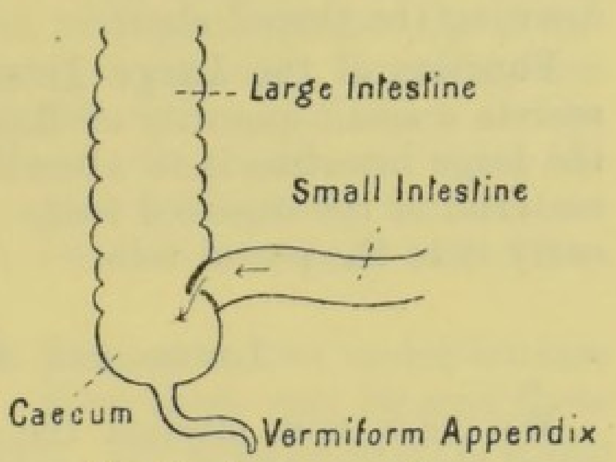


Fig. 67.—Ileocaecal Valve.

The coats of the large intestine are the same as those of the small intestine: mucous membrane inside, then muscle, and outside peritoneum. The mucous membrane is quite smooth and has no villi, but it contains a large number of tubular glands which secrete mucus and intestinal juice. The muscular coat is peculiar because the longitudinal muscular fibres are gathered up into three bands, arranged symmetrically round the intes-

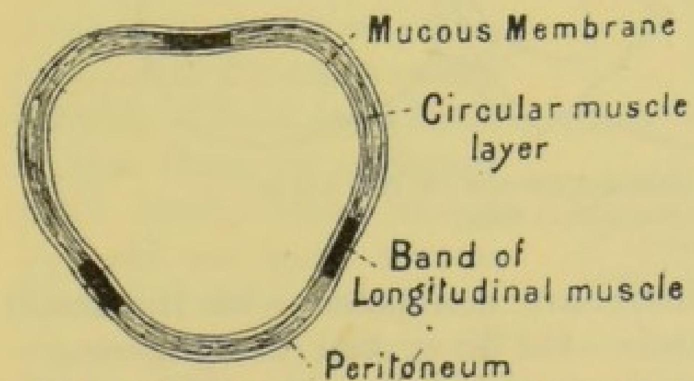


Fig. 68.—Cross Section of Large Intestine.

tine. These bands are rather shorter than the rest of the wall, and so they produce the characteristic puckering of the walls of the large intestine—just as a piece of cloth may be puckered up by running a thread along it and drawing the thread short.

Function of the Large Intestine. The tubular glands secrete a small quantity of fluid, but the chief function of the large intestine is to absorb what is left of the useful material of the digested food. The veins receive this and carry it to the portal vein.

Liver and Pancreas.

We have now studied the structure of the long tube which connects the mouth and the anus, and we have seen that in its walls are various glands which have a digestive action on the food. These glands alone, however, would be insufficient to carry on the digestive process in the best

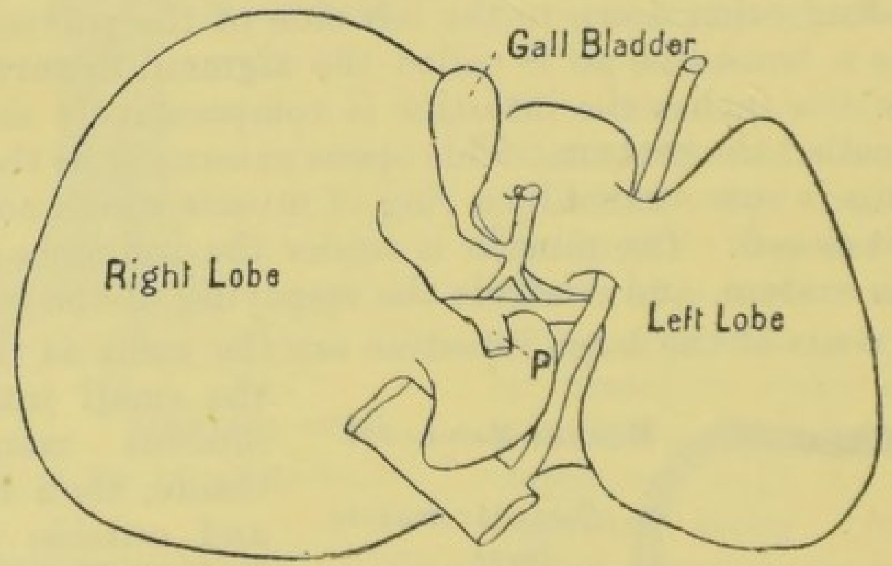


Fig. 69.—The Under Surface of the Liver.
P = Portal Vein.

possible way, and so there are connected with the small intestine two large glands—the liver and the pancreas—which secrete two very important liquids—the bile and the pancreatic juice. These two liquids are poured together into the small intestine near its commencement, and therefore are able to act upon the food as it passes from that point to the end of the alimentary canal.

The **Liver** is placed immediately under the diaphragm, and its upper surface is convex, so as to fit the concave under side of the arch. It is the largest gland in the body, weighing about 50 ounces. It is usually dark red and fleshy looking, and is covered with peritoneum—the covering common to all the abdominal organs. Running from front to back on its under surface is a cleft, which divides the liver into two unequal lobes—the right one being the larger. The right lobe is again indistinctly marked out into 3 lobes, and the left is divided into 2, so that there are 5 lobes altogether.

The most distinct of the fissures on the under surface is called the portal fissure. Here there may be seen three large vessels entering the liver: the **hepatic artery**, which brings blood to the liver from the aorta; the **portal vein**, which brings venous blood from the stomach, intestines, spleen, and pancreas; and the **bile duct**, which carries off the bile from the liver to the duodenum or first part of the small intestine. From the posterior edge of the liver there emerges a large vein called the hepatic vein.

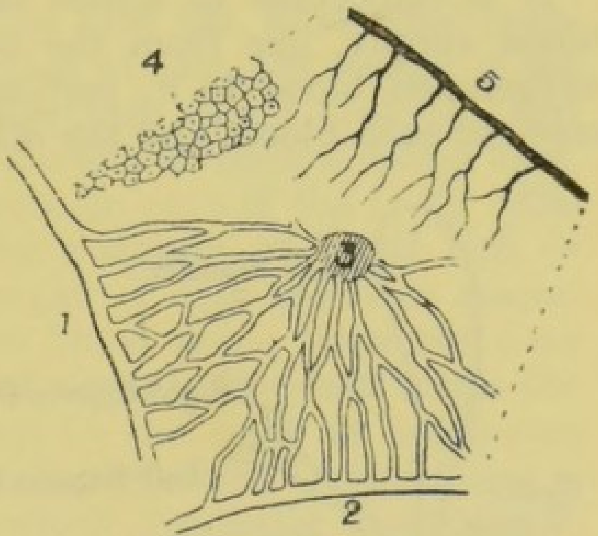


Fig. 70.—Diagrammatic Representation of Lobule of Liver.

1, Branch of Hepatic Artery; 2, Branch of Portal Vein (Interlobular Vein); 3, Branch of Hepatic Vein (Intralobular Vein); 4, Liver Cells (which make up the substance of the Lobule); 5, Branch of Bile Duct.

The substance of the liver is made up of small many-sided masses called **lobules**. These are a little bigger than an ordinary pin's head, being about $\frac{1}{10}$th of an inch across. Each lobule is composed of a great number of **liver cells**, each of which is about $\frac{1}{1000}$th of an inch in diameter. Between the cells are very fine capillary vessels, which are the beginnings of small bile ducts. These vessels carry away the bile, which is secreted by the cells.

The three vessels that enter at the portal fissure—the hepatic artery, the portal vein, and the bile duct—are found to divide and subdivide together, and finally there are the very small branches of them running together round each lobule. These small branches of the portal vein that pass between the lobules are called **interlobular veins.** These veins and the small branches of the hepatic artery both give off tiny capillaries which pass between the liver cells and run towards the centre of the lobule. Before they reach the centre, the capillaries from the vein and the artery join together, so there is now no distinction between the two. The blood from both sources is finally collected into a vein which passes through the centre of the lobule—an **intralobular vein.** This intralobular vein unites with other veins from neighbouring lobules and forms a larger vein ; these again unite with similar veins, and so on until we get finally one large vein—the **hepatic vein**—taking the blood from the liver to the inferior vena cava.

It is important to notice that the liver has a double blood supply, one from the hepatic artery which brings oxygenated blood to it, just as every organ in the body receives such blood, and the other supply from the portal vein which brings blood rich in food, so that the liver may perform its function before the food passes into the general blood stream.

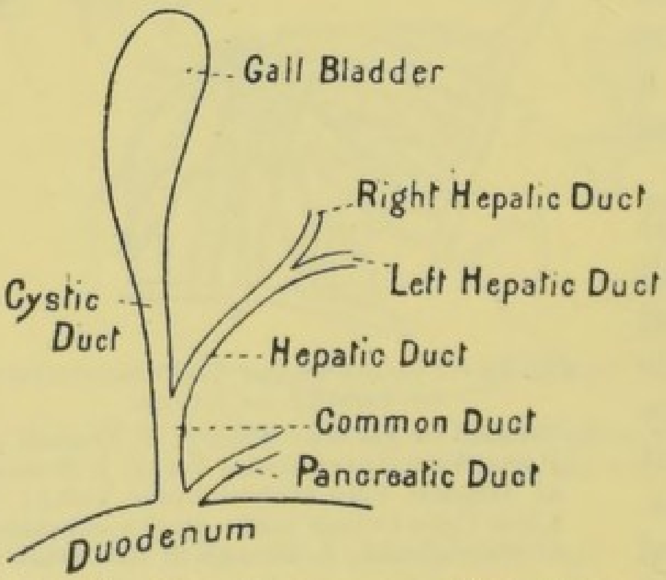


Fig. 71.—Gall Bladder and Bile Ducts.

Bile Ducts and Gall Bladder. The fine bile ducts between the liver cells pour the bile into the larger vessels that pass between the lobules. These unite together and form larger ducts again and again, there being finally one large bile duct coming from the right lobe and one from the left lobe. The right and left ducts join together and form one duct. This duct passes into the duodenum, but on its way it gives off a side tube leading to the gall bladder, which serves as a reservoir into which the bile may flow when it is not required in the intestine. The gall bladder is placed on the under-surface of the liver, in front. When there is no food in the intestine the bile flows along the side duct into the gall bladder, but on food entering the small intestine the accumulated bile is discharged amongst it.

The bile is a yellow liquid containing water, mucus, and salts. Among these salts are those which are found in the blood, and, in addition, peculiar salts of sodium called **bile salts**. There is also colouring matter or pigments, and a peculiar fatty substance called cholesterin. The bile acts upon the fat in the food in the intestine and emulsifies it, or breaks it up into very tiny particles. It also is an antiseptic and a stimulant to the bowels.

Functions of the Liver. The liver has three chief functions. The first is the secretion of bile, the second is the storing up of a starch-like substance called glycogen, and the third is the formation of a waste substance called urea, which is produced from the protein part of the food. The portal vein brings to the liver a stream of blood rich in food materials. From the sugar of this the liver manufactures glycogen, so that the blood going from the liver does not contain any excess of sugar. Between meals the sugar in the blood is used up by the body in producing energy and heat, but the amount of sugar in the blood is kept constant by the liver, which gradually changes the glycogen back into sugar as the demand arises. The liver has the power of making glycogen from proteins, but it does so slowly, and probably under difficulties.

The Pancreas, or sweetbread, is situated in the bend of the duodenum on the right, and stretches across to the spleen on the left. It is about seven inches long, and is of a reddish-yellow colour. In structure it resembles a salivary gland, being composed of a number of lobules loosely bound together by connective tissue. The duct of the pancreas enters the duodenum at the same point as the bile duct. It passes obliquely through the wall so as to form a valve to allow the pancreatic juice to pass into the intestine, but not back again. If the duct is traced backwards, it divides and subdivides until it becomes microscopically small. Each small duct ends in a tubular enlargement

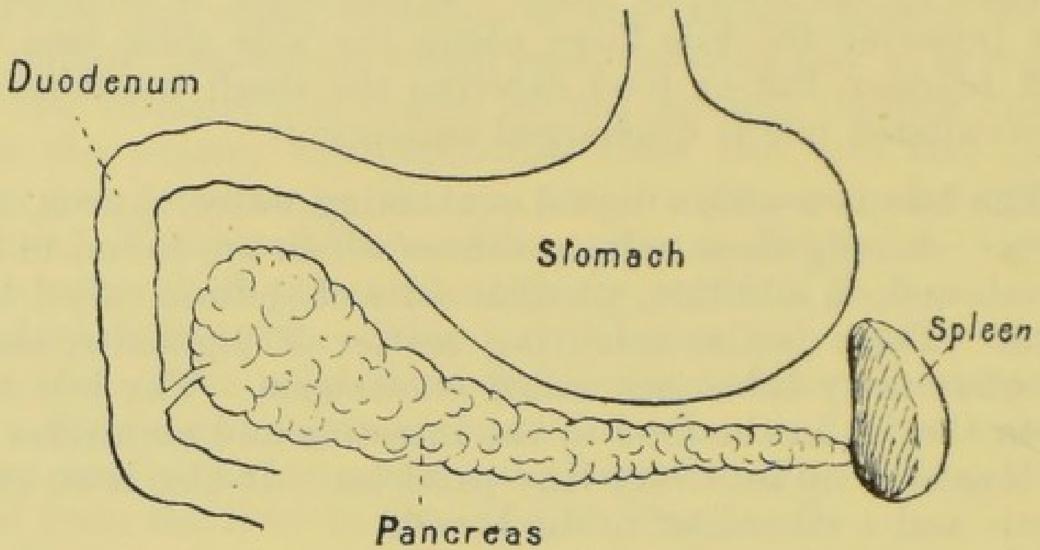


Fig. 72.—The Pancreas.

called an **alveolus**, which is lined with columnar epithelium. These cells lining the alveolus produce the pancreatic juice.

Pancreatic juice is a colourless liquid composed of water, salts—chiefly sodium carbonate—and ferments. The carbonate of sodium causes the pancreatic juice to emulsify

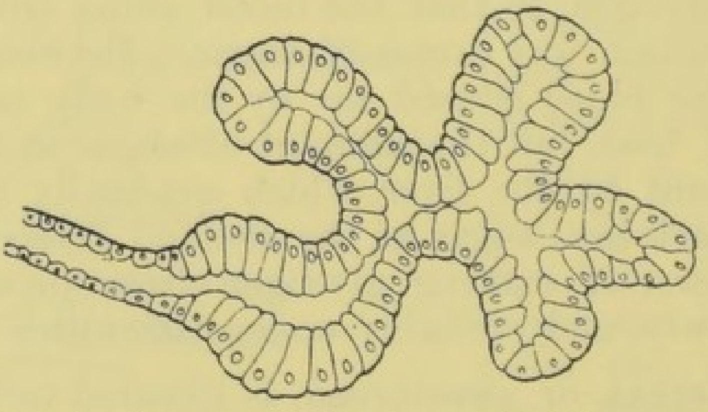


Fig. 73.—An Alveolus of Pancreas. (Highly magnified.)

fats. The ferments present enable the pancreatic juice to act upon all kinds of food. The proteins are turned into peptones; the starch is changed into sugar; and the fat is, to a small extent, decomposed into a fatty acid and glycerine.

Practical Work.

I. Mucous Membrane.

Scrape a little of the mucus from the inside of the cheek and spread it on a microscope slide and examine under the high power of the microscope. Note the numerous flat cells.

II. Stomach.

(*a*) A pig's stomach can be obtained from a pork butcher. Notice the glistening peritoneum on the outside. Open it with scissors and observe the folds into which the lining is thrown.

(*b*) Scrape off the lining membrane, cut it up finely, and cover it in a dish with a weak solution of hydrochloric acid (2 parts in 1000), cover over, and leave in a warm cupboard for 12 to 24 hours. Pour off the liquid into a bottle, and use it for the digestion experiments described at the end of the next chapter. This is an artificial gastric juice.

III. Pancreas.

A pig's pancreas can also be obtained from a pork butcher. Examine its structure. Cut it up finely and cover it in a dish with a weak solution (1 in 100) of carbonate of soda. Keep in a warm cupboard for 6 to 12 hours, strain off the liquid, bottle it, and use it for the digestion experiments at the end of the next chapter. It is an artificial pancreatic juice.

IV. Liver.

(*a*) Examine the surface of a piece of liver obtained from the butcher. Note its dark red colour and mottling with little patches measuring about $\frac{1}{20}$ inch across. These are the liver lobules.

(*b*) Cut across the liver and notice the gaping blood-vessels—branches of the hepatic vein.

(*c*) Remove the liver of a rabbit immediately after death. Cut it into pieces and throw these into a beaker full of boiling water acidified with a little vinegar. After boiling a few moments remove the liver to a mortar, smash it up with the pestle, and transfer it again to the boiling water. The liquid has now become milky. Filter it, and notice the milky opalescent appearance of the filtrate. This is a solution of glycogen. Allow to cool, and add a few drops of iodine. A port-wine colour is produced.

(*d*) Treat a piece of liver from the butcher in the same way. In this case a clear filtrate is obtained which gives no result with iodine solution, showing that no glycogen is present. After death the glycogen in the liver cells has been changed into dextrose. Prove this by adding to a portion of the filtrate some Fehling's solution and obtain the characteristic red precipitate.

(*e*) Obtain some bile from the butcher. Note its colour and appearance. Place a little in a porcelain basin and add a few drops of strong nitric acid. A rapid play of colours is produced—the characteristic test for bile colouring matter.

To another portion in a test-tube add a little cane sugar and sulphuric acid, and warm. A fine purple colour is produced—the test for bile salts.

Shake up the bile with twice its bulk of water. Then add a few drops of oil and shake again. The oil has disappeared, being broken up (emulsified) into fine droplets by the bile.

V. Small Intestine.

Open the small intestine of a rabbit. Note the mucous membrane thrown into folds which ran round the inside of the intestine (valvulae conniventes). Notice also the smooth velvety feel of the mucous membrane, like the pile of velvet, and observe the tiny projections (villi).

CHAPTER VII.

DIGESTION AND DISPOSAL OF FOOD.

We have seen that the food may be divided up into water, salts, proteins, fats, carbohydrates and vegetable acids, and it now remains for us to trace each constituent in its journey through the alimentary canal, the blood stream, the tissues and the excretory organs. The water that we drink is probably absorbed into the blood-vessels all along the alimentary canal, beginning with the stomach. The salts accompany the water into the blood stream and are used up, in growing children, to manufacture bone and other tissues requiring salts. Part goes, as we have seen, in producing the hydrochloric acid of the gastric juice, the iron of the haemoglobin, etc. Eventually the salts are excreted by the body, some in their original form, but others with an altered composition. The salts are got rid of in the sweat, the urine and the excreta from the intestine. The water is got rid of through the same channels and in addition a large quantity is excreted with the breath.

The solid part of the food is broken up by the teeth, and at the same time is mixed with the saliva. The ptyalin in the saliva slowly converts the starch into grape sugar. At the same time the sugar and the salts present dissolve in the saliva. As the time during which the food remains in the mouth is somewhat limited, it is obvious that this conversion of starch into sugar is necessarily only on a small scale.

The food is then swallowed, and reaches the stomach. Here it is quickly mixed with the gastric juice which, being acid, puts an end to the action of the saliva, because ptyalin is destroyed by acids. The pepsin in the gastric juice, together with the hydrochloric acid which accompanies it, converts the proteins into peptones. Peptones differ from other proteins in being very soluble and are, moreover, **diffusible**, that is, they are able to pass through a membrane from a solution rich in them to a solution poor in them. These peptones rapidly pass through the lining membrane of the stomach and are absorbed into the blood-vessels which lie beneath the mucous membrane.

The muscular coats of the stomach contract, first in one part and then in another, and so move the food about and churn it up thoroughly with the gastric juice. This churning goes on until the whole of the contents of the stomach is brought to a semi-fluid consistency. The turbid fluid that thus results is called **chyme**. The gastric juice has no action on carbohydrates or on fats, but it assists the digestion of these bodies by dissolving away the proteins amongst which they lie. It also dissolves the protein walls of the fat cells, while the warmth of the stomach melts the fat.

After a variable time—usually between three and four hours—the chyme passes through the pylorus into the duodenum, or first part of the small intestine. Here it is acted upon by two important liquids—the bile and the pancreatic juice. The first effect of these liquids is to make the acid chyme alkaline. This stops any further action of the pepsin. The pancreatic juice then converts any starch that may be present into malt-sugar. Any proteins that have escaped the action of the gastric juice are also attacked by the pancreatic juice and converted into peptones. The peptones and the sugar pass directly into the blood-vessels which lie in the villi. The bile has no action on proteins or starches.

Both the bile and the pancreatic juice act upon fats. They mainly produce what is called emulsification. This simply consists in breaking up the fat into very tiny globules, which remain suspended in the liquid and do not run together again. If oil is shaken up briskly with water it is broken up into small globules, but these run together again on standing. By first adding a little carbonate of soda to the water, and then shaking up with oil, a much more permanent effect is produced, and this milky fluid may be allowed to stand for some time without any of the oil running together again. The emulsification of fats by the bile and the pancreatic juice is greatly aided by the chemical change that the pancreatic juice causes fats to undergo. It acts upon a very small portion of the fat, and changes it into glycerine and a fatty acid. The fatty acid unites with the alkaline salts of sodium that are present and forms a soap, which greatly increases the power of the pancreatic juice to emulsify fats.

Unlike the sugars and the peptones, the emulsified fat is unable to pass direct into the blood-vessels which lie below the mucous membrane of the villi. It can, however, pass through the epithelium covering the villi, and makes its way into the irregular vessel which occupies the centre of each villus—the **lacteal vessel**. Shortly after a meal, therefore, the lacteals will be filled with a milky fluid which contains fine globules of fat. This milky fluid is called **chyle**. The chyle passes from the lacteal vessels into the lymphatic vessels, which finally pass it into the blood stream.

The food in the small intestine is moved along by a peculiar movement called **peristaltic contraction**. The circular fibres of the intestinal wall at any place contract, thereby decreasing the capacity of the intestine there, and so squeezing out the greater part of the contents at that point. This contraction is next taken up by the fibres adjoining these, and then by their neighbours, and so on, the contraction passing along the intestine like a wave, and always towards the large intestine.

By the time the food reaches the end of the small intestine it is semifluid, and has very little serviceable material left in it. It passes through the ileocaecal valve into the large intestine. Here the remains of the useful material are absorbed, together with the greater part of the water, into the blood-vessels which lie below the mucous membrane. These convey the food to the portal vein. As the contents are passed along they become more and more solid, until the remainder, which is chiefly the indigestible part of the food, is discharged from the rectum as faeces.

It is sometimes useful to consider the process of digestion from another standpoint, namely by considering each chief food-stuff separately. Starch is acted upon in the mouth by the saliva, and is converted into sugar; the same change of starch into sugar is also carried on by the pancreatic juice in the small intestine. Proteins are changed into peptones by the gastric juice in the stomach, and by the pancreatic juice in the small intestine. Fats are emulsified in the small intestine by the pancreatic juice and the bile.

After it is digested, the food reaches the blood. In the case of sugar and peptones the passage seems to be direct from the alimentary canal to the blood-vessel, but the emulsified fats pass first into the lymphatic vessels and then into the blood-vessels. The blood brings all these foods to the various tissues of the body. Eventually all the food becomes changed into carbon dioxide, water, and urea, but this change may either be brought about very quickly or may be postponed for a long time by the food being converted into the tissues of the body.

The net result of the above digestive processes is that in the case of children there is a gradual gain in weight, while in the case of adults the weight remains practically stationary. If a child is weighed at intervals the weight is found to increase, although between meals there is a loss. If an adult is weighed at short intervals it is found that there is a continuous loss of weight between meals and, of course, a sudden gain immediately after a meal. The net result in twenty-four hours is that the weight is the same, or in other words the gain and the loss are equal. If no food is taken there is a continuous loss of weight.

The total loss from the adult body is about 8 lb. daily. This is made up as follows:—

Loss from kidneys	55 ounces urine.
Loss from lungs	35 ounces carbon dioxide and water.
Loss from skin	25 ounces sweat.
Loss from bowel	5 ounces faeces.
	120 ounces

About 90 ounces of this loss is water.

PRACTICAL WORK.

I. The Action of Saliva.

(*a*) Mix a small quantity of starch with water, and boil it. Add water, if necessary, to make it rather thin. Let it cool, and then add to a small portion of the liquid a few drops of iodine solution. A blue colour is produced. This is the test for starch.

(*b*) To the remainder of the solution of starch add a little of your own saliva, and keep the liquid at about the body temperature for half an hour. The liquid becomes thinner and more watery. Pour a small quantity into a test-tube and add iodine solution again. This time there is no blue colour formed, showing that the starch has disappeared.

(*c*) Taste the liquid formed by the action of the saliva on the starch. The sweetness tells you that the starch has been turned into sugar. To test for sugar, add a little Fehling's solution and boil. A red precipitate is produced.

II. Action of Gastric Juice.

(*a*) Make a solution of white of egg in water. Add to it one drop of copper sulphate solution and some solution of potassium hydrate. A violet colour is produced, which is a characteristic reaction for albumin and globulin.

(*b*) Use another portion of the solution of white of egg and add to it some of the artificial gastric juice prepared from the pig's stomach. Keep the test-tube at about the same temperature as the body for half an hour. Then add one drop of copper sulphate and some potassium hydrate solution. This time a rose-coloured liquid is produced, showing that a peptone is present.

(*c*) Into another part of the prepared gastric juice put a few fragments of hard-boiled white of egg and keep the tube at about the body temperature. In less than an hour the white of egg will probably have disappeared. It has been changed into peptone, which may be identified as in (*b*).

(*d*) Add some gastric juice to some starch solution, and to a little oil, and show that no effect is produced upon these substances.

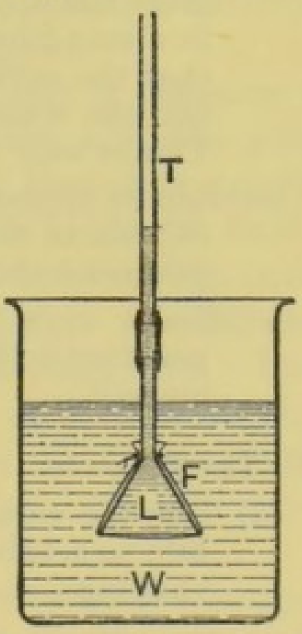


Fig. 74.—APPARATUS TO TEST DIFFUSION OF A LIQUID THROUGH A MEMBRANE.

(*e*) Fit up the apparatus shown in Fig. 74, *F* being a funnel inverted and with a piece of parchment paper tied securely across the mouth of the funnel. This is filled with the liquid to be tested, and is immersed in a beaker of water for three hours. In the first test use a solution of white of egg and show that no diffusion of the albumin through the parchment takes place. In the second test a solution of peptone is used and the water in the beaker, if tested after three hours, is found to contain peptone.

(*f*) To some milk warmed to about the body temperature add some rennet (obtained from the calf's stomach). In a short time the milk clots and forms a junket, which is a pleasant and nutritious food. The rennin ferment in the stomach causes the clotting of all the milk that is swallowed.

III. **Action of Pancreatic Juice.**

Use different portions of the prepared pancreatic juice for the following experiments :—

(*a*) Show that it is capable of turning starch into sugar.

(*b*) Repeat experiment II. (*b*) above, using pancreatic juice instead of gastric juice, and show that it converts proteins into peptones.

(*c*) Similarly repeat II. (*c*) above.

IV. **Emulsification of Fats.**

(*a*) Pour a few drops of linseed oil into a test-tube, and add a little water (about one inch deep). Place your thumb over the end of the test-tube, and shake the contents vigorously. Note the appearance of the mixture, and put the test-tube in a stand for a quarter of an hour. It will then be noticed that the milky appearance has disappeared, and that the oil and the water have separated again into two distinct layers. This is only temporary emulsification.

(*b*) Repeat experiment (*a*), but this time add a pinch of carbonate of soda to the water before shaking up. The emulsification produced this time is of a much more permanent character.

(*c*) Shake up a few drops of oil with a little of the prepared pancreatic juice. An emulsion is formed which is fairly permanent.

V. **The Bile.**

(*a*) Test the emulsifying action of bile by adding a little fresh bile to a tube containing water and a few drops of oil, and shaking.

CHAPTER VIII.

DIETS. EXAMPLES OF FOODS.

A DIET consisting of carbohydrates, water and salts would support life for a short time only. Practically no advantage would be gained by substituting fats for carbohydrates. On the other hand, a diet of proteins, salts and water would support life for a much longer period, but even in this case the actual duration of life on such a diet would be short. If we take a protein and a non-nitrogenous principle together in the diet, an enormous advantage is gained, especially if the two are present in the necessary proportions. For the very best forms of diet, the three great classes of foods must be all represented, namely proteins, carbohydrates and fats, and even then a variety in the form of protein chosen is very beneficial.

Obviously the actual quantity of food that is necessary will vary greatly according to the climate, the age, the sex, and the amount and nature of the work that has to be done. For example, a larger amount of all kinds of food, but more especially heat-producing food, is required in cold climates and for laborious occupations. Also women are said to generally need one-tenth less food than men; but if such is really the case, it is probably only due to the fact that their work is of a much lighter character than men's work. The proper food for children will be discussed at the end of the chapter.

It is found that the average individual loses by the lungs, kidneys, skin and bowels about 300 grains of nitrogen and 4800 grains of carbon in twenty-four hours. This loss must be made good by means of the food supplied. If too much nitrogen or too much carbon is supplied we say that the diet is **wasteful** or **unbalanced**. The above quantities of carbon and nitrogen are supplied in a diet of the following composition:—

	Ounces.	Grains of Nitrogen.	Grains of Carbon.
Proteins	$4\frac{1}{2}$	310	1040
Fats	3	0	1040
Carbohydrates	14	0	2720
Salts	1	0	0
Total	$22\frac{1}{2}$	310	4800

If a man attempted to live on meat alone he would have to eat 75 ounces of meat to get 4800 grains of carbon, while 29 ounces would be sufficient to supply 300 grains of nitrogen. This is an example of an unbalanced diet. Similarly if we had to live on bread alone we should require 54 ounces to supply the necessary nitrogen, but only 40 ounces would supply the 4800 grains of carbon. There would obviously be a great waste in a diet of this kind, but by having mixed foods it is possible to have an economical diet, without any waste at all. For instance, 11 ounces of meat and 34 ounces of bread would supply the required carbon and nitrogen without any excess or deficiency of either.

Meals. The method of taking food is of very great importance. All food should be chewed thoroughly and slowly before it is swallowed. The habit of reading and studying during meals should be discouraged in favour of bright conversation, but the reading of light literature during a solitary meal is probably beneficial. Large quantities of fluids should be avoided at meals, as they dilute the gastric juice, and prevent or retard its action on the food. A short rest after meals, before resuming work, undoubtedly aids digestion.

With regard to the **times for meals**, the chief points that deserve attention are regularity and the observance of a proper interval between successive meals. Very long intervals are undoubtedly injurious, but the other extreme is harmful and is far more common, especially among women. It is found that an ordinary meal remains in the stomach for about four hours, and is then passed on.

This interval should therefore be the minimum one between any two successive meals. Three meals are often sufficient, and more than four per day should never be taken. The best times for most people are breakfast at eight o'clock, dinner at one or two o'clock, and tea at five or six o'clock. If supper is taken, tea should be rather a light meal, but if tea is the last meal of the day it should be substantial. With regard to supper, it is difficult to make a hard and fast rule. Some people sleep well after a good supper, while others would be certain to be kept awake by indigestion if they retired to rest soon after a meal. Personal peculiarity has to be respected in these matters. Many people find that supper about ten o'clock and bed about eleven is a convenient rule to follow.

Examples of Food.

Milk is a liquid consisting of emulsified fat, water, proteins, salts and carbohydrates, and having a specific gravity of 1032 (water being 1000). The proteins are mainly casein and a little albumin; the carbohydrate chiefly present is lactose or milk sugar. The salts include phosphates of calcium, potassium and magnesium. It is obviously a perfect food because it is the sole nourishment provided for the young of the higher animals; and, moreover, it will maintain adults in perfect health for an indefinite length of time. With regard to its composition, it is important to notice that it contains representatives of the four great food classes—proteins, fats, carbohydrates and salts, as well as water. The average composition of cow's milk is given below, and for the sake of comparison the composition of human milk is given at the same time.

Milk.	Water.	Sugar.	Proteins.	Fats.	Salts.
Cow's	87	4·5	4	3·8	·7
Human	87	6·5	2·2	4	·3

Human milk contains more sugar than cow's milk, but less proteins and salts—hence the general rule of diluting cow's milk and adding a little sugar when preparing food for infants.

When milk is allowed to stand, about 10 per cent. of its volume of cream should rise to the top. The cream consists of the greater part of the fat, together with a small amount of the other constituents. The liquid left after skimming the milk is called skimmed milk, and contains casein, milk sugar, and salts; it forms an excellent drink for children. "Separated milk" is similar to skim milk, being the residue left after cream has been removed by centrifugal force. It is less nutritious than skim milk, because the fat has been more completely removed. By adding rennet or very weak acid to milk it is separated into a solid called the curd, and a clear liquid called whey. The solid consists of coagulated casein with the fat and some of the sugar and salts. The whey contains lactose and salts.

When milk is boiled, the albumin is coagulated, and other rather obscure changes are produced, which cause the milk to possess an altered flavour. The coagulated albumin collects on the top as a kind of skin. The most important effect of boiling milk is the destruction of all kinds of disease germs and ferments that the milk may contain. For this reason milk should always be boiled before being used. Milk may be preserved by boiling, and then corking up tightly in a bottle, after adding a little sugar; or by adding a few grains of sugar and bicarbonate of soda to each pint.

Goat's milk is a valuable food for children, and these animals should be kept more commonly.

Diseases connected with Milk.

It is a well-known fact that if milk is allowed to stand for some time it turns sour and coagulates. Sour milk is liable to cause sickness and diarrhœa in children, and under some conditions the parasitic disease of the mouth known as "thrush" has been caused by this.

It is possible that certain diseases from which the cow suffers may be transmitted through the milk; instances of scarlet fever, diphtheria, and foot and mouth disease have been recorded. Milk containing the germs of tubercle or consumption may give rise to tuberculosis in children.

Milk, however, more frequently acts as a carrier of infection from other human beings, and owing to the present lax system of dairy inspection it is advisable to avoid risk by actually boiling the milk for three or four minutes. In addition to the danger mentioned above of disease being transmitted from the cow through the milk, there is always the possibility of

(1) Accidental contamination from an outside source, such as may happen when scarlet fever or diphtheria occurs at the dairy or farm, or at the house of one of the workpeople.

(2) The washing of the milk cans or other vessels with water which has become contaminated in some way (as from sewage percolating into a well), and germs of cholera or typhoid fever thereby entering the milk.

(3) Or in some cases milk may be adulterated with such water.

In those epidemics of scarlet fever which have been traced to milk, it is usually found that the milk has been infected through human agency by a previous case of the disease at the farm or dairy.

A milk epidemic is characterised by the suddenness with which it makes its appearance, the sufferers being usually attacked about the same time, and the houses affected being as a rule those which have received milk from the same source. Owing to the ease with which milk transmits diseases, the greatest possible cleanliness should be observed in collecting, storing, and distributing milk. Milk should be thoroughly cooled after being obtained from the cow before being sent out. Special attention should be paid to dairy inspection.

It has also been proved that the milk from cows suffering from tuberculosis can convey that disease to animals and also to human beings.

Eggs. As the chick is developed from the egg it is obvious that the egg must contain everything that is required for the construction of the body; but it is not such a perfect food as milk, because an egg is deficient in salts. A hen's egg consists of 70 per cent. of water and 30 per cent. solid matter. Of the solids, the white is mainly albumin; the yolk contains fat, albumin and phosphates. Eggs form a very valuable article of diet, being rich in proteins and fat. They should never be over-cooked, because a hard-boiled egg is particularly indigestible. *To preserve eggs* they should be coated over completely with oil, wax, lard or such like while they are fresh, or they may be immersed in a solution of "waterglass." A stale egg is easily detected by testing whether it will float or not in a solution of two ounces of common salt in a pint of water. A fresh egg sinks in this liquid.

Cheese is a food rich in nitrogenous matter. It consists of coagulated casein, with varying quantities of fat and salts. If fat and ripe it is easily digested and forms an excellent food. Those cheeses which are prepared from skim milk—Dutch cheese for example—are more indigestible and less nutritious. In the preparation of cheese, the casein is usually coagulated by means of rennet, which may be obtained from the stomach of the calf.

Butter is almost pure fat. It is obtained by churning the cream that has been skimmed from the milk, or the pure milk itself. The liquid left behind is called buttermilk, and still contains enough of the original constituents of the milk to make it a good food, especially if eaten with some starchy substance such as potatoes.

Margarine was originally prepared mainly from beef-fat, flavoured and coloured to resemble butter. It is now commonly made from vegetable oils. It is an excellent food, and usually much cheaper than butter.

Meat. Fish. Poultry.

All these are examples of nitrogenous foods, containing variable quantities of fats and salts, but practically no carbohydrates. As a general rule these foods are more easily digested than those of vegetable origin.

Beef is more nutritious than mutton or pork, and at the same time it contains a less proportion of fat. The best beef is that which is obtained from a young ox. Veal is far less digestible than beef, and is also less nutritious.

Mutton has a shorter fibre and is usually more easily digested than beef. The mutton from a three-year old sheep is the best. Lamb is more watery and less digestible than mutton.

Pork is often difficult to digest owing to the large quantity of fat that is present. The muscle fibres are hard and are surrounded with fat. It should be more thoroughly cooked than the other meats, owing to the frequency with which the pig suffers from parasitic worms. **Bacon** is much more digestible than pork, and is one of the best of the foods containing an excess of fat.

In choosing meat see that the muscle is firm and elastic, with a bright colour, and the fat firm, with a clear yellowish-white appearance. The odour should be faint but pleasant. There must be no smell of decomposition or physic.

Fish must always be eaten fresh, unless they are specially cured. A fresh fish is firm and stiff, the eyes and the scales are bright. The surface should be unbruised and unbroken.

The flesh of fish contains more water and less nitrogen than butcher's meat, but it forms usually an easily digestible and cheap food. The protein constituents are albumin, gelatin and fibrin. It contains a larger percentage of phosphates than meat, and on this account it is popularly regarded as "brain food"; but it is very probable that it possesses no superiority whatever over meat in this respect.

Fish are conveniently divided into the white and the red varieties. The commonest example of the red fish is the salmon, which contains rather a large proportion of fat, and is not easily digested. The white fish are divided into those which contain fat and those which contain no fat at all. The cod contains no fat, and its fibres are hard and difficult to digest. Of the fish which contain fat, those which contain the least are the most digestible. Thus whiting and sole contain less than one-half per cent. of fat and are very light and digestible; mackerel contain 6 per cent. fat and are less digestible; eels contain 24 per cent. of fat and are very indigestible.

Among the shell-fish, crabs and lobsters are notoriously indigestible; oysters are nutritious and easily digested, but if eaten raw are liable to convey typhoid germs; mussels and cockles are also good, although they occasionally produce poisonous symptoms.

Poultry and Game are rich in proteins and phosphates. They contain very little fat as a rule, and are easily digested unless too highly flavoured. Ducks and geese have more fat than the others, and are less digestible. Hares and rabbits have much the same value as poultry.

Diseases caused by Meat.

If decomposed or putrid meat is eaten, it usually gives rise to vomiting, diarrhoea, collapse, and sometimes death.

In some cases very severe symptoms of poisoning have been set up by eating food in which the decomposition is extremely slight. This is especially the case with sausages, canned meats, and fish. These effects are probably not produced by the slight decomposition, but by poisonous alkaloids which have been formed by certain bacteria, and the most thorough cooking fails to remove entirely the danger from these poisons. Shellfish taken from beds which may be contaminated with sewage have in many cases produced fatal results.

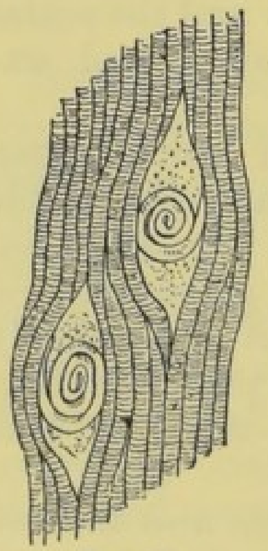


Fig. 75.
TRICHINAE IN MUSCLE FIBRES.

Parasitic diseases are sometimes conveyed by imperfectly cooked meat. There are certain organisms which appear to have more than one stage in their life-history, *e.g.* some organisms live during one period of their existence in the body of some animal, and the second period in the body of a human being. There is one called the *Cysticercus bovis*, which is sometimes found in beef (especially in N.W. India); this, if not killed by thorough cooking, gives rise to a kind of tapeworm in human beings.

Another organism of this class, which is more common in England, is the *Trichina spiralis*, so called because, when seen under the microscope, it is coiled up in a kind of spiral. This organism is, as a rule, only found in the flesh of the pig. When meat containing these is eaten, the small organisms begin to bore their way through the walls of the alimentary canal, causing severe pain, great prostration, and weakness, and frequently producing death. This disease is called *trichiniasis*. If the general health of the patient is good, if he has a strong constitution which has not been weakened by alcoholic stimulants, and is able to retain vitality until the trichinae have found their way into the muscular tissue and settled down there, the patient may recover. *Trichiniasis* is most prevalent where pork is eaten in the form of sausages, ham, etc., either uncooked or very imperfectly cooked.

Vegetable Foods.

These foods usually contain proteins, starch, sugar, and fats in varying proportions. As a rule, however, the starch or the sugar is very greatly in excess. The only vegetables that contain any important amount of proteins are the pulses—peas, beans, lentils, etc.—which contain over 20 per cent. of proteins, and some of the cereals—wheat, oats, barley, and maize—which contain more than 10 per cent. of proteins. The proteins present are mainly albumin, legumin or gluten. It is usual to divide vegetable foods into six classes—(1) the cereals ; (2) the pulses ; (3) roots ; (4) green vegetables ; (5) fruits ; (6) edible fungi.

