THE TEMPLE PRIMERS

THE HUMAN FRAME
AND THE
LAWS OF HEALTH

By

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Translated from the German
By
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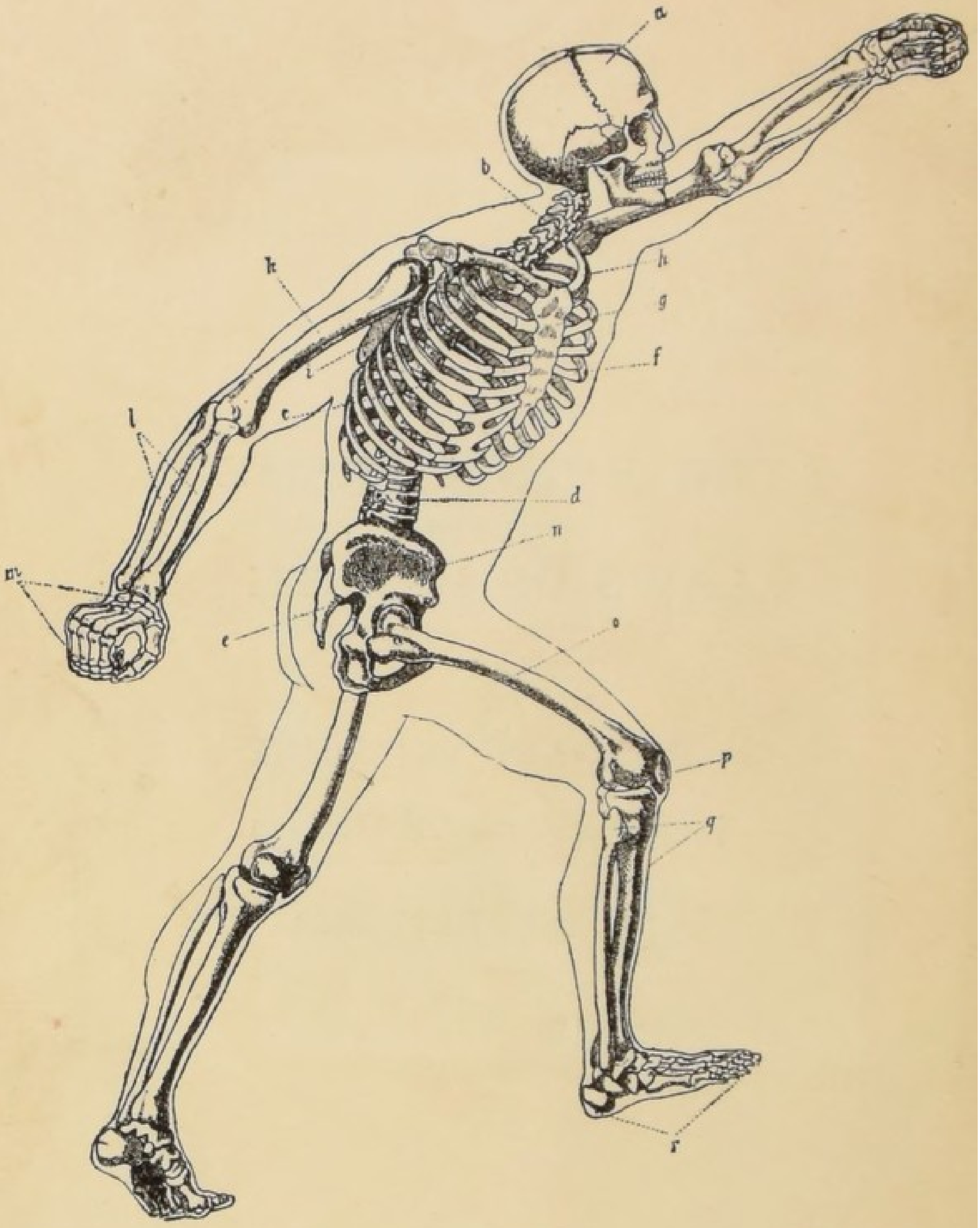

THE HUMAN SKELETON

a Skull.
b Cervical vertebræ.
c Thoracic vertebræ.
d Lumbar vertebræ.
e Sacrum and coccyx.
f Sternum.
g Ribs.
h Clavicle.
i Scapula.
k Upper arm.
l Forearm.
m Hand.
n Pelvis.
o Thigh.
p Patella.
v Leg.
r Foot.