(1) **The cereals** include wheat, oats, barley, rye, maize and rice. Wheat contains a large quantity of gluten, which gives it the property of being made into a coherent dough, and then into bread. With the exception of rye, the other cereals contain too little gluten to make bread without mixing first with wheat flour. In the preparation of **wheat flour** the outside shell may be retained with the flour when brown bread is required, or separated entirely

in the form of bran when the flour is to be used for white bread. The bran undoubtedly contains a large amount of nutritious matter, but it is very doubtful whether any of it can be absorbed by the body. It is often useful in cases of constipation, but for habitual use the white bread is usually the best. **Oatmeal** is highly nutritious if well cooked. It contains proteins, fats, starch, and salts. **Maize** is also rich in fats. Cornflour contains only the starch of maize. **Barley** is used chiefly by brewers and distillers. It is allowed to sprout, and is then called **malt.** During the process of germination or sprouting a ferment is formed called **diastase,** which is capable of converting starch into sugar. Extract of malt is a treacly fluid obtained from malt. It is nutritious and is a useful food for delicate children, because the diastase it contains helps the digestion of starch. **Rice** is the least valuable of the cereals, as it contains very little protein, fat or salts. Its value depends on the large amount of starch it contains.

(2) **The pulses.** The commonest of these are peas, beans, and lentils. They are distinguished from all other vegetables by possessing a large proportion of a protein called legumin. They are the richest protein foods that we have, except cheese; and they approach more nearly to perfect foods than any other vegetables. Unless very well cooked they are somewhat difficult to digest, and are often the cause of flatulence. If combined with fatty foods, such as bacon, they are very important articles of diet, and are especially useful for making nutritious soups, for which purpose lentils are the best.

(3) **Roots and tubers** are chiefly used for their starch, and in some cases for their salts as well. They include potatoes, carrots, parsnips, turnips, beetroots, arrowroot, artichokes, and tapioca. They contain very little nitrogen. Beetroots, carrots, and parsnips contain cane sugar. Arrowroot and tapioca are pure starches derived from the tubers of different plants. Sago is a pure starch obtained from the pith of the stems of certain palms, and is conveniently included in this class.

(4) **Green vegetables** contain very little nutritive ma-

terial, but are valuable chiefly on account of their salts. We include in this group cabbages, cauliflowers, lettuces, vegetable marrows, tomatoes, etc. They give variety and relish to the food, and also act as anti-scorbutics in preventing scurvy—a disease that used to be common among sailors and those classes who were unable to obtain fresh vegetables or fruits. Another rather important use of these foods is due to the cellulose they contain. This is a substance resembling starch, but it is indigestible: it is useful, however, in forming a bulk in the intestines, thereby stimulating their movements and preventing constipation. The onion, leek, shallot, etc., possess essential oils which are useful in flavouring food.

(5) **Fruits** are usually rich in salts of potash and vegetable acids. They contain very little nutritive matter, but are valuable on account of their anti-scorbutic properties. Many of them, however, contain a considerable amount of sugar; and a few—the banana, date, and fig, for example—are nutritious on account of the sugar and starch they contain. Lime juice and lemon juice contain citric acid: they are valuable in preventing scurvy. With water they form refreshing drinks, and are useful as antidotes for alkali poisoning. Raw fruit should only be eaten when quite ripe and perfectly fresh.

(6) **The edible fungi**, as mushrooms, contain about 91 per cent. of water and a little nitrogen. They are usually very indigestible and are of practically no value as foods.

The Feeding of Infants.

This is a subject on which the greatest ignorance prevails, and the enormous infantile mortality is undoubtedly due to this fact. The following are some of the rules which should be strictly observed by every mother or nurse.

An infant should be fed upon human milk until it is eight or nine months old, and during this time it should have **no other food** whatever. If for some reason or other the mother cannot suckle the child, then the child must be fed from the bottle with cow's milk that has been made as nearly as possible like human milk; but it should be distinctly understood that the child will thrive most on the mother's milk, and that rearing a child by the bottle means that additional risks are run.

If fed by the breast, the child should be put to the breast every two hours, from about six in the morning till twelve at night, during the first two months. During the third month it should be fed every three hours, and from the third to the eighth month every four hours. About the ninth month the child may be weaned, and for several years from this age the main food should be cow's milk.

If there is no human milk forthcoming, an artificial human milk is most easily prepared as follows:—Measure **twelve tablespoonfuls of cow's milk**, having previously boiled it and allowed it to cool. A convenient measure is the ordinary medicine bottle which contains sixteen tablespoonfuls and is usually graduated at the back. It must be kept scrupulously clean. Add to this **one tablespoonful of cream, nine tablespoonfuls of boiled water, six tablespoonfuls of lime water**, and **two teaspoonfuls of sugar**. If the cream cannot be afforded it must be dispensed with. This mixture should be given for the first month. It must be kept in air-tight bottles. For the second month and up to the fourth, reduce the boiled water to five tablespoonfuls, and after that age add only the lime water to the milk. For the sake of variety, barley water may be occasionally substituted for lime water. The best form of sugar to use is lactose or milk-sugar, which can be easily obtained. The child will probably consume more than half a pint of the mixture per day for the first few days, and then the amount will increase to about two pints per day at three months of age.

Improper Feeding of Infants.

As the salivary glands are not fully developed during the first few months of an infant's life, the food of the infant should not contain starchy matter, as there are no salivary juices to digest this. Milk is the best food for infants. If starchy or other unsuitable food is given to infants, they are liable to attacks of vomiting, convulsions, and diarrhœa—the latter being a particularly fatal disorder. Rickets, also, may occur in children who are fed too early on starchy foods, especially if at the same time their surroundings are not hygienic.

Condensed milk should never be used where it is possible to obtain fresh milk. It is very greatly inferior to fresh milk. If it has to be used, the unsweetened brands are the best. It should be mixed with sixteen parts of water for children under one month, and then the amount of water gradually decreased until only seven parts are added when the child is eight months old.

Two or three feeding bottles should be kept, and scrupulous cleanliness is absolutely essential. After the child has finished its meal, the bottle and tubes should be thoroughly cleaned with hot water, and a new teat put on frequently. The best kind of bottle is the "lamb feeder," which is easily cleaned and dispenses with the objectionable tubing.

After nine months of age, small amounts of other foods may be given with the milk, such as milk pudding, custard pudding, sop, broth, bread crumbs soaked in gravy, etc., but the staple food for several years should be boiled cow's milk.

Diet for Invalids.

During and after illness the digestive powers are weak and great care should be taken in the judicious selection and preparation of the food. As a rule it is advisable to supply the food frequently and in small quantities. In **fevers**, liquid foods should be given, the most valuable being milk, beaten-up eggs, soups, and beef tea. Cooling drinks are also necessary, such as lemon water, soda water, etc. For diarrhœa, milk, and well-cooked rice or corn-flour are the best. For constipation, oatmeal porridge, fruits, vegetables, and brown bread are useful. In rheumatism, avoid beer and animal foods. In cases of dyspepsia or indigestion, vegetables are not as a rule well taken, and salty and greasy foods should be avoided.

Effects of too much Food.

If more food is taken than can be properly digested, the digestive organs are overworked, and undigested food is passed along the intestines to be got rid of. This material sets up irritation, which gives rise to diarrhœa, and this may be followed by constipation. A certain amount of decomposition of the undigested matter may take place, gaseous products being formed which give rise to a large amount of discomfort. Continued effects of this kind impair the digestive powers, and indigestion, dyspepsia, and other similar troubles are caused.

In some cases gout is a result of overfeeding.

Practical Work.

I. Milk.

(*a*) Place a drop of milk on a microscope slide, cover with a cover-slip, and examine under the low and also the high power. Note the small clear round globules of fat (emulsion).

(*b*) Fill a test-tube with new milk and put it aside for twelve hours. Note the formation of cream on the top, and estimate roughly the proportion of cream to milk. Remove the cream with a pipette, leaving skim milk in the tube.

(*c*) By means of a lactometer ascertain the specific gravity of (i) new milk, (ii) skim milk, (iii) new milk with about $\frac{1}{10}$th of its volume of added water, and (iv) skim milk with about $\frac{1}{10}$th of its volume of added water. The specific gravity of new milk is usually about 1030, reckoning water as 1000. By removing cream (the lightest part of the milk) the specific gravity of the skim milk is raised to about 1035. By adding water to milk its specific gravity is lowered. By removing cream and also adding water the specific gravity can be kept at about 1030, so that the specific gravity alone is of little value as a test of the purity of milk.

(*d*) To a cupful of milk warmed to about the body temperature add a teaspoonful of essence of rennet, and, after stirring, put it aside. The milk rapidly sets to a solid (curd). If the curd is broken up a watery liquid separates from it (whey).

(*e*) Prove the presence of sugar in whey by adding Fehling's solution and warming.

(*f*) Dilute a small quantity of milk with an equal volume of water; add a few drops of vinegar, or dilute acetic acid, until a slight precipitate is formed. Then warm the liquid gently (do not boil). Filter. The white solid left on the filter paper is mainly **casein**.

(*g*) Boil the clear filtrate from (*f*). Any albumin that may be present will be coagulated. Filter this off.

(*h*) Test the clear filtrate from (*g*) for sugar. To do this, add a few drops of Fehling's solution and boil. If sugar is present a red precipitate will be produced.

(*i*) By keeping some milk for a few days a sample of sour milk is obtained. Test this with litmus. The reddening of the litmus shows that an acid has been produced.

(*j*) Butter may be produced by shaking some cream in a wide-mouthed bottle, or by beating cream with a wooden spoon.

II. **Eggs.**

Prove the presence of albumin in white of egg, and in the yoke also, by mixing each with a little water and boiling the mixture in a test-tube. Albumin is coagulated by heat.

III. **Meat.**

(*a*) Press a piece of blue litmus paper against a piece of raw meat. The litmus is reddened, showing that meat has an acid reaction. When the meat has begun to decompose the reaction is alkaline.

(*b*) Weigh a clean porcelain dish and cover the bottom of it with very thin slices of raw meat. Then weigh the dish with the meat in it. The difference in the two weights will represent the weight of meat that is being used for the experiment. Place the dish in an oven at about 105° C. for about three hours. Allow it to cool and then weigh it again. The loss of weight represents the amount of water that was present in the meat. From this calculate the proportion of water in meat.

IV. **Wheat Flour.**

(*a*) Take about three tablespoonfuls of flour, tie it in a double muslin bag, and gently knead it under water. For this purpose use a large basin holding about a quart of water. Eventually a sticky mass is left in the bag, and a milky liquid in the basin. The sticky mass is **gluten.**

(*b*) Place a little of the sticky substance in a test-tube and warm it. Notice that the heat causes it to solidify.

Starting again with a weighed quantity of flour (about 10 grammes) estimate the amount of dry gluten in flour, by a procedure similar to that in experiment (*b*) above (see Meat). Wheat flour usually contains about 10 per cent. of gluten.

(*c*) Take a little of the milky liquid from the basin. The milkiness is due to starch granules. Boil it ; this makes it go clear.

Cool the clear liquid and add a few drops of solution of iodine. A deep blue colour proves the presence of starch.

(*d*) Filter some of the milky liquid from (*a*), and boil the filtrate. A faint precipitate is produced, showing the presence of albumin.

(*e*) Place a small quantity of flour in a porcelain dish over the Bunsen flame. It is first turned black, but finally a grey ash is left behind. This is chiefly phosphate of potassium.

(*f*) Make a thick paste with flour and water, and mix with it some extract of malt. Keep the mixture about the same temperature as the body. The milk quickly liquefies the paste. Test for sugar in the liquid by tasting it, and by Fehling's solution.

CHAPTER IX.

COOKING.

Reasons why we cook food. These may be summarised as follows:—

(*a*) The food is rendered more attractive to the sight, taste, and smell. The appearance of raw meat, for example, is repulsive, whereas, when cooked, it not only looks far more attractive, but its smell is tempting, and its taste is pleasing. As a result of this the flow of the digestive juices is increased and the appetite is stimulated.

(*b*) Not only is the food rendered more attractive, but also it is made more digestible by cooking. Cooked food is more easily broken up by the teeth and attacked by the digestive juices than raw food is.

(*c*) Certain changes take place in the food when cooked. The most useful of these is, perhaps, the breaking up of the starch granules, without which we should not be able to digest the starch in our food. Some of the starch becomes converted into dextrin. Albumin, myosin, and gluten are coagulated by the heat. The connective tissue in meat is changed into gelatin.

(*d*) By means of good cooking a great variety in the preparation of food can be obtained; the same material may be prepared in many ways. This stimulates the appetite and the digestion, and prevents that disgust which always arises from an unchanged diet.

(*e*) The warmth of the food helps digestion, and has a reviving effect upon the system.

(*f*) Any germs of disease, or parasites, that may be present in the food are killed by cooking. Moreover, if putrefaction has just begun in the food, its ill effects are minimised by thorough cooking.

(*g*) Putrefaction and decay are delayed by cooking. Everyone knows that cooked food keeps better than uncooked.

The Cooking of Animal Food.

There are six methods commonly employed, viz. roasting, broiling, baking, frying, boiling, and stewing.

Roasting. The joint should be first exposed to a great heat by placing it close to the fire. The effect of the heat is to form a crust of coagulated albumin on the outside of the joint. This impermeable crust prevents the escape of the juices from the inside of the meat. In about ten minutes the joint should be drawn about twelve inches from the fire, and the cooking completed at that distance. To prevent it from scorching the joint must be kept constantly in motion, and the surface "basted" with fat. The general rule as to the time required to cook a joint is to allow a quarter of an hour for every pound, and a quarter of an hour over. This should be the minimum.

The roasting coagulates the albumin and myosin, and converts the connective tissue into gelatin, thereby loosening the muscular fibres. There are also the characteristic odorous compounds produced. The loss of weight during roasting varies from one quarter to one third, and is due mainly to loss of water.

Broiling, or grilling, is roasting on a small scale on the top of the fire. The scorching is greater than in roasting owing to the greater surface exposed to the heat. The chop or steak should be placed on a clean hot gridiron over a clear fire, and turned every two minutes. The surface must not be pierced by any fork or skewer during the cooking.

Baking. In a well-ventilated oven the process of baking corresponds exactly to roasting, but meat baked in the old-fashioned non-ventilated oven has a flavour quite different from that of roasted meat. The joint should be placed on a small wire table in the baking dish so as to prevent the meat soaking in the grease. The oven should be very hot at first in order to form the crust of coagulated albumin on the outside of the joint.

Frying is boiling a food in fat. The meat cooked in this way is usually soaked with fat and is very indigestible. This penetration of the fat is prevented somewhat by having the fat very hot to begin with. This method is often used for fish, but boiled fish is much more digestible.

Boiling. If the object of boiling is to simply cook the meat and retain in it all its flavour and nourishment, the method employed is precisely the same in theory as the method of roasting. The joint is plunged into **boiling** water, and the boiling is maintained for five minutes. This coagulates the albumin on the outside, and forms a coat through which the meat juices cannot escape. For the remainder of the time the water should not be allowed to boil at all, but should be kept at about 170° F. or about 40° below the boiling point. If the water is kept boiling the whole time, the meat is made hard and indigestible.

The object in boiling the meat may be not only to cook the meat, but also to make good broth. In this case the meat is put into warm water, and the water is not allowed to boil at all—the meat being kept at about 170° F. the whole time. In this way the albumin is not solidified but dissolves in the water, together with a part of the meat juices. The meat when so cooked retains a considerable portion of the nourishment, but is rather more tasteless and less digestible and nutritious than when prepared by the first method.

Another object in boiling meat may be the preparation of a soup. In this process the object is to extract as much as possible of the nutritive principles from the meat. The meat should be cut up in small pieces and placed in **cold** water. After it has soaked for some time, the heat should be applied very slowly, and the temperature gradually raised to about 170°. This temperature is maintained for two or three hours, and then it is brought up to boiling point for another hour. This treatment extracts practically all the nourishment from the meat—which is left as a hard, tasteless, stringy mass.

The difference between broth and soup is merely one of degree, soup obviously containing a greater proportion of meat juices, albumin, myosin, gelatin, etc., than broth.

To boil **fish**, water just below boiling should be used, as many kinds of fish would break if placed suddenly in boiling water. Care should for the same reason be taken to prevent the water boiling vigorously at any time.

Before dismissing the subject of boiling, it would perhaps be advisable to state here that water which is boiling very gently is just as hot as water which is vigorously bubbling.

Stewing is by far the most economical cooking process, because by this method there is absolutely no waste. Unfortunately it is a process that is but little practised in England. Any kind of meat may be used. The meat should be cut up into slices, seasoned, placed in the stew-pan, and just covered with cold water or stock. It should never boil during any part of the process. Vegetables or flour are often mixed with the water to make it thicker and richer. By cooking in this way the meat is softened and made digestible. The best possible results are obtained by using a water-bath for stewing. This simply consists of an inner and an outer vessel. The stew is made in the inner vessel, and the outer vessel is filled with water which is kept boiling. The water in the inner vessel remains just below boiling point all the while. If the stew is boiled, the meat becomes hard, tough, curled up, and indigestible. For **hashing**, the same method should be adopted as for stewing, but in this case the meat has been previously cooked, and so extra care should be taken to prevent the liquid boiling.

Beef-tea. To properly prepare beef-tea, the beef—free from fat—should be cut up into very small pieces, and put into a jar. A little salt is added, and cold water in the proportion of one pint to one pound of beef. The jar is covered with a lid and allowed to stand for two hours. It is then surrounded with boiling water by placing it in a pan for one or two hours. Prepared in this way, beef-tea contains albumin, gelatin, salts, and extractives derived from the meat, and it is fairly nutritious and stimulating. The nutritive properties are greatly increased by adding oatmeal or cream. Patent preparations and extracts of beef are stimulating, but have practically no nutritive qualities.

The Cooking of Vegetables.

Potatoes should be placed in boiling water from the first. They are preferably either steamed or cooked with their skins on, because boiling in the ordinary way dissolves out the greater part of the salts that the potatoes contain. When thoroughly cooked, the starch granules swell up and burst, and part of the starch becomes converted into dextrin.

Green Vegetables should be cooked, if possible, in soft water. If hard water has to be used, a little carbonate of soda should be added first.

Bread. On a small scale, the flour is mixed with a liquid consisting of warm water, yeast, and a little salt. The mass is then kneaded into dough, and is set aside in a warm place for three or four hours. The yeast sets up a process of fermentation, resulting in the formation of alcohol and carbon dioxide in the dough, making it light and porous. The dough is then made into loaves and is baked.

During the baking the starch granules are broken, and part of the starch is changed into sugar and dextrin. At the same time the gluten is coagulated.

Stale bread is more digestible but not so palatable as new bread. Toasting bread makes it more easily broken up by the teeth and therefore more digestible. Pastry is much more difficult to digest than ordinary bread, owing to the starch granules being coated over with fat, which retards the action of the saliva upon them.

Cooking Apparatus.

All **cooking utensils** should be kept scrupulously clean and dry, by carefully scalding, cleaning, and drying after each time of use. The best substance with which to clean greasy cooking utensils is common washing soda, and so all greasy pots and pans should be scrubbed thoroughly with a strong solution of it. Special care should be taken to keep copper vessels dry and clean, and to cook nothing of an acid nature in them.

The "double saucepan" with the inner vessel of glazed earthenware is a very useful cooking utensil, especially for cooking food containing acids, such as fruits.

Cooking Ranges. If possible, meat should always be roasted before an open fire. The disadvantages of baking are, however, overcome to a certain extent by ventilated ovens. Open fires require more fuel than a closed cooking range.

Gas Stoves are gradually gaining in favour for cooking purposes. Their chief advantages are their cleanliness and the ease with which the heat can be regulated. They are rather more expensive than ovens heated with coal. The proper place for a gas stove is in the recess of an open fireplace, and it should not be placed in the open room unless it has a special chimney made for it, to carry away the impure gases formed by the combustion of the coal gas, and also the smell of the cooking.

Practical Work.

I. **Starchy food.**

Tests showing the effects of heat upon starch have already been performed. Test for the presence of starch in bread, cooked potatoes, cooked cabbage.

II. **Flour.**

Repeat experiment of obtaining gluten from flour. Note carefully effect of heat upon gluten. Test solubility of the heated (cooked) gluten, and note that it will not return to its original condition by the addition of water.

III. **Bread.**

(*a*) Put 1 lb. of flour into a basin and add half a teaspoonful of salt. Into a hollow made in the middle of the flour pour half an ounce of yeast which has been rubbed down to a thin cream with warm water in a teacup. Gradually mix the flour with the yeast, adding more warm water sufficient to make a "dough" on kneading the mixture thoroughly. Cover with a cloth and put aside in a warm place for an hour and a half. Cut the dough into pieces and bake in a hot oven.

(*b*) Put a little baking powder into water. It effervesces and produces a colourless gas which has the property of turning lime water milky. This is carbon dioxide, the same gas as is produced by the action of yeast. Bread may be made by using baking powder instead of yeast.

IV. **Meat.**

(*a*) Place a piece of meat in some cold water. Warm it gently until the temperature reaches about 30° C., and keep it at this temperature for half an hour. Pour off some of the water and heat it. At about 60° C. the liquid turns milky owing to the coagulation of the albumin that had been extracted from the meat.

(*b*) Into a beaker containing boiling water put a piece of meat. Notice that the water in this case does not become cloudy, showing that albumin is not dissolved from the meat.

CHAPTER X.

BEVERAGES.

The stimulant beverages may be conveniently divided into non-alcoholic and alcoholic.

Non-alcoholic Stimulant Beverages.

These are tea, coffee, and cocoa. These three substances each possess an active stimulating principle, the effect of which is somewhat similar in each case. The stimulating principle in tea is called **theine**, and this has the same composition as the active part of coffee, which is called **caffeine.** In cocoa there is a similar substance called **theobromine**. The action of these substances in moderation is to quicken and strengthen respiration and the heart's action. They also stimulate the nervous system and lessen fatigue and the desire for sleep, for which they are valued among brain workers. Cocoa contains much less stimulating properties than tea or coffee, its chief value being as a food and not as a stimulant.

Tea, coffee, and cocoa also contain characteristic volatile oils, which give to each its distinctive and peculiar smell. Tea also contains about 14 per cent. of an astringent substance called **tannin**, to which are largely due its injurious effects when taken in excess. Coffee also contains a small amount of tannin, but cocoa contains practically none.

Tea consists of dried leaves of the tea-plant, which grows in China, Japan, India, and Ceylon. Chinese teas are the best because they contain less tannin than the other varieties. When uncurled by hot water the tea-leaf is seen to have a characteristic ovate shape and a serrated margin. The smaller the leaves are the better the quality of the tea. The colour of the dried leaf is green when the leaves are dried over a wood fire while they are quite fresh. Black teas are prepared by allowing the leaves to lie in damp heaps for about twelve hours, and then drying them slowly over charcoal fires.

The tea-leaf yields to the boiling water chiefly theine, tannin, and volatile oil. The value of tea depends upon the theine it contains. This, as we have said, stimulates the heart and respiration, and acts as a restorative to the nervous and muscular system. Its great value lies in the fact that the stimulation produced by theine is followed by *no after-depression.* Tea has been found to be of great benefit to soldiers on active service, and in all cases where continuous exertion is required it is enormously superior to alcohol as a stimulant. If prepared badly, or taken in great excess, it disorders digestion and gives rise to nervousness and palpitation.

Tea should not be drunk too hot, and should not be taken with meat. Also it should not be drunk by itself, but only when other food is being taken. When taken with milk and sugar a cup of tea contains a fair amount of nourishment.

To make tea. The tea-pot should first of all be made hot by partly filling with boiling water, which is then emptied out again. The water that is used should be actually boiling, but if it has been boiling for some time previously the tea will not be so good. The water should be soft if possible, and when hard water is used a pinch of bicarbonate of soda should be added to it. Tea should not be allowed to stand for more than five minutes, and at the end of this time it should be poured off the leaves into another pot. If tea is brewed for a longer time than five minutes it is liable to contain excessive quantities of tannin, and is very injurious.

Coffee is the berry of a plant growing in Arabia, Ceylon, the West Indies, and other places. The seeds are roasted until they are of a dark brown colour, and are then ground to powder. Coffee contains caffeine, a little tannin, and some volatile and aromatic oils.

The action of coffee upon the body is very similar to that of tea. It stimulates the heart and the nervous system, quickens the rate of breathing, and lessens the sense of fatigue and the desire for sleep. It also slightly increases the secretion of the kidneys, and acts with many as a gentle purgative. When made chiefly with milk, and sugar added, it is nutritious as well as stimulating.

The stimulating action of coffee differs from that of alcohol in not being followed by depression. Coffee, like tea, is of great value to those engaged in laborious occupations, and for counteracting the effects of exhaustion, cold, opium poisoning, etc. In excess, it acts injuriously on the heart and nerves, and disorders digestion. Coffee is commonly adulterated with chicory. This is the roasted and powdered root of a plant. It imparts a darker colour to the infusion, and is considered by some to improve the taste when added in about the proportion of two ounces of chicory to one pound of coffee.

To make Coffee. The coffee should be freshly roasted and ground. About one ounce of coffee is required for making one large cup. The coffee pot should be hot, and the water must be actually boiling. It may be allowed to stand ten or fifteen minutes, but should not be boiled.

Cocoa is the seed of a plant growing chiefly in the West Indies. The seeds are taken from the pod and allowed to undergo a kind of fermentation, during which the characteristic aromatic odour is said to be developed. The seeds are then roasted and deprived of their husks. Cocoa-nibs are the seeds simply broken up very roughly. The "prepared cocoa" is obtained by grinding the seeds, and afterwards removing the fat or cocoa butter, leaving the cocoa perfectly dry. Sometimes starch is added in the cheaper cocoas in order to cover the excess of fat that is present, and it is moreover a cheap form of adulteration.

Cocoa contains a substance called theobromine, which is similar to theine and caffeine in composition and properties. It also contains starch, fats, nitrogenous bodies, and salts, and so it is almost a perfect food. Obviously it resembles tea and coffee in having stimulating properties on a smaller scale; and differs from them in having a large nutritive value. **Chocolate** is prepared from cocoa by mixing with sugar and starch and pressing into moulds.

Preparation of Cocoa. In making cocoa we do not prepare an infusion as in tea and coffee, but we drink the whole. Cocoa may be prepared with water, but is much better when prepared mainly with milk. It should always be well boiled, on account of the starch that it contains.

Alcoholic Beverages or Fermented Drinks.

Fermented drinks may be defined as those liquids which contain the products of a process of fermentation—the most important product being alcohol. The term "fermented drinks" is intended to include beers, wines, spirits, etc. Their common constituent is alcohol, and they also contain variable quantities of sugar, acids, salts, and aromatic oils, which give to each its characteristic taste and smell.

In the preparation of these drinks either sugar or starch may be the starting-point. If starch is used, the first process is to change it into sugar. This change is usually effected by the ferment **diastase**, which is present in malt. A solution of the sugar is then made, and the sugary liquid is fermented by adding yeast or some other ferment. The sugar is changed by the yeast into carbon dioxide and alcohol, and at the same time various ethers and acids are formed.

Beers and **Ales** are prepared in the above way, but hops or some other bitters are added. The definition of a beer or an ale should be that it is a fermented infusion of malt flavoured with hops. The modern beers are, however, prepared from sugar instead of malt, and other vegetable bitters are added instead of hops. **Porter** is nothing more than a weak mild ale, coloured and flavoured with burnt malt. **Stout** is similar, but is rather stronger.

The chief constituents of beer, ale, stout, and porter are—water, alcohol, dextrin, sugar, hop extracts, gluten, acetic and lactic acids, carbon dioxide, salts, and water. The **effects** of these drinks are mainly those due to alcohol in large or small doses, as the case may be, but in addition they appear to interfere with the tissue change, resulting in a tendency to accumulate fat, and a liability to gout and rheumatism. With most people they tend to produce stupor, while of course in excess they will produce intoxication.

The nutritive value of beer, although higher than that of any other alcoholic drink, is extremely small. Practically all the nourishment that is present is a very small amount of sugar.

Wines are, or should be, prepared by fermenting the juice of the grape. They contain variable quantities of water, alcohol, carbon dioxide, ethers, colouring matter, vegetable acids, tannin, and sugar. Any nourishment they contain is due to the small amount of sugar that is present. Their effects are due to the alcohol they contain.

Spirits are prepared by distilling a fermented liquor. **Brandy** should be made by distilling wine, but it is usually potato spirit; **whiskey** by distilling the liquor obtained by fermenting malt with other forms of starch; **gin** in the same way, but with the addition of oil of juniper, oil of turpentine, orange peel, and other aromatic substances. **Rum** is obtained by distilling fermented treacle. All spirits contain water, alcohol, and fusel oil, together with aromatic bodies which give to each its characteristic taste and smell. They contain no nourishment whatever, and their effects are due to the alcohol they contain.

Alcohol. The amount of alcohol in fermented drinks varies very greatly. The following list gives roughly the quantities in some of the commoner beverages:—

Brandy	55	per cent.	Madeira	19	per cent.
Whiskey	54	,,	Champagne	12	,,
Rum	53	,,	Claret	8	,,
Gin	52	,,	Ale	7	,,
Sherry	23	,,	Porter	5½	,,
Port	22	,,	Beer	3	,,

Effect of Alcohol. When alcohol is swallowed, it passes directly through the lining membrane of the stomach, and reaches the blood. The heart is stimulated and caused to beat more quickly and more forcibly for a time. Respiration is also similarly affected; in fact, all the organs of the body may be said to be stimulated by alcohol. The smaller blood-vessels become dilated, which effect has an important bearing upon the old tradition that alcohol warms the body and therefore should be taken when the body is about to be exposed to severe cold. This is a most dangerous fallacy. As a matter of fact, alcohol lowers the temperature of the body by dilating the blood-vessels just beneath the skin, and so increasing the loss of heat from the skin. At the same time the skin **feels warmer**, and this sensation has given rise to a fallacy that has probably cost many lives. In the case of the regular tippler, the vessels beneath the skin become permanently dilated, especially about the nose.

Not only does alcohol lower the temperature of the body, but it also lessens the power of the body to resist cold, and is therefore totally unsuited for those who are exposed to low temperatures. Even in small doses alcohol is the reverse of helpful when either muscular or mental work is required. The acuteness of all the senses is quickly diminished by it. Any stimulation produced by alcohol is always followed by a period of depression. In large doses alcohol depresses and paralyses the nervous system, and in still larger quantities it acts as a narcotic poison like opium, producing sensibility and sometimes death.

If taken in repeated large quantities, the various organs become rapidly diseased and premature old age soon comes on. It increases the tendency to gout and Bright's disease, and produces diseases of the stomach, liver, kidneys, heart, brain, and nerve—sometimes leading to delirum tremens or insanity. There can be no doubt whatever that a person can do quite as hard or harder work without alcohol than with it. It is a matter of experience that soldiers on the march, in all climates, can endure more fatigue, are healthier, and fight better without alcoholic stimulants than with them. The infinite amount of suffering caused by alcohol is a matter of common knowledge. About three-quarters of the people in workhouses are there, directly or indirectly, owing to alcohol; at least half the crime in the country is caused by it, and about one-third of the insanity. Many eminent medical men have expressed their opinion that alcohol should be regarded as a drug and only employed when prescribed by a doctor, the prescription being used only while the symptoms remain for which it was originally demanded.

For all practical purposes, alcohol has no value whatever as a food. Its value, when used by a scientific medical man, depends upon its physiological effects.

The maximum amount of alcohol that may be drunk without producing *obvious* ill effects is two ounces per day. This amount of alcohol is contained in two pints of beer, or half a pint of claret, or four ounces of spirits. Even if this amount is taken, the following conditions should be strictly observed:—

(*a*) Alcohol should never be drunk between meals—it should be taken only with food.

(*b*) It should not be taken during working hours, but rather when the day's work is done.

(*c*) Children should never be allowed to touch alcoholic drinks.

(*d*) People with insanity or epilepsy in the family should always abstain from the use of alcohol.

The hereditary effects of alcohol are unfortunately only too common. Many of the ill effects of alcohol seem to be transmitted to the children, and manifest themselves either in a defective bodily structure or a depraved mental condition.

Practical Work.

I. Tea and Tannin.

(*a*) To test for tannin in tea. Take some strong tea in a test-tube. Add a few drops of ferric chloride solution. An inky liquid is formed which shows that tannin is present.

(*b*) Make a solution of tannin in hot water. Also dissolve a small quantity of isinglass in boiling water. Add the tannin solution to the isinglass. A white precipitate is produced. The experiment illustrates the action of strong tea on any proteins such as meat.

I. **Fermentation.**

(*a*) Fit up the apparatus shown in Fig. 76. Put in the flask sugar and water, and add some brewers' yeast. Leave it in a warm place for several hours. A clear colourless gas collects in the

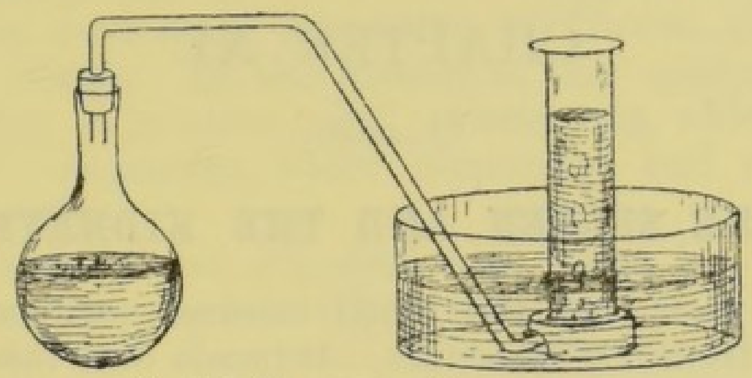


Fig. 76.—Flask for Fermentation.

gas jar. Add some lime-water and shake it up. The lime-water is turned milky, showing that the gas is carbon dioxide.

(*b*) Filter the contents of the flask, and pour the clear liquid into a retort fitted with a condenser as in Fig. 77. When about a teaspoonful of liquid has collected in the cooled receiver, pour it into a watch glass and apply a light. The liquid burns with a pale flame, showing that alcohol has been formed.

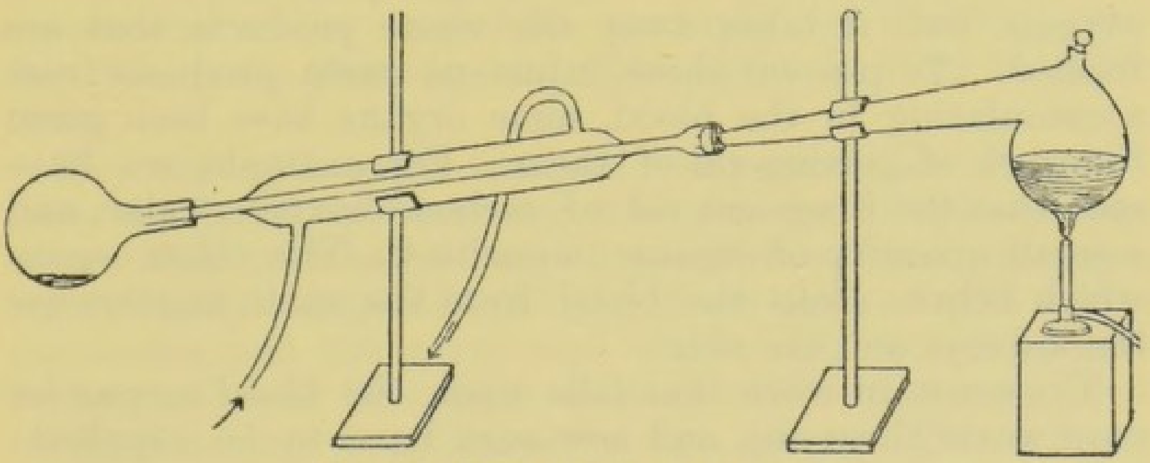


Fig. 77.—Distillation Apparatus.

(*c*) Repeat experiment (*b*), using some ordinary beer for distillation. In order to prevent excessive frothing the beer should be poured rapidly from one vessel to another for a few minutes.

(*d*) Mix a tiny fragment of yeast with a drop of water on a microscope slide. Examine it with the low and also the high power of the microscope.

(*e*) Find the specific gravity of spirits of wine. This liquid usually contains 84 parts of alcohol with 16 parts of water. Notice its colour, taste, smell, effect on litmus, volatility, and inflammability.

CHAPTER XI.

THE SPLEEN AND THE KIDNEYS.

We have seen that the blood receives various nutrient principles from the intestines. It hands over this nourishment to the different organs, to be disposed of in the ways that we have already discussed. From the air in the lungs the blood receives a supply of oxygen which is used up all over the body in oxidising the foods which have been taken. As a result of these oxidation processes, various waste products (water, carbon dioxide, urea, etc.) are formed, and these are poured into the blood again. The blood, therefore, not only brings up the foods and the oxygen, but it takes away the waste products that are formed. To prevent these injurious waste products from accumulating in the blood, some organs have been given the work of getting rid of them. For example, we have seen that the lungs get rid of carbon dioxide, water, and a small quantity of organic impurities. The other organs which help to clean the blood from the waste matters are the kidneys and the skin.

The constant work that falls upon the blood corpuscles soon wears them out, and new ones have to be supplied; and not only must there be a supply of new corpuscles, but there must be a disposal of the old worn-out ones. The spleen probably plays the chief part in the performance of both these duties.

The Spleen.

The spleen is situated, as we have seen, to the left of the stomach and pancreas. It is a dark purple mass about five inches long by three broad, and weighs about five ounces. On the outside it is covered with peritoneum, in common with the other abdominal viscera, and also with a special **capsule** of its own. Inside it is soft and spongy, and is full of blood. In structure it is made up of a close meshwork, consisting of fibrous, elastic, and muscular tissue. In the meshes of this spongy tissue is a soft pulpy substance called **spleen-pulp**, which contains red blood corpuscles, white corpuscles, and some large branched cells.

The spleen is well supplied with blood by the splenic artery, and the blood is taken away by the splenic vein, which runs into the portal vein. The **functions** of the spleen are not very definitely known. About five hours after a meal it becomes largely distended with blood, and later on shrinks again. Sometimes it varies in size every two or three minutes. From these phenomena it is inferred that the spleen has some function relating to the absorption of digested fluids, and to the blood pressure. Another very important function of the spleen is to supply white corpuscles to the blood. In the spleen the white corpuscles multiply by dividing into two, the parts growing and then again dividing in their turn.

The old and worn out red corpuscles are removed from the blood by becoming entangled in the spleen-pulp, where they gradually break up. The spleen has been rather aptly described as "the birth-place of the white corpuscles, and the grave-yard of the red," but it should be remembered that it is quite possible that new red corpuscles may be formed in the spleen. The colouring matter—the haemoglobin—of the broken-up red corpuscles is carried by the splenic vein to the liver, where it is used up in making the colouring matter of the bile.

Ductless glands. The spleen is an example of what are called ductless glands. These are bodies which bear an external resemblance to ordinary glands, but, as they have no duct, they are given the above name. The most important of them are the lymphatic glands, the spleen, the thyroid body, and the supra-renal capsules.

THE KIDNEYS.

The kidneys are two in number, and are situated in the abdomen, one on each side of the vertebral column, in the lumbar region. They are of well-known shape, and are dark red organs, about four inches long and two and a half inches across, and each weighs about five ounces. In front they are covered with peritoneum, the back being attached to the body wall.

They are so placed in the body that the concave edges face each other, the outer edge being convex. The depression at the middle of the concave inner edge is called the **hilus.** At this point the renal artery and the renal vein enter and leave the kidney, the one bringing blood from the aorta, and the other taking away blood to the inferior vena cava. Nerves, lymphatics, and a narrow tube called the **ureter** are also found at the hilus. As it approaches the kidney, the ureter expands like a funnel, this dilated part being called the **pelvis of the kidney.**

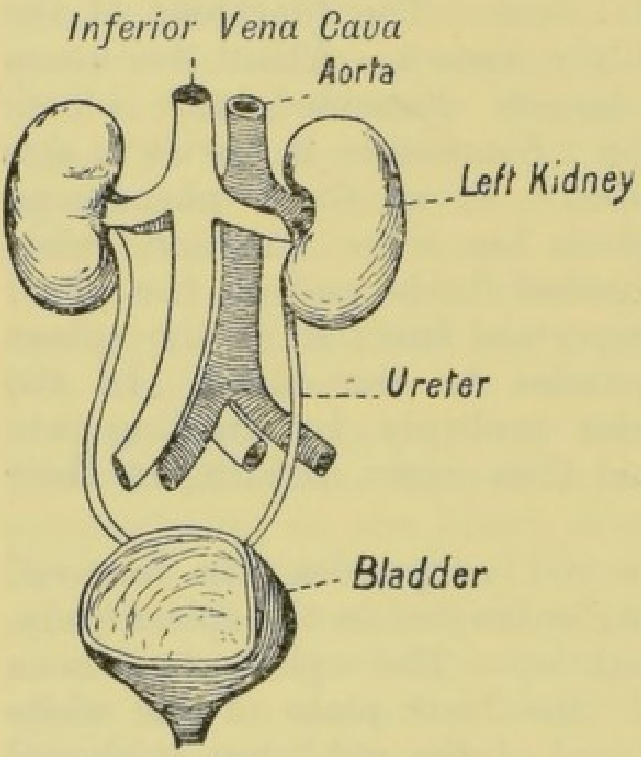


Fig. 78.—THE URINARY ORGANS.

Each ureter is about fourteen inches long. It passes down from the kidney to the bladder, which is situated in front of the bony pelvis. The **bladder** is a muscular bag lined with mucous membrane, and is partly covered with peritoneum.

The ureters enter in an oblique manner, so that a little flap is formed inside the bladder, and this flap acts as a kind of valve, preventing the urine from passing back up the ureter. The function of the bladder is to store the urine which is constantly trickling into it from the ureters, and to discharge it at intervals. When moderately distended, it will hold a pint.

If a kidney is cut into two, it seems to be formed of two portions, an outer layer which is dark brown, smooth, and uniform in appearance, and an inner part which is paler,

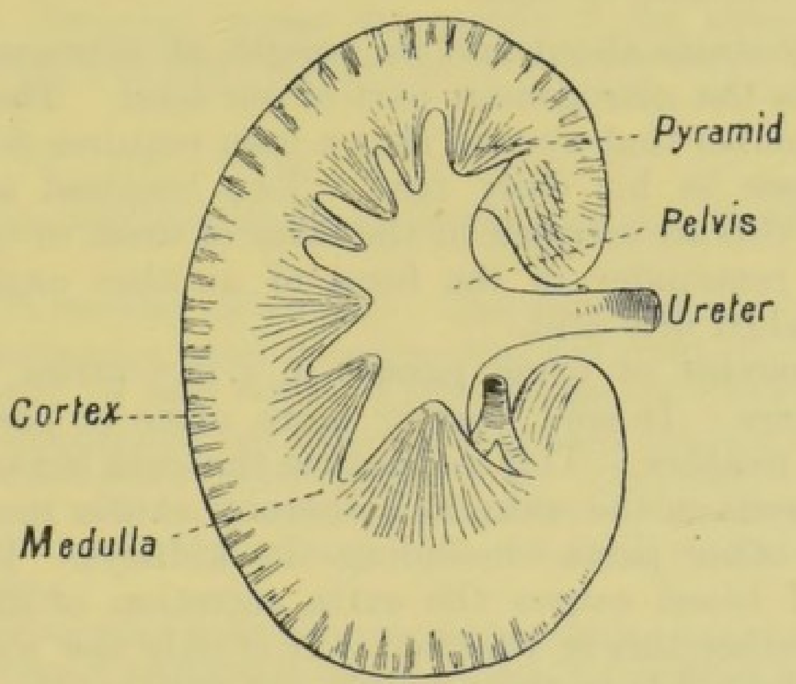


Fig. 79.—SECTION OF KIDNEY (Diagrammatic).

and is composed of a finely striped substance arranged in several **pyramids**. The outer layer is called the **cortex** of the kidney, and the inner part the **medulla**. The apex of each pyramid—called the **papilla**—projects into the pelvis of the kidney.

The substance of the kidney is composed of an enormous number of minute **tubules**. These are straight in the medulla, and convoluted in the cortex. They are richly supplied with blood-vessels, which form a network all round them. The whole of each tube is lined with epithelium, and the epithelial cells separate the **urine** from the blood. The urine passes along the tube until it reaches a common opening, at the tip of a papilla. It then trickles into the pelvis of the kidney, and down the ureter to the bladder.

The function of the kidney is to secrete urine from the blood. Healthy **urine** is a clear pale yellow fluid consisting of water in which are dissolved various substances: these are mainly common salt, phosphates and sulphates of sodium and potassium, and an organic substance called **urea**. About 50 ounces—from two to three pints—of urine are excreted in twenty-four hours. This quantity contains about two ounces of solid matter, one and a quarter ounces of which consists of urea.

Urea contains about half its weight of nitrogen, and it represents the nitrogenous part of our food. The student will remember that we said that a man requires 300 grains of nitrogen in his daily food. Two hundred and forty grains of this are secreted in the form of urea, in the urine, and the remainder in the form of another organic substance, called uric acid.

The amount of urine passed in a day varies with the temperature. In cold weather more urine is passed than in warm weather. This is because the cold contracts the blood-vessels in the skin, and thereby causes more blood to go to other parts—including the kidneys. The extra supply of blood causes the extra secretion of urine. In warm weather this is reversed. It is only the water that varies; the solids in the urine do not vary much.

Practical Work.

I. The Spleen.

Obtain the spleen of an ox or sheep. Notice its colour and other obvious characters. Look for blood-vessels entering and leaving the organ.

Cut it across. Note fibrous capsule, spleen pulp, and also a number of white spots in the dark red pulp. These are called Malpighian corpuscles.

Cut away a slice of the spleen and hold it under the water tap in order to wash away the pulp. This brings to light a meshwork of connective tissue.

II. The Kidney.

(*a*) Take a sheep's kidney. Notice its shape and draw it. Carefully remove the fat from the hilus, and look for the artery and vein, which will look rather red; and the ureter, which looks much paler. Cut along the ureter, and follow it until it expands into the pelvis. If you cannot do this, cut open the pelvis, and trace it to the ureter, by cutting it along. Note the papillae, or tips of the pyramids, projecting into the pelvis. On close examination, these papillae will be found to be finely pitted on the surface. These small holes are the openings of the tubules.

(*b*) Cut the kidney in two halves on the flat. Notice the difference between the cortex and the medulla. The pyramids occupy the centre portion or the medulla, while outside them is the dark brown granular cortex.

(*c*) With dissecting forceps the capsule of the kidney can be peeled off, leaving the dull red smooth surface of the cortex exposed.

III. **Urine.**

(*a*) Find the specific gravity of a sample of urine. This is usually 1020.

(*b*) Test its reaction with litmus. This should be acid.

(*c*) Put some urine into a porcelain dish and evaporate down to dryness. A solid residue is left composed of urea and salts.

(*d*) Into another dish put some more urine and evaporate down to about one-fourth of its original bulk. Then add two or three drops of nitric acid and cool. Examine a drop of the liquid under the microscope, and note the small crystals of urea nitrate.

(*e*) By adding some sodium hypobromite solution to urine an effervescence of nitrogen is caused owing to the decomposition of the urea.

(*f*) To some urine in a test-tube add a few drops of nitric acid and a little silver nitrate solution. A white precipitate of silver chloride proves the presence of chlorides.

CHAPTER XII.

THE SKIN. SOAP. CLEANLINESS.

THE uses of the skin may be classified as follows :—

(1) It serves as a protective layer on the surface of the body.

(2) The skin is really one of the **excretory organs** of the body. By means of the sweat glands that it contains it gets rid of about one pint of water in twenty-four hours. Small quantities of other substances are also got rid of in the sweat. The skin therefore forms one of the three organs of the body that get rid of water—the other two being the lungs and the kidneys.

(3) By the special arrangement of the nerves in it, the skin serves as an organ of touch.

(4) The sweat glands in the skin have the power of covering the skin with water, which, by its evaporation, causes heat to be lost, and the body is thereby cooled. On the other hand, if the sweat is not secreted so abundantly as to make the skin actually wet, the loss of heat from the body is minimised, although loss by evaporation from the skin is continually going on.

Structure of the Skin. The skin is made up of two layers, an outer layer called the **epidermis**, and an inner layer called the **dermis**.

The epidermis varies greatly in thickness in different parts of the body, being thickest on the soles of the feet, the palms of the hands, and on the back.

The deepest or **Malpighian** layer of the epidermis is next to the dermis, and is formed of columnar cells lying perpendicularly to the surface of the dermis. These cells are soft and contain a nucleus. The dark colour of the skin of the negro and other races is due to a deposit of dark pigment in the lowest cells of the Malpighian layer.

The cells above the Malpighian layer are shorter and rounder in shape than those in the lowest layer. The layers still nearer the surface of the skin consist of cells which have lost their nucleus and become flatter and flatter as they approach the surface, until those on the

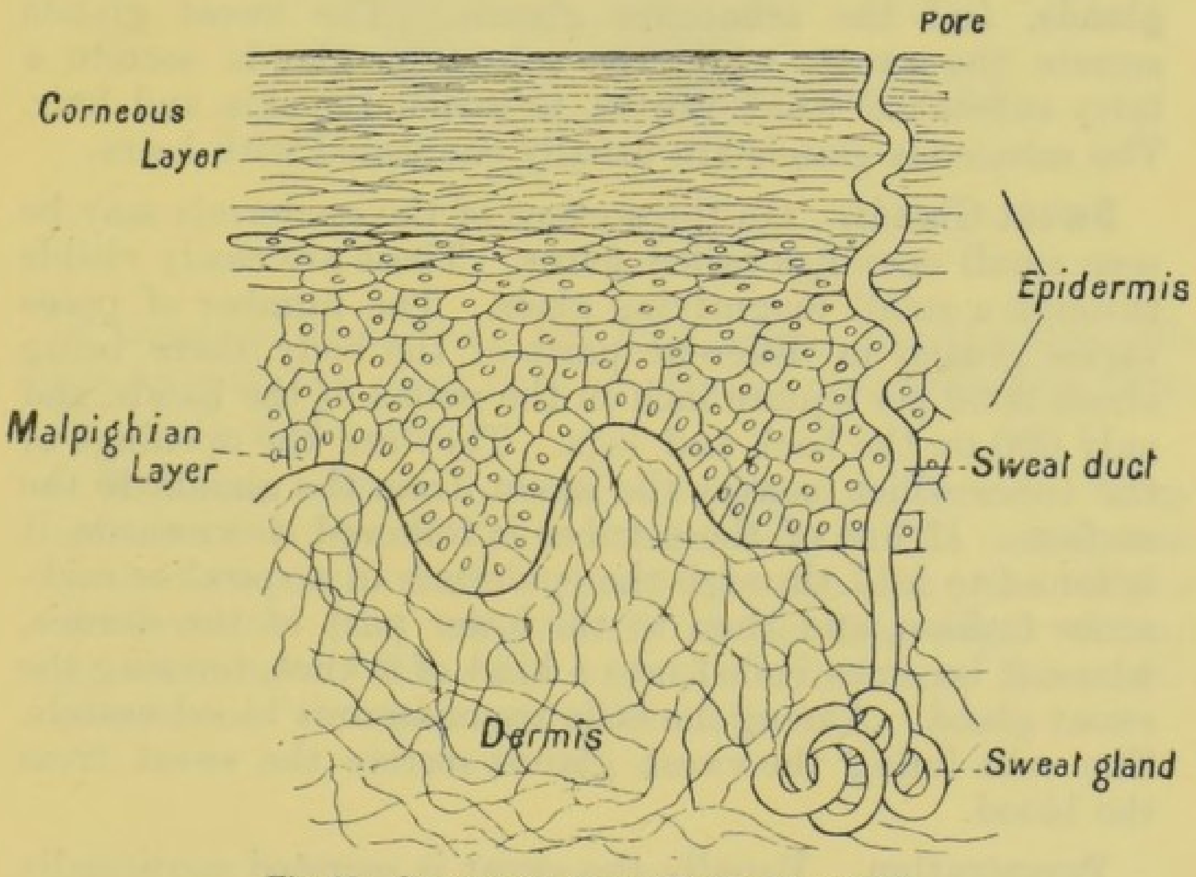


Fig. 80.—Section of Skin (Highly Magnified).

outside are merely scales. The superficial layers are hard and horny and form the **corneous** layer. This is the part of the skin which is raised as a blister. The epidermis forms the protective layer of the skin. It is transparent, and is impermeable to liquids. There are no nerves or blood-vessels in it.

The dermis, or true skin, consists of a strong network of connective tissue, which contains blood-vessels, nerves, glands, and the roots of hairs. The surface of the dermis is thrown up into small conical processes which project into the epidermis. These processes, called **papillae**, are highly developed in those parts where the sense of touch is acute, and so probably they represent that part of the skin which acts as the organ of the sense of touch. They are well supplied with blood-vessels and nerves. The deeper part of the dermis is connected to the bone or muscle underneath by loose connective tissue which usually contains a considerable quantity of fat.

The Glands of the Skin are of two kinds, the **sweat glands,** and the **sebaceous glands.** The sweat glands secrete the sweat, while the sebaceous glands secrete a fatty substance which serves to soften the skin and hair. The sebaceous glands are usually connected with hairs.

Sweat Glands. On the surface of the epidermis may be seen small openings called **pores.** These are easily visible through a small magnifying glass. The number of pores varies greatly in different parts of the body, there being about 3000 per square inch on the palms of the hands, and only 600 on the back and legs. They are the openings of the tubes which convey the sweat from the glands to the surface. If one of these tubes is followed downwards, it is found to lead through the epidermis in a spiral or cork-screw fashion, and then to the lower part of the dermis, where it becomes coiled into a kind of a knot, forming the sweat gland. Among the coils are numerous blood-vessels. The cells lining the sweat glands secrete the sweat from the blood.

Perspiration. Usually the sweat is secreted continually but in small quantities, so that it evaporates from the skin as fast as it reaches the air. This is called **insensible perspiration.** During exertion, or in hot weather, the sweat is poured out in large quantities so that it is visible on the surface of the skin, and is called **sensible perspiration.** As the water evaporates it absorbs heat from the body, thereby lowering the temperature.

Composition of Sweat. The sweat consists mainly of water with a very small amount of substances dissolved in it. The dissolved substances are chiefly common salt, some organic bodies, and a little carbon dioxide.

Hairs are formed of horny cells from the epidermis. Each hair lies in a deep pit called the **hair follicle**. The pits are lined with epidermis, which forms a sheath for the root of the hair. At the bottom of the follicle is a papilla covered with cells of epidermis, and by the multiplication

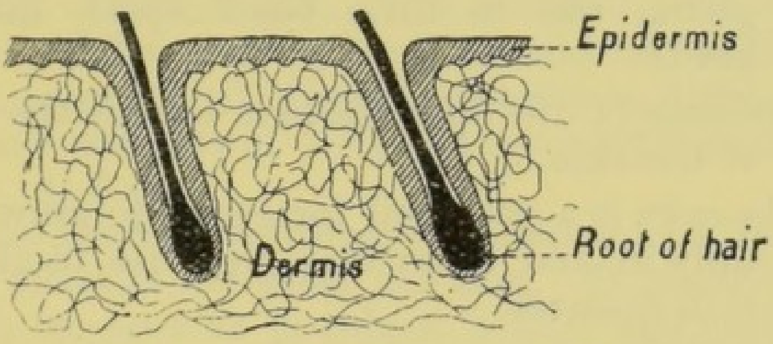


Fig. 81.—Section of Skin with Hairs.

of these epidermal cells the hair grows. As the new cells are formed, the older ones are thrust outwards and form the shaft of the hair.

Nails are another form of specialised epidermis. They consist of two parts—a root and a body. The root is that part of the nail which is covered by the skin; the body is the external part which ends in the free edge. A nail grows in much the same way as a hair, *i.e.* by the multiplication of the epidermal cells at its root.

Cleanliness.

The surface of the skin is constantly receiving sweat from the sweat glands, and greasy matter from the sebaceous glands. These keep the skin moist and greasy, causing the dead scales of epidermis to remain sticking to it, and also rendering the skin liable to accumulate dirt, dust, and particles of clothing. If the skin is not regularly cleaned, a cake or plaster forms upon it consisting of dried sweat, dirt, scales of dead skin, and grease. This **uncleanliness** leads to injurious and disagreeable results, the chief of which are :—

(1) The sweat glands are obstructed by the dirt. This puts an end to their use in getting rid of some of the waste matters of the body, and throws an extra amount of work on the other organs, *i.e.* the kidneys and the lungs.

(2) The sebaceous glands also may become stopped up, giving rise to little black spots, called black heads.

(3) The cake of dirt upon the skin lessens the sensibility of the skin.

(4) The cake is a good soil for germs to grow and multiply in, and these may give rise to all kinds of skin diseases.

(5) The dirt may putrefy and cause the stench that always surrounds dirty people.

(6) Dirty people are always liable to have parasites living upon them.

The use of water alone is not sufficient to remove this greasy dirt, but something must be used that will combine with the grease and make it soluble. Such a substance is soap.

Soap. In order to understand what soap is, we must refer back to the chapters about foods, where it says that a fat is a compound of a fatty acid with glycerine, *i.e.*

$$\text{A Fat} = \text{Fatty Acid} + \text{Glycerine}.$$

If a fat is boiled with potash (or soda), the potash combines with the fatty acid forming a soap, and the glycerine is set free. Soap may therefore be defined as a compound of a fatty acid with potash or soda, or more scientifically, a soap is either the potassium or sodium salt of one of the fatty acids. Potash forms the soft soaps, and soda forms the ordinary hard soaps.

There is often an excess of alkali in soap; on the other hand, a soap that possesses no free alkali is not so efficient for cleaning, because the alkali aids the action of the soap in removing the grease. If too much alkali is present, the soap is bad for personal washing, as it tends to roughen and harden the skin.

Baths. Warm water is necessary to thoroughly clean the skin, and a warm bath should be had once a week, whether a daily cold bath has been indulged in or not. A warm bath should have a temperature of about 110° F., and should be taken the last thing at night, because it renders the skin very susceptible to cold, and thereby increases the tendency to take a chill. The face and neck should be washed twice daily, and the hands should be washed before each meal, especially if the employment is dirty, so as to prevent the possibility of dirty or poisonous particles being eaten with the food.

A cold bath every morning is valuable as a tonic, and not for its effect in cleansing the skin. It should only be indulged in by persons in robust health, and even then it may be sometimes injurious. If it is followed by a sense of warmth and well-being, it is probably doing a certain amount of good.

Sea-bathing is an excellent tonic in the summer. It should not be indulged in when fasting, nor immediately after a full meal. The best time for sea-bathing is about eleven o'clock in the morning, when the resisting power of the body is probably at its maximum. There is a popular fallacy that the best time to bathe in the sea is before breakfast. As a matter of fact there is no time in the day that for many people could be worse suited for such a performance, but strong vigorous adults may derive benefit from it. Whenever the dip is taken, it should not be unduly prolonged. From five to ten minutes is usually sufficient for most people, but many can remain in for much longer periods without any ill effects. A chilly feeling, with blueness about the fingers and toes is a sure indication that the bath has lasted too long.

Turkish baths, where the body is subjected to heated air, are very useful to people of sedentary habits. They tend to keep the skin healthy by thoroughly cleaning its surface and pores.

PARASITES.

The parasites found on the surface of the body are divided into two groups—the animal and the vegetable.

Animal Parasites. The commonest are fleas and bugs. These cause much irritation of the skin, producing small spots and lumps. They are the result of continued uncleanliness, and are easily got rid of by systematic killing and cleaning.

The louse may infest the hair of the head or the body, giving rise to much itching. Scrupulous cleanliness, with the constant use of soap and warm water, is the simplest method of getting rid of these insects. Sometimes these means are ineffectual; in which case the best plan is to either shave the part affected or to rub in well some white precipitate ointment.

An excellent plan is to apply paraffin to the hair thoroughly every evening for three days, washing carefully with hot water and soft soap on each succeeding night.

There is a common superstition that nits and lice are inevitable in the hair of weakly children. Dirty mothers are very fond of making this statement in excuse of the fact that the hair of one or more of their children is verminous. Of course there is no foundation for such an absurd idea. Nits and lice are the result of lack of care and cleanliness.

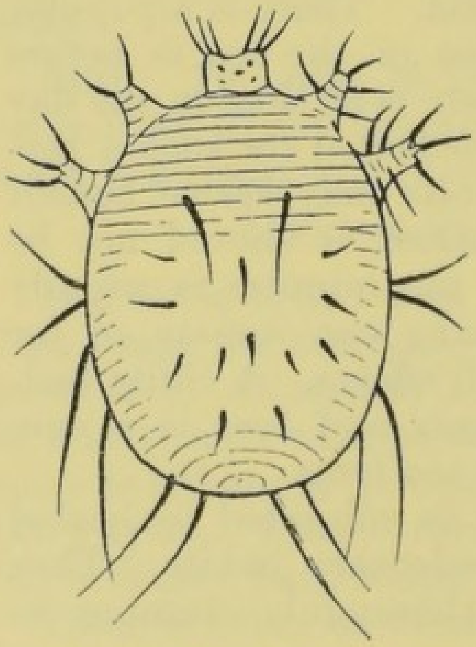


Fig. 82.—The Itch Insect.

The itch insect usually attacks the skin between the fingers. It is very minute, and the female insect burrows into the skin, causing intense itching and redness. Under the skin she lays her eggs, which hatch in about fourteen days. The female young ones then burrow afresh on their own account, and so the disease spreads. The itch is very contagious, the shaking of hands being sufficient to cause infection.

To get rid of this parasite, the affected parts must be well scrubbed with soft soap and water in order to remove all scales of skin, and to expose the burrow. Sulphur ointment is then to be well rubbed in. The clothing must be cleansed by boiling water. All clothing that cannot be boiled must be carefully ironed with a hot iron.

Vegetable Parasites. The vegetable parasites which attack the body are very minute, and are only visible by the microscope. Their presence is known by the diseases that they set up. The commonest are ring-worm and thrush.

Ring-worm includes a group of skin diseases produced by a kind of fungus. It may attack the scalp, beard, or any part of the body. The roots of the hairs are attacked by the fungus, causing the hair to become brittle and break off. This causes the well-known bare patch that is so characteristic of ring-worm.

Ring-worm is very contagious, and is easily spread by means of hats, gloves, towels, hair brushes, etc. The simplest treatment is the painting of the affected parts with a strong solution of iodine. The iodine should be applied every day until the skin begins to peel. All caps that have been worn by affected persons should be destroyed. Other forms of treatment include the application of mercurial preparations and X-ray treatment.

A very bad form of ring-worm is known as **Favus.** It usually attacks the scalp, where it forms a number of yellow cupped discs. It is much more difficult to cure than ordinary ring-worm.

Thrush is often met with in dirty and ill-fed infants. It appears as greyish patches on the inside of the mouth, and especially on the tongue. These patches are produced by a kind of mould, the growth of which is brought about by improper food, or by dirty feeding-bottles. For treatment, a mild aperient, such as magnesia, should be given, the patches should be wiped out, and the mouth smeared with glycerine and borax.

Internal Parasites. The consumption of infected meat, or of vegetables carrying on their surface the ova of intestinal worms, will give rise to these parasites in the human being. The tape-worm gains access in this way from infected beef or pork. Similarly other worms, the round worm and the thread-worm, may be acquired. Another parasite may gain access to the body from the eating of pork infected with the tiny worm called *trichina spiralis*, while uncooked vegetables, such as watercress or lettuce, may introduce the eggs of a tapeworm from the dog which, when swallowed, will develop and may cause death.

Germs of Disease.

All diseases that are transferable from one person to another (and probably most of the other diseases) are caused by minute bodies called germs or bacteria. These germs cannot develop from dead matter of any kind, but each family of germs is produced from ancestors of the same species. Thus tuberculosis or consumption is caused by a germ called the tubercle bacillus, and these germs can produce bacilli of the same kind, *i.e.* germs which are capable of producing consumption, and no other disease. Similarly, such diseases as diphtheria and typhoid fever are caused by bacteria which can only produce diphtheria or typhoid fever, as the case may be.

Whenever a case of these diseases occurs we may be certain that, in some way or other, the germs from a previous patient have obtained access to the infected person. Dirt and insanitary surroundings may predispose persons to give way to an attack of disease, but these conditions will not actually cause the disease, and so we must dismiss as mere foolish nonsense such statements as "small-pox is caused by dirt and insanitary conditions," or "diphtheria is caused by bad drains or bad smells."

Germs of disease may be conveyed from one person to another through the air (in dust), by infected water and food, by clothes which have been infected, or by living creatures such as flies or fleas.

Practical Work.

Soap.

(*a*) Place a small quantity of "olein" in a porcelain basin and warm. When it is melted add sodium carbonate, a pinch at a time. Note effervescence. Add the carbonate of soda until the contents of the dish become thick and pasty. Then cool. The solid now formed is soap or sodium oleate. Use a little as soap.

(*b*) Oleic acid ("olein" in commerce) may be obtained from the above soap by dissolving the soap in water and adding dilute acid. Oleic acid separates out as an oily layer.

(*c*) Similarly soap may be made from suet by putting some melted suet with water into a beaker and adding caustic soda [one part melted suet, three parts water, six parts caustic soda solution]. Surround the beaker with boiling water and stir. The melted suet gradually disappears. Then add to the uniform liquid half its volume of a saturated solution of common salt. A curd of soap separates out and rises to the top. The liquid below this layer contains glycerine.

CHAPTER XIII.

THE NERVOUS SYSTEM—THE EYE—THE EAR.

The nervous system includes :—

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

(2) The nerves directly connected with the brain and spinal cord, called the peripheral nervous system.

(3) Nerves only indirectly connected with the spinal cord, but connected with a series of small masses of nerve tissue found at intervals in the body cavity, in front of the spinal column. This is called the sympathetic nervous system.

The Brain.

The cavity of the skull contains a mass of nerve tissue called the brain, a large organ consisting of several parts. If it is examined it is found to have on the outside a layer of greyish material called "grey matter" which covers material of a lighter colour called "white matter." The grey matter consists of nerve cells which are formed into groups called "centres." These groups of cells are called centres because certain places on this grey matter have been proved to be associated with special parts, sensations, or acts. In other words, the grey matter is believed to be divided up, as it were, into pigeon-holes or compartments, each having special work to do. Thus special parts of the brain deal with sight, hearing, muscular movements of the face, arm, leg, etc.

The weight of the brain averages about 50 ounces in the adult. Its soft yielding tissue makes it necessary for special means of protection to be provided. These protections are as follows :—

(1) The general shape of the cranium. This is rounded on the tops and sides, and all corners and angles are conspicuous by their absence. The force of a blow directed upon the skull is thus scattered.

(2) The structure of the bones forming the vault of the skull. These consist of two layers or tables. If the outer one be fractured by external violence the inner may escape.

(3) The presence of the membranes. The outermost membrane, the dura mater, is very strong and tough, and it also sends processes inwards which, being attached to bony projections in the interior of the base of the skull, afford support to different parts of the brain-substance.

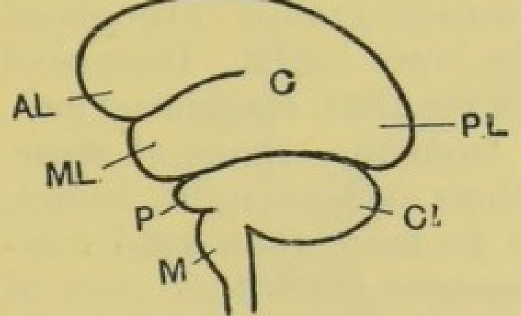


Fig. 83.—Diagram of the general divisions of the brain (left side).

C, cerebrum ; AL, anterior lobe ; ML, middle lobe ; PL, posterior lobe ; P, Pons ; M, medulla ; Cl, cerebellum.

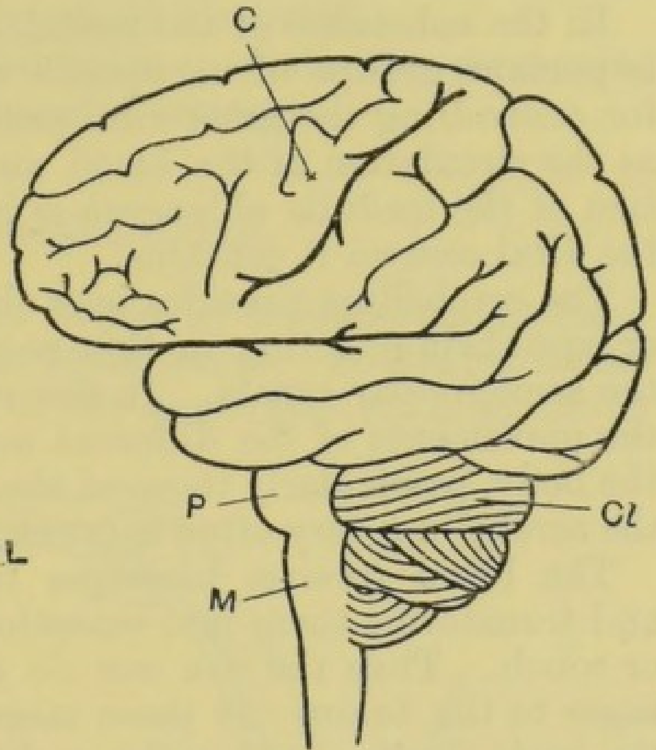


Fig. 84.—Diagram of brain showing convolutions and fissures of external surface on left side of brain.

The line from C leads to the place near which most of the motor areas of the brain are situated.

(4) The water cushion which surrounds the brain and spinal cord.

(5) The curves of the spinal column and the structure of the column itself. The presence of the separate vertebrae with their intervertebral discs, and the fact that the spinal column is not a stiff vertical rod, show that the brain is protected from shocks and jars while running, jumping, etc.

Parts of Brain. The brain is divided into four chief parts, (*a*) the cerebrum, (*b*) the pons, (*c*) the medulla, and (*d*) the cerebellum. These are shown in Figs. 83 and 84.

Functions of Brain. The higher centres of the mind and intellect are contained in the frontal lobes of the cerebrum. If these be destroyed or are deficient the sense of the individual is impaired or lost.

In the substance of the medulla itself are placed certain important groups of nerve-cells which are the "centres" for controlling the great vital processes of the body, such as the circulation of the blood and respiration. Destruction of the medulla oblongata is instantly fatal, because of the vital centres it contains.

The cerebellum presides over the mechanism of balance or equilibrium, acting in this respect in conjunction with the semicircular canals. It also regulates, to some extent, the movements of the different muscle-groups throughout the body, particularly those of the lower limbs. Disease of the cerebellum very often causes a peculiar, staggering gait.

The brain receives messages from the organs of sense, and transforms them into sensations such as sight, sound, or touch. Thus the eye can do no more than send messages to the brain. If these messages reach that part of the brain dealing with sight, and if that part of the brain is properly developed, is healthy, and is educated to interpret these messages, then, and only then, does the individual see. It is the same with the ears and the other organs of sense. The full possession of any one of the senses therefore is only possible when the three essential parts and their connections are perfect. These are (1) the sense organ, such as the eye, (2) the connection of this organ with the brain, *i.e.* the sensory nerve, and (3) the centre of the brain, whose special function it is to deal with and properly interpret these messages. Of such sensory centres the positions of those concerned with smell, taste, hearing, sight, and ordinary sensation are known.

The brain also contains centres, called motor centres, concerned with movements. The positions of the centres concerned with movements of the face, tongue, lips, arms, legs, trunk, and head are known. Such centres are double, one on each side of the brain, and, curiously enough, centres on the right side of the brain govern movements on the left side of the body, and *vice versa*. Thus, in an ordinary right-handed individual, the arm centre on the left side of the brain would be more frequently used, and would become more highly developed than the corresponding centre on the right side. Such an act as writing would therefore have its centre on the left side of the brain.

Other functions of the brain include the process of thought and the phenomenon of memory.

The Spinal Cord.

The spinal cord occupies the cavity in the spinal column, and is continuous with the brain above. If it is cut across it is seen to be composed of the same two kinds of tissue

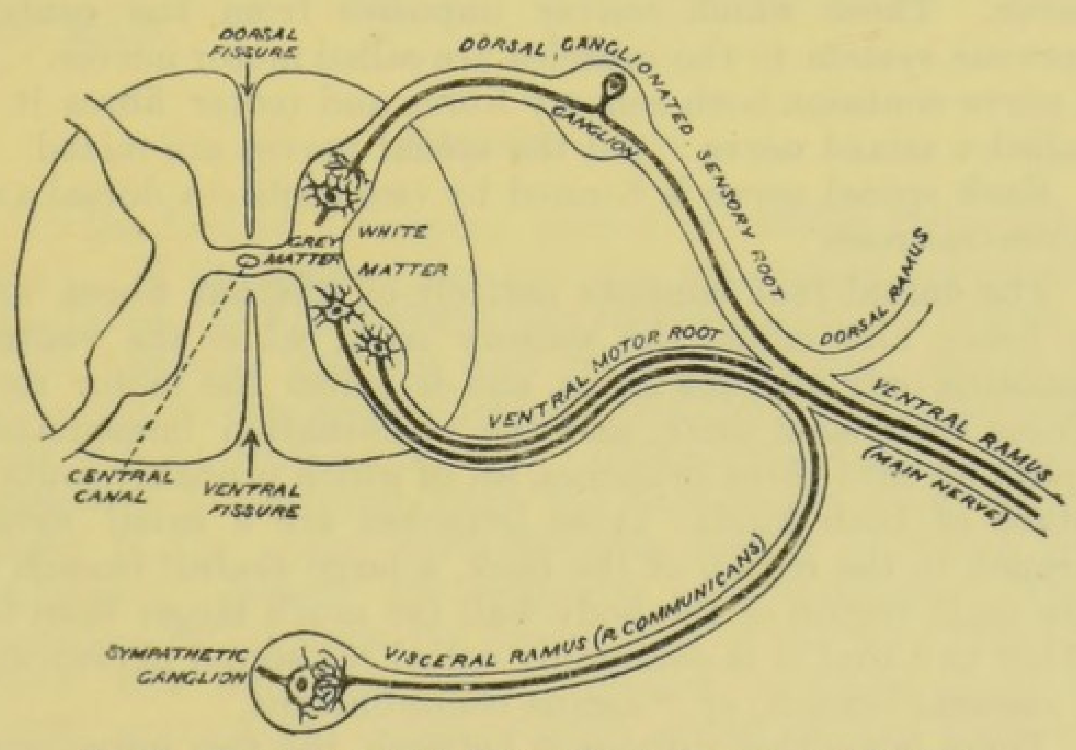


Fig. 85.—Diagram of the Spinal Cord, Dorsal and Ventral Nerve-roots, and the Ganglia.
(The thick black lines represent nerve-fibres.)

as the brain, but the white matter here is arranged outside the grey. The white matter forms the paths of communication with the brain, while the cells of the grey matter can act as "centres" for what are called "reflex actions."

The spinal cord gives off a paired series of **spinal nerves**. These nerves are numbered according to the vertebra *in front of* them—thus the nerve-pair between the third and fourth lumbar vertebrae is called the third lumbar pair of nerves. An exception is made for the cervical region, because the first spinal nerve emerges between the skull and the atlas; thus there are eight pairs of cervical nerves.

The Nerves.

Connected with the brain there are twelve pairs of nerves, and from the spinal cord there pass thirty-one pairs. Nerves carry impulses either to the central nervous system or from it. If a nerve brings impulses from the skin or from the organs of special sense, such as the eye or the ear, to the brain or spinal cord it is called a sensory nerve. Those which convey impulses from the central nervous system to the muscles are called motor nerves. If a nerve contains both sensory fibres and motor fibres it is called a mixed nerve. All the spinal nerves are mixed.

Each spinal nerve is formed by two roots—a dorsal and a ventral root.

The **dorsal root** consists entirely of **afferent** fibres, and is hence also called the sensory root; while the **ventral** contains only **efferent** fibres, and is called the motor root. These roots soon unite, and the combination immediately splits up into three branches, all of which probably contain fibres of both kinds: these branches are a small *dorsal* branch to the region of the back, a large *ventral* branch to the main region of the body-wall (so much larger than the other two that it is commonly called *the* spinal nerve), and a visceral branch, or "ramus communicans."

There is another difference between the two nerve-roots besides the difference in the direction in which they convey impulses. On the dorsal root there is a swelling called a ganglion; these **spinal ganglia** on the dorsal roots form an important distinction from the ventral roots.

Nerve-impulses. A muscle-fibre or gland-cell may be compared to the charge of explosive in a loaded gun; it contains a store of energy and is capable of doing a definite piece of work, but in order to start it to work, some relatively small amount of work—the pulling of the trigger—must first be done upon it by an external agent. So a muscle (or, at least, a striped muscle) will not work until it receives a **stimulus** from without. Effective stimuli of various kinds can be artificially applied to muscles,—a sharp blow on the bare muscle, a drop of acid, or an electric discharge. But under normal circumstances the stimulus is always an impulse sent from some nerve-cell along its axis-cylinder, which ends in a fine ramification over the surface of the muscle-fibre.

What the nature of this propagation of a stimulus may be we do not know. It may perhaps be comparable to the firing of a train of gunpowder, if we could imagine only a small portion of the gunpowder to be burnt when the train was fired, so that the same train could be fired again and again.

Reflex Acts.

If the foot of a sleeping person is tickled it is jerked away. If the soles of the feet of a man whose spinal cord is injured anywhere above the sacral region be tickled, it often happens that his legs will be suddenly drawn up, although he can neither feel the tickling nor is able, of his own will, to draw up his legs. The explanation is that the sensation is conveyed from the foot along sensory nerve fibres to the spinal cord, the grey matter of which constitutes a "centre" for receiving such messages. These impulses so act upon the grey matter of the cord that they cause new impulses, motor impulses, to travel along the motor nerve fibres to the muscles of the leg and foot, with the result that the foot is jerked away. These movements are produced without the action of the will or brain, and take place perfectly when all connection with the brain has been destroyed. As long as there are the proper connections between the brain and the spinal cord, the brain exercises a controlling effect in limiting the violence of the movements caused by reflex acts. This is called inhibition.

Also, when conscious, the will, or volition, comes into play, and the brain can limit or prevent the motor impulses being sent in response to a sensory stimulus. Thus, by an effort of the will, it is possible to prevent the foot being jerked away when the sole is tickled.

For a purely reflex act there are therefore three necessary parts: (1) a sensory nerve, (2) a nerve centre, and (3) a motor nerve. Many of the ordinary acts and movements of human beings are reflex acts. Some of them are

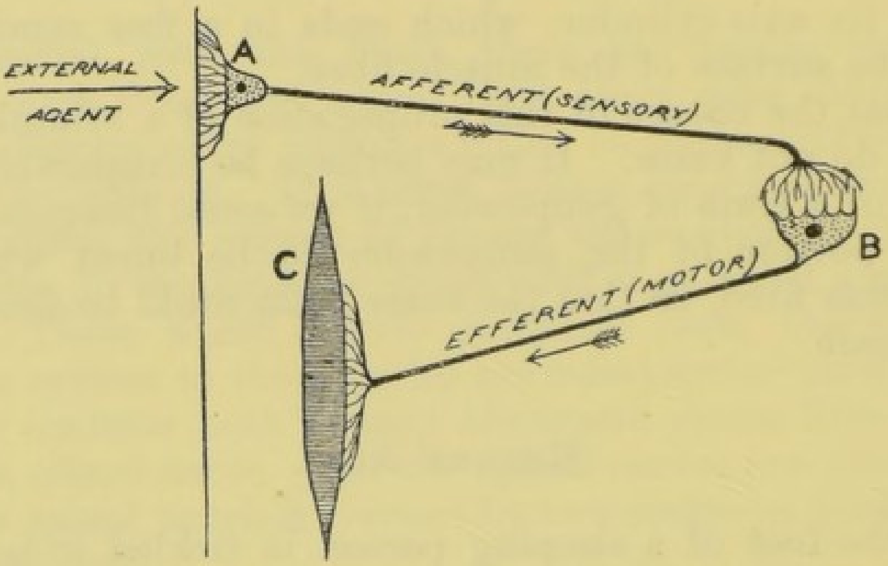


Fig. 86.—DIAGRAM OF REFLEX ACTION.
A, Nerve Cell; B, Cell in Nerve Centre; C, Muscle Fibre.

involuntary or automatic, and take place with or without the will. Some acts that originally required considerable effort and a good deal of will control become more or less automatic afterwards. Thus we can go on walking without thinking about it. Among the purely automatic centres which require no stimulus from the outside are those concerned with circulation and respiration. These acts are continually performed during life, but the rate at which the work is done is constantly varied in response to impulse.

The start that one gives in response to a sudden noise; the jerking away of the hand if it touches a hot body; the closing of the eyes in response to a sudden flash of light; these are common reflex acts. The centres for most of the reflex acts are situated in the spinal cord. This is proved by the case of a man whose spinal cord is damaged by disease or injury, so that communication with the brain is impossible. In this case—

(1) If the feet are tickled, the legs are sharply drawn up;

(2) The restraining action of the brain being withdrawn, the reflex excitability of the nervous structures is increased, and the responsive movements are more violent;

(3) In the disease known as *lateral sclerosis*, where, owing to degenerative changes, the path from the brain to the nerve-cells of the cord is discontinuous, there is a great increase of responsivity, slight stimuli such as a movement of the bed-clothes causing convulsive movements of the legs.

Voluntary Acts.

Voluntary actions on the other hand are controlled by the will acting through the brain; but even these actions are usually the result of impulses transmitted to the brain through the spinal cord by the nerves. If a person is standing resting his hand on a table and a mischievous boy pricks it with a pin, an impulse is transmitted along the nerves through the spinal cord to the brain, the man becomes conscious (in some inexplicable way) of pain, and efferent impulses may be instantaneously transmitted to various parts, *e.g.* to the muscles of the arm, causing the hand to be snatched away,* and to the muscles of the neck, causing the head to turn round to see what caused the sensation.

In the latter case afferent impulses would be transmitted from the eye along the optic nerve, and the man would become conscious of the presence of the boy and the pin. Motor impulses would probably pass from the brain-cells to the muscles of the larynx, tongue, and mouth, and he

* This action will probably be performed as a reflex action before the brain has time to act.

would speak, questioning as to why it was done or warning the boy not to repeat the action, or motor impulses might pass to the muscles of the arm, causing it to strike at the boy. If the boy ran, afferent impulses by means of the eye along the optic nerve would enable the man to become conscious of this and impulses might pass to the muscles of the leg, and the man might run after the boy.

Thus the object of the nervous system is to enable us to recognise when we are affected by external objects and to respond or act in such a way as will tend to preserve the body from injury.

Many voluntary actions can, however, be performed almost unconsciously, *e.g.* walking. In this case there is a conscious effort of the will to start, stop, or alter the action.

Sympathetic Nervous System.

Lying on each side of the front of the vertebral column is a row of small beads or ganglia connected together by a greyish-coloured cord. This is called the sympathetic chain, and extends from the base of the skull to the bottom of the spine. The ganglia are connected by fibres with the spinal nerves, and therefore with the spinal cord, and immense numbers of nerve fibres pass from the sympathetic chain to the various internal organs, such as the heart, lungs, stomach, intestines, and also to the walls of the blood-vessels all over the body. These sympathetic nerves chiefly carry impulses which govern the muscular tissue of the internal organs and the muscular coat of the blood-vessels.

The Eyes and Eyesight.

Structure of the Eye.

The human eye is often likened to a camera, and, as most people have had to do with photography either in the active or the passive sense, the comparison is a convenient one. The essential parts of a camera are a box to give and maintain the necessary shape to the instrument, a convex lens to produce the picture, and a sensitive plate to receive and record it. In addition to this the box must be blackened inside to prevent reflection of light, and there must be some mechanism for focussing if pictures of objects at varying distances are to be photographed.

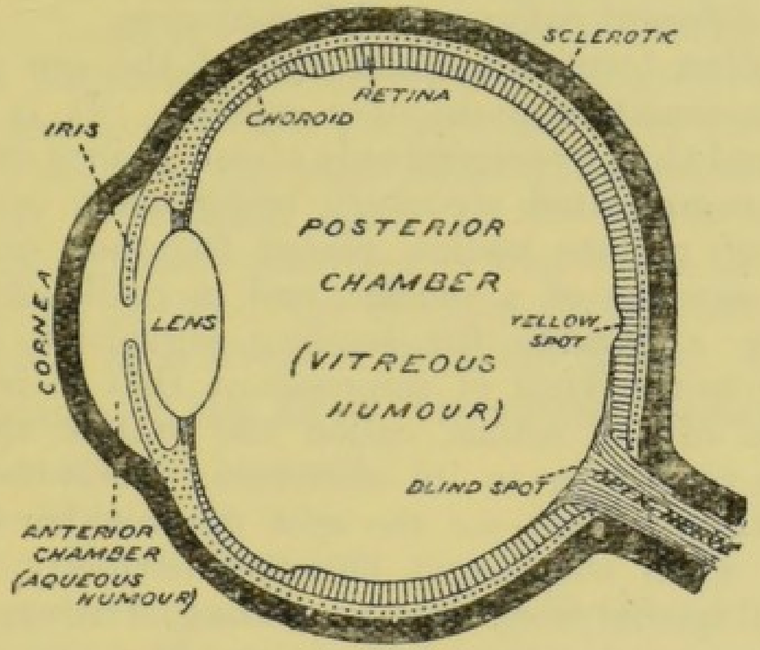


Fig. 87.—The Eye.

The Coats of the Eye. The eye is nearly spherical in shape (see Fig. 87), bulging a little in front, and able to turn freely in a bony socket called the orbit. The shell or wall of the eye has three layers—

1. The sclerotic and cornea.
2. The choroid and iris.
3. The retina.

The **sclerotic** or the white of the eye is a tough, dense, fibrous membrane forming the greater part of the substance of the eyeball. It is the only part of the eye that is capable of resisting any strain, so that if by any chance it stretches or gives way the rest of the structures will at once follow suit. In front it is continued as the **cornea**, which, being transparent, forms the window of the eye.

The **choroid** lies internal to the sclerotic, and is a network of blood-vessels. Its inner surface is black in order to prevent reflection, which would cause confusion of the images. This layer of black pigment is absent in albinoes, who, in consequence, are almost blind in bright daylight. Under the cornea the choroid is represented by a specialised structure called the **iris**, which is a circular contractile diaphragm. The central hole is called the **pupil.** Varying proportions and distribution of pigment deposited here give the different colours to different eyes.

The **retina** forms the inner coat of the eye, and represents the sensitive plate of a camera. It is extremely delicate and thin, averaging only about $\frac{1}{80}$ inch in thickness. It has a complicated structure, being made up of a vast number of minute bodies, placed together side by side like the squares of a mosaic, and is really an elaborate signalling apparatus for sending signals to the brain referring to the kind of impressions that it is receiving. One spot of the retina, called the **yellow spot**, differs from the remainder in its structure. It is the region of most distinct vision—*i.e.* the spot upon which objects are focussed when they must be seen distinctly, as in the case of all special work such as reading, writing, or sewing. The enormous number of tiny nerve fibres from all parts of the retina are collected together at the back into a large trunk or cable called the **optic nerve.** The messages pass along these fibres to the part of the brain that has to deal with them. This part of the brain is best regarded as a kind of central office for receiving and interpreting these multitudes of messages.

The Blind Spot. One part of the eye very happily illustrates an important point in the physiology of nerves. The function of a nerve *fibre* is *conduction* pure and simple; the nerve fibre does not itself receive impressions, but merely conveys impressions from the sense organ to the central nerve system. Thus, in the case of an eye the nerve fibres themselves are not directly affected by the light, but merely transmit the stimulus received by the specialised sensitive part of the retina. It follows from this that at the point where the optic nerve leaves the retina and where there are nerve fibres only, without any of the special structures which are sensitive to light, there is a **blind spot** which is not sensitive to the action of light. If there is any doubt as to the existence of a blind spot in the retina, the proof is easy. Let the reader shut his left eye and regard these two asterisks with the right eye, fixing his gaze intently upon the left-hand asterisk.

*   *

If the eye is at a distance of three or four inches from the paper, both asterisks will be distinctly visible. Now, if the eye is withdrawn slowly, the right asterisk will, of course, appear to approach the left, but when the eye is six or eight inches from the paper, the right-hand asterisk will vanish, only to reappear again as the eye is withdrawn still further. The explanation is that when the eye is in this particular position the eye lens throws the image of the right-hand asterisk on to the blind spot.

The Contents of the Eye. The eyeball contains—

1. The aqueous humour.
2. The crystalline lens.
3. The vitreous humour.

The **aqueous humour** is a watery liquid occupying the chamber between the crystalline lens and the cornea. The **crystalline lens** is a translucent solid body, composed of soft gelatinous living tissue, situated immediately behind the pupil and partly imbedded in the vitreous humour. It is convex on both sides, but more so behind. In early life it is nearly spherical and soft, but becomes more flattened, firmer, and amber-coloured with advancing age. The lens is held in position by its capsule and suspensory ligament. The **vitreous humour** is a jelly-like material lying at the back of the lens and occupying about four-fifths of the interior of the globe. The above

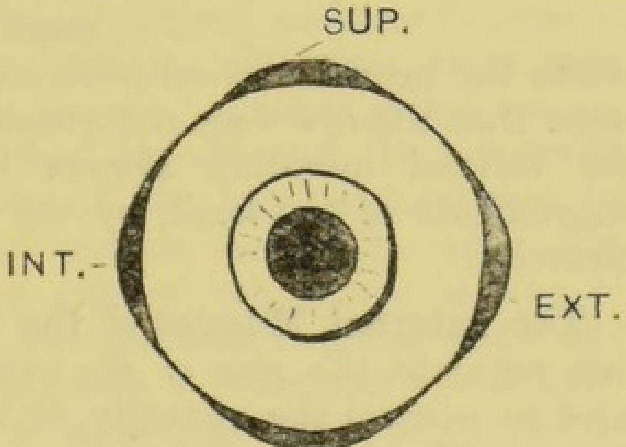


Fig. 88.—Insertion of the Straight Muscles.
SUP., Superior Rectus; INF. (below), Inferior Rectus; EXT., External Rectus; INT., Internal Rectus.

three substances are transparent, and with the cornea constitute the refractive media of the eye, which conjointly act as a converging lens, the function of which is to bring the rays of light to a focus upon the retina.

The External Muscles of the Eye. Attached to the outside of the eye are six muscles, four straight and two oblique. The four straight muscles are attached symmetrically round the globe, above, below, right, left. These muscles, by their contractions, enable us to direct the eye towards different points. It is obvious that by the single action of one, or the combined action of two, the eye can be turned towards any direction. The two oblique muscles are inserted, slantwise, one above and one below the eye. By their contraction they can rotate the eye on its axis. Their action is best understood if a mark in the iris be watched while the head is moved from side to side. It will be then seen that the eye does not rotate with the head, but keeps its vertical meridian always vertical, during moderate movements of the head, by the contraction of its oblique muscles.

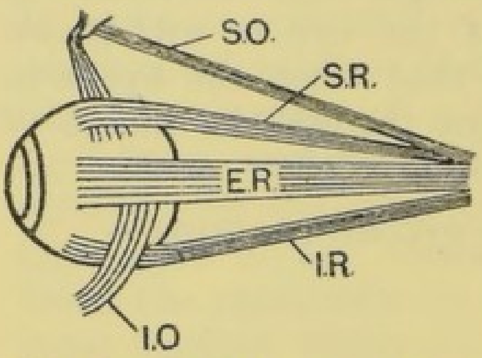


Fig. 89.—Muscles of the Eye.

SO, Superior Oblique; IO, Inferior Oblique; SR, Superior Rectus; IR, Inferior Rectus; ER, External Rectus.

The Internal Muscles of the Eye. The muscles of the iris regulate the *size of the central aperture* (the pupil) and so control the quantity of light which enters the eye; in a dim light the pupil is large, and in a bright light it is small. The ciliary muscles regulate the *curvature of the surfaces of the lens* so that the rays from any point focus exactly on to the retina; a greater curvature is required for near objects than for distant objects. Both the iris and the ciliary muscles work by reflex actions, of which we are not conscious and over which we have no control.

Accommodation. Suppose the eye is looking at some object, say a stick. The rays of light coming from any one point on the stick are focussed by the lens to a single point on the retina; the rays from some other point on the stick are focussed by the lens to some other point on the retina; and so on. In this way a picture or **image** of the stick is thrown on to the retina, and the optic nerve conveys the impression to the brain. Thus the action of the eye is like that of the photographic camera, where, by means of a lens or a group of lenses, a picture or image of an object is thrown on to the negative; in both the eye and the camera the image is **inverted**, that is, right becomes left, and top becomes bottom.

If a candle, a convex lens, and a screen are held in line it is easy, by adjusting the distances separating them, to get a clearly defined image of the candle flame upon the screen. The image is then said to be *in focus*. If the candle is moved further away or nearer to the lens the image on the screen will become indistinct and is out of focus. In the same way it is necessary to adjust, or focus, a telescope or field-glass in order that the desired object may be seen clearly.

Now we know that the normal eye has the power to direct its attention to a distant object and see it clearly, and then immediately to turn its attention to a near object and see that equally clearly. This is called accommodation. It is accomplished by altering the convexity of the lens. The convexity of the lens is increased by the contraction of a small muscle inside the eye. The more convex the lens the greater the power it has of turning the rays of light out of their original path and causing them to come to a focus. When the eye is looking at distant objects it is receiving light composed of rays that are practically parallel to each other, and the normal lens is capable of bringing these to a focus on the retina. Rays are practically parallel when springing from a point 20 feet or more distant. From near objects, however, the rays are divergent, and need more turning to bring them to a focus. In order to focus such rays the convexity of the lens is altered to the necessary extent by the contraction of the muscle already referred to. So that when looking at distant objects there is no muscular strain, and hence no fatigue, but looking at near objects involves contraction of the muscles and is liable to bring about strain and fatigue.

When looking at near objects there is necessarily contraction also of the external muscles of the eye in order to pull the eyes towards each other, and so that the axis of each eye is directed towards the object to be seen. It

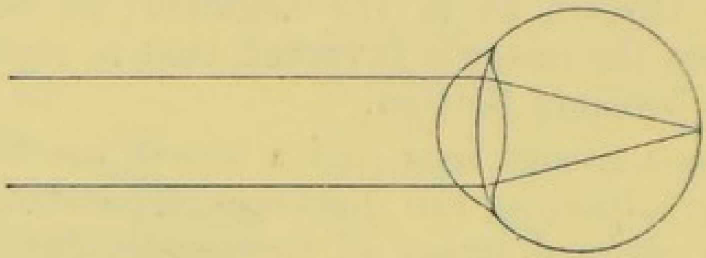


Fig. 90.—Normal Eye receiving Parallel Rays (from distant objects) and bringing them to a Focus on the Retina.

therefore follows that the nearer the object is that we look at the greater is the muscular strain inside the eye, the greater the tension on the sclerotic by the muscles pulling outside, and the greater the pressure exerted by the semi-liquid contents of the eyeball. These strains are likely to distort the shape of the eye. Looking at near objects involves muscular effort and exertion, and if unduly prolonged will cause fatigue, a condition which still further increases the tendency towards distortion.

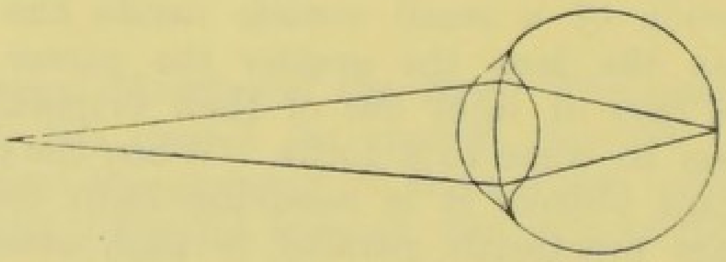


Fig. 91.—Normal Eye receiving Rays from Near Object and bringing them to a Focus on the Retina by increasing the Thickness of its Lens (accommodation).

Eye Strain. It has already been pointed out that when the eye is looking at objects 20 feet or more away it is at rest, and no muscular effort is required. On the other hand, in looking at a near object, the eyes assume a position of convergence. Each eye is pulled towards the other by the muscle which is attached to its inner side. The nearer the object the greater the pulling required. The object of convergence is to bring the yellow spot of each retina to bear on the same point. This pull puts the sclerotic coat on the stretch, and is the direct mechanical cause leading to the production of short sight. If the twenty-first year, or perhaps to be quite safe it should be the twenty-fifth year, is reached without any stretching of the sclerotic coat it is extremely unlikely that short sight will ever be developed. By that age the coat is sufficiently tough to resist all ordinary strain.

It has been proved beyond all doubt that our educational methods are chiefly to blame for the production of short sight.

Signs of Eye Defects. All persons who show any of the following signs should at once consult a doctor about their sight. On no account should a chemist or "optician" be consulted: the eye is too important an organ to be doctored by amateurs.

1. All those with sore eyes.
2. All those whose eyes are congested and red.
3. All those who peer and blink when they wish to see anything particularly well.
4. All those who appear to be in difficulty when they are reading from map or diagram or blackboard.
5. All those who complain of headache, or who appear to fear a bright light.
6. All those who turn the head sideways or slanting in order to read.
7. All those who hold the book nearer than one foot when reading. Also those who hold the book at arm's length.
8. All those who squint constantly or occasionally.

The Ear and Hearing.

The ear is divided into three parts, (1) the external, (2) the middle, and (3) the internal ear. These together make up the receptive part.

The **auditory nerve** (the eighth cranial nerve) forms the conducting part, while the perceptive portion is found in certain nerve-cells in the brain.

The **external ear** is that external structure which is usually described as "the" ear. It serves as a means of collecting waves of sound. An open tube, called the auditory canal, leads inwards from it. The canal is about an inch long, and is set near its mouth with fine hairs, while within, embedded in the walls, lie some small glands, which secrete wax. The hairs help to prevent the entrance of insects. The wax serves to entangle bacteria and insects

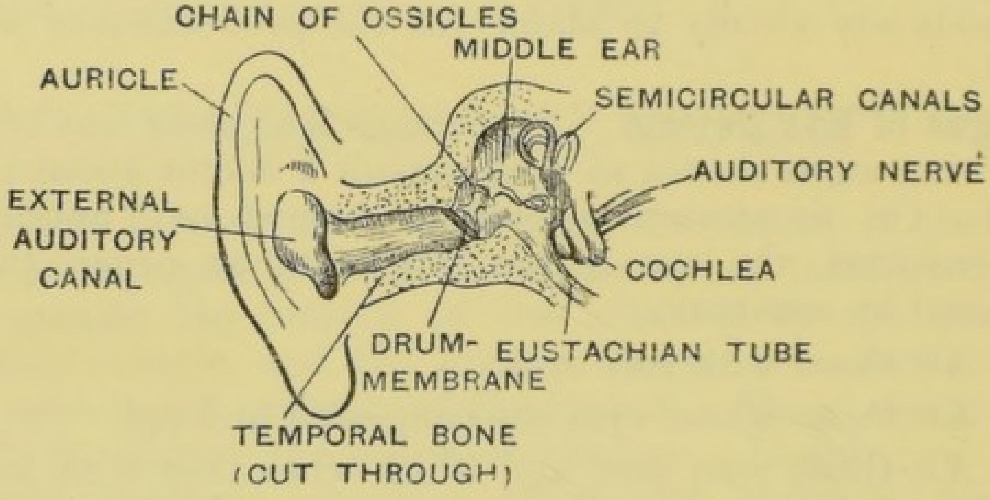


Fig. 92.—Diagram showing the parts of the External, Middle, and Internal Ear.

that have gained admission. If the wax collects in too great quantity it will block the passage and cause deafness. This can easily be removed by syringing with hot water.

The external **auditory canal** is about one inch long, and leads from the external ear to the middle ear. At its inner end is the **tympanum** or **ear drum**. This membrane divides the external from the middle ear. It is not set at right angles to the canal, like a door at the end of a passage, but obliquely, so that the floor of the meatus is longer than its roof. In appearance and thickness the drum somewhat resembles an oval piece of gold-beaters' skin. The handle of the **malleus** or hammer-bone, one of the small bones (ossicles) of the middle ear, is attached almost vertically to the inner side of the tympanic membrane.

The drum vibrates in response to sound-waves travelling along the external auditory canal.

The Middle Ear. This is a cavity in the temporal bone of the skull. It is separated from the external auditory canal by the ear drum. From the floor of the middle ear there passes downwards a tube (the **Eustachian tube**) which opens into the pharynx. The walls of the middle ear, and the blood in the capillaries there, absorb the air, and would cause a decrease in pressure in that cavity if the **Eustachian tube** did not admit air, and so equalise the pressure on both sides. If the tube gets blocked, by a severe cold or by the pressure of adenoid growths, for instance, this absorption takes place, the pressure in the middle ear falls, the tympanic membrane becomes tense and is unable to vibrate, and deafness results.

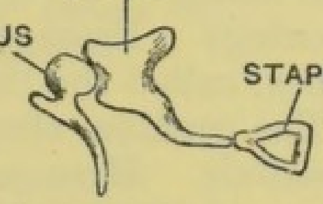


Fig. 93.—The three small bones contained in the Middle Ear.

A chain of three little bones, the **auditory ossicles**, runs through the centre of the cavity, joining the outer with the inner walls. These ossicles are (*a*) the **malleus** or hammer-bone, which we have seen is attached to the inner side of the tympanic membrane; (*b*) the **incus** or anvil-bone, in the middle, and (*c*) the **stapes** or stirrup-bone (Fig. 93). The three bones are all delicately joined together, and the base of the stapes fits into an opening in the inner wall of the middle ear. This opening, called the **fenestra ovalis** or the oval-shaped window, is also occupied by a membrane, on the inner or deep side of which is the internal ear.

The Internal Ear. The internal ear or labyrinth is the most important part of the organ of hearing and it is also the most complicated. It consists essentially of a membranous bag fitted into a cavity of complicated shape within the substance of the temporal bone. There is a thin, watery fluid (*perilymph*)* outside the bag, and another (*endolymph*)* within it. The bag is called the *membranous labyrinth*, and the cavity the *bony labyrinth*.

* From two Greek words, *peri*, around, and *endo*, inside.

The **bony labyrinth** is made up of three principal parts—

(1) the vestibule,
(2) the cochlea,
(3) the semi-circular canals.

The **vestibule** is the central cavity of the internal ear. Its outer wall presents the opening for the foot-plate of the stapes, the **fenestra ovalis**, covered in by a membrane. The auditory nerve pierces its inner wall by several small openings. From the back of the vestibule three curved tubes, called the three semi-circular canals, project.

The **cochlea**, shaped like a snail-shell, lies in front of the vestibule. Here is found the most delicate part of the organ of hearing. It is made up of two-and-a-half turns of a spiral canal, while at its base there is a small round opening which would communicate with the cavity of the middle ear but for the fact that it is closed in by a membrane.

Within the spiral canal of the cochlea the branches of the auditory nerve (nerve fibrils) are connected with patches of special sensory cells with hair-like processes.

The **semicircular canals**, three in number, are not directly concerned with the function of hearing. They contain fluid in the same way as the rest of the labyrinth. A special branch of the auditory nerve enters their lower ends. It is supposed that the varying degrees of pressure within the six canals (three on each side) give us the sense of position in space, and they are in some way connected with the maintenance of equilibrium. When they are destroyed in an animal oscillatory movements are performed and the power of preserving the balance is lost.

The Auditory Nerve This nerve emerges from the base of the skull, enters the temporal bone through a small canal, and then runs up the axis of the shell-like cochlea. Here it gives off branches which split up into innumerable fine filaments which find their way to the base of each patch of special sensory cells.

The Path of the Sound Waves. We are now in a position to understand something of what happens when a sound is heard. The following is the sequence of events :—

1. The waves of sound are collected by the external ear and reflected towards the external auditory meatus, along which they travel.

2. They next beat up against the tympanic membrane, causing this to vibrate in sympathy.

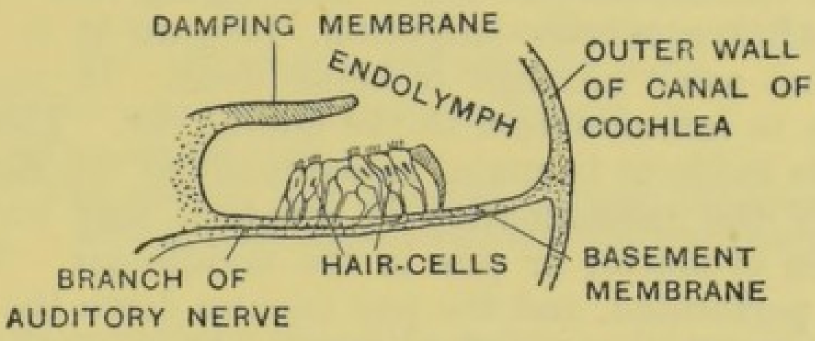


Fig. 94.—Diagram showing Hair Cells connected with branch of Auditory Nerve in Spiral Canal of Cochlea.

3. The vibrations of the drum of the ear are conducted by the three auditory ossicles which stretch across the middle ear to the base of the stirrup-bone, which produces corresponding vibrations of the fluid on the other side of the membrane closing in the oval window in the internal ear.

4. These vibrations of the perilymph excite corresponding vibrations of the endolymph, acting through the wall of the membranous labyrinth.

5. The excitation of the endolymph so produced stimulates the hair cells, setting up impulses which are transmitted by the fine branches of the auditory nerve along its trunk towards the brain.

6. In the temporal lobe of the brain, on each side, is situated the "centre" for hearing, and it is here, in the delicate nerve-cells, that sound is really perceived or "heard."

Deafness may be due to some comparatively simple cause, such as an accumulation of wax in the external auditory canal, or adenoids blocking up the Eustachian tube; but on the other hand it may be due to more serious and complicated defects, such as diseases of the middle or inner ear, interference with the auditory nerve, or defective development of, or damage to, the hearing centre situated in the brain.

Earache and Ear Discharge. These are unfortunately of frequent occurrence in school children. At least one per cent. of the children have discharging ears. Earache should always receive attention, because it is the first signal that some mischief is being done. In many cases it is due to inflammation in the middle ear. This part of the ear is liable to bacterial invasion along the Eustachian tube. If the inflammation is severe it may lead to the formation of matter or pus in the middle ear. Then the drum is perforated, and the pus trickles down the external auditory canal as "ear discharge." It is of the utmost importance that such a discharge should be medically treated and cured at once. A child with an ear discharge should be likened to a person living on the edge of a precipice: it may continue for years, but disaster may occur at any moment. If treated at once the discharge will stop, and the hole in the drum will probably heal up, and the loss of hearing will only be very slight. If it is neglected it will become chronic and the ear may be permanently damaged. If it is treated afterwards it is very difficult to cure, and the hole in the drum will not heal up, so that some loss of hearing is inevitable. Moreover the trouble may cause death at practically any time. There is only a thin plate of bone separating the middle ear from the brain, and this may be attacked and perforated by the inflammatory process. The next step would be the formation of an abscess in the brain, and death may be rapidly brought about.

PRACTICAL WORK.

Nerves.

Remove a small piece of nerve from a rabbit. Place it on a glass slide and tease it into fine threads by means of two mounted needles. These are the nerve fibres. Examine them under the high power of the microscope. You will now see that the nerve fibres are bound up in bundles. The bundles bound up together form the nerve.

Spinal Cord.

I. Procure from a butcher a cow's spinal cord or spinal marrow. Cut it across with a knife and examine the cut ends. Note the following points :—

(*a*) The membrane (*pia mater*) covering the cord.

(*b*) The white substance on the outside of the cord.

(*c*) The pinkish grey matter surrounded by the white matter. This is roughly in the shape of the letter H. Note the anterior and posterior horns.

(*d*) The anterior and posterior fissures.

(*e*) The central canal.

(*f*) The anterior and posterior roots of the spinal nerves arising from the anterior and posterior horns of grey matter.

II. Remove a little of the white matter and tease it on a glass slide by means of two mounted needles. Then examine under the high power of the microscope. It will be seen to be composed of nerve fibres.

III. Place a piece of the cord in diluted methylated spirit for a week. Remove a fragment of the grey matter to a watch glass. Cover with glycerine and break up the fragment by means of needles. Add three drops of red ink and stir thoroughly. Remove a portion to a glass slide and examine under the high power of the microscope. Note the granules of fat (colourless) and the nerve cells (stained red by the ink) with nuclei and processes.

IV. *The Knee-jerk in Man.*—Seat yourself comfortably in a chair ; cross the left leg over the right and let it hang quite freely and loosely. Do not hold the leg stiffly at all, and do not think anything about your knee, but look up at the ceiling and clasp your hands tightly together. If now somebody else taps your ligamentum patellae rather smartly, just below the patella, your foot will be instantly jerked forwards. If the tap is made in the wrong place, on the knee cap or on the tibia, instead of on the tendon, nothing will happen. Try and tap somebody else's tendon who is sitting in the same position as you were, and note precisely the order of events.

The Brain.

Obtain from a butcher a sheep's head sawn accurately in two. Examine the brain and note the following points :—

(*a*) The membranes surrounding the brain.

(*b*) The blood-vessels running over the surface.

(*c*) The cerebrum and cerebellum.

(*d*) Remove the brain and observe the cranial nerves passing through holes in the skull.

(*e*) Cut open the cerebral hemisphere and note the arrangements of grey and white matter.

(*f*) Examine the grey and white matter in the same way as II. and III. above.

The Eye.

I. Examination of a Bullock's Eye.

This is easier to dissect if it has been hardened by freezing for some hours previously. Notice the thick white sclerotic coat, with the clearer thin cornea in front. The place where the optic nerve enters the eye-ball should be found and the stump of the nerve carefully preserved. The attachment of the orbital muscles can also be seen. Prick the cornea with the tip of a small scalpel and observe the thin fluid that escapes. This is the aqueous humour. The crystalline lens will be seen through the pupil.

Cut through the entire thickness of the globe very carefully by an incision vertical to the surface, beginning close up to the optic nerve. As soon as the posterior chamber is opened the jelly-like vitreous humour will escape, sometimes whole. The interior of the posterior chamber is now exposed to view. Notice the bluish, glistening surface of the retina, through which the darker choroid can be seen. One place, the spot where the optic nerve enters the globe and spreads out into the retina, should be observed. This is a small, dull, whitish, oval spot, known as the **optic disc.** The minute point in the centre of this area is where the central artery of the retina enters the globe.

The lens may now be examined, and it can usually be turned out of its capsule like a pea. It is of much firmer consistence than the vitreous humour, and should be perfectly transparent. The front surface is seen to be a little flatter than the back.

Using a fresh eye, cut out with a pair of sharp-pointed scissors a small window in the back of the eye. Hold the eye between your eye and a lighted candle so that the cornea points towards the candle and the small window is opposite your eye. In this way you will see, through the small window, an inverted image of the candle. If the window is closed by fastening over it a piece of tissue paper the image is thrown clearly on the paper, showing that the eye is an optical instrument fashioned so as to throw an inverted image of any external object on to the back of the eyeball.

II. The Human Eye.

(*a*) *Movements of the Iris.*—Place a friend in a chair in front of a window in a good light. Let him keep both eyes open. Note the size of his pupil and then cover over one of his eyes gently with your hand for a few seconds. Take your hand quickly away and notice that the pupil, which had dilated during the temporary darkness, now contracts rapidly as the daylight once more falls upon the eye.

(*b*) *Changes occurring during Accommodation.*—Ask the person to keep looking far away out of the window. Bring a pencil, held vertically, to a point about nine inches away from the middle of his face, telling him to take no notice of it but to keep on gazing into the distance. Now ask him to look at the pencil, and you will then observe that the eye-balls seem to roll slightly inwards towards each other (convergence of the visual axes), and that both pupils contract as he accommodates his eyes to the near object. You cannot, of course, see the changes that take place in the lens.

III. Using a candle, a convex lens, and a paper screen, confirm the statements made on page 167.

IV. Demonstration of the Blind Spot.

Make a cross and a dark circle with ink upon a sheet of note-paper like the above. The cross should be three inches away from the circle. Hold the paper one foot and a half away from the eyes. Close the right eye and fix the gaze of the left steadily upon the circle on the right. Bring up the paper gradually nearer and nearer to your eyes, still looking at the circle with the left eye, and you will find that when the paper has come within a certain distance, generally about five or six inches, from the eyes the cross will suddenly vanish, returning as the paper gets nearer still to the eyes.

The explanation of this curious phenomenon is that when the cross is at a certain distance from the eye the image of the cross falls upon that point of the left retina where the optic nerve enters the eye-ball, which spot is devoid of the sensitive covering. Hence it is named the **blind spot**. The image reappears because it has travelled beyond this spot.

The Ear.

I. *External Ear.*—Examine the structure of the external ear of a fellow-student, using an ear speculum to examine the external auditory canal and tympanum.

II. *Internal Ear.*—Remove the top and side of the skull of a rabbit or guinea pig. On the region of the ears a small canal opens into the cranial cavity. This is occupied by the auditory nerve. Pass a probe down the external auditory meatus and snip away the bone in order to uncover the end of the probe. In this way the roof of the middle ear is removed and the ear drum and the ossicles exposed. Careful removal of more of the bone reveals the internal ear, and the cochlea —a hard piece of bone shaped like a shell—is easily identified.

III. *The Ear.*—A large model of the ear should be carefully examined in order to realise the relative positions of the different parts.

IV. *Hearing.*—(*a*) Stop both ears tightly, and let someone place the stem of a vibrating tuning-fork between your front teeth. Unstop the left ear, and you will notice that the sound seems loudest on the right side. This is because sound-conduction is more rapid through the bones of the skull than through the external and middle ear.

(*b*) Blindfold a person, and test his ability to judge of the direction of a sound by shaking a small bunch of keys on different sides of him. No other noises must be made except that of the jingling of the keys. His judgment will not always be correct, but it will be still more faulty if one ear be well stopped.

CHAPTER XIV.

PERSONAL HYGIENE—EXERCISE—HABITS.

THE judicious combination of exercise, rest, and sleep plays a very important part in the health of the individual. Lack of exercise is soon followed by atrophy, or wasting away of the parts that are not used. A muscle that is not exercised, but lies idle, soon wastes away and becomes useless. This is particularly noticeable in the case of a broken or paralysed limb. The lack of use soon produces wasting and loss of power of the limb. The brain also, when not exercised by study and reading, does not develop to its fullest possible extent. On the other hand, unless the exercise is combined with the proper amount of rest, the results are even more disastrous, as the body becomes overworked and exhausted.

Exercise is necessary at all periods of life, but especially so during childhood and early manhood or womanhood. It is the duty of all parents to see that their children enter into the school games, and spend a great deal of time in the open air. Practically all schools have now adopted physical exercises as part of their curriculum in recognition of the importance of these to the children. In the case of adults the exercise that should be indulged in must depend upon the nature of the daily work. Thus, if a man is doing bodily work all day, his muscles have had quite sufficient exercise, and mental exercise is what he needs for his spare time. On the other hand, those whose occupation is sedentary, such as clerks, students, etc., need physical exercise in their spare time, in order to bring their muscular, circulatory, and respiratory systems to the proper pitch of development.

All parents should see that their children join in the school games, and grow up with a love of exercise and outdoor habits. The habit of breathing through the nose, with mouth completely closed, should be observed always.

For any beneficial result, the exercise taken must be systematic and regular, and not indulged in by fits and starts. By gradually and steadily increasing the work done by them, a set of muscles may be greatly increased in size, but there is a limit to this increase, and if the work be carried to excess the muscles will begin to waste away. Care should be taken to give every muscle of the body its necessary exercise. Many of our sports are faulty in leaving most of the muscles idle. The best real exercise for all the muscles is probably obtained by boxing, lawn tennis, and Rugby football.

Violent exercise should never be taken without proper training. By training, we do not mean the old-fashioned idea of feeding a man on limited rations of half-raw meat, but simply an outdoor life, with plenty of good, nourishing food, and no lack of exercise for all the muscles. Violent exercise, without proper training of this kind, is likely to lead to most disastrous results, the commonest of which is heart disease resulting from overstrain. Violent exercise such as hockey is not suitable for girls.

Some of the physiological effects of exercise deserve special mention. We have already mentioned that the muscles are increased in size and are rendered capable of doing more work. By exercise they are also brought more under the control of the will. The first effect of exercise is, perhaps, the quickening of the heart beat and the rate of respiration. The **heart** beats more rapidly and more forcibly, causing an increased flow of blood through the blood-vessels all over the body. If the exercise be sudden and violent, the heart may be incapable of meeting this sudden demand upon it, and the valves may be rendered incompetent, giving rise to heart disease. But by gradually increasing the exercise, the heart is strengthened and the coats of the arteries are made stronger and healthier.

Respiration is also quickened by exercise. The amount of air taken in at each inspiration is increased, and larger quantities of water and carbon dioxide are given out in the expired air. Thus, a man at rest draws into his lungs each minute about 480 cubic inches of air, but if walking at the rate of three miles per hour he takes in 1550 cubic inches of air, and if he increases his rate to six miles per hour, the amount of air that he inspires is raised to 3250 cubic inches.

The **skin** acts freely while exercise is being taken. The blood-vessels surrounding the sweat glands are distended with blood, and the secretion of sweat is increased. In this way an extra quantity of waste matter is removed from the body by the skin.

Other effects of exercise include the exhilaration and strengthening of the **nervous system**, the improvement of the appetite and **digestion**, and the stimulation of the **kidneys** and **bowels**, thereby aiding the elimination of waste matters from the body.

Rest. Without proper rest the organs of the body would soon become worn out. The most absolute rest is that obtained by **sleep**. The amount of sleep required varies with the age and occupation, but, speaking generally, the average adult requires seven or eight hours sleep a day. Children require more sleep than adults because their bodies are working at a greater rate, and they are more easily exhausted: those under four years should have sixteen hours sleep a day; from four to twelve years of age they require twelve hours sleep; from twelve to sixteen ten hours sleep is necessary.

The sleeping-room should be quiet and well ventilated. Bedsteads should always be used, if possible, as sleeping upon the floor is less healthy on account of the interference with the free circulation of air around and under the sleeper, and also the increased liability to inhale dust or gases from the floor. A hair mattress is very much to be preferred to a feather bed. Infants should not sleep with adults, as the risk of "overlaying" is very great under these circumstances. They should always sleep in a separate bed or cot, which may be easily constructed out of an ordinary clothes'-basket or box.

Habits. Either good or bad habits are bound to be formed by children as they grow up, and so it behoves all good parents to see that the habits that the children form are those which are conducive to their health and happiness. The habit of eating slowly and chewing the food well, and of having regular meals, has already been referred to. The danger of forming the habit of taking alcoholic drinks has also been mentioned. Among the necessary and important habits are cleanliness, proper attention to the teeth, and the regular action of the bowels.

The bowels should be freely opened at least once a day. The best way to secure this is to cultivate the habit of evacuating the bowels at the same time each day. If a regular habit is not formed, constipation is bound to occur, and this will produce indigestion, haemorrhoids or piles, and sometimes inflammation of the bowels. Aperients should rarely be needed. A far better way to procure proper action of the bowels is to take regular exercise, and eat brown bread, oatmeal, vegetables, and fruit.

The Care of the Teeth. It has already been pointed out in considering the structure of teeth that when the enamel of a tooth is cracked or chipped there is danger of the germs of decay attacking the dentine and, after dissolving part of this substance, entering the pulp cavity. If noticed reasonably early the decaying tooth may be repaired by a dentist and its life prolonged many years. For this reason it is advisable for all persons to have their teeth carefully examined every year by a dentist. In the case of children this is particularly desirable, and such a routine procedure on the part of education authorities and parents, if combined with the provision of the necessary treatment, would prevent a great deal of illness in later years. It is difficult to exaggerate the ill effects of bad teeth. They are the commonest cause of dyspepsia, and frequently give rise to all kinds of obscure illnesses. This should always be remembered in connection with all cases of ill-health. Consumptive patients, for example, are not likely to improve in health if they have bad teeth.

Prevention, however, is better than cure, and if the teeth are brushed carefully every night at bedtime the chances of decay are greatly decreased. The simplest and cheapest tooth powder is bicarbonate of soda, which can be bought at about twopence per pound. Every child should be taught to acquire the habit of using this every night. A little of the powder should be placed in the left hand; the tooth-brush held in the right hand is dipped into tepid water and then into the powder and then vigorously brushed round the teeth, care being taken to clean all sides and to brush up and down as well as across.

The Care of the Hair. Careful and regular brushing and combing of the hair is usually repaid by a greatly improved appearance. The hair should be brushed and combed thoroughly every day and kept clean by regular washing. Children's hair should be carefully washed at least twice a week. In washing hair it is not necessary to use much soap unless parasites are present. Singeing the hair, after cutting it or at any other time, is useless. Regular rinsing of the hair and scalp with hot water is beneficial.

Children's hair needs careful examination to detect early signs of parasites or ring-worm or other skin disease. In case of any abnormality of the skin a doctor should be at once consulted, as any neglect may lead to permanent baldness and disfigurement. Much harm is done by consulting chemists and other unqualified persons instead of going to a doctor.

CHAPTER XV.

CLOTHING.

THE value of a material for clothing depends upon its non-conducting properties with regard to heat. By a **good conductor** of heat we mean a substance through which heat rapidly travels. In other words, if one part of a good conductor becomes warm, then the heat will rapidly spread over the whole of it. A bad conductor of heat, or a **non-conductor**, has the opposite properties, so that if one part of a non-conductor becomes heated, the heat spreads very slowly to the other parts. The application of this to clothing is easily understood when we remember that the temperature of the body is always about 98·6° F., while the external temperature rarely exceeds 90° F. in Great Britain.

The temperature of the body is therefore higher than that of the surrounding air, and so the inside of our clothing will be warmer than the outside. Now if the clothing material is a good conductor of heat, the heat will rapidly pass from the inside to the outside, and on the outside it will be lost in warming the air in contact with it. On the other hand, if the material be a non-conductor, the heat will only very slowly pass to the outside and very little will be lost.

As a matter of fact the body loses heat in several ways, *e.g.* (1) By the skin. This is probably about 90 per cent. of the total loss. (2) By respiration, the expired air being warmer than the inspired air. Moreover, heat is lost by evaporation in the breath, the expired air being saturated with water vapour. (3) With the excreta. The first of these, the loss by the skin, is the only one that we can in any way control.

The loss of heat by the skin takes place in three ways:

1. By conduction, as we have explained above. This loss is very greatly augmented by wearing clothes made of a good conducting material.

2. By radiation of the heat. The result of radiation is best illustrated by the warmth experienced when sitting near a bright fire. In this case the body receives the heat which is radiated from the fire. Similarly the body itself radiates heat.

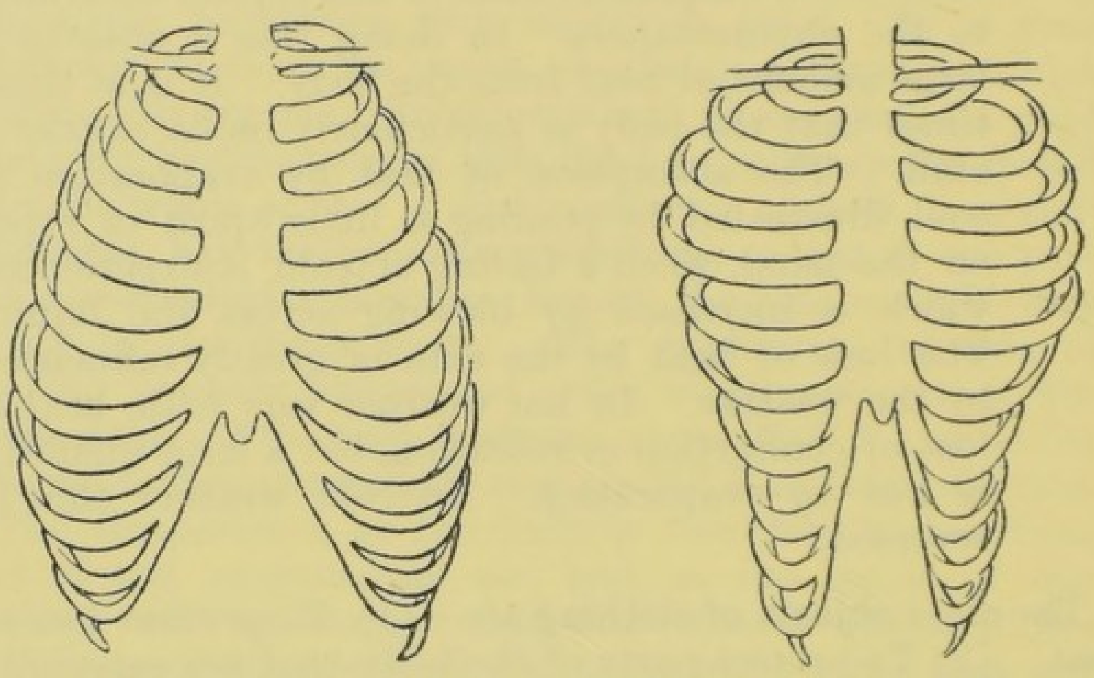
3. By evaporation. When the body is heated by exercise the surface of the skin becomes covered with moisture, which evaporates more or less rapidly according to the circumstances. In doing this it absorbs a large amount of heat from the body. It is at these times that the body is particularly liable to take a chill. The absorption of heat by evaporation is well illustrated by pouring a little spirit or ether on the hand, when a feeling of cold is experienced which is increased by blowing across the liquid. The loss of heat by the skin is greatly influenced by the weather. In hot weather very little heat is lost by conduction or radiation, but a large quantity is lost by evaporation. In cold weather this is reversed.

The chief **objects of clothing** are—(1) To prevent loss of heat. (2) To protect parts of the body that are especially liable to injury, *e.g.* the feet. (3) For ornament. The following **rules** should be observed with regard to clothing:—

(1) **It should be light.** If proper attention is paid to material, there is no need for heavy clothes. In fact light clothes made of a non-conducting material are much warmer than heavy clothes made of material which conducts heat well.

(2) **It should be loose.** Everyone knows how cold a pair of tight gloves are on a cold day. Air is a bad conductor of heat, and fluffy materials which contain much air in their interstices are far warmer than those which are closely woven. In the same way loosely fitting clothes are much warmer than those which fit tightly. Certain parts of the body are peculiarly liable to be constricted by clothing. For instance, the **head** is often surrounded with a tightly fitting hat which must press upon the blood-vessels

and prevent the proper circulation of blood, thereby increasing the tendency to baldness. The **neck** is often constricted by a tight collar which interferes with the circulation and gives rise to headache. In women the lower part of the chest and the upper part of the abdomen are habitually constricted by corsets in order to produce the "waist." As a result of the constant pressure—which



NATURAL THORAX. THORAX DEFORMED BY CORSETS.
Fig. 95.

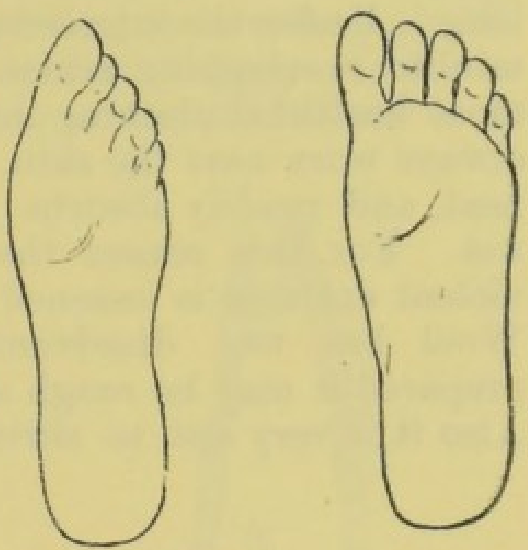
is often begun at a very early age—the ribs are permanently distorted and displaced inwards, causing compression and displacement of the lungs, heart, liver, stomach, and intestines. The natural waist is below the ribs and above the hips.

The **knee** is often constricted with garters. The pressure here prevents the return of the blood through the veins, giving rise to varicose veins. The **foot** is almost always distorted by misshapen boots. In a properly made boot the great toe should be in a straight line with the inside of the foot, whereas it is usually bent towards the other toes in order to make the foot come to an unnatural point.

In summing up we may say that tight clothes possess the following disadvantages:—(*a*) They are less warm than loose clothes. (*b*) They are also less comfortable, and prevent the free movements of the limbs. (c) Any tightness across the chest will interfere with free respiration. (d) They are very liable to displace internal organs and produce various ill effects in different parts of the body.

(3) **It should be porous.** If clothing is not porous it will interfere with the evaporation resulting from perspiration. For this reason waterproof materials should never be worn habitually.

(4) **It should be a bad conductor.** The reason for this has been already explained.



FOOT DEFORMED BY POINTED BOOTS. NATURAL FOOT.
Fig. 96.

(5) **The weight** of the clothing should be mainly borne by the shoulders. Some of the weight may be thrown on the hips, but the waist should be relieved of the weight of clothes in order to avoid displacement of the internal organs.

MATERIALS FOR CLOTHING.

The materials used for clothing are of animal and vegetable origin. From the animal world we obtain wool, silk, furs, feathers, leather, etc. The vegetable kingdom provides cotton, linen, hemp, jute, and gutta percha. The commonest and most important materials are silk, wool, cotton, and linen.

1. **Silk** is the thread spun by the silkworm. It consists of fine smooth fibres, which under the microscope are seen to be round and structureless. It is worked up into satins, plush, velvet, crape, etc. These materials, however, often contain a considerable proportion of cotton. Silk is an excellent clothing material, but its costliness prohibits its general use. It is a bad conductor of heat, and is less irritating to the skin than wool. Also it has not the tendency of wool to shrink when it is washed.

2. **Wool**. The materials made of wool include flannel, cashmere, alpaca, and mohair. Wool from the sheep consists of soft elastic fibres from three to eight inches long. Under the microscope it is seen to be covered with minute overlapping scales. Wool is by far the best and most healthful clothing at our disposal, and should be always worn next the skin. It is a very bad conductor of heat, and readily absorbs perspiration without becoming wet. For this reason the liability to take a chill after violent exertion is lessened when woollen clothing is worn. Wool has two disadvantages. Unless it is carefully prepared it may be rough and irritating to sensitive skins. Also it is very apt to shrink in washing. To avoid this,

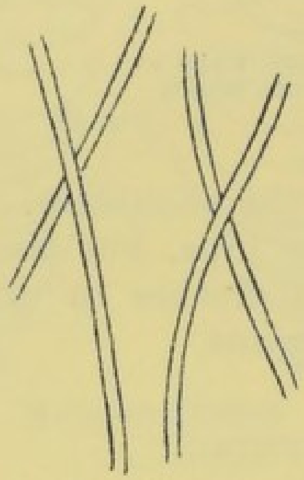


Fig. 97.—Silk Fibres under Microscope.

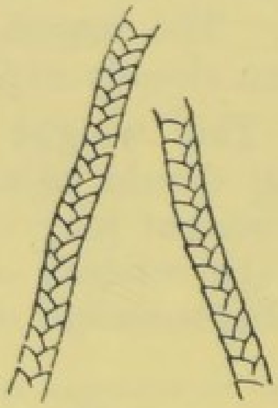


Fig. 98.—Wool Fibres under Microscope.

all woollen materials should be washed in lukewarm water, in which the soap has been previously dissolved. The tendency to shrink or become hard is increased by the use of washing soda and by scrubbing or wringing. It should then be washed in clean water, folded, passed through a wringing machine, and dried as quickly as possible.

3. **Cotton** consists of the fibres surrounding the seeds of the cotton plant. Under the microscope the fibres appear flat, ribbon-like, and twisted. These fibres are worked up into calico, velveteen, flannelette, and muslin. Cotton is a good conductor of heat, and quickly becomes wet by perspiration. For these reasons it is not at all a good mate-

rial for clothing. It has the advantage, however, of being fairly durable, and it does not shrink.

Flannelette is a popular material for underclothing, but, owing to its great inflammability, it is commonly the chief cause of fatal burning accidents. Care should be taken to purchase only such kinds as are *guaranteed* to be non-inflammable.

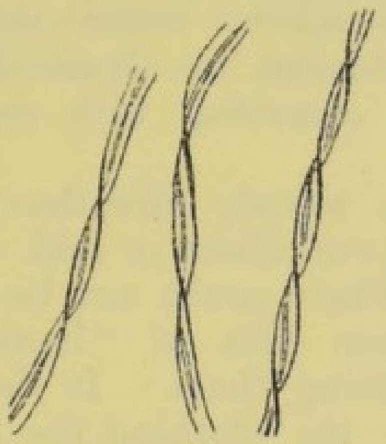


Fig. 99.—COTTON FIBRES UNDER MICROSCOPE.

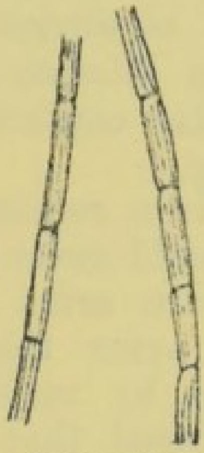


Fig. 100.—LINEN FIBRES UNDER MICROSCOPE.

4. **Linen** is obtained from the fibres of the flax plant. Under the microscope these fibres appear round and jointed.

The smooth surface of linen makes it very useful for collars, etc., but as a clothing material it is bad. It is a better conductor of heat than cotton and it becomes wet with perspiration more easily.

RELATIVE VALUE OF MATERIALS.

For protection against cold the colour of the clothing counts nothing, and the material with which the clothing is made counts everything. The order of merit of the three commonest materials is (1) wool, (2) cotton, and (3) linen. White flannel is just as warm as red for underclothing, in spite of the popular fallacy to the contrary.

For protection against heat, colour counts almost everything and material very little. The best colour for protection against heat is white. Then comes grey, and then yellow, pink, blue, and last of all black.

Amount of Clothing.

The amount of clothing required varies according to (1) health, (2) climate, (3) age.

With regard to health, it is a general rule that sick and feeble people require to be more warmly clad than those in robust health. The variation of clothing with climate is obvious, but it should be noted that in a variable climate such as we have in Great Britain, particular caution should be exercised with regard to clothing.

Children require to be more warmly clad than adults, and should never be allowed to run about in cold weather with bare arms and legs. There could not be a more serious error than the common idea of "hardening" children by insufficiently clothing them. It should be remembered that the warmer the clothing the less the amount of food required, as the greater part of our food is used in keeping up the bodily warmth. Children require more clothes than adults for the following reasons :—

(*a*) The circulation of the blood in a child is quicker than in an adult. This causes a greater loss of heat by bringing more warmth from the inner parts to the surface.

(*b*) The amount of surface compared with the bulk of the body is greater in a child than in an adult, and so there is relatively a larger area from which heat is lost.

(*c*) A certain proportion of the child's food must be devoted to growing purposes and building up the body. Warm clothes check the loss of heat from the skin, thereby causing less of the food to be used in producing heat, and leaving more to be used for growing.

With old people the circulation is feeble, and their power of heat production is small. It is therefore important that they should be warmly clothed, and the extremities especially protected.

Practical Work.

(*a*) Examine some **cotton-wool** under the microscope. A convenient method of mounting these fibres is to spread them out carefully and thoroughly with two mounted needles, moisten with turpentine, and cover with a cover slip.

(*b*) Similarly examine fibres of **silk, linen, and wool**. If threads of these materials are used they must first be carefully teased with mounted needles into as fine fibres as possible.

(*c*) Examine fibres of **flannelette** and identify them.

CHAPTER XVI.

ACCIDENTS AND EMERGENCIES.

In all ordinary cases of illness, no attempt should be made to treat the patient without the advice of a medical man. The old saying that "a little knowledge is a dangerous thing" is never more true than when applied to the individual who has culled some elementary ideas of medicine or surgery from some text-book, or who has attended "first-aid" lectures. Such an individual may have it in his power to render the greatest possible assistance in cases of accidents, or sudden illness, but if he becomes possessed with the idea that a medical man is unnecessary as long as he is there, he may at any time find himself held responsible for a person's death, by not calling in proper medical aid. The author can recall many instances in which the possession of the St. John's Ambulance certificate for first aid has been regarded as something very near to a medical qualification, and probably many readers have heard of the retired constable who, on the strength of one of these certificates, was running a kind of "practice" among people who were, possibly, a little more ignorant of medicine and surgery than he was!

It is, however, absolutely necessary that the public should be educated up to a knowledge of what they may do while waiting for the doctor to come. Any moment an accident may occur, or an emergency arise, endangering life and limb. In many cases, immediate measures are necessary, but a doctor can rarely be found at once. Fortunately an intelligent bystander may often be of great service until the medical man arrives. This immediate treatment, which should be well known by everybody, is called "first aid."

In all cases a doctor should be sent for at once, and the message should state precisely the nature of the accident.

It will often save much time if the doctor knows what kind of case he is being called to.

Small wounds or cuts. In an ordinary small cut the bleeding is not usually extensive, and soon stops. If the cut, and the skin round it, are perfectly clean, the best treatment is to carefully adjust the edges, place over the cut a strip of clean linen soaked in clean water, or, better still, in a solution of carbolic acid (about one of carbolic acid to eighty of water), and bind up the part with clean rags or bandaging. Do not bandage too tightly. If the wound is at all dirty it must be washed carefully by bathing with clean water. Do not use sponges or soiled rags for this; everything that touches a wound must be scrupulously clean. Above all things, **do not use cobwebs**, or any other dirty abominations.

In some cases the bleeding does not stop by this simple treatment. If the bleeding is not very bad, it may be stopped by bringing the edges of the wound together, and fixing them in position by narrow strips of sticking-plaster laid across the cut, at short distances apart. The wound should then be dressed as above. If this treatment does not stop the bleeding, further measures must be taken, as described below.

Bleeding takes place when a blood-vessel is wounded. The three kinds of blood-vessels give rise to distinct kinds of bleeding:—(1) capillary bleeding, (2) arterial bleeding, and (3) venous bleeding.

Capillary bleeding is the commonest and simplest form of haemorrhage. The blood oozes slowly from the raw surface, and appears at many points. This bleeding is easily stopped by bathing the part with cold water, or by tying firmly over it a pad of lint soaked in cold water.

Arterial bleeding is much more serious, especially if the artery involved is a large one. The blood is of a bright red colour, and is forced out in jets if the artery is large, or in a continuous forcible stream from the smaller arteries. Arterial bleeding is always stopped by **pressure**, which should be first applied *over the wound itself*. To do this, in urgent cases, press with the thumb over the point in the wound from which the blood is seen to be spurting. In less severe cases the bleeding may be stopped by tying a pad of linen firmly over the wound.

Fig. 101.—Method of Compressing Artery in Thigh.

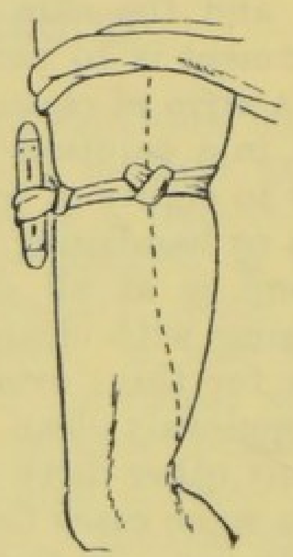


Fig. 102.—Tourniquet applied to Thigh.

Where the artery is at all large, and the bleeding is occurring from a limb, the most satisfactory method is to apply pressure to the main artery at a place higher up the limb than the wound is. The reason for this is obvious, as the blood in the arteries is flowing from the heart towards the extremity of the limb. By closing the artery at a point nearer to the heart, the blood is cut off from the wound, and so the bleeding stops. This pressure is best exercised at a point in the course of the artery where it passes near to a bone. The artery can be easily identified by its pulsation, and it should be pressed against the bone by the two thumbs, one over the other. The points to be chosen for this pressure are difficult to explain in a book, but may

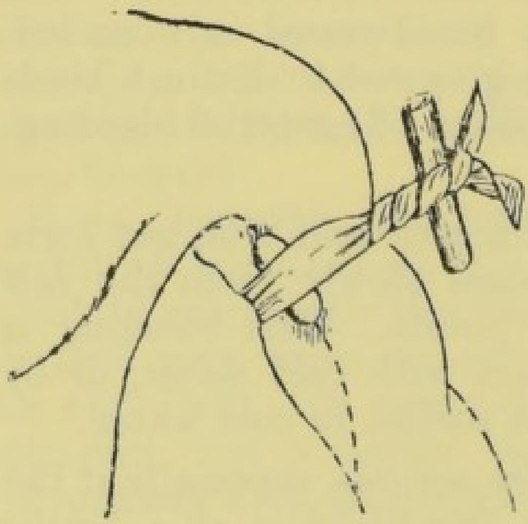


Fig. 103.—Tourniquet applied to Arm.

be easily learned by a few attendances at an ambulance class. For keeping up continuous pressure it is necessary to employ some form of **tourniquet.**

A good tourniquet may be made by tying a knot in the middle of a handkerchief, placing this on the spot where it is desired to produce compression, and tying the handkerchief tightly round the limb. Instead of the knot, a piece of wood, or a flat stone may be tied on by means of the handkerchief. If this does not stop the bleeding, pass a stick or a penknife under the handkerchief, and twist it round until the pressure is sufficient.

Arterial bleeding from the palm of the hand may be stopped by pressing a pad upon the wound and tightly binding the fingers over it. Similarly, if from the forearm, place a pad in the fold of the elbow, bend the forearm upon it, and tie it tightly to the arm. If from the arm, press a large pad into the armpit and bind the arm to the side. In the same way, bleeding from the foot may be stopped by direct pressure, and binding the leg upon a pad behind the knee will stop much of the bleeding below the knee. In addition to these special methods the spots should be learned where the artery may be found and compressed against a bone before it reaches the wound. These points are illustrated by Figs. 101, 102, 103. Bleeding from the head and face can usually be checked by pressure against the bony surface below.

Venous bleeding is distinguished by the colour of the blood, and the absence of spurting. The blood is purple in colour, and wells up from the wound in a dark steady stream. To check this, a pad of lint, soaked in cold water, should be firmly bound over the wound, sufficient pressure being employed to stop the bleeding. The limb should be elevated and kept at rest. If the bleeding continues, a tight bandage must be applied round the limb, an inch or so nearer the extremity of the limb than the wound is. The reason for this is that the blood in a vein is flowing from the extremity of the limb to the heart. A most serious form of venous haemorrhage sometimes occurs from ruptured varicose veins in the arm or leg. It is, however, easily stopped by adopting the above measures.

Bleeding from the Nose is sometimes difficult to stop. The arms should be raised, and the head, face, and neck freely douched with cold water. If this is not sufficient, syringe out the nose with a strong solution of alum in iced water, or take powdered tannic acid as snuff.

Haemorrhage from the **lungs** or the **stomach** is very dangerous. Place the patient in the recumbent position, with the head raised; and give ice to suck. If ice is not at hand, give a teaspoonful of vinegar in a little water every five minutes, or cold strong tea, or cold alum water may be used. Obtain medical aid as soon as possible. Bleeding from the tongue may usually be stopped by ice or cold water.

Bleeding in general. The general treatment may be summed up as follows:—

(1) Apply cold and pressure.

(2) Give plenty of fresh air, loosen clothing, etc.

(3) **Never give brandy** or any stimulants. A dose of brandy will often start the bleeding afresh, after it has once stopped. If the patient faints, it is the best thing that could happen.

If an **accident** has occurred, first of all try to stop any bleeding that may be going on. When this is done, examine for broken bones, and, if any are found, give them the proper treatment.

Fractures.

When a bone is broken, the greatest possible care should be taken to prevent any movement of it. Sometimes the force producing the fracture is so great that one of the broken ends of bone gets forced through the flesh and skin to the outside, forming an open wound as well as the fracture. This is called a **compound fracture**. When the skin is not broken the fracture is **simple**. Unless means are taken to ensure immobility of the parts involved, a simple fracture may easily be converted into a compound fracture. A compound fracture is a much more serious matter than a simple one, because the air can get into the wound, and may take with it some germs, which are liable to do serious injury, and even cause death. An additional danger that may arise from the unskilful handling of a simple fracture is the possibility of causing one of the broken ends of bone to tear through a main artery or vein.

The **signs of fracture**, by which it is possible to tell whether a bone is broken, are:—

(*a*) The limb or the part has lost most of its power of movement.

(*b*) If a limb is injured, a difference will be noticeable between the injured limb and the sound one. The injured one may be lengthened or shortened, or may lie in an unnatural position.

(*c*) There is pain and swelling at the place of injury.

(*d*) If the bone is near the skin, the place of fracture may be felt as a small depression in the bone.

(*e*) By gently moving the limb below the point of fracture a grating sensation is perceived, where the two rough bony surfaces rub together.

When any individual has broken a bone, no movement whatever should be allowed until means have been taken to ensure immobility of the part. If the fracture is a compound one, the wound should be washed, if possible, with some clean water, or, better, with a disinfecting lotion, such as a solution of carbolic acid (one in forty of water). Then place a pad of lint or a clean handkerchief over the wound, to prevent the entrance of more air.

In the case of a **fractured skull** very little can be done until the doctor arrives. The patient should be placed on a bed or couch, with the head raised. Cloths soaked in cold water should be repeatedly applied to the head.

Fig. 104.—Method of Applying Bandages to Broken Jaw.

A **broken jaw** is recognised by the patient being unable to speak, and also by feeling a depression at some point in the bone. If possible a bandage should be applied, as shown in Fig. 104, after gently raising the jaw to its natural position. One handkerchief is fastened round the top of the head and below the jaw, and the other passes round the chin to the back of the neck.

A **broken collar-bone** is a common result of a fall, especially among children. An irregularity will be detected by passing the fingers along the collar-bone. Another sign is the inability of the patient to raise the arm above the shoulder. Place a pad, such as a rolled-up handkerchief, in the armpit, and, after placing the arm in a sling, tie it to the side by means of a broad bandage passed round the arm and chest, outside the sling.

Broken ribs are also of common occurrence. The patient complains of a sharp pain on drawing his breath, and a grating sensation at each breath may be detected by placing the hand over the spot. A broad bandage should be fastened tightly round the chest, and this is usually found to give great relief.

In the case of a **broken arm-bone** temporary splints should be cut, so as to reach from the armpit to the elbow. Roughly pad the splints by wrapping them round with handkerchiefs; and place one from the shoulder to the outside of the elbow, and the other from the armpit to the inside of the elbow. Bandage the splints firmly to the arm, and put the forearm in a sling.

Broken forearms are treated by fastening the arm to an angular splint. To make this, bind two pieces of wood at right angles to each other. Next, bend the arm to a right angle at the elbow, and fasten it to the splint with handkerchiefs; then put the arm in a sling. Broken bones of the **hand** or **finger** are best treated by fastening the whole hand flat against a broad splint, and then putting the arm in a sling.

A **broken thigh** requires very careful treatment. First take hold of the foot with both hands, and pull steadily until the injured limb is the same length as the other. Then tie the feet together. Next obtain, if possible, a long splint—a broomstick or an umbrella will do—and tie it as shown in Fig. 105. The splint should go from the armpit to the foot. If no splint can be obtained, tie the legs firmly together at several places.

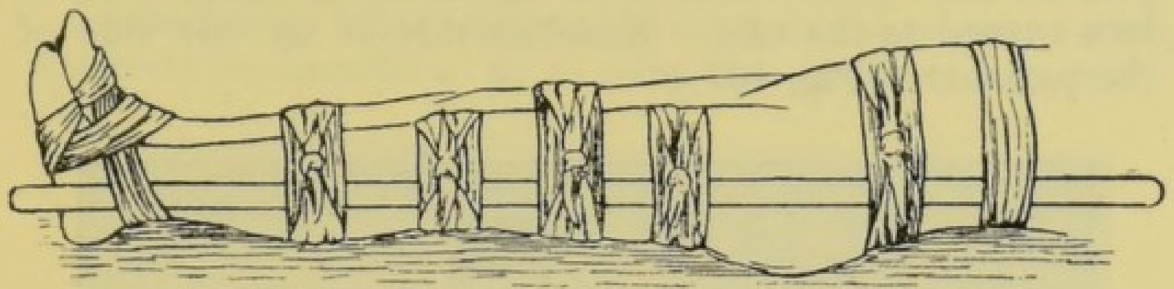


Fig. 105.—Splint applied to Broken Thigh.

A **broken leg** is treated in a similar way. The splint should reach well up above the knee, and down below the foot. In all injuries to the knee, leg, foot, or ankle, it is a good rule to tie the two legs together, so as to prevent any further injury being done by movement.

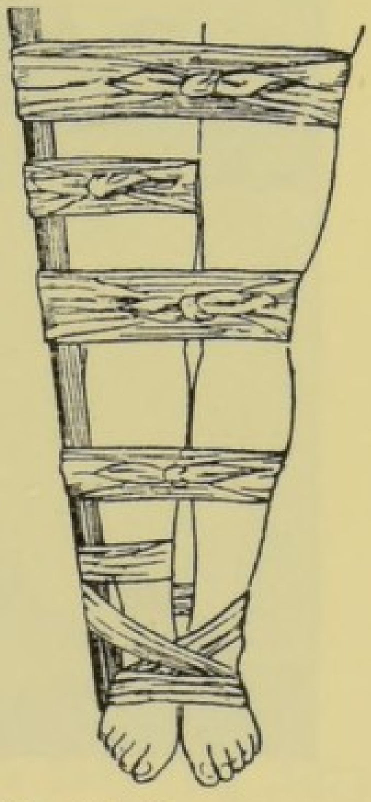


Fig. 106.—Splint applied to Broken Leg.

Sprains and dislocations should be treated by a medical man. In the case of a slight sprain the joint may be firmly bandaged, so as to keep it at rest, with a bandage which has been well soaked in cold water. The bandage should be kept wet. Another method is to soak the joint for an hour in water as hot as can be endured, and then bandage it and keep at rest for some time.

Drowning.

The best and the most modern method of performing artificial respiration for the resuscitation of a person apparently drowned is that devised by Professor E. A. Schäfer, and this has been formally adopted by the Royal Life-Saving Society. The following instructions issued to the Metropolitan Police may be followed:—

Instructions.

"Immediately after removal from the water lay the patient face downwards with the arms extended and the face turned to the side. Kneel astride or on one side of the patient. (Fig. 107.)

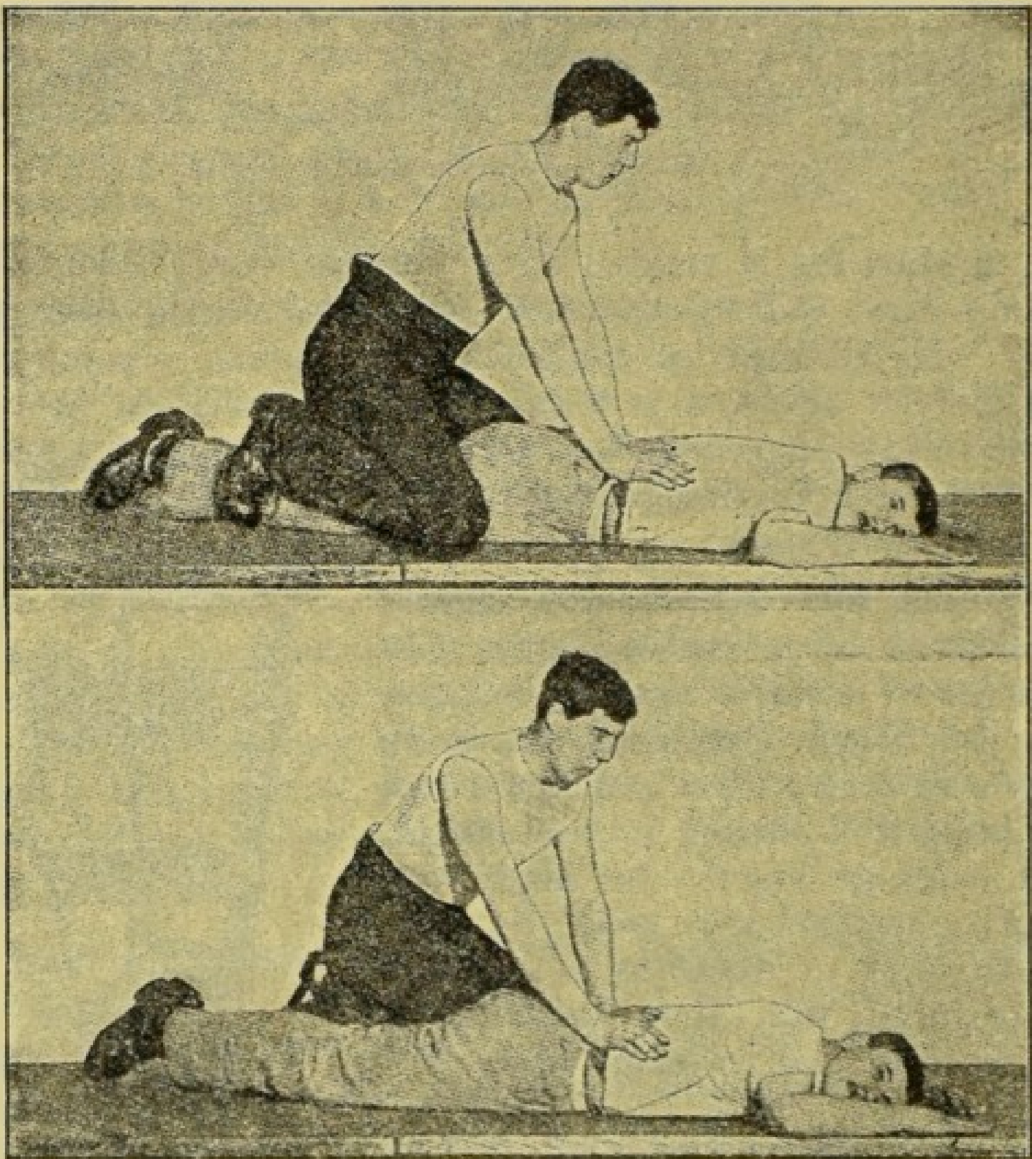


Fig. 107.

Place the hands on the small of the patient's back, one on each side, with the thumbs parallel and nearly touching. (Fig. 107.)

Bend forward with the arms straight so as to allow the weight of the operator's body to fall on the wrists and thus make a steady, firm, downward pressure on the lower part of the back (the loins), as shown in Fig. 108. (This part of the operation should occupy the time necessary to count—slowly—*one, two, three.*)

Immediately after making the downward pressure, swing the body backwards so as to relax the pressure, but with-

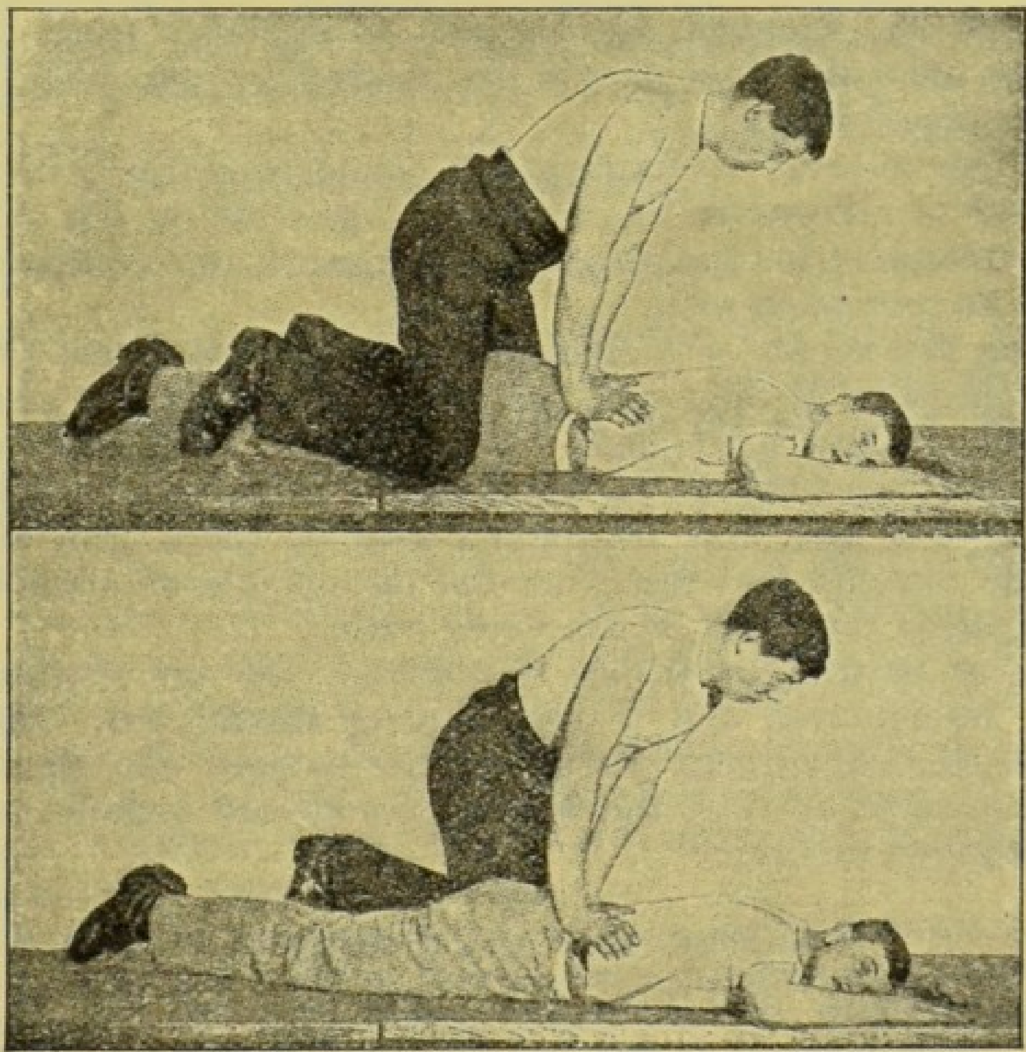


Fig. 108.

out lifting the hands from the patient's body (Fig. 107). (This part of the operation should occupy the time necessary to count—slowly—*one, two.*)

Repeat the forward and backward movements (that is, the pressure and the relaxation of pressure) without any marked pause between the movements. The downward pressure forces the air out of the lungs and the relaxation of pressure causes the air to be drawn in again.

Continue the movements at the rate of about 12 per minute until natural respiration has recommenced.

When natural respiration is fairly resumed, cease the artificial movements. Watch the patient closely, and, if natural respiration ceases, repeat the pressure and relaxation of pressure as before.

The movements of artificial respiration should be commenced the moment the patient is removed from the water, and no time should be wasted in removing or loosening clothing.

When natural respiration has commenced, the patient should be allowed to lie in a natural position on one side, and treatment for the promotion of warmth and circulation may be proceeded with.

The movements of artificial respiration are of the first consequence. If the operator is single-handed, he must attend to these alone until natural breathing is restored. If other assistance is at hand, warm wrung-out flannels, hot bottles, etc., may be applied between the thighs, and to the armpits and feet; but the movements of artificial respiration must not be interfered with.

After natural breathing is restored, the wet clothing may be removed and a dry covering substituted. This must be done without disturbing the patient, who should be allowed to lie quiet and watched for at least an hour and encouraged to sleep."

Suffocation and Choking.

Suffocation. This may have been produced by hanging. If a body is found hanging, **cut it down at once.** It seems unnecessary to give such obvious advice, but, as a matter of fact, in ninety-nine cases out of a hundred, the individual who makes the discovery runs for the police, thereby wasting valuable time, and losing all chance of saving the life. In such an emergency, cut down the body at once, loosen the rope and all clothing about the neck and chest, and apply artificial respiration without delay.

Suffocation may have been produced by inhaling foul gases, coal gas, or charcoal fumes. Remove the body to the fresh air, and apply artificial respiration. When this is successful, give stimulants.

Choking. If a solid, such as a lump of food, a coin, or a piece of bone, is sticking in the throat, pass the forefinger into the mouth, reach down the throat as far as possible, and try to hook out the foreign body. Sometimes a sudden slap on the back is effectual. With children, the old way of holding them up by the heels is often successful. When a child has **swallowed** some solid object, a plum stone for instance, give plenty of bread and vegetables for a meal or two. Do not give aperient medicines.

Burns and Scalds.

First remove any clothing covering the injured part. To do this, use a large pair of scissors, and cut the clothes in such a way that they fall off. Do not pull them at all. If any of the clothing sticks to the skin, leave it there, but cut off the loose parts all round. The burn or scald should then be covered up with pieces of linen or cotton, soaked in a mixture of linseed oil and lime water (Carron Oil); or, if this is not at hand, use some oil such as olive oil, linseed oil, or almond oil (do not use paraffin or naphtha); or again, a strong solution of carbonate of soda in water or milk may be used. Next apply a thick layer of cotton-wool or flannel. Keep the patient warm, and, if there is much shock, give strong coffee.

A common accident is the catching fire of a woman's or child's clothes. When this happens, the best thing for the woman to do is to throw herself on the floor, and roll rapidly over and over. The duty of a bystander is to wrap round the burning person a rug, carpet, blanket, or coat, and then, laying her on the floor, roll her about rapidly until the flames are extinguished.

Children sometimes scald their mouths or throats by drinking out of teapots or kettles. In these cases the scalded parts swell up quickly and suffocation comes on. Send for a doctor at once, as a slight operation will probably be necessary. While the doctor is coming, wrap the child in a blanket, apply hot flannels to the outside of the throat, and give a little oil to drink.

Unconsciousness.

Unconsciousness may be caused by many conditions, the commonest of which is **fainting** or **syncope**. This is usually caused by temporary feebleness of the heart's action, and is accompanied by paleness of face, and some perspiration. Give the patient fresh air, and put the head as low as possible, either by laying full length on the floor, or by bending the head and body forwards, until the head is below the knees. Apply smelling-salts to the nostrils, or, better, give half a teaspoonful of sal volatile, in water, to drink.

Hysteria may sometimes be accompanied by unconsciousness. This is not real insensibility, and may be distinguished by the patient resisting an attempt to raise the upper eyelid; also, when the eyelid is raised, the pupil will not be visible. The best treatment is either to leave the patient entirely alone, or to dash a glass of cold water over the face.

Apoplectic fits or **strokes** are due to the rupture of a blood-vessel on the brain. They are usually accompanied by unconsciousness and a loss of power in one or more limbs. The breathing is usually laboured and noisy. Raise the head slightly and apply cold bandages to it. Put warm flannels to the feet. Keep absolutely quiet, and do not give any stimulants whatever, nor attempt to rouse the patient.

Epileptic fits are a common cause of insensibility. The sufferer first screams and then falls down unconscious. The hands are clenched, the legs and arms are jerked to and fro, the face becomes purple, and foam often comes from the mouth. A common accident at this stage is the biting of the tongue if it happens to get between the teeth. These symptoms gradually subside, and the patient usually falls into a deep sleep. When a fit of this kind occurs the only thing to be done is to prevent the patient injuring himself. Loosen all clothes about the neck, put something soft under his head, and, if possible, put a piece of wood between the teeth to prevent the tongue being bitten. Do not give stimulants or throw cold water on the face. Allow the patient to go to sleep as soon as possible. The most serious accidents due to an epileptic fit are either falling on the fire, or suffocation during sleep. Suffocation is caused by the patient, when in bed, turning on his face during the fit. The possibility of this is lessened by sleeping on a horsehair mattress, which does not impede respiration so much as a flock or feather bed.

Infantile convulsions are best treated by putting the child into a hot bath while waiting for the medical man to arrive.

Insensibility from Alcohol is common, and is often mistaken for apoplexy, and *vice versa*. The face is flushed and the breath smells of alcohol. The pulse is feeble but rapid, and the breathing is shallow. Place the patient on his back, and douche the head freely with cold water. Keep the body warm. Give an emetic of salt and water, or mustard and warm water, if possible.

Bites and Stings.

Bites. The immediate treatment for all bites is thorough and vigorous sucking of the wound, and spitting out the saliva. There is no danger in doing this, unless there are cracks or sores on the mouth or lips.

If the part bitten is a limb, it should be at once tied round with string above the wound. The string must be tied tightly enough to arrest the flow of blood along the veins, and so prevent the blood flowing from the bite into the general circulation. This also tends to encourage bleeding, by causing congestion. The wound should then be again well sucked. Then clean the wound, first with hot water, and afterwards with a strong solution of permanganate of potash (Condy's fluid). The wound may advantageously be painted with strong carbolic acid. Lunar caustic is of very little or no use.

The bite of a dog or cat is liable to cause rabies or hydrophobia, but only when the animal is actually suffering from this disease. Do not have the animal destroyed at once, but keep it fastened up. If it remains well and healthy, the wound is harmless as far as hydrophobia is concerned. If it goes mad, or is evidently suffering from disease, have the animal examined by some competent person. When it has been proved that the animal was suffering from rabies at the time of the bite, or when there is a probability of that being the case, the person should be treated by inoculation (Pasteur's method), without any further delay.

Stings. If the sting has been left in the skin, it must be pulled out very carefully. Then rub on the spot a strong solution of washing soda, or ammonia. If there is any shock, give stimulants.

Poisoning.

Poisoning may be suspected under the following circumstances: (1) When an apparently healthy individual is suddenly seized with serious symptoms. Of course, some diseases are sudden in onset, and these must be taken into consideration.

(2) The symptoms appear shortly after taking medicine, or food, or drink. In these cases the poison may have been taken by mistake, or mixed with the food; or it may be the food itself that had poisonous properties. Tinned foods have often produced symptoms of poisoning.

(3) If more than one person has partaken of the suspected food, they will probably suffer from similar symptoms.

Corrosive poisons, or poisons which corrode or burn the lips and mouth, include acids and alkalies. The commonest acids are sulphuric acid or oil of vitriol, hydrochloric acid or spirits of salt, oxalic acid, and carbolic acid. The commonest alkalies are caustic soda, caustic potash, washing soda, and ammonia.

All these poisons destroy the mucous membrane of the mouth, throat, and stomach, causing great burning and intense pain. In treating poisoning by these substances **do not give any emetic**, as this would only make matters worse.

For poisoning by **acids** give magnesia, chalk, or a piece of plaster from the ceiling or wall powdered and mixed with milk. Then give raw eggs with milk, and olive oil. For poisoning by **alkalies** give vinegar and water, lemon juice, or orange juice. Then raw eggs with milk, and olive oil.

For **carbolic acid** poisoning do not give alkalies, but raw eggs and milk, followed by olive oil. Stimulants may be specially necessary in cases of poisoning by oxalic acid or carbolic acid.

Emetics. For all poisons except the above, the first thing to do is to **give an emetic.** There are several emetics that may be used. (1) Large quantities of warm water mixed with a little mustard. (2) A tablespoonful of common salt in a tumbler of warm water, repeated every quarter of an hour till vomiting occurs. (3) Half a teaspoonful of sulphate of zinc mixed with warm water. Vomiting may often be caused by tickling the back of the throat with a feather, or with the finger. When vomiting has occurred give raw eggs and milk, and then strong tea.

Corrosive sublimate. If this has been taken, give an emetic, then several raw eggs, and large quantities of milk.

Phosphorus poisoning, from taking rat-paste or from sucking the ends of matches, sometimes occurs. Give an emetic followed by large doses of magnesia or chalk and water. **Do not give any oils.**

Lead poisoning. Give an emetic, and then 2 oz. of Epsom salts dissolved in a pint of warm water.

Laudanum or **opium** poisoning. Give an emetic, and then devote yourself to keeping the patient awake. Do not let him sit down, but keep him trotting about. If he gets drowsy give a cold douche to the head and neck. Administer about a pint of very strong coffee, and then milk and beef tea. If unconsciousness comes on, in spite of all efforts to prevent it, use the galvanic battery, and, if breathing fails, perform artificial respiration for several hours, if necessary.

Golden Rules for Poisoning Cases. If you do not know what the poison is, or if you know what the poison is but cannot remember the special antidote, proceed on the following lines :—

(1) If the person threatens to go to sleep, keep him awake (see directions above for laudanum poisoning).

(2) If there are stains about the mouth, with signs of blistering and destruction of the mucous membrane, do not give an emetic, but give raw eggs, milk, and then oils (linseed oil, olive oil, salad oil).

(3) When there are no stains about the mouth, give an emetic, then raw eggs, milk, and oils. Then give strong tea. Do not give oils if there is a possibility of the poison being phosphorus.

CHAPTER XVII.

SOILS AND SITES. CLIMATES.

Soils. It is often convenient to divide soils into two parts, namely, a deeper portion, called the **sub-soil**, and an upper portion, called the **surface soil**. The sub-soil consists of inorganic materials only, and is the result of the breaking up of the various rocks by the wearing action of the rain and frost. The surface soil consists of the materials of the sub-soil mixed with organic substances of animal and vegetable origin.

For hygienic purposes it is better to divide soils into two classes according to whether they allow water to pass easily through them or not. Soils that allow water to pass easily through them are called **permeable** or **porous**, while those through which water cannot pass are called **impermeable**. The permeable soils are gravel, sand, sandstone, and chalk; the impermeable soils include clay, limestone, granite, etc. In most localities it is usual to find a layer of permeable soil of greater or less thickness lying upon an impermeable layer. Water will obviously accumulate on the impermeable layer and form what is known as **ground water**. The pores of the permeable soil above the ground water are filled with air of a special character, called **ground air**. Ground air contains less oxygen and more carbon dioxide than ordinary air, as well as variable quantities of organic impurities. A sudden rise in the level of the ground water will expel the ground air, which will enter a house unless the precaution has been taken to build it on an impervious layer of concrete.

The Drainage of the Soil. The ground water may be hundreds of feet below the surface of the soil, or it may be only one or two feet. If it is less than 10 feet from the surface it will be necessary to drain the soil before such a site is fit to build upon. For the thorough draining of the soil the following steps should be taken :—

(1) Surface drains should be provided to carry off rain as quickly as possible.

(2) The natural water courses in the neighbourhood should be cleared out and any obstruction removed.

(3) A system of drains with open joints may be laid about 10 feet deep, and made to slope towards the nearest water course.

The Site.

There are three chief points to be considered in choosing a site for a house, namely the soil, the aspect, and the surroundings.

The **soil** should be permeable. For this reason gravel, chalk, and sandstone make excellent building sites as a rule. If, however, the permeable layer is thin, and rests upon an impermeable layer such as clay, it is obvious that the upper layer will be continually soaked in the water which cannot get through the impervious layer. Also a flat site is much more liable to be damp than one which slopes. An impermeable soil, such as slate, rocks, etc., makes very good building sites, as these formations allow no water to pass through them, and absorb none. Marls and clays are examples of the best kind of soils. "Made soils," where excavations or hollows have been filled up with all kinds of rubbish, are likely to be injurious and should not be built over until many years have elapsed.

The depth of the ground water below the surface is a very important consideration. If it is not more than 10 feet from the surface the site is wholly unsuitable without drainage. Striking evidence of the effect of lowering the level of the ground water upon the health of the district is furnished by the town of Salisbury, where the death rate from consumption was reduced about 50 per cent. by a thorough system of sub-soil drainage. Rheumatism, bronchitis, catarrh, ague, neuralgia, and even typhoid and cholera are attributed to the dampness of the soil. There is every reason to believe that frequent and sudden changes in the level of the ground water are specially harmful, and so a site where the level of the water in a well is apt to rise and fall a good deal should never be chosen.

Peaty soils and reclaimed land at the mouth of rivers are very damp and usually unfit for habitation. Made soils, or artificial sites prepared by filling up large hollows with rubbish of all kinds, always contain a large amount of organic matter which may take years to completely decompose. This kind of soil should not be built upon for several years, and, if it is used after that time, the whole of the ground covered by the houses should be protected by a layer of concrete. If this is too expensive there should be efficient ventilation provided between the soil and the lowest floor.

If a house is built on a damp site, it will certainly be damp unless very great precautions are taken to prevent it being so. Also a wall may be made damp by being exposed to the rainy point—the West in England. **To prevent damp** rising up the walls it is necessary to lay a course of glazed tiles, slate, sheet lead, or any other impervious material set in cement between the courses of bricks just above the highest point at which the wall is in contact with the earth, and below the level of the floor. Such a layer is called a **damp-proof course**. Other precautions to prevent dampness in houses will be found in advanced text-books.

Aspect. The aspect should be such as to allow free access of sunlight and air. Light and a free circulation of air are essential to health, and a house therefore should not be hemmed in by surrounding buildings or trees. In this country a south or south-westerly aspect is by far the warmest, and so the very best position for a house would be on a slope exposed to the south. The chief windows of the house should face west and south.

Shelter from the cold winds is an important consideration. This may be afforded by neighbouring hills or trees situated at the north or east side.

Surroundings. The neighbourhood of trees, provided they are not too close, is undoubtedly beneficial, as they not only serve to ward off the cold wind but also assist in drying the soil. The eucalyptus plant and our common sunflower are particularly efficient drying agents. The surroundings that are **injurious** and should be avoided are:—

(1) Heaps of decaying animal or vegetable matter such as are met with in marshy districts.

(2) The immediate vicinity of ponds, lakes or rivers is to be avoided, especially if they are polluted with sewage.

(3) Chemical works are undesirable neighbours owing to the noxious gases they evolve.

(4) The neighbourhood of graveyards is likely to be unhealthy.

(5) Brickfields may also produce injurious gases.

We may sum up the most important points with regard to the **choice of a site** for building as follows:—

(1) The spot should be moderately elevated, sheltered from the north and east, and with a free circulation of air.

(2) The soil must be porous, such as gravel or sand.

(3) The ground water should not be less than 10 feet below the surface of the ground, and it should not be liable to sudden or great fluctuations in level.

(4) There should be no decaying organic matter in the soil such as is found in made soils and soils of a peaty nature. Sewage in the soil is obviously injurious.

(5) There should be no injurious surroundings.

Climate.

By the climate of a place we mean the average character of the weather there. Climate is judged by the mean temperature of the air, the direction and force of the prevailing wind, the rainfall, etc. Climate depends upon, and is modified by, the following conditions and circumstances:—

(1) The distance from the equator.
(2) The distance from the sea.
(3) The height above the sea level.
(4) The direction of the prevailing winds.
(5) The presence or absence of vegetation.
(6) Ocean currents.
(7) The neighbourhood of mountains.

Distance from Equator. At the equator the sun's rays fall vertically at noon, and so produce the maximum possible effect. As the distance from the equator is increased the rays fall more obliquely and become feebler in effect.

Distance from the Sea. The land is heated quickly by the sun during the day, but at night it very quickly cools again. The sea on the other hand warms and cools very slowly. On a hot day, therefore, the land is at a much higher temperature than the sea, but at night the sea is warmer than the land. The sea has, therefore, a great influence in moderating summer heat and winter cold. Places near the sea have equable climates, with no extreme heat in the summer and no extreme cold in the winter.

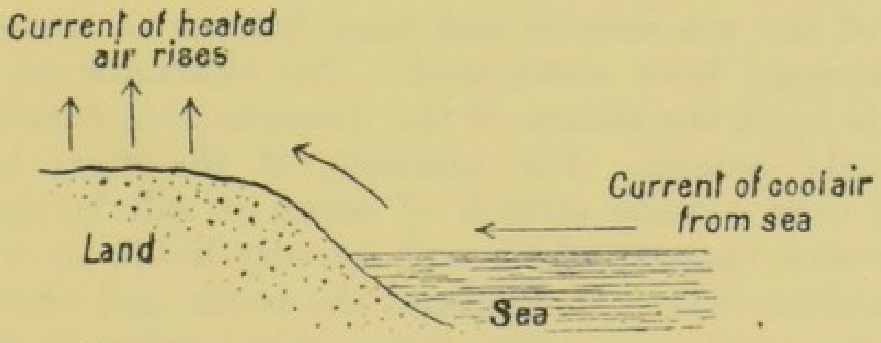


Fig. 109.—Production of Sea Breeze during day.

Land and Sea Breezes. We have seen that during the day the land becomes greatly heated while the sea remains comparatively cool. The air over the land will, therefore, be heated and will expand and rise owing to its decreased density. Its place will be taken by a current of cool air from the sea, giving rise to a **sea breeze**. During the night the land rapidly cools, soon becoming cooler than the sea. The air over the sea is now warmer than the air over the land, and so it rises, its place being taken by the cooler air from the land. This is the **land breeze**.

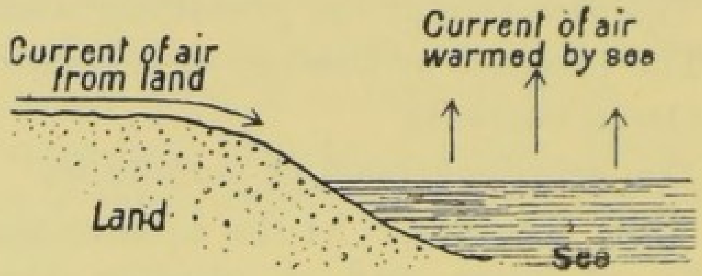


Fig. 110.—Production of Land Breeze during night.

The healthiness of sea-side places is mainly due to these breezes. They cause the days to be cooler and the nights warmer than further inland, besides producing a free circulation of air.

Altitude above Sea. As a general rule the air becomes colder as the height above the sea is increased. The fall in temperature amounts roughly to about 1° Fahr. for every 300 feet of ascent. The air of the mountains is also more rarefied, and drier and purer than that of the lower regions.

Winds have a great influence on climate. The action and effect of the sea breezes and land breezes at the sea-side have already been mentioned. The character of a wind depends upon the nature of the districts over which it has previously passed. For instance, if the wind has just passed over a wide stretch of ocean it will be saturated with water vapour, which will be very liable to condense and produce rain. In England the south and west winds are warm, and very often bring rain, owing to the fact that they are saturated with water vapour and come from a warmer to a colder region. The north and east wind, on the other hand, come from Siberia and Northern Russia and are therefore unsaturated and cold.

Vegetation protects the soil and prevents extremes of heat and cold. The effect of **forests** in modifying climate is well known. Besides making the climate more equable, they increase the humidity of the air by the enormous evaporation from the leaves, and thereby tend to increase the rainfall.

Ocean Currents. As far as England is concerned, the most important ocean current is the Gulf Stream, which is an immense stream of warm water stretching from the Gulf of Mexico across the Atlantic. It greatly modifies the climate of Great Britain and Ireland.

Neighbourhood of Mountains. These, as we have already seen, afford a very valuable shelter from the cold winds. They tend to increase the rainfall, especially when near the coast.

Practical Work.

(*a*) Weigh a new dry **red brick.** Then immerse it in water for ten minutes. Wipe it dry and weigh again. The gain in weight represents the water absorbed by the brick. Calculate the volume of the brick and the volume of the water it holds.

(*b*) Repeat the experiment with a **blue brick.**

(*c*) Repeat the experiment with a piece of slate, a glazed tile, and a piece of sheet lead.

CHAPTER XVIII.

THE WATER SUPPLY.

When we talk about pure water from a hygienic point of view, we mean something quite different from the pure water of chemistry. **Hygienically pure water** may have many substances dissolved in it, but they must be present only in very small quantities and must not have any injurious properties. It must fulfil the following conditions :—

(*a*) It must be quite free from smell. Any smell whatever shows contamination of some sort, and the probability is that such contamination is harmful.

(*b*) It should be colourless, or rather blue when in large quantities.

(*c*) There must be no suspended matters, *i.e.* no deposit should be formed after the water has stood for some time.

(*d*) The taste should be pleasant. Any bitterness or saltness is always suspicious.

(*e*) It should not be very hard.

(*f*) It should be well aerated. This is shown by its sparkling appearance.

Chemically pure water contains nothing whatever dissolved in it. Water in nature is never chemically pure, because of its great solvent properties. Rain water is the purest form of water in nature.

The Impurities in Water.

The impurities in water may be either suspended or dissolved.

Any **suspended impurity** will usually settle to the bottom if the water is allowed to stand, or it may be removed quickly by filtering. **Dissolved impurities** are not removed by filtering the water or by allowing it to stand.

The Suspended Impurities in Water. These may be either of a harmful or harmless nature.

(1) The harmless impurities include such substances as fine sand, minute fragments of wood, etc. These do not injure the body by producing disease directly, but they may set up diarrhoea by their mechanical irritation of the intestines.

(2) The harmful impurities may be (*a*) disease germs, especially those of cholera and typhoid fever, or (*b*) the eggs of parasitic worms, which when swallowed develop in the body.

Common Dissolved Impurities in Water.

The dissolved impurities more commonly met with are :—

(1) **Lime Salts**, including carbonate of lime and sulphate of lime.

These salts may be detected by adding a solution of ammonium oxalate to the water, causing a white cloud of oxalate of lime to appear.

If lime salts are found, it is of importance to know whether the sulphate is present. The test for any sulphates is to add nitric acid and barium chloride solution to the water, which precipitates white barium sulphate.

(2) **Chlorides**—chiefly common salt or sodium chloride.

The test is to add nitric acid and silver nitrate solution to the water. A white precipitate, or simply a milkiness due to silver chloride, shows chlorides are present.

(3) **Lead Salts.** To test for these, boil down the water to about one-fourth its original bulk, and then add a little ammonium sulphide solution. A dark coloration shows lead is present.

(4) **Organic Impurities** or impurities of animal or vegetable origin.

The test for this kind of impurity is to take equal quantities of pure distilled water, and the water to be tested. Add to each a sufficient quantity of Condy's fluid to colour the liquid a bright pink; then cover up the glasses and put them away for three hours. If, on examining them again, the colour has faded in the glass containing the water to be examined, then you may conclude that there are organic impurities present.

How these Impurities get into the Water.

(1) **The lime salts.** The sulphate of lime is present in the earth in various localities. It is slightly soluble in water and so, when the water comes in contact with it, it dissolves in just the same way as sugar dissolves in water. The carbonate of lime is, however, quite insoluble in pure water, but it will dissolve freely in water containing the gas called carbon dioxide dissolved in it. Now this gas is always present in the air in small quantities, and as the rain falls through the air it dissolves some of it. When the rain reaches the earth it is really a weak solution of carbon dioxide, and the strength of this solution is increased by the carbon dioxide in the ground air. It is this solution of carbon dioxide that has the property of dissolving carbonate of lime.

(2) **Chlorides.** Common salt, of course, dissolves easily in water. If it is found in a water supply near to the sea, or salt deposits, it would be of no importance perhaps, but when there is no possibility of such an explanation the presence of common salt points to **sewage contamination,** as sewage always contains large quantities of it.

(3) **Lead** may be dissolved by the water in lead pipes and lead cisterns, or in slate cisterns with red lead joints. As a general rule the purest and the most impure waters dissolve lead most readily. **The conditions assisting the solution of lead** are :—

(*a*) When the water is pure and soft, like rain water.

(*b*) Common salt dissolved in the water.

(*c*) The presence of organic matter in the water.

(*d*) Hot water dissolves lead more readily than cold water, other conditions being equal.

(*e*) Similarly water under high pressure dissolves lead more readily than water under less pressure.

The conditions preventing the solution of lead are :—

(*a*) When the water is hard, *i.e.* contains carbonate of lime.

(*b*) Minute quantities of sand (silica) dissolved in the water prevent the solution of lead.

Both these substances form a protective lining inside the lead pipe so that the water is no longer in contact with the lead.

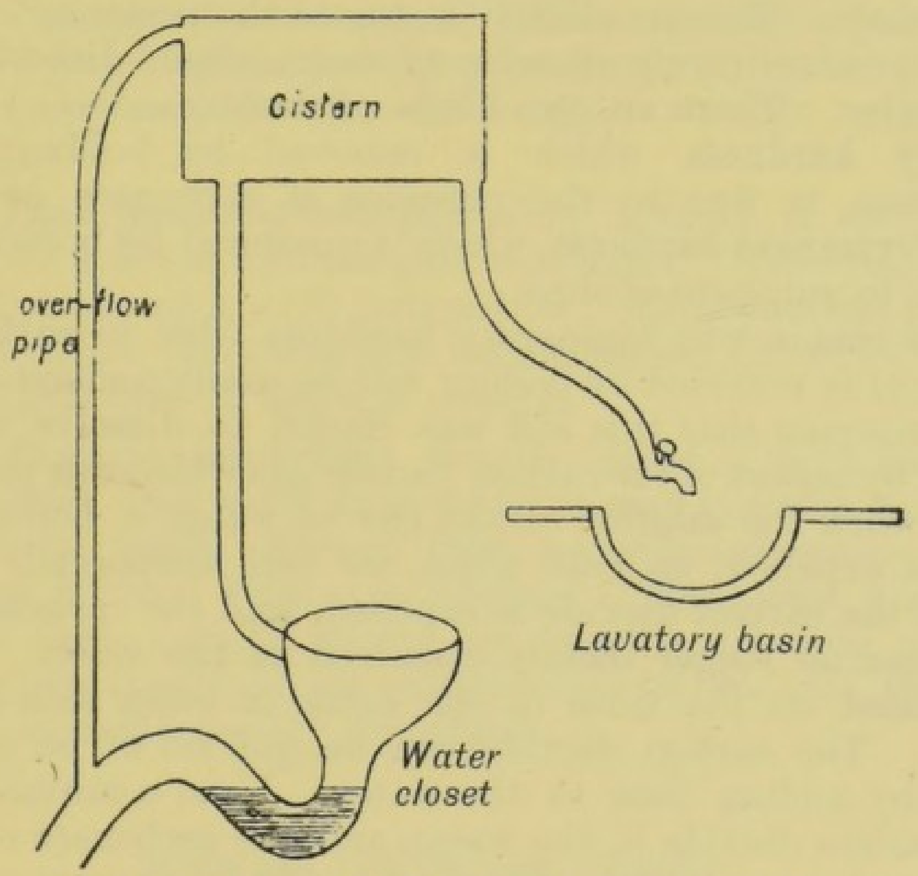


Fig. 111.—Cistern with Insanitary Arrangements.

(4) **Organic impurities.** The sources of these impurities are various. (*a*) Animal or vegetable refuse may have obtained access to the water. Rivers are particularly liable to this kind of pollution.

(*b*) The usual source is **sewage** that has leaked into the water supply. For example, sewage matter may leak into a shallow well, or it may be run direct from a house or village into the neighbouring stream.

(*c*) Water from marshes would naturally be very liable to contain considerable quantities of organic impurities.

(*d*) Sewer gas may obtain access to the water through the unsanitary arrangement of the cistern pipes, the overflow pipe from the cistern being often run direct into a drain pipe.

Effects of these Impurities.

(1) **Lime salts** cause **hardness** of the water. Hard waters may be defined as those which form a curd or scum with soap. This peculiarity is due to the presence of lime salts, or more rarely of salts of magnesium, dissolved in the water. There are two kinds of hardness :—(*a*) **Temporary hardness,** which is removed by boiling; this hardness is due to the presence of carbonate of lime. (*b*) **Permanent hardness,** which is unaltered by boiling and is due to sulphate of lime.

The reason why temporary hardness (due to carbonate of lime) is removed by boiling will be easily understood by remembering that this salt was caused to dissolve in the water by means of the carbon dioxide gas which was present. Now when the solution of any gas in water is boiled, the gas is expelled, so that when we boil temporarily hard water the carbon dioxide is expelled, and the carbonate of lime can no longer remain dissolved in the water. It is deposited on the sides of the kettle or boiler as a brown crust. The carbon dioxide can be got rid of on a large scale by adding lime to the water. Lime combines with the carbon dioxide in the water, and the carbonate of lime can no longer remain dissolved, so it is thrown out of solution and settles to the bottom as mud. This method of softening water in reservoirs by adding lime is known as Clarke's process. Hard water is harmless unless the hardness is excessive, when it may cause dyspepsia or diarrhoea. Goitre or Derbyshire neck is thought by some to be caused by water from magnesium limestone districts.

Although hard water is harmless, it may be said to possess many disadvantages. These are :—

(*a*) The soap is wasted. Instead of the soap forming a lather, it combines with the lime in the water, forming the scum.

(*b*) This scum is very objectionable, as it clings to the skin, or to the clothes that are being washed.

(*c*) Temporary hardness forms a coat inside the kettle. This makes the kettle thick and a bad conductor. Moreover, in boilers a thick crust is a frequent cause of explosions.

(*d*) Hard water is considered to be inferior to soft water for cooking purposes. For making tea, soft water is much better than hard.

(2) **Chlorides** (common salt). This impurity is harmless in itself, but it often indicates a serious pollution due to sewage matter. In this case organic matter would be found.

(3) **Lead** produces **lead poisoning** if there is only one-tenth of a grain of lead per gallon of water. The symptoms of lead poisoning are (*a*) indigestion ; (*b*) abdominal pains, or lead colic ; (*c*) a blue line on the gums ; (*d*) wrist drop, due to paralysis of the arm muscles.

(4) **Organic impurities** usually cause diarrhoea and dysentery. The water from marshes may give rise to ague or malarial fever. Sewage from an infected source will produce typhoid fever and cholera. These two diseases are, in fact, usually spread by impure drinking water. Sewer gas dissolved in water may set up sore throat, diarrhoea, and possibly diphtheria.

Sources of Water Supply.

The original source of all water supplies is of course the rain. The rain that falls on the earth is disposed of in three chief ways :—(1) Part of it evaporates and is carried away, to fall again as rain ultimately. (2) Another part runs along the surface of the ground into the nearest watercourse. (3) The third part sinks into the ground and reappears later on as spring water or well water.

The actual sources may be divided into unusual and usual or common. Among the **unusual sources** of water we may mention distilled sea water, melted snow or ice, and dew. Distilled water is quite pure, but it tastes very flat and insipid. It is improved by allowing it to drop slowly from one vessel to another, during which process it dissolves some air and becomes much more palatable. Melted snow or ice has the same objectionable feature, and is moreover very liable to contain disease germs.

The usual sources of water supply include (1) Rain water, (2) Upland surface water, (3) Springs, (4) Wells, (5) Rivers, (6) Lakes.

Rain Water is the purest form of water in nature. It contains no hardness, but dissolves gases from the air, especially carbon dioxide, oxygen, nitrogen, and ammonia, and carries down with it any suspended matters that may be present in the air. In towns, rain water is generally very impure for the following reasons :—(*a*) The air contains impure gases, soot, etc. (*b*) It falls on dirty roofs. (*c*) It is collected in filthy cisterns and water-butts. When rain water is collected from roofs it is advisable to allow the first portion to run to waste. This is effected by means of a rain-water separator, the separator of which is pivoted so that it directs the first portion into the waste pipe, and then turns over and directs the clean water into the cistern. Rain water is very liable to dissolve lead, and so it should never be stored in lead cisterns. If it is collected in the open country and in clean vessels it forms a pure and wholesome source of water supply.

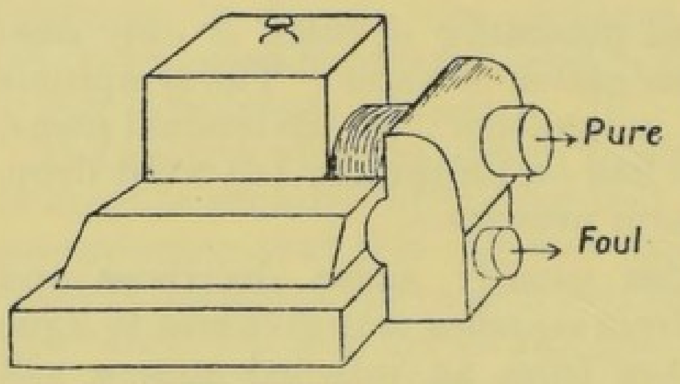


Fig. 112.—Rain-water Separator.

The average annual rainfall in England is about 35 inches. It is lowest on the East coast, where it is about 20 inches, and highest on the West coast, where it averages about 70 inches.

Upland Surface Water is water collected from moors and hills. It is very largely used as a source of water supply.

The water is collected in natural or artificial lakes, and is brought to the towns by long conduits. It is usually very soft, and is liable to dissolve lead. For this reason it is sometimes filtered through limestone in order to make it harder.

Springs. Part of the rain water soaks into the ground as we have already pointed out. This water sinks through the upper or pervious layer of soil until it reaches the impervious layer below (a layer of clay, for example). The

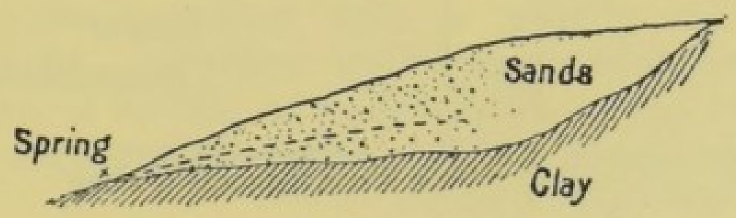


Fig. 113.—LAND SPRINGS.

water cannot get through the layer, and so it runs along the top of it, forming an underground river, called **ground water**. The impervious layer eventually reaches the surface, commonly at the foot of a hill, or in valleys, or in the bed of a river. Obviously at this point the water will run out of the ground and a spring will be formed. When

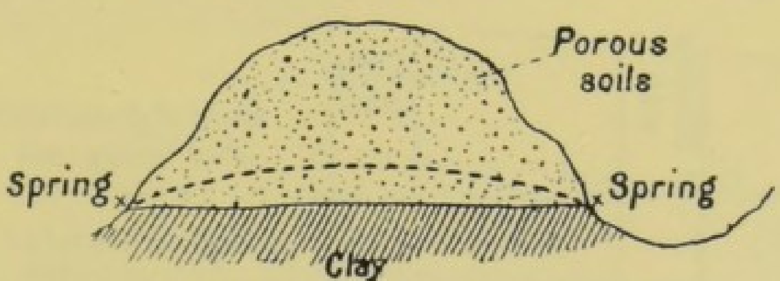


Fig. 114.—MAIN SPRINGS.

the porous layer of soil only consists of a localised patch of gravel or sand the spring is called a **land spring**, and in all probability will dry up during the summer. On the other hand the porous layer may consist of a range of hills, and in this case the spring would be a **main spring**, and would be of a much more permanent character.

The character of spring water will obviously depend upon the nature of the porous layer through which the water has percolated. Sand, for example, would yield a pure water; and water from the chalk would be very hard, but probably a good drinking water in other respects.

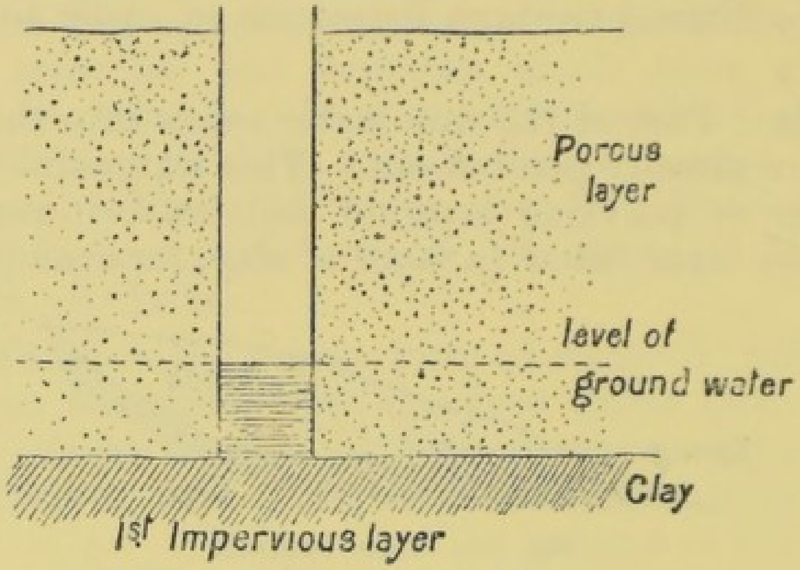


Fig. 115.—Shallow Well.

Spring water is usually well aerated, and is a good drinking water.

Wells.—These may be defined as artificial springs. There are two kinds: (1) Surface or shallow wells, (2) Deep wells.

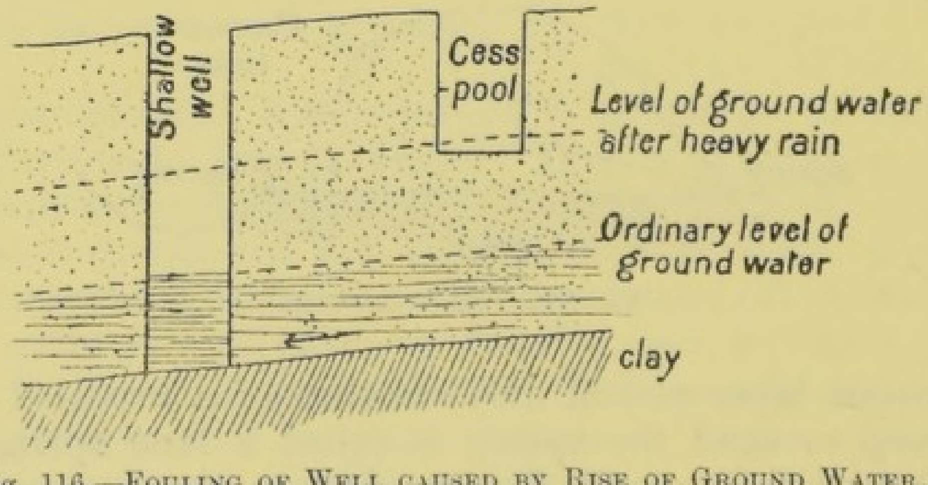


Fig. 116.—Fouling of Well caused by Rise of Ground Water.

A surface well is one that is dug down to the first impervious layer of soil, *i.e.* one that draws its water from the ground water resting on the first impervious layer. This water has evidently percolated from the surface of the ground around the well, and if there is sewage matter near, this will find its way into the well. This renders shallow wells especially liable to pollution from neighbouring cesspools, middens, or farm yards. The proximity of a cesspool to a shallow well should always arouse suspicion as to the quality of the well water, although some positions may be more dangerous than others (see Fig. 116). A sudden rise in the level of the ground water will sometimes cause sewage matter to be carried direct from a cesspool to the well. The effect of this pollution would be to spread such diseases as cholera and typhoid.

The water from shallow wells is usually well aerated and fairly hard. Shallow wells *may* yield good water provided there is no risk of pollution from the surface or from neighbouring drains or cesspools. To get rid of this

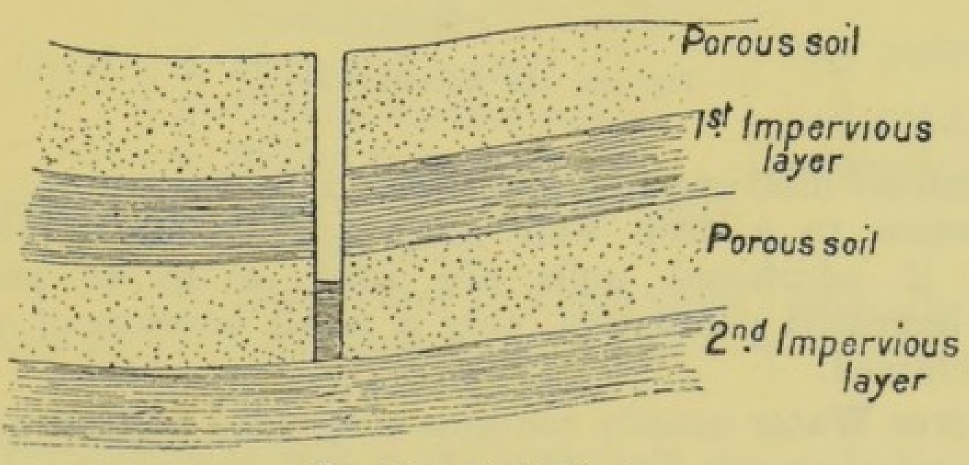


Fig. 117.—DEEP WELL.

danger to some extent we may (1) line the well thoroughly with bricks and cement down to the water line; (2) build a wall about three feet high all round the top; (3) pave the ground all round the wall. The only way to entirely get rid of all danger from this source is to bore through the first impervious layer down to the water resting on the second impervious layer, *i.e.* make a deep well.

A **deep well** is bored through the first impervious layer down to the second, and therefore it taps the water resting on the second impervious layer. By reference to Fig. 117 it will be seen that this water must have percolated from the land at some distance, probably many miles from the well.

A special kind of deep well is the **artesian** well. This is a deep well which taps water between two impervious layers, the level of which water is as high as, or higher than, the level of the ground where the well is sunk. In this case the water will rise like a fountain to the ground level, or even above it. Deep well water is usually free from organic impurities, but is sometimes very hard, *e.g.* from chalk or limestone districts. In granite, slate, or

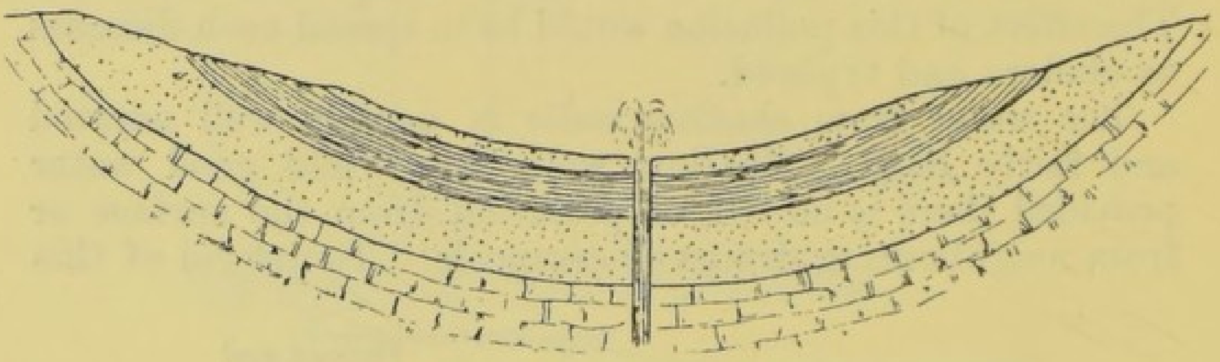


Fig. 118.—An Artesian Well.

sandstone districts the water would be very pure. An objection to a deep well water supply for a town is that if additional wells are sunk, so as to provide for increased population, only a small increase of water is obtained.

River Water usually contains suspended matters and so particularly needs filtration. It is well aerated and is not so hard as spring or well water. On the other hand more organic impurity will, as a rule, be found in river water than in spring or well water. If the supply is taken from a river before it reaches houses or cultivated land it is generally pure. Under all circumstances the water from rivers should be filtered and, if possible, boiled. The sewage and other impurities a river receives does not necessarily make the water unfit for drinking a few miles further on. The reason for this is that rivers possess a **self-purifying action**, by means of which they are enabled to get rid of their impurities. This is strikingly illustrated in the case of the Thames water which contains no more organic matter at Hampton Court than the Lechlade, 116 miles higher up, although it has received the sewage of several towns on the way! This purification is due to—

(*a*) Oxidation of the impurities by the oxygen in the air.
(*b*) Absorption of the organic impurities by all kinds of animal and vegetable life.
(*c*) The settling of the solid matter to the bottom.
(*d*) Dilution by the tributaries.

Lakes. The water of lakes is generally very pure and soft, with hardly any organic impurities. The waters of Loch Katrine, Bala Lake, and Thirlmere are good examples of the excellent quality obtainable from this source.

The following **classification** of the sources of water supply according to general fitness for drinking, etc., may be useful (Rivers Pollution Commission Report) :—

Good	1. Spring water.	very palatable.
	2. Deep well water.	
	3. Upland surface water.	moderately palatable.
Suspicious	4. Stored rain water.	
	5. Surface water from cultivated lands.	palatable.
Dangerous	6. River water to which there has been sewer access.	
	7. Shallow well water.	

Classified according to softness :—

1. Rain water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Lake water.
5. River water.
6. Spring water.
7. Shallow well water.
8. Deep well water.

Water Supply in Towns.

Any public service of water is usually too costly for country villages and so these places depend upon wells for their water supply. In towns, however, a public water supply is necessary. The best source for this is either a large lake, or else upland surface water collected in huge artificial lakes. For storing the water, a reservoir is constructed near the town, and as high as possible. All reservoirs should be capable of holding two or three months' supply.

The amount of water required for each individual per day is usually estimated at a **minimum** of fifteen gallons. For a good service, thirty gallons should be allowed for each person per day. This is made up as follows:—

12 gallons for cooking, washing, drinking, and general domestic use.

8 gallons for flushing drains and sewers, etc.

10 gallons for town and trade uses, public baths, etc.

If a sufficient supply of water is not available the public health must suffer and so a proper water supply should always be one of the first considerations of all sanitary authorities.

Effects of an insufficient supply of water:—

1. The general cleanliness is bad and an increased tendency towards the spread of disease results.
2. The skin, as a result of the accumulation of secretions and dirt, is more liable to contract various skin diseases.
3. Parasites are very likely to be numerous.
4. Clothing and houses are rarely or insufficiently cleaned.
5. The general standard of decency and self-respect is lowered.
6. The drains and sewers become choked owing to lack of flushing water.

Filtration of Water on a large scale. The water is first passed into a reservoir, where the greater part of the suspended matter settles to the bottom. The clear liquid is then siphoned off into the filter beds. **A filter bed** consists of layers of sand and gravel as shown in Fig. 119. The top layer is of fine sand and is two feet thick. The other layers are of gravel, and gradually get coarser towards the bottom. These layers rest on two layers of bricks, and from these the water is collected by pipes which convey it to the reservoir.

For success in the filtering process the following rules must be observed :—

(1) Each filter bed must be used at intervals only, and there must be free exposure to air.

(2) The upper layers soon get clogged with impurities, and need constant renewal to the depth of two or three inches.

(3) The whole filter bed should be renewed in two years.

(4) All filtering processes must be *slow* to be effectual. The maximum rate should not exceed four inches per hour.

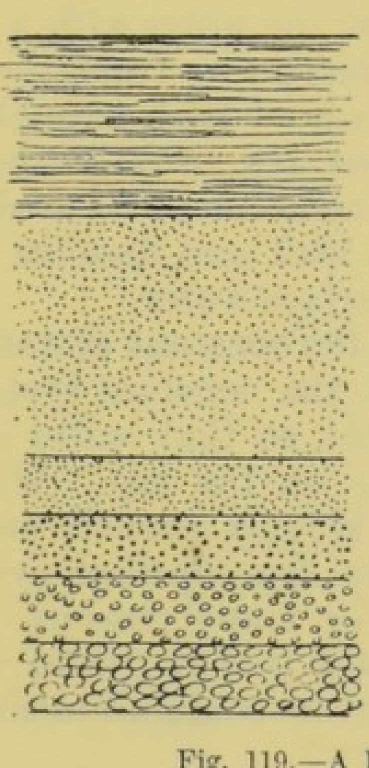


Fig. 119.—A Filter Bed (Section).

Action of the Filter. The action is partly mechanical and partly vital. The mechanical action consists of the removal of the suspended matters that are in the water. The vital action lies in a peculiar layer of gelatinous matter which becomes deposited on the surface of the sand after the filter has been in use for two or three days. The micro-organisms present in this layer tend to oxidise the organic matter dissolved in the water, and also to remove any injurious microbes. As this layer does not form until the filter has been in use for some days it is important to remember that the water passing through the filter during that time is only imperfectly filtered.

The **results** of such a filtration may be summed up as follows:—

(*a*) The dissolved organic impurities are partly oxidised.

(*b*) All suspended matters are removed.

(*c*) Micro-organisms are removed to a great extent.

Distribution of Water. After filtration, the water has to be distributed to the town. For distribution to the streets iron pipes called **mains** are used, and are laid from two-and-a-half to four feet underground. They should be protected inside from the action of the water with a coat of preservative material. **Service** pipes run from the mains to the houses. These may be made of lead, wrought iron, or galvanised iron. Lead pipes are usually the most serviceable, but they should on no account be used if the water is such as would act upon lead and dissolve it—for example rain water, or upland surface water.

The water may be supplied on the **constant system** or on the **intermittent system**. With the constant system the pipes are always filled with water, so that water may be obtained at any time by turning on the tap. With the intermittent system the water is only turned on for a few hours each day. Obviously the constant system is by far the better of the two for many reasons, one of which is that the drinking water is not drawn from a cistern, but from a pipe in direct communication with the main.

Cisterns. The materials of which cisterns may be made include slate, stone, iron, galvanised iron, lead, and zinc. Slate makes a good cistern, but the junctions are apt to leak, and if these are filled with red lead it is open to the same objections as lead cisterns. Lead should never be used for a cistern for drinking water. Stone cisterns are not acted upon by water, but they are very heavy, and so are only suitable for underground use. Iron may discolour the water by rusting. Galvanised iron cisterns are generally the most suitable, because they are not appreciably acted upon by the water.

The **objections** to cisterns are:—

(1) The water soon becomes flat and insipid.

(2) Dirt and dust are liable to accumulate in them.

(3) Cisterns are usually placed by builders in inaccessible positions.

(4) Occasionally the same cistern is made to supply the water-closet and the tap for drinking water. Many cases of disease have arisen from such an arrangement.

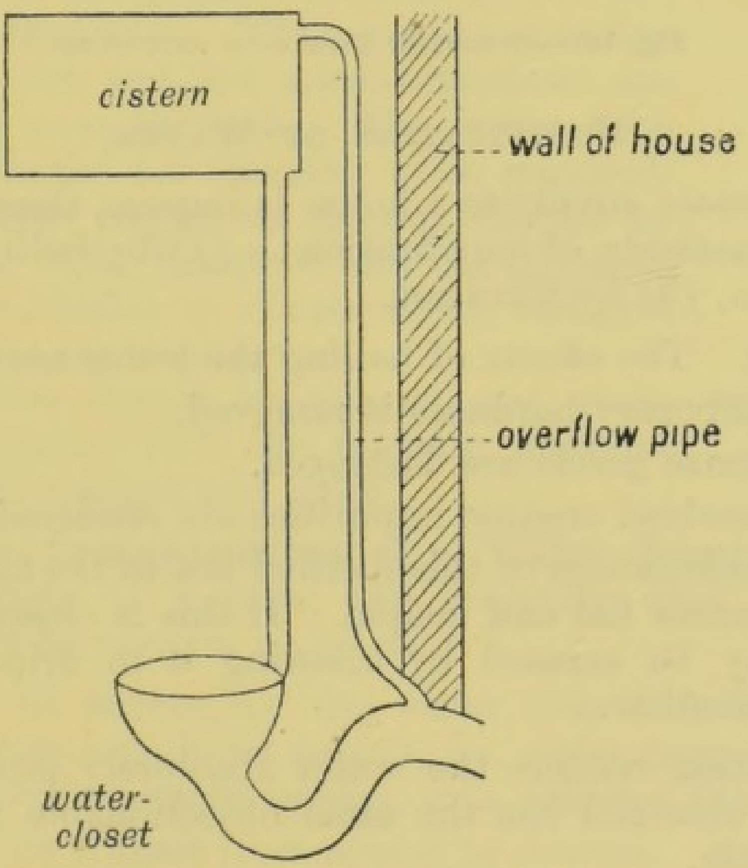


Fig. 120.—Overflow Pipe of Cistern (wrong).

(5) The overflow pipe from a cistern is often carried directly into a drain or soil pipe. Sewer gas then escapes over the surface of the water, and the water may become dangerously impure.

If a cistern is absolutely unavoidable the following are the **conditions** under which it should be kept:—

(1) It should be easy of access and easily cleaned.

(2) Its overflow pipe should go directly to the outside of the house, and not go near any drain pipe.

(3) It should have a well-fitting lid.

(4) The water-closet must have a separate cistern.

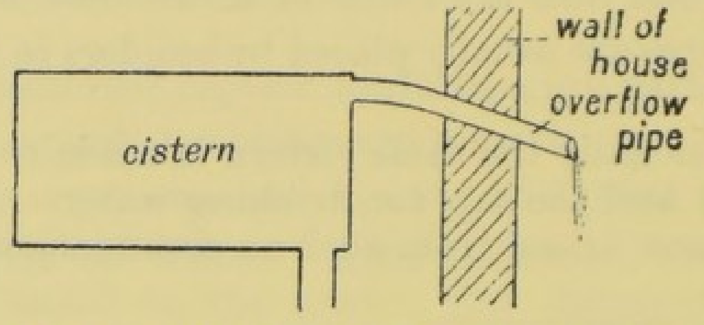


Fig. 121.—Overflow Pipe as it should be.

Purification of Water.

If the water supply to a house is impure, there are three possible methods of purification :—(1) by boiling, (2) by distillation, (3) by filtration.

Boiling. The effects of boiling the water are :—

(1) Temporary hardness is removed.

(2) Disease germs are destroyed.

(3) Dissolved organic impurities are rendered harmless.

The disadvantage of this method lies in the fact that the water is rather flat and insipid. If this is objected to, the water may be aerated by allowing it to drip from one vessel to another.

Distillation renders the water absolutely pure, but the water so obtained has the same objectionable feature as boiled water.

Filtration on a small scale, or domestic filtration, is generally the most popular method of purification of water. At the same time there is no doubt that the ordinary filter employed is not only of no use in purifying the water, but it actually renders the water more impure and more dangerous for drinking purposes. The commonest filtering materials are (1) animal charcoal, (2) coke, (3) spongy iron, (4) unglazed earthenware, (5) sponges. The worst of these is undoubtedly the old-fashioned sponge filter in which the sponge—in itself an abominable filtering medium—was usually fastened up, and could not be got at in any way.

The best filters are those made after the type of the Pasteur-Chamberland variety, in which the filtering materials are unglazed earthenware or other fine material which can easily be sterilised. These filters consist of an inner and an outer tube. The outer tube is of ordinary glazed earthenware and is fitted on the tap so that it contains the tap-water at the ordinary pressure. This pressure forces the water through the pores of the inner tube, which is composed of unglazed earthenware. These pores are so fine that even the smallest micro-organisms are unable to pass through. The inner tube can be removed for cleaning when required. The dissolved impurities are not affected by this filter. The Berkfeld and the Doulton filters are similar in construction, but give rather more rapid filtration.

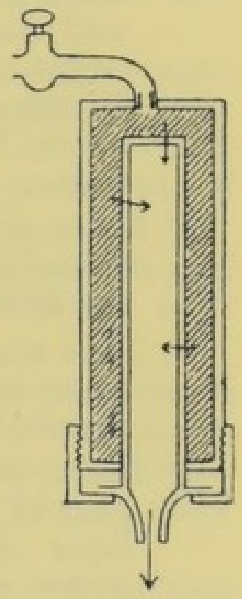


Fig. 122. PASTEUR-CHAMBERLAND FILTER.

All filters should be cleaned and sterilised regularly, and the filtering material thoroughly washed and dried.

Possible Contaminations of a Water Supply. If the water supply is impure, the impurity may have been introduced in various ways:—

(1) At its **source**, *i.e.* the water may have been drawn from a polluted supply, *e.g.* water from a marsh, a river receiving sewage, or a polluted shallow well.

(2) In its **transit** from source to storage. For instance, the washings from cultivated lands, or sewage from drains may have obtained access.

(3) During **storage**. This would include impurities derived from dirty cisterns, cisterns exposed to sewer gas, and lead cisterns.

(4) During **distribution**. Lead may be dissolved from lead pipes.

(5) During **filtration**. A bad filter will often render water impure.

Practical Work.

I. Filtration.

(*a*) Add a few drops of Condy's fluid to some water in a tumbler. Fold a filter paper for filtration, place it in a filter funnel and filter the pink liquid.

(*b*) Next take the clear filtered liquid and add to it a pinch of black powder (either manganese dioxide or charcoal does very well) and shake up, then filter the liquid.

The above experiments illustrate the important fact that filtration does not affect substances that are dissolved in the water, but will remove matters that are suspended in the water.

(*c*) Shake up some litmus solution, or some port wine, with fine animal charcoal. Filter the mixture and note the colour of the filtrate.

(*d*) Take about a tablespoonful of sulphuretted hydrogen water. Note its smell. Shake it up well with finely powdered charcoal and then filter it. Note smell of liquid now.

(*e*) Use a clean flower pot. Fill the hole at the bottom with a plug of glass wool, and then fill the bottom of the pot with a layer of small pebbles. This layer should be about two inches deep. Above the pebbles place a layer of sand four inches deep. Use this as a filter, and show how it is capable of producing clear bright water from a turbid sample.

II. Evaporation.

Place in separate weighed basins a measured quantity (say 250 cubic centimetres) of (*a*) clear rain-water, (*b*) tap-water, and (*c*) sea-water. Evaporate the water away by placing the basins on a water-bath. When quite dry weigh the basins again. The gain in weight of the basins will give respectively the amount of solids dissolved in rain-water, tap-water, and sea-water.

III. Distillation.

Colour some water with Condy's fluid, place it in a flask and fit the flask with a Liebig condenser, or use a glass retort with a receiver cooled by cold water. Boil the water in the flask, and notice that water begins to drop into the cooled receiver. This is pure distilled water.

IV. Impurities in Water.

Test the tap-water for the various impurities described in the foregoing chapter.

V. Hardness in Water.

(*a*) Pass a stream of carbon dioxide (prepared by the action of hydrochloric acid on chalk) through some clear lime-water in a test-tube. Continue passing the gas after the white precipitate of chalk has been produced. The second effect illustrates the action of the carbon dioxide from the air in causing the solution of the limestone or chalk and producing temporarily hard water. The clear liquid now obtained is temporarily hard water. Divide into two parts, (*a*) and (*b*).

(i) Boil. } Carefully note the results in each
(ii) Add lime-water. } case.

The effect of the boiling or the addition of lime-water is the same, *i.e.* both processes serve to remove carbon dioxide from the water. When the carbon dioxide is removed the chalk can no longer remain in solution, and so a white precipitate of chalk is produced.

(*b*) To 50 c.c. of distilled water in a 100 c.c. stoppered bottle add a few drops of "soap solution" and shake. A lather is at once formed.

(*c*) Repeat the above experiment using 25 c.c. of the clear liquid obtained in experiment V. (*a*) above. No lather is formed, but a scum or precipitate is produced. Add more soap solution a little at a time until a lather is produced after shaking. Note amount of soap solution used.

(*d*) Take another 50 c.c. of the clear liquid formed in experiment V. (*a*). Boil it for two minutes, and then filter off the precipitate formed. Now use the clear filtered liquid as in experiments (*b*) and (*c*) above, and ascertain how much soap solution is required to produce a lather after shaking. The liquid now requires little soap solution to produce a lather, because the hardness (temporary) has been removed by boiling.

(*e*) Use 50 c.c. solution of calcium sulphate and ascertain the amount of soap solution required to produce a lather. Boil another 50 c.c. and test again with soap solution. In this case the boiling produces no effect (permanent hardness).

CHAPTER XIX.

HEATING THE DWELLING-HOUSE.

Heat is transmitted from one part of a body to another, or from one body to another, in three ways. These are (*a*) conduction, (*b*) convection, and (*c*) radiation.

(*a*) *Conduction.* This method of the transfer of heat has already been discussed with regard to the prevention of loss of body heat by clothing. It is the term used when heat passes from one molecule of a body to an adjacent molecule, just as an article can be passed along a row of people standing in a line.

(*b*) *Convection.* The transference of heat by convection is the result of the mobility of the particles of liquids and gases. When matter is heated it, as a rule, expands and therefore becomes less dense. Heated gases and liquids are therefore lighter bulk for bulk than the cooler parts of the same gas or liquid. The heated parts therefore tend to rise, and their place is taken by the cooler parts. When a flask of cold water is heated by a Bunsen flame below it the layer of water next the bottom of the flask is heated by means of conduction from the hot glass. The heated part of the water is lighter than the remainder, and so it rises and conveys heat to particles with which it comes in contact. To take its place at the bottom of the flask a stream of colder particles descends. These currents of ascending hot par-

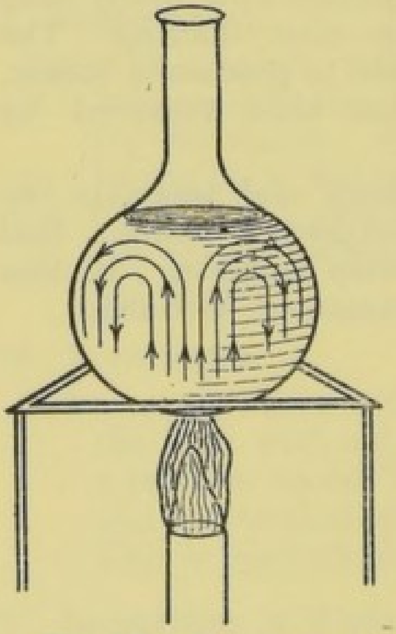


Fig. 123.—Convection Currents.

ticles and descending cooler ones are called convection currents.

(*c*) *Radiation.* Heat also passes from one body to another without warming the intervening space. In this way the heat of the sun reaches the earth, or the warmth of a fire is felt at some distance away.

Fuel.

Fuel includes the combustible substances we use to produce heat. The chief are (*a*) coal, (*b*) coke, (*c*) peat, (*d*) wood, (*e*) coal gas, (*f*) oil, (*g*) artificial fuels.

(*a*) **Coal** is *mineralised vegetation*, consisting of plants which flourished in the Carboniferous era, but have been changed by the action of heat and pressure.

(*b*) **Coke** is the residue of coal which has deen distilled to obtain coal gas.

(*c*) **Peat** is decayed vegetable matter, similar in origin to coal, but it has not been changed so much. It is formed in bogs and marshy places.

(*d*) **Wood** is obtained from the harder parts of plants.

Each of the above materials consists of substances whose molecules have been built up under the influence of the light and heat of the sun, when the plants were growing. The solar energy is changed into chemical energy. When these substances are burned the complex molecules break down, and relatively simpler molecules are formed. (These are chiefly CO_2 and H_2O.) These require less energy to hold their atoms together than the original molecules, and the difference is changed into heat energy.

(*e*) **Coal gas** is obtained by the distillation of coal in closed retorts. The coal is heated without contact with air, and the products of the destructive distillation are made to pass through condensers in which they are cooled, and coal tar and ammoniacal vapours are condensed and collected. The gas is then passed through purifying chambers containing moist slaked lime and ferric hydrate. These remove gaseous sulphur compounds, and the lime also removes CO_2. The gas is then stored in gas-holders or gasometers for use. The coal left in the retort becomes **coke**. **Charcoal** is produced from wood, this being heated to a red heat out of contact with the air.

(*f*) **Oil**. Liquid fuels are obtained from Pennsylvania, Baku, and Texas. These are supposed to be of organic origin, and derived from the remains of animals or plants. They may be obtained also by distillation of shales of various kinds.

(*g*) Recently fuel-blocks, or **briquettes**, have come into use. They usually consist of fine coal or other combustible material, cemented together by pitch. Sawdust, spent tan, and peat have been used, but have not proved so successful as coal.

Methods of Heating.

The following methods of heating rooms are in common use :—

1. By Coal or Coke.

Coal may be used in open fires, in ventilating grates, or in stoves. Coke may be used either alone or mixed with coal in any of these appliances, but is more commonly used in stoves.

2. By Coal Gas.

The use of coal gas in refractory fuel stoves is now common. The heat of the combustion of the gas is used to raise the refractory fuel, such as asbestos, to a white heat. Gas is still better used for ventilating stoves, where the heat is used to raise the temperature of the incoming fresh air. Reflector stoves, where a reflector is placed at the back of a bright flame, or condensing stoves where a condensation of all the products of combustion is supposed to take place, are of little value.

3. By Oil.

Oil may be used in ventilating stoves very effectively. It is also often used in the form of a reflector stove.

4. **By Hot-water Pipes.**

Hot-water pipes may be arranged either on (*a*) the low pressure system or (*b*) the high pressure system.

(*a*) *Low pressure.* Water is heated in a boiler having a pipe leading upwards from the top to various parts of the building, branching as required. The heated water flows along this system of pipes, which finally conducts the water back to the lower part of the boiler. Heated water rises and the cooled water falls. The pipe entering the boiler is connected with a cistern, which makes good any leakage or waste through evaporation, and the highest point of the pipes is provided with a valve, to allow the air and vapour to escape.

The water being under the ordinary pressure of the atmosphere, and not allowed to boil, its temperature does not exceed 212° F., and the vapour pressure within the pipes is always below that of the atmosphere.

(*b*) *High pressure.* The pipes are arranged to form a complete circuit, and these are *not* open to the air, so that the temperature of the contained water may rise above 212° F.

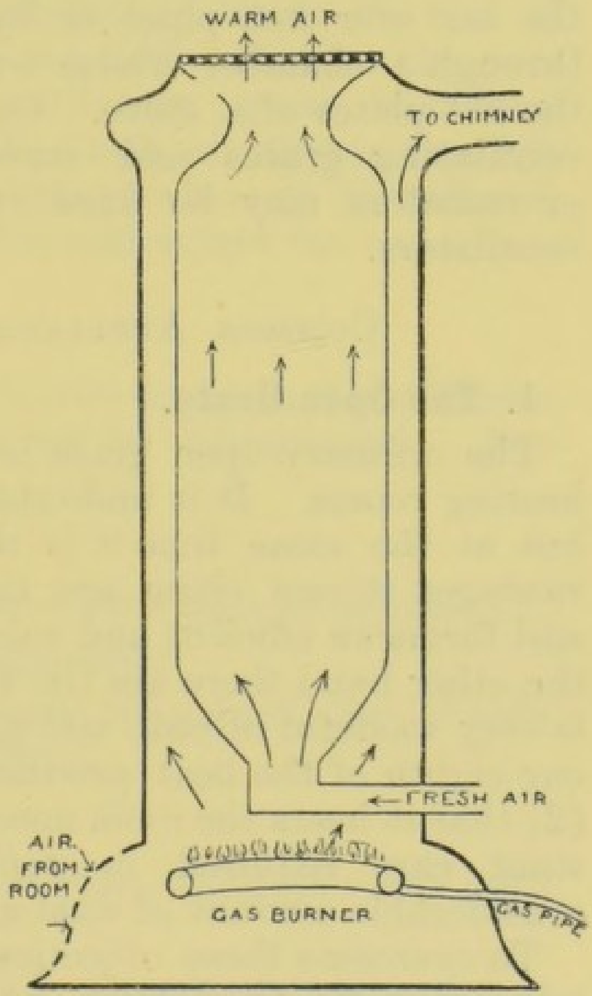


Fig. 124.—Ventilating Stove (Bond's).

A coil of piping is arranged in the furnace, and the pipes connected with this pass through the rooms to be heated and back to the furnace.

5. **By Steam Pipes.**

In places where large quantities of waste steam are available, as in factories, it may be economical to heat the building by means of steam pipes. The steam passes along pipes in which it condenses and gives up a large amount of heat, thereby raising the temperature of the pipes. The condensed water runs back to the boiler. The temperature of the pipes can be regulated by valves.

6. **By Heated Air.**

The heating and ventilation of many buildings may be economically combined by warming the incoming fresh air. This on a large scale is arranged either by passing the air over hot pipes or by arranging for it to pass through a chamber whose walls are partly composed of the hot plates of a stove. On a smaller scale the various ventilating grates and stoves supply fresh warm air, or radiators may be fixed in connection with the inlet ventilators.

Common Appliances for Heating.

1. **The Open Grate.**

The ordinary open grate is the commonest method of heating rooms. It is undoubtedly the most pleasant way, but at the same time it is the most wasteful. The advantages it can claim are that it is bright and cheerful, and forms an efficient and valuable outlet ventilator. On the other hand there are the serious objections (1) that it is very wasteful of coal, and gives to the room only about one-eighth of the heat produced during the combustion; (2) that it heats the room unequally; (3) that there is constant care required in replenishing; and (4) that a considerable amount of dust and smoke is produced.

To overcome these objections as far as possible various improvements have been introduced. To decrease the wasteful consumption of fuel and to increase the proportion of heat available for the room, the following alterations have been made to the old-fashioned type :—

(*a*) The rate of combustion of the fuel is decreased by narrowing the opening of the chimney and by cutting off the air from the space under the grate, or in some grates by abolishing the space altogether.

(*b*) The combustion is made as complete as possible, and the radiation of heat into the room is increased by constructing the grate almost wholly of fire-brick and by arranging the back of the grate to lean over the fire.

(*c*) The heat of combustion is economised as far as possible by placing the grate in the centre of an inner wall (if the grate is placed on an outer wall some of the heat is used in warming the outside air), and in some cases by building the grate out into the room instead of placing it in a recess.

A considerable economy is effected by using the heat of combustion to warm the fresh air that enters for the purpose of ventilation. The ventilating grate has been devised for this purpose. The fresh air passes through a chamber at the back of the grate, where it is warmed. It then passes up a separate flue and enters the room.

2. Gas Fires.

These are increasing in popularity on account of the ease with which they can be started or discontinued. The chief advantages are :—

(1) They are clean ;
(2) They are convenient and save time in lighting ;
(3) They can be easily regulated ;
(4) They are more economical than a coal fire, if only required occasionally.

The disadvantages are :—

(1) They are expensive as a rule—the cost varies with the cost of gas ;
(2) They vitiate the air of a room, unless a flue is provided to carry off the products of combustion.

3. Stoves.

Stoves are not popular in England, but are in common use on the Continent and in America. The more important advantages are :—

(*a*) They are economical ;

(*b*) The rate of combustion can be regulated, and so the heat produced is under control;

(*c*) They are cleaner than open fires;

(*d*) Little attention is required.

The objections to stoves include the following:—

(*a*) They are less healthy than open fires. Headaches are often produced on account of the defective ventilation of the room in which the stove is placed;

(*b*) Carbon monoxide may be produced if part of the stove is made of cast-iron. Cast-iron when red hot is permeable to carbon monoxide, which may pass into the room in poisonous quantities;

(*c*) The air of a room heated by stoves tends to become unduly dry and unpleasant. This is usually prevented to some extent by placing a vessel of water on or in front of the stove;

(*d*) The organic particles floating about in the air come in contact with the heated surface of the stove and become charred, thus producing an unpleasant smell.

Practical Work.

I. Conduction.

Obtain pieces of wire made of different metals but of same size. Arrange the wires on a fire-clay tile so that the ends are close together, projecting over the edge of the tile, while the other ends are far apart. Support the tile horizontally by means of a clamp or a tripod, and apply a flame to the ends marked *A* in the diagram. At the end of a minute test the temperature of the distant ends by means of a match.

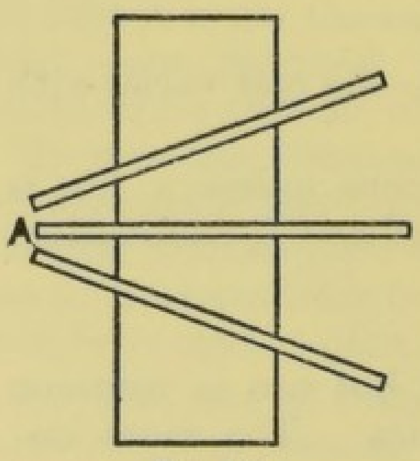


Fig. 125.

II. Convection.

Fill a round-bottomed flask about two-thirds full of water. Add about a teaspoonful of bran. Place the flask on a retort ring or tripod stand and apply a small

Bunsen flame to the centre of the bottom of the flask. Note the convection currents set up.

III. **Hot Water Apparatus.**

Fit up the apparatus shown in Fig. 126 and fill with water. Then add a few drops of red ink to the water in the top vessel. Apply the flame of a spirit lamp or a small Bunsen flame to the side tube at *A* and note the circulation that takes place.

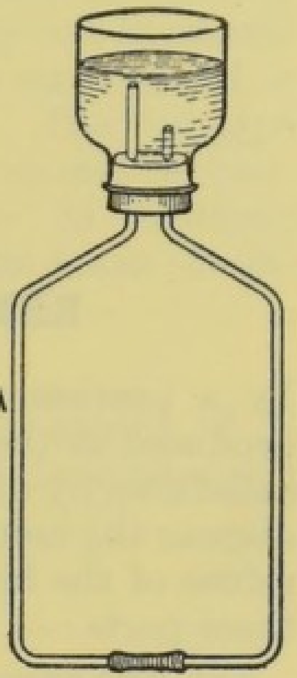


Fig. 126.

IV. **Convection compared with Radiation.**

Place a thermometer two feet away horizontally from a bright gas flame, and another thermometer two feet above the flame. Note the reading of each. The thermometer above the flame is heated by convection, while the one at the side receives radiant heat only.

V. **Radiation.**

(*a*) Obtain two bright tin cans and fit each with a cork through which a thermometer passes. Hold one can over a flame of burning camphor, turning it round so that the whole surface becomes covered with dull lamp-black. Fill the two cans with water from the tap, replace the corks, and note that the thermometers register the same temperature. Place the two cans at the same distance from a gas or coal fire, or other source of heat, for half an hour, and then note the temperatures recorded by the two thermometers. The blackened vessel will be found to have absorbed more heat than the bright one.

(*b*) Use the same two cans, and put into each an equal quantity of boiling water. Note that the thermometers record the same temperature in each case. Place the two vessels aside in a cool place free from draughts for half an hour, and then read the temperatures. The black can will be found to have lost more heat than the bright one.

These two experiments show that dull surfaces radiate more heat and absorb more heat than bright surfaces.

CHAPTER XX.

REMOVAL OF HOUSE REFUSE.

In a previous chapter we have seen that the impurities produced in the air by respiration and combustion may be satisfactorily disposed of by ventilation. We now have to discuss the methods of dealing with the solid and liquid refuse of the house. The **house refuse** may be divided into three parts:—

(*a*) The excreta, *i.e.* the urine and faeces.

(*b*) Kitchen refuse, including animal and vegetable waste, and also dust and ashes.

(*c*) Waste water from house cleaning, washing, and cooking.

The Excreta. There are two systems of dealing with these waste matters, the conservancy system and the water carriage system.

The conservancy systems include the use of cesspools, middens, pails, dry-earth, etc. Of these systems we may mention three. (*a*) In the **midden** system the ashes and the excreta are mixed together and are removed at intervals. (*b*) The excreta may be kept in **pails** and removed at short intervals. (*c*) For large country houses a very satisfactory method is to sprinkle the excreta with **dry earth** each time the closet is used. All these methods leave the waste water to be disposed of, and as this is almost as offensive as if it contained the excreta, it is probable that for towns and large villages the **water carriage system** of removing the excreta and all waste water together is the best.

A **first-rate** water supply is, however, absolutely necessary for the successful working of water-closets. Also the ordinary water-closet is rarely found to work satisfactorily for lower-class houses, and when they are thrown out of order by carelessness or by frost they are most unsanitary. In the water carriage system the water-closet is connected with the drain by the **soil-pipe**. The soil-pipe should always be outside the house, and should be continued upwards above the roof in order to ventilate itself and to act as an outlet ventilator to the house drain.

Water-closets.

These are used to get rid of excreta by means of a flush of water, which carries it along a soil-pipe and drain into a sewer.

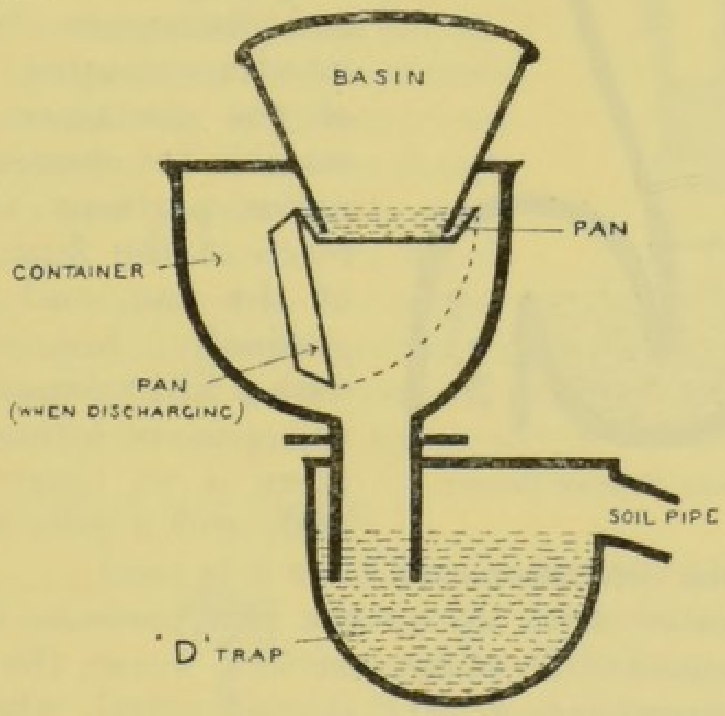


Fig. 127.—Pan Closet.

An arrangement is required which will—

(1) Prevent any sewer gas passing into the house;

(2) Not become foul itself and cause a bad smell;

(3) Produce a good flush of water, when required, without waste.

There are many varieties of water-closets, and it is not practicable within the limits of a small text-book to describe all the types. The types of closets that we shall refer to include (i) the old-fashioned pan closet, (ii) the long hopper, (iii) the short hopper, (iv) the wash-out, (v) the wash-down closet.

(i) The Pan Closet.

This is very unsatisfactory in various ways. It consists of a conical basin fixed with a cast-iron vessel called a *container*. The outlet of the basin is into a movable pan of tinned copper, containing a little water, which is supposed to act as a water-seal and prevent foul air escaping.

Each time it is used the hinged pan is tilted down, and discharges its contents into the container. The sides of the container are inaccessible for cleaning and the upper portions are out of reach of the flushing action of the pan, and thus they gradually become coated with a filthy deposit. When the pan is swinging down there is no longer a water-seal, and a gust of foul air rises from the container each time it is used.

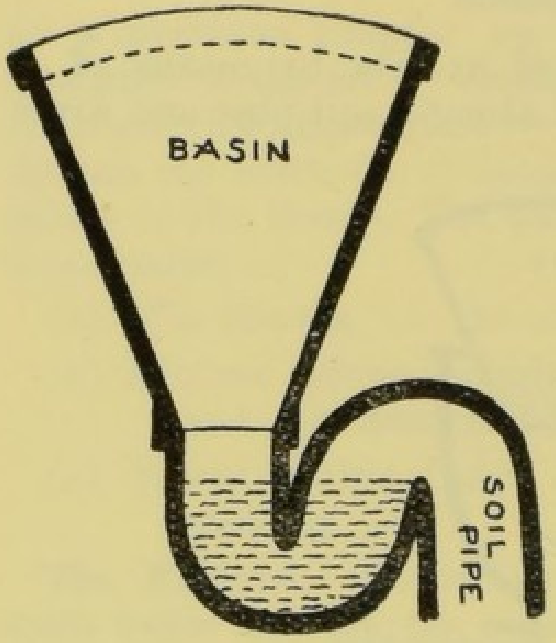


Fig. 128.—Long Hopper Closet.

If the water dries up or the pan becomes foul a bad smell is caused. To make matters worse, the container frequently opens into a "D" shaped vessel, which is also liable to become a gathering place for filth.

The Model Byelaws issued by the Local Government Board for the guidance of Sanitary Authorities prohibit the fixing of a "Container" or "D" trap to any new water-closet.

(ii) The Long Hopper Closet.

This consists of a deep conical basin ending in an "S" shaped pipe, in which water stands. There is no container, the excreta falling straight into the trap and being carried over the projection with the flush of water. Owing, however, to the shape of the basin, the sides are apt to become fouled to a great extent, and the flow of water fails to cleanse them. This is a cheap closet, but it is not satisfactory for slum property or common closets.

(iii) **The Short Hopper Closet.**

This is generally made of stoneware and is a great improvement on the Long Hopper. It is an admirable closet for general use. It has a smaller surface to be flushed and is cleaner. The basin fits into a stoneware trap in which the excreta falls direct.

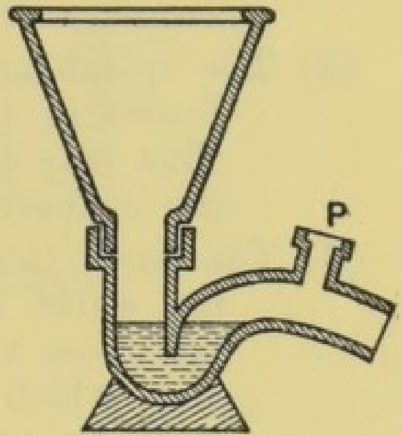


Fig. 129.—Short Hopper Closet.
P = Anti-syphon pipe.

There is occasionally a difficulty in joining the *stoneware* trap to a *metal* pipe, and special joints are required. Indiarubber is sometimes placed between the stoneware and the lead pipe, but it is apt to decay. There are some patent joints (*e.g.* Doulton's and Twyford's) in which a lead pipe is soldered to the stoneware by a special process before it is fixed, so that the soil-pipe has only to be connected to lead, which can be made watertight very easily by means of a wiped joint.

(iv) **The Wash-out Closet.**

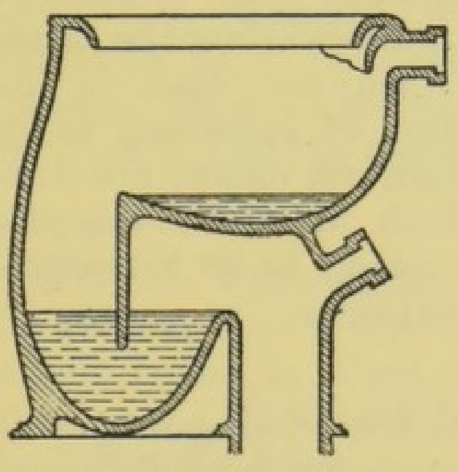


Fig. 130.—Wash-out Closet.

This is constructed of stoneware, and differs from the short hopper, as follows :—

(1) The basin and trap are constructed in one piece.

(2) The basin is shaped so as to form a shallow container in which the excreta falls.

The flush of water carries it over the ledge and into the siphon-trap below. The layer of water is placed in the basin to prevent it being fouled by excreta.

The advantages are:—

(1) It is cheap.

(2) It has no mechanical parts to get out of order.

(3) It is open to inspection.

(4) It is not necessary to enclose it in a case.

The disadvantages are:—

(1) The water in the basin is not sufficient to cover the excreta and is apt to splash.

(2) The splashing causes portions of the basin to be fouled in a position out of reach for cleansing. This may cause the glaze to crack, thus rendering it absorbent instead of impervious.

(3) The basin interrupts the downward flush, so that the water loses the energy gained by the direct fall from the cistern and only partly clears the trap, which may become fouled by deposits on the sides and give rise to bad smells.

(v) The Wash-down Closet.

This is one of the best water-closets in use. It differs from the short hopper in that the basin and trap are in one piece.

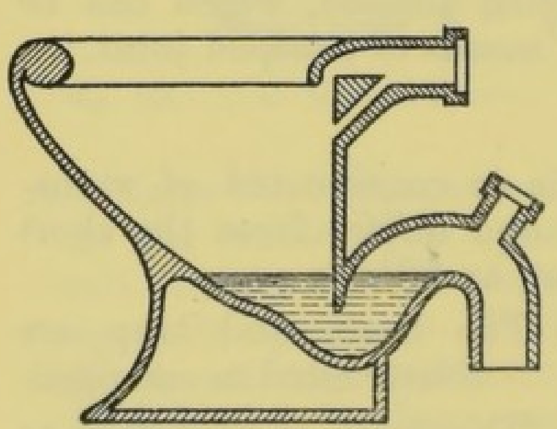


Fig. 131.—Wash-down Closet.

There should be sufficient water in the basin to prevent the excreta fouling the sides. It is then not open to the objection of splashing as in the wash-out closet, nor does the flush of water lose its force owing to an intercepting container.

Flushing Cisterns.

To prevent the flushing of closets from being imperfect through carelessness, many plans have been devised for ensuring that once the flow of water is started it will continue until a given volume has been discharged. A good arrangement is shown in Fig. 132. When the plug is removed, water rushes down the pipe and sets the siphon into action; then, even if the plug is replaced, the pressure of the air keeps the water flowing down the siphon until the surface is lowered so much that air is admitted to the short end of the siphon-pipe. A ball-tap is used for automatically refilling the cistern after discharge.

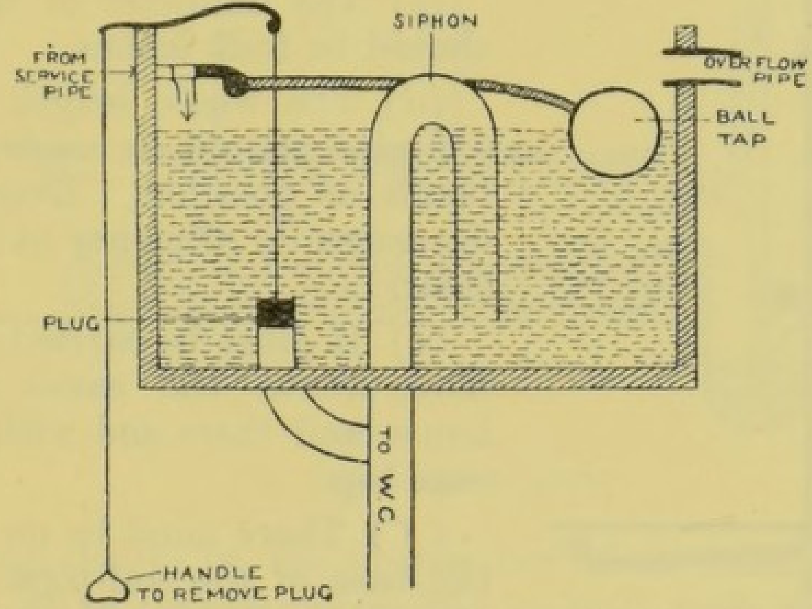


Fig. 132.—Flushing Cistern or Water Waste-preventer.

The cistern may be made of enamelled iron, or of wood lined with lead.

The quantity of water required for flushing a closet is 3 gallons, and to prevent waste it should not exceed $3\frac{1}{2}$ gallons. The pipe which carries the water to the W.C. should be $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter, as a rule, but the diameter must be increased if the vertical distance between the cistern and the closet is less than four feet.

Soil-pipe.

When a water-closet is placed inside the house above the ground-floor a pipe is necessary in order to carry the excreta from the closet to the drain. Such a pipe is called a soil-pipe. It should be constructed in accordance with the following rules:—

(*a*) It should be entirely outside the house. The best position is against a wall of the house which is not exposed to the rays of the sun.

(*b*) The best material is drawn lead weighing 7 or 8 lb. per foot, but more commonly cast-iron pipes are used. These should be protected from the action of the water by some effective coating. The joints should be made with lead.

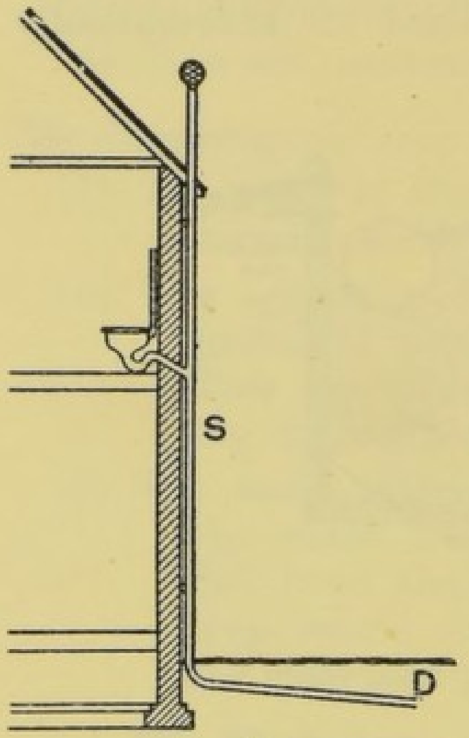


Fig. 133.
S = Soil-pipe. D = House drain.

(*c*) The diameter of the pipe should be four inches.

(*d*) The whole length of the soil-pipe should be as free from bends as possible. Every bend decreases its efficiency as a ventilator.

(*e*) It must be carried up, full bore, above the eaves of the house and there end with a wire cage top.

(*f*) There must be no trap at the base of the soil-pipe. It is connected direct with the house drain, and usually constitutes the head of the drain.

Trough Closets.

A trough closet is shown in Fig. 134. It consists of a stoneware trough above which is a series of closets built side by side. At the lower end of the trough its floor turns upwards so that there is always a depth of from one to four inches of water in it. The excreta fall into the water. At the upper end of the trough, four or five feet above it, is an automatic flush tank, which should be arranged to flush every six hours at least. The frequency of the flush is arranged by regulating the tap which fills the flush tank.

The only advantage of the trough closet is that it is more or less independent of rough and careless use. There are still large numbers of people whose degree of civilisation is such that they are not fit to be trusted to use an ordinary water-closet properly, and it is an utter waste of money to provide such an appliance in some neighbourhoods. Trough closets serve very well for such districts, and for factories.

Trough closets are not suitable for schools. They have a bad educational effect upon children, part of whose

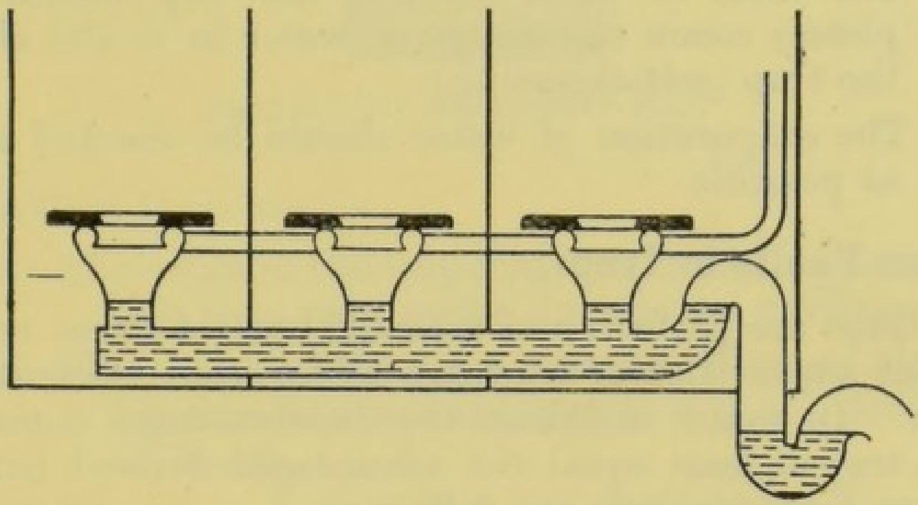


Fig. 134.—Trough Closet

education should be the proper use of an ordinary water-closet. It is almost impossible to keep such closets free from objectionable odours.

Traps.

A trap is a contrivance intended to prevent the passage of gases from the sewer into a drain or from a drain or house pipe into a house. This is usually effected by the blocking of the passage by a volume of water which remains in position until it is removed and renewed by a flush of water through the trap. In the past there has been a great extension of the trapping of drains and pipes, and traps will probably tend to be less used in the future.

A Good Trap.

A good trap should fulfil the following conditions:—

(*a*) The depth of water making the trap (the water-seal) should be at least one and a half inches. The effective depth of the water-seal is the depth a swimmer would have to dive in order to pass through the trap.

(*b*) There should be no projections or angles for the deposit of filth.

(*c*) The position should be such that the trap can be flushed without causing siphonage.

(*d*) The flush of water through the trap should completely renew the charge of water in it and cleanse the trap (self-cleansing).

(*e*) The evaporation of water should be checked as far as possible.

Common Faults in Traps.

No traps are perfect, and even the best of them require constant supervision if they are to form an efficient protection. In many instances the disadvantages connected with a trap at least equal the advantages derived from it. Common faults include the following:—

(*a*) Liability to unsealing through evaporation of the water, if seldom used.

(*b*) Liability to unsealing through siphonage unless guarded against.

(*c*) Pressure of gas may force water out. (Ventilation of drain prevents this.)

(*d*) The water may absorb sewer-gases at one opening until it is saturated and these gases will be given off at the other surface unless the flush is frequently used.

(*e*) They always obstruct the flush of water to some extent.

(*f*) Some are filthy and should be discarded altogether if not self-cleansing.

Bad Traps.

1. *The Mid-feather Trap.* This is also called the dipstone or mason's trap. It consists of a rectangular brickwork box into which water flows from the house pipe or drain and then passes out on its way to the sewer. A slab of stone is built vertically into the walls to divide the upper part into two sections. This is arranged to dip into

the water, as shown in the figure. The water which is left in the trap prevents gas passing the partition.

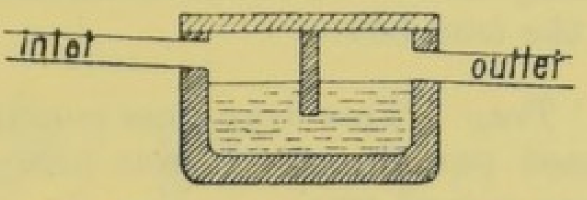


Fig. 135.—THE MID-FEATHER TRAP.

Objections to its use :—

(*a*) The water in the trap may evaporate and sewer-gas will then pass under the vertical partition.

(*b*) The shape of the trap prevents it being cleaned, hence matter accumulates in it to the detriment of health.

(*c*) The vertical stone slab (on which the trap entirely depends) is liable to get broken and so the trap rendered altogether ineffective.

2. *The Bell Trap*. This consists of a receptacle or box with a grating for the upper covering, and attached to this is a bell-shaped piece of iron which dips into the water. The outlet pipe opens under the bell as in the figure. These traps are frequently found on sinks. Any offensive gas from the drain is prevented from reaching the house so long as the grating is in its place, and so long as the bell is intact. These traps should not be used.

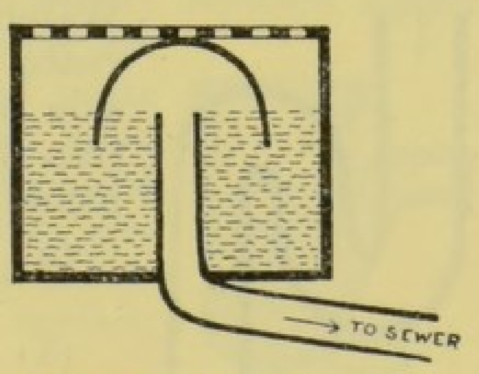


Fig. 136.—THE BELL TRAP.

Objections to its use :—

(*a*) The trap is valueless whenever the grating is raised, and this with the attached bell is liable to be left off. The bell is moreover liable to be broken, and the trap thereupon ceases to exist.

(*b*) Water may evaporate as in the dipstone trap.

(*c*) The shape of the box favours accumulation of filth. It is obviously not self-cleansing, and decomposing filth must accumulate in the lower parts of the iron box.

3. *The "D" Trap.* This trap was commonly a part of the old-fashioned pan-closet. It was also produced in a modified form as a yard trap.

The chief objections are:—

(*a*) Too much surface is exposed to be coated with filth.

(*b*) There are too many angles and bends, which prevent it being self-cleansing.

(*c*) The accumulation of filth thus caused gives rise to bad smells.

Modern Traps.

1. *The Siphon Trap.* The simplest form of the siphon trap is a bend in an ordinary pipe. Water remains in this bend and prevents the passage of gases from one side of it to the other. This form of trap is adapted for various positions, including the following:—

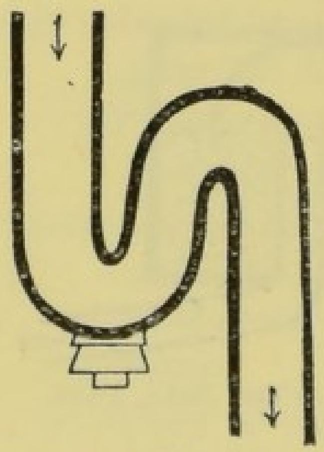


Fig. 137.—"S" Trap for Sink.

(*a*) The trap for all forms of modern water-closets.

(*b*) The trap for lavatory basins and sinks. This trap is made of lead and is fitted with a plug at the bottom of the bend in order that the bend can be cleaned out if it becomes obstructed.

(*c*) The trap placed near the sewer end of the drain in order to provide for the disconnection of the drain from the sewer (Buchanan's disconnecting and ventilating trap, made of glazed earthenware). This or some similar trap is usually placed on the sewer side of the manhole or inspection chamber of the drain. The ventilator serves for the admission of fresh air, which passes along the drain and escapes through the soil-pipe ventilator.

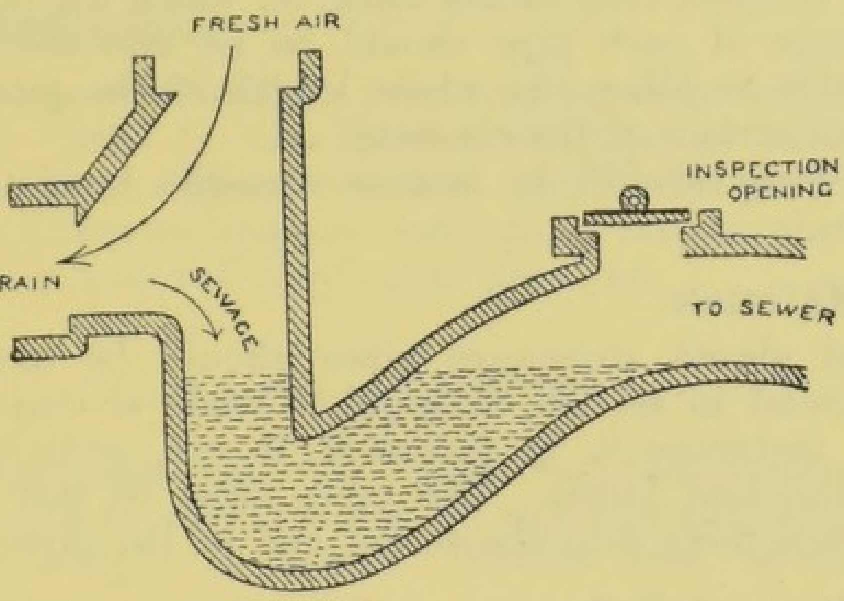


Fig. 138.—Buchan's Disconnecting and Ventilating Trap.

2. *The Gully Trap.* These are merely modified siphon traps for use as yard gullies. They are placed to receive yard drainage and waste water from sinks and baths. They must never be placed inside a house. The waste pipes from sinks or baths sometimes discharge into the side of the gully below the grating, or on to a sloping surface 18 inches away from the grating.

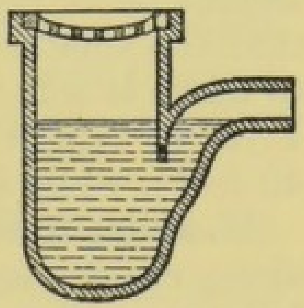


Fig. 139.—Gully Trap.

Drains.

Every house should be provided with efficient drains to carry waste water to the sewer or to a cesspool. In constructing a drain the following rules should be observed:—

(1) **Course.**

The drain should not pass under a house if it can be avoided. When a drain passes under a house it should be surrounded with concrete.

When constructing the drain the whole of the trench in which it is to lie should be dug out before any pipes are laid. The floor of the trench should be covered with a layer of concrete four inches thick, on which the pipes rest. The flange of each pipe should be let into the concrete sufficiently to allow the whole length of the pipe to rest upon the surface of the concrete.

The drain should be laid in straight lines as far as possible.

(2) **Materials.**

Sound glazed stoneware pipes should be used, perfectly round in section, with joints made of cement. In certain instances it is necessary to use protected iron pipes with lead joints. The pipes must be laid so that the sewage flows into the socket end of the pipes.

(3) **Size and Fall.**

A common rule is to make the main drain of pipes measuring six inches in diameter (six-inch pipes), and the branches of four-inch pipes. The fall in each case should be as regular and even as possible, the rule being that the smaller the pipe the greater is the fall necessary to make it self-cleansing. Four-inch pipes need a fall of 1 in 40 (*i.e.* a vertical fall of one foot in a length of 40 feet), while six-inch pipes need a fall of 1 in 60.

If a drain is laid with too much fall the liquids run along rapidly and leave the solids behind. When adequate fall cannot be obtained it is usually necessary to fix an automatic flush tank at the head of the drain which, by discharging suddenly at intervals, flushes the drain.

(4) **Junctions and Bends.**

All junctions and bends in a drain must be made by means of pipes specially manufactured for the purpose.

(5) **Connections.**

The soil-pipe enters the drain without any trap intervening, and it usually forms the head of the drain. Yard gullies also connect directly with the drain. Waste pipes and rain-water pipes must never be connected with a drain, but must discharge over or near a gully which is connected with the drain. Overflow pipes from cisterns must not be connected with a drain.

(6) **Ventilation.**

Drains are ventilated by providing an outlet and inlet for air. The outlet is usually the soil-pipe or some pipe similarly placed and constructed. An inlet is provided by placing a disconnecting and ventilating trap in the course of the drain just before it enters the sewer.

Ashpits and Dustbins.

All animal and vegetable refuse from the kitchen must be burned, and should never on any account be thrown into the dustbin or ashpit. Refuse such as cabbage leaves, potato peelings, bones, and waste food are very liable to become a nuisance if not burned instead of putting them directly into the dustbin.

The best receptacle for the ashes, soot, and inorganic refuse is a dustbin consisting of a small wooden tub or galvanised iron box. If an ashpit is built, it should conform with the regulations below. The best possible conditions for an **ashpit** or **dustbin** are attained when the following rules are followed:—

1. It must be at least six feet from the wall of the house.

2. Means of emptying it should be provided without carrying the contents through the house.

3. It should be small—not above six cubic feet in capacity—to ensure frequent emptying.

4. Only indestructible matter must be put into it.

5. A good lid or a water-tight roof must cover it to protect the contents from rain, as moisture favours decomposition.

If an **ashpit** is built it should fulfil the following conditions in addition to rules (1), (2), and (4) above:—

1. It must be constructed of impervious material, such as nine-inch brickwork lined inside with good cement.

2. It should be roofed over and properly ventilated.

3. The floor should be three inches above the level of the ground outside.

4. There must be a door of convenient size for removing the contents.

5. There must be no connection whatever with any drain.

Conservancy Systems.

In some districts the provision of water-closets is difficult or undesirable, and other methods than the water carriage system are used for dealing with the excreta. These are called conservancy systems and include the following:—

(1) The Privy or Midden Closets.

The old-fashioned plan, still often met with in country places, was to dig a hole in the ground at the back of the closet. This received the excreta for an indefinitely long period. The more modern midden consists of a comparatively water-tight shallow pit which receives the excreta, and into which are thrown the ashes from the house. It should be at least 6 feet away from any dwelling, and 50 feet away from any spring, well, or stream. Rain must be excluded by a suitable roof, and proper ventilation must be provided. To enable ashes to be readily mixed with the excreta the seat should be hinged. The capacity should be small so that a removal of the contents is frequently necessary. The floor of the privy must be six inches above the ground outside, and should slope towards the door. It should be made impervious by covering with flags or tiles. Means of access for the scavenger should be available without passing through the dwelling, and, lastly, the midden must not be connected with any drain or sewer.

Under these conditions there seems a great deal to be said in favour of the midden system, especially for small houses. Properly managed they should give rise to no pollution of the air, especially if people are instructed to apply the ashes and cinders uniformly over the excreta, thereby ensuring dryness of the contents. The advantages of this method over the water carriage system lie in the fact that there is no possibility of anything getting out of order and that it is independent of all weathers.

(2) The Pail or Tub Closets.

These are really middens on a small scale. The seat of the closet has a tub or pail placed under it for the reception of the excreta. The pail should be made of galvanised

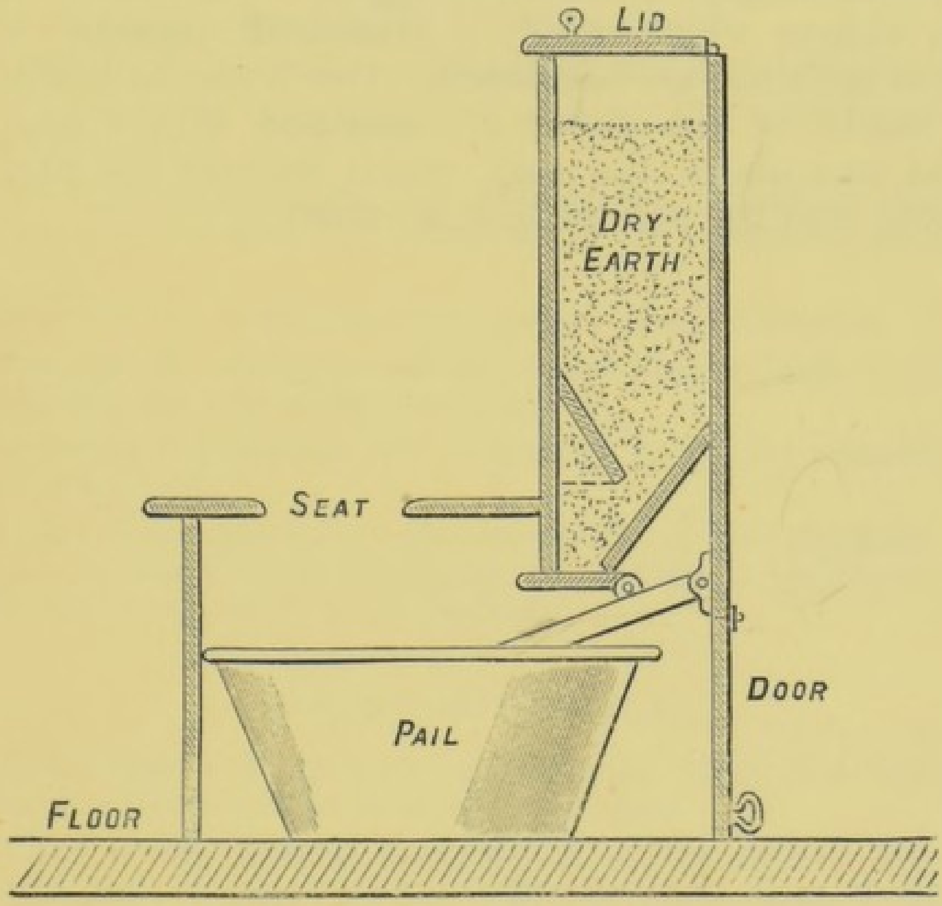


Fig. 140.—AUTOMATIC EARTH CLOSET.

iron with a well-fitting lid, and must be perfectly watertight and nearly air-tight. At intervals of not more than a week it is removed and a clean one put in its place. Such is the outline of a system that is undoubtedly superior to the midden system for towns.

(3) Dry Earth Closets.

These form undoubtedly the best of the conservancy systems. Faecal matter, with which dry earth has been mixed, becomes not only inoffensive, but after a short time unrecognisable as such. The best soils for this purpose are moderately dry and loose loams, garden soils, dry clay and brick earth. Sand, gravel, and chalk are unsuitable and inefficient. The method of use is to cover each stool at once with one and a half pounds of dry earth. When the pail is full its contents may either be applied at once to the garden or removed to a dry shed where, after frequent turning over and exposure to the air, the earth may be used again as many as eight or ten times. Automatic closets which apply a measured quantity of dry earth at each use are obtainable. One is shown in Fig. 140. The handle of the closet is connected with a receptacle behind and above the seat, which delivers the regulated quantity into the pail when it is raised.

TEST QUESTIONS.

Questions on Chapter I.

1. Describe the position and relation to one another of the various organs contained in the thorax or chest.

2. Describe the structure and function of the vertebral column.

3. What are the boundaries and position of the contents of the thorax or chest?

4. What structures form the walls of the thorax or chest, and what important organs are contained in it? State the position of each.

5. Describe the vertebral column, and a single vertebra.

6. Describe the abdomen and its boundaries; explain the general arrangement and uses of its contents.

7. Describe the human foot and show its special adaptation to the act of walking.

8. What bones enter into the formation of the shoulder joint? Describe the movements which can be performed by the arm, and explain the causes of its great mobility.

Questions on Chapter II.

1. Give a brief description of the arteries, veins, and capillaries, and the circulation of the blood through them.

2. What is the general composition of the blood? State the form, size, and structure of the corpuscles, and describe both the phenomena presented by the blood when drawn from the body, and its functions when circulating within the body.

3. Describe the position of the heart in the body, and explain the course of the blood through it.

4. Where are the mitral and the tricuspid valves placed? What is their structure? Explain their actions.

5. What is the portal vein? Where does it begin and where does it end? Is the blood flowing through it always of the same quality, or does it vary? if so, where and how?

6. Describe the difference between an artery, vein, and capillary; explain how these differences affect the circulation of the blood.

7. Describe the phenomenon of blood coagulation.

Questions on Chapter III.

1. What is the composition of expired air, and why is it unfit to breathe again?

2. What impurities in air are caused by various manufacturing processes?

3. What are the chief causes of escape of coal gas into houses? What should be done when an escape of gas is detected?

4. Describe the lungs and the process of respiration.

5. What are usual impurities in the air of inhabited rooms?

6. What are the changes that take place during respiration, (1) in the air breathed, (2) in the blood?

7. Compare the compositions of expired and inspired air. Explain the bearing which the differences between the two airs have upon the necessity for ventilating a room.

8. What is meant by inspiration and expiration? How are they brought about, and what changes take place in the air and blood as the result of them?

9. What impurities does lighting by gas give to the air? Compare it with candles in this respect.

10. What is carbonic acid? What are its sources? What part does it play as a sign of good or bad ventilation?

11. What is the external appearance and position of the lungs? Explain their structure.

12. What are the changes that the blood undergoes in its passage through the lungs, and how are they affected?

13. What are the principal impurities in the air of a large town? How does wind act as a natural agent in ventilation?

14. Enumerate the bones which form the framework of the thorax. Explain how the movement of the ribs causes changes in the size of the chest.

15. Describe the course of the pulmonary artery, and explain in what respect it differs from the arteries of the body.

16. Explain the changes which occur in the blood during the circulation through the lungs.

17. Describe the circulation of the blood from the right auricle until it enters the left ventricle. Explain the changes which the blood undergoes during its passage through the lungs.

18. Explain in detail the changes which take place during respiration in (1) the blood, and (2) the respired air.

Questions on Chapter IV.

1. What natural forces may be utilised in the ventilation of rooms? Give sketches of some simple appliances which may be used for this purpose.

2. How are movements of the air in rooms produced? How large an inlet opening for air is required for each person, and why?

3. What are the forces which produce natural ventilation? How may the action of the wind be practically utilised?

4. Give some simple methods of ventilating rooms. Illustrate your answer by sketches.

5. How is air vitiated in the process of respiration? How many people may be allowed to sleep in a room twelve feet long, eight feet broad, and ten feet high?

6. What is understood by natural ventilation? Give illustrations of its mode of working.

7. What are the best means of ventilating a room without causing draughts? Illustrate your answer by a sketch.

8. What are the causes of natural ventilation? Describe any method of ventilating a room with which you are acquainted, and illustrate your answer by a sketch.

9. What is meant by the diffusion of gases? How does it affect the question of ventilation?

10. How much fresh air per hour is required for a man doing ordinary work? Describe a good method of introducing the necessary fresh air into a work-room.

11. Describe a system of ventilating an ordinary sitting-room, and explain how the change of air is effected. A room of 1,000 cubic feet is occupied by one person; how often should the air be changed each hour?

Questions on Chapter V.

1. Why is common salt a necessary food? Whence is it obtained? What important mineral salts are contained in foods?

2. Classify the food substances which do not contain nitrogen.

3. What are the uses of fat in a diet, and in what common foods is it contained?

4. What are the uses of albumins in a diet? In what common foods is albumin contained?

5. What are the carbohydrates? Describe briefly their uses.

6. What is the general use of food substances? State how they are classified.

7. What are proteid food substances? What is their essential element? Describe briefly their uses.

8. Give a classification of food substances, with examples, and explain their respective uses.

9. What is the usual classification of food substances? Why is meat so largely used as an article of food?

10. Into what classes are food stuffs divisible, and what are their functions?

Questions on Chapter VI.

1. Describe the small intestine, and the digestive changes which food undergoes in it. [See Chapter VII. also.]

2. Describe the position of the liver in the body. What are its functions?

3. Explain the structure of a tooth. Into what classes are teeth divided? How do the teeth of a child six years of age differ from those of an adult?

4. Where and how is the saliva formed? What is its composition and uses?

5. Describe the structure of a tooth. How do the different parts differ from each other?

6. What is the form, general structure, and position of the pancreas? What are its uses?

7. Give a description of the pancreas (with sketch), and explain its function.

8. Give a short account of the teeth, more particularly with reference to their situation, number, names, and structure.

9. What is the composition and action of the gastric juice? Where is it secreted?

10. Describe briefly the general structure of the liver. What are its functions?

11. Describe the structure of a tooth. Why are teeth necessary for the process of digestion?

Questions on Chapter VII.

1. Classify the food substances which do not contain nitrogen. How are they disposed of in the system?

2. What are the most important food substances containing nitrogen, and how are they disposed of in the system?

3. What are the carbohydrates? How are they disposed of in the system? What are the chief foods containing them?

4. Mention the changes which the food undergoes in the stomach.

5. What are fats, and what changes do they undergo (*a*) in the mouth, (*b*) in the stomach, and (*c*) in the intestine?

6. What is the large intestine, and where is it placed? State where it begins and ends, and what changes the food undergoes in it.

7. Where does the small intestine lie, where and how does it begin, and where and how does it end? What is the general structure of its walls? What changes does the food undergo in the small intestine?

8. Describe the structure of the stomach, and the process of digestion in it.

9. What are the functions of the large intestine?

10. What changes take place in the food during its passage through the small intestines?

Questions on Chapter VIII.

1. Compare the flesh of fish with butcher's meat as food. Mention some important differences in the flesh of various kinds of fish.

2. How does human milk differ in its composition from cow's milk? Why is milk the best food for infants?

3. Which is the most nutritious, rice or pea-flour? Upon what do their relative qualities depend?

4. What is the usual classification of food substances? Why is milk so largely used, and so desirable an article of food?

5. What is arrowroot? Explain its value as an article of food.

6. What are the characteristics of good meat? Explain how to make a good meat stew. [See Chapter IX. also.]

7. Why is milk a good food for young children? What is the average composition of cow's milk?

8. What is lime-juice? Explain its uses.

9. What diseases may be produced in man from the consumption of meat?

10. What diseases may be caused by impure milk?

Questions on Chapter IX.

1. What are the advantages of cooking by gas? What conditions should a gas-cooking oven fulfil?

2. How should good meat broth be made? What food substances does it contain?

3. How would you make bread from wheat flour?

4. What is the essential object of cooking processes? Explain the changes which meat and bread respectively undergo when baked.

5. How is meat changed by the processes of roasting and boiling? What precautions are essential for the proper cooking of meat by each of these methods?

6. How is meat changed by the process of roasting? What rules would you observe in roasting a joint?

7. Explain the changes which meat undergoes in cooking, indicate the essential differences between the processes of boiling and stewing.

8. How should beef tea be made? What food substances does it contain, and what value has it as a dietetic?

9. Explain the differences between boiling, roasting, and stewing meat.

Questions on Chapter X.

1. What are the physiological effects of alcohol and alcoholic drinks used in moderation and in excess?

2. Compare and contrast tea and cocoa as beverages.

3. What is meant by fermented drinks? State the value of alcohol as a food substance.

4. What are the most important substances contained in the tea-leaf? How should good tea be prepared? What is its action on the system?

5. State what you know concerning the composition of, and the effects of drinking (*a*) tea, (*b*) coffee, (*c*) beer.

6. State what you know concerning the composition and the effects of drinking (*a*) tea, (*b*) cocoa, (*c*) brandy.

7. What do you know concerning the composition and effects of fermented drinks?

8. Compare and contrast tea, coffee, and cocoa as beverages.

9. What is cocoa? Explain its value as an article of food.

10. Describe the method of preparing coffee and cocoa as beverages, and explain the chief differences in their effects on the system. What is the composition of tea?

Questions on Chapter XI.

1. What is the spleen? Where is it situated? Describe its structure and functions.

2. Where is the bladder situated? Describe briefly its structure and functions.

3. Describe the structure and functions of the kidney.

Questions on Chapter XII.

1. What is the importance of cleansing the skin? What are the results of want of cleanliness?

2. What is soap? Of what use is it in cleansing the skin?

3. Why is cleanliness of the skin essential to the health?

4. Explain the structure of the skin. How do its parts differ from each other, and what are the chief uses of each part?

5. What animal parasites may be found on the surface of the human body, and how may they be got rid of?

6. Why is daily cleansing of the skin necessary? Explain the action of soap in effecting this.

Questions on Chapter XIII.

1. What do you understand by reflex action? What structures are essential for the recurrence of a reflex action? Give two or three examples of reflex action as it may be observed in your own body.

2. Where and how is the spinal cord placed in the body? How does it end above and how does it end below? What structures are given off at repeated intervals from the spinal cord, and what are the uses of these structures?

3. A brainless frog will move its hind limb when the toe of the limb is touched. What various structures are involved in this movement, and why is it termed a purposive reflex?

4. What muscles are attached to the eyeballs? What movements of the eyeball are brought about by the contraction of these muscles?

5. How can you show that there is a "blind spot" in each of your eyes? What does the blind spot teach us as to the nature of sight?

6. Draw a diagram to illustrate the relative positions of the contents of the eyeball. What happens to (*a*) the pupil, (*b*) the lens, when the visual gaze shifts from a distant to a near object?

7. What is the blind spot? How would you convince yourself of its existence as regards each of your eyes?

8. What means are adopted for the protection of the brain within the skull?

9. How are sound-waves conducted to the internal ear? What are the auditory ossicles?

10. Why is it important that a free communication should exist between the ear and the throat? Specify exactly what parts so communicate and point out how the connection is effected.

11. Explain how it is that sounds can be heard through the cranial bones.

12. Give a concise account of the ordinary manner in which the brain becomes conscious of a sound, describing very briefly the different parts of the ear that transmit it.

Questions on Chapter XIV.

1. Explain the importance of bodily exercise. Why is rest necessary?

2. Why is sleep necessary? Do children or adults require more sleep, and why?

3. What food substances specially aid the action of the intestines? What is the importance of regular action?

4. In what various ways may the action of the bowels be promoted? What is the importance of this?

5. Why is exercise essential to health? What is the effect of it upon the heart, respiration, skin, muscles, nervous system, and digestive apparatus?

6. What is the effect of exercise on the skin?

7. Why are proper exercise and rest so necessary? What are the chief physiological effects of exercise?

Questions on Chapter XV.

1. At what periods in life is warm clothing most necessary, and why?

2. Describe the appearance of wool, cotton, and silk fibre, and state the advantage of each as a material for clothing.

3. Contrast wool and cotton as materials for underclothing.

4. What are the best materials for clothing in hot countries, and why?

5. What are the advantages of woollen clothing? Explain its action in preventing chill.

6. What materials are used for clothing? Mention the advantages and disadvantages of each.

7. Why do children need to be well clothed? Explain the important points to be borne in mind in constructing clothing generally.

8. What are the comparative advantages of cotton, linen, and wool for underclothing?

9. Explain the advantages of woollen underclothing.

10. Explain why warm clothing is so necessary in the case of young children. Compare the advantages of wool and linen as a material for underclothing.

Questions on Chapter XVI.

1. A person has swallowed oil of vitriol: what would you do?

2. A person has been run over by a cab, his arm is apparently broken and is bleeding fast: what would you do?

3. How would you detect and arrest bleeding from an artery?

4. Describe Sylvester's method of inducing artificial respiration?

5. What assistance should you give to a person whose clothes have caught fire?

6. What assistance would you render to a child who has been badly bitten by a dog?

7. What treatment would you adopt to resuscitate a person apparently drowned?

8. What accidents are likely to happen to a person in an epileptic fit? What would you do for a person suddenly attacked by a fit?

9. In the case of a wound, how would you determine that the bleeding was from an artery and not from a vein? What treatment would you adopt in either case?

10. What would you do for a person who has swallowed carbolic acid by mistake?

11. How would you treat a bad burn or scald?

12. A person has been run over by a cart, his leg is apparently broken and bleeding fast: what would you do?

13. What measures would you adopt in the case of a bite on the finger from a rabid dog? Give reasons for your treatment.

14. What "first aid" could you give to a man suffering from a ruptured vein in the leg?

15. What first aid treatment would you adopt in the case of a person in an epileptic fit? Describe the symptoms which would enable you to recognise this disease.

Questions on Chapter XVII.

1. How are the breezes at the seaside produced? What effect have they upon the health of seaside places?

2. How does height above the sea affect the climate of a place?

3. Why does the ground under houses require to be drained? What is meant by a damp-proof course?

4. What is the importance of houses being situated on a dry soil? How can a damp site be rendered dry?

5. How does damp soil affect health? What are considered to be healthy and what unhealthy soils?

6. What do you understand by the term "ground water"? What bearing has it upon the healthiness of a locality?

7. State what you think would be the influence upon health, and why, if a town be built upon gravel, or on clay, or on chalk.

8. What are the causes of dampness in houses? How may it be prevented?

9. What are the essentials of a good site for a house? What are the chief causes of dampness in a house?

10. What is the best site for a house, and how is it likely to be influenced by surrounding objects?

11. What conditions generally give rise to the entrance of coal gas into houses? What would you do if an escape of gas were detected?

12. Which of the following soils is the most healthy to live upon,—gravel, clay, sand, chalk? Give your reasons.

13. What influence has distance from the sea upon the climate, air, and water supply of a place?

14. What precautions should be taken to secure a healthy site for a dwelling house to be erected upon (*a*) the side of a clay hill, (*b*) fen land, (*c*) a sandy soil containing springs?

15. What do you understand by (*a*) healthy, and (*b*) unhealthy soils?

16. What effects have soil and configuration of ground on health? What diseases are favoured by a damp condition of the soil?

Questions on Chapter XVIII.

1. What kinds of wells are there? What are the characters of the water yielded by them?

2. How is the water of shallow wells liable to pollution? What diseases have been produced by the use of such waters?

3. What are the characteristics of good drinking water? From what sources is such water obtained?

4. How may water stored in cisterns become impure?

5. How may the water of rivers and streams become polluted? In what way can such water be purified?

6. Give the characters of (*a*) rain water, (*b*) water from a spring in the chalk, (*c*) water from a shallow well.

7. What are the dangers of storing water in house cisterns, and how may they be obviated?

8. What are the general or usual sources of pollution of drinking water? What are the best sources of supply?

9. What is meant by hard and soft waters? What advantage has the one over the other for domestic purposes?

10. What are the objections to the use of shallow wells, and what are the diseases generally to be attributed to impure water?

11. How is drinking water likely to be contaminated (*a*) in wells, and (*b*) in cisterns?

12. What are the best means of purifying water? Describe any filter with which you are acquainted.

13. What are the characteristics of rain water, and what are the dangers attending its use?

14. What are the precautions necessary to secure a pure supply of drinking water from a well? What diseases are believed to be propagated by water?

15. Describe three efficient methods of purifying water and explain the action in each case.

16. Enumerate some sources of water supply, and point out the objections or advantages of each.

17. What dangers may be incurred by storing drinking water in cisterns? Of what material should cisterns be made, where should they be placed, and how often cleansed?

18. What are the chief ways in which drinking water may become contaminated with lead? How can this be obviated?

19. What are the chief characteristics of (1) rain water, (2) river water, and (3) chalk water? What are their relative advantages for domestic water supply?

20. What are the characteristics of rain water? How should it be collected and stored for use?

21. Under what conditions is the water in a shallow well liable to pollution?

22. How should a well be constructed so as to avoid pollution from the surface of the ground surrounding it?

Questions on Chapter XIX.

1. Describe in detail a grate or stove provided with an arrangement for the introduction of warm fresh air.

2. Explain the principle of construction of an ordinary fireplace, and state its advantages and disadvantages.

3. On what principles should fireplaces be constructed? Explain their advantages and disadvantages as a means of heating rooms as compared with hot-water pipes.

4. Describe a method of warming a building by means of low pressure hot-water pipes.

5. What are the respective advantages, disadvantages, and dangers (if any) attendant upon the use, for warming rooms, of (*a*) open fires, (*b*) slow combustion, (*c*) closed coke stoves, (*d*) gas stoves, and (*e*) hot-water pipes?

6. What are the advantages and disadvantages of stoves? Describe a good form of ventilating stove.

Questions on Chapter XX.

1. Sketch and describe a good form of hopper water-closet. How should it be supplied with water?

2. What means would you adopt to prevent the entrance of sewer-gas into a house?

3. Describe and illustrate by means of a diagram a good and bad form of water-closet. Explain its proper connection with any system of drainage.

4. Describe briefly the essential points to be observed in the construction and arrangement of water-closets for a house.

SPECIMEN EXAMINATION PAPERS

SET BY THE

BOARD OF EDUCATION.

No. 1.

(*a*) Write a short account of the nature and use of the blood.

(*b*) What are the boundaries of the thorax, and what organs are contained in that body cavity?

(*c*) State what you know as to the position, structure, and use of the kidney.

(*d*) Describe the position, general form, structure, and function of the liver.

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1. Give the characteristics of (*a*) rain water, (*b*) river water, (*c*) water from a spring in the chalk. (20)

2. What are the precautions necessary to procure a pure supply of drinking water from a well? Enumerate the diseases which are believed to be propagated by drinking water. (20)

3. Give the average composition of ordinary air. What are the impurities added to air in inhabited rooms, and whence are they derived? (20)

4. What is the usual classification of food substances? Explain the uses of these different classes of food. (20)

5. Contrast the general composition and dietetic value of beef, bread, and tea. (20)

6. Describe and contrast the action of ordinary fire-places and hot-water pipes in warming and ventilating rooms. (20)

7. What are the essentials of a good drain-trap? Where are traps generally placed, and what are the common causes of their becoming inefficient? (20)

8. Why is exercise essential to health? What is the effect of it upon the heart and skin? Which form of exercise do you think is better for a man, a bicycle ride or a game of football? Give your reasons. (20)

9. Describe a method of carrying out artificial respiration. (20)

No. 2.

(*a*) Write a short account of the structure and functions of the skin.

(*b*) Where are the salivary glands situated? What action has the juice secreted by these glands upon food taken into the mouth?

(*c*) Explain the following terms:—serum, cartilage, peptone, chyme.

(*d*) What are the changes which take place during respiration (1) in the air breathed, (2) in the blood?

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1. Name three common sources of drinking water, and, in respect of each, point out the probable risks of pollution, and how they can be best prevented. (20)

2. What rules and precautions should be observed in the storage of water in a house? Explain the chief risks attaching to this practice. (20)

3. What is carbon dioxide? What are its sources, and what part does it play as a sign of good or bad ventilation? (20)

4. What is the use of food? Explain the chief changes which a piece of bread undergoes during the act of digestion. (20)

5. What diseases are occasionally caused by milk, and how should milk be collected, stored, and distributed? (20)

6. What are the advantages of woollen clothing? Explain its action in preventing chill; explain also the more important points to be borne in mind in making clothing of any kind. (20)

7. How should an ash pit be constructed, and why is it likely to become a nuisance? (20)

8. What is the use of traps, as met with in a drain-system? Where are these contrivances usually placed, and what are the common causes of their being rendered useless? (20)

9. A child falls out of a swing, cutting the forehead badly, with much bleeding, and becomes unconscious; what would you do? (20)

No. 3.

Elementary Human Physiology.

(*a*) Write a short account of the forms and relative positions of the bones which make the upper limb.

(*b*) Give an account of the structure of the spinal cord, so far as it can be made out with the naked eye. Explain the meaning of reflex action and state what structures are concerned in a reflex act.

(*c*) Give a brief description of the kidney and explain its functions.

(*d*) Write a short account of the structures and uses of the lungs.

Hygiene.

1. How is water likely to be contaminated in (*a*) a well, (*b*) a cistern? Explain how, in each case, the contamination can be prevented. (20)

2. What is the composition of inspired and expired air? By what standard is respiratory impurity expressed? Describe a simple experiment to indicate the effect of respiration on air. (20)

3. What general properties characterise the carbo-hydrates? Explain the purposes they serve in the body. (20)

4. Explain the changes which meat undergoes in cooking, and indicate the essential differences between the processes of stewing and boiling. (20)

5. Name three soils with which you are familiar, and state what precautions should be taken in erecting healthy dwellings upon each of them.

6. Describe a good form of dust or ash pit, and explain some good methods for the disposal of house refuse in town and country. (20)

7. Describe and illustrate by means of a diagram a good form of water-closet. Explain its proper connection with any system of drainage. (20)

8. What materials are in common use for clothing? Mention the advantages or disadvantages of each and indicate the more important points to be borne in mind in the construction of clothing. (20)

9. How is the disease called tuberculosis spread? Explain the principles which should be observed to prevent the spread of tuberculosis. (20)

No. 4.

Elementary Human Physiology.

(*a*) Describe the general structure, position and chief functions of (1) the pancreas, (2) the liver.

(*b*) Explain the difference in structure and use between an Artery and a Vein.

(*c*) What is a Salivary Gland? Where are these Glands situated, and what is the use of their secretion?

(*d*) Write a short account of the composition and function of the blood. What is lymph, and how does it differ from blood?

Hygiene.

1. Describe a spring or bourne. If a house is depending upon a spring for its supply of water, explain how that spring should be protected, and why. (20)

2. What are the objections to shallow wells; and what are the diseases to be attributed generally to impure water? (20)

3. What is the composition of ordinary air? What impurities are given into the air in ordinary respiration? Give a simple experiment to indicate the effects of respiration on air. (20)

4. Compare the composition and dietetic value of bread, cheese and milk. Suppose you had only one of these three kinds of food to live upon for a week, which would be the best, and why? (20)

5. Describe how you would boil (*a*) a potato, (*b*) an egg. Explain the changes which take place in each as the result of boiling. (20)

6. A house is to be erected on a damp subsoil. Describe in detail what you would do to make it perfectly dry and healthy. (20)

7. It is sometimes necessary to pass the drain of a house into a cesspit. Describe how the cesspit should be constructed and what arrangements should be made for its connection with the house. (20)

8. What is the difference between a cotton and wool fibre? Explain the advantages and disadvantages of cotton and wool clothing generally. (20)

9. If a child's clothing caught fire whilst she was standing in front of a grate, state in detail what you would do. (20)

No. 5.

Elementary Human Physiology.

(*a*) State, shortly, what can be seen on inspecting the widely-opened mouth. Give the functions of four of the structures which you deem of the most importance.

(*b*) An ordinary meal, of neutral reaction to litmus, is eaten. Give the variations in acid or alkaline reaction usually occurring in its passage from the mouth to the small intestine. State the locality of any of these changes and mention the agents effecting the change.

(*c*) Draw a diagram of the eyeball with its structures and show on it how the image of a distant object (*e.g.* a lamp-post) is formed on the retina.

(*d*) State the situation of the clavicle. Why is a broken clavicle so common in violent games?

Hygiene.

1. Mention any other materials in addition to water (H_2O) which commonly occur in drinking-water. State which are to be regarded as beneficial, harmless, or undesirable. (20)

2. What difference might be noticed in a draught of moist air and in a draught of dry air at the same temperature and velocity? State which is most likely to be harmful and give any reasons for this. (20)

3. Enumerate the main classes of food stuffs, hygienically considered. Illustrate this answer by three typical examples, and mention two materials in the body for which mineral salts might be expected to be useful in the diet. (20)

4. State the main sources of damp in houses, giving signs which would lead to the suspicion of dampness. How can this fault be minimised in the construction of a building? (20)

5. Why is it important to chew the food thoroughly? Are any special dietetic substances useful for preserving the teeth? What precautions are most important to maintain sound teeth? (20)

6. Make a sketch to show the soil pipe and drain of a house, and how it is ventilated. What prevents the access of sewer air to dwellings? (20)

7. Sketch a water-waste preventer as used for flushing closets. How much water is usually allowed for each flush? (20)

8. What is the hygienic purpose of a cold bath? Under what circumstances would you advise against its use? What time, in relation to digestion, would be best for bathing? (20)

9. Describe and illustrate a system of natural ventilation. Mention conditions necessary for success, and any conditions under which it is likely to fail. (20)

No. 6.

Elementary Human Physiology.

(*a*) Describe shortly the structure of one of the intestinal villi. What part do they play in connection with digestion?

(*b*) State what is meant by a reflex action. Describe two examples of such action.

(*c*) Describe the form and situation of the sternum and name the important organs which it protects.

(*d*) Give an account of the structure of an artery and a vein, as seen in one of the limbs, mentioning why no pulse is noticeable in the vein.

Hygiene.

1. What causes hardness in water, and how far is this objectionable (*a*) in a country house, (*b*) in a manufacturing town supply? (20)

2. Give the commonest constituents of the atmosphere and show how these may be affected by any very considerable fall or rise in temperature. (20)

3. Using meat and potatoes as examples, describe the effect of cooking on these substances and how it will affect them in respect to digestion. (20)

4. Mention three circumstances which would lead you to decide that a site was bad for a dwelling-house, and give suggestions as to how it could be improved. (20)

5. Describe the usual means of ventilating in a dwelling-house, stating what is meant by perflation. (20)

6. Sketch the connections from a bathroom and a w.c. to the sewer. (20)

7. State how want of personal cleanliness may lead to dangers in respect to teeth, eyes, and ears. (20)

8. Explain why woollen clothing is considered superior to other materials, especially during (*a*) cold and (*b*) damp weather. (20)

9. A couple of hours after having eaten "some little apples in the garden" two young children are ill. The elder is feeling sick, in a cold sweat, and crying out with pain in the stomach; the other, not so bad.

Describe what should be done at once, and what is likely to be wrong. (20)

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PRINTED AT THE BURLINGTON PRESS, CAMBRIDGE.