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ALDINE HOUSE
J M DENT & CO

1900 29 & 30 BEDFORD STREET LONDON

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THE HUMAN FRAME

STRUCTURE AND ACTIVITIES OF THE BODY

I. The Skeleton

(*a*) ***The Structure of Bones and Cartilages.***—The bones, collectively called the skeleton, serve as a supporting framework to the rest of the body. To fulfil this *rôle* two things are required in a bone: firmness and a certain degree of elasticity. Its component parts are likewise two: an organic part, the bone-matrix; and an inorganic part, the bone-ash. If a bone be placed in dilute hydrochloric acid, the mineral substances are dissolved away, and it becomes soft and flexible. So treated a bone retains its shape, though it consists only of the organic part. By burning, the organic part of bone is destroyed, and a white, friable mass, the bone-ash, also retaining the shape of the bone, is left.

The inorganic constituents, which make up about two-thirds of a dry bone, consist mainly of phosphate of lime, 56 per cent.; carbonate of lime and other mineral salts, 13 per cent. The rest, 31 per cent., consists of organic matter. These proportions, however, vary in different bones, and in a given bone at different periods of life (see Table II. p. 94).

Most bones are formed from *cartilage*, which gradually gives place to bone by a series of changes, which include the deposition of mineral matter. In the young state, before these changes occur, the cartilage-masses which are being changed into bone are incapable of supporting heavy weights, or of resisting strong pressure of any kind.

The increase of a *long* bone in length is due to the formation of new layers of cartilage near the ends. Its increase in thickness is effected by the deposition of new layers of bone by the activity of the vascular membrane, the *periosteum*, surrounding the bone. In the interior the previously-formed bone-mass is again broken down, and a hollow space, the medullary cavity, running down the centre of the shaft, is formed. The *medullary cavity* is filled with marrow—a tissue containing fat and many blood-vessels. Throughout the rest of the bone-mass which has replaced the cartilage, destruction, followed by fresh bone-formation, takes place repeatedly. In old age the bone-matrix wastes away, and is not replenished. So old bones, losing firmness and elasticity, become brittle.

Different bones possess different degrees of solidity. Sometimes they consist of a loose network of intercrossing bone fibrils or *spicules*. The heads of the long bones have such a spongy structure (Figs. 11 and 12), but the shafts are built up of a number of systems of thin bony lamellæ. The layers of each system are arranged concentrically about a central canal, running longitudinally and opening here and there into its fellows, or into the central medullary cavity. In spongy bone the medulla and its blood-vessels occur in the meshes between the spicules. In all cases the structure is such as to secure to the bones, with an economical use of material, a high degree of strength and durability. Thus the bone-spicules in the upper end of the thigh-bone are arranged in two systems of lines crossing one another. These pull against each other in such a manner that, on the one hand, the bone can resist the pressure of the weight of the trunk resting upon it, and on the other hand, can endure the strain put on it by the weight of the leg when unsupported by the ground. In this way also the pressure is evenly distributed over all parts of the surface of the joint.

If, during the first years of life, the formation of mineral matter in the bones does not keep pace with the increase in the weight of the body, more or less severe, and in many cases permanent, curvatures or distortions of the bones take place. If a bone receive a blow too violent to be counteracted by its elasticity, it breaks, but the surfaces will grow together again fairly readily, unless the bone be that of an aged person.

(*b*) ***Sutures and Joints.***—The strength of the connections between bones varies very much. Two bones may be connected immovably with one another by means of a *suture*, e.g. those of the skull (Fig. 6). These are dovetailed into each other, without any cementing substance, by means of zigzags, or at least uneven edges and surfaces. The strength of such connections is shown by the fact that a violent blow on the head more readily breaks a bone than ruptures a suture.

If the opposed surfaces of two bones are connected together by means of softer or harder cartilage, so that slight movements and displacements are possible, we speak of the junction as a *synchondrosis*. In this case a considerable degree of force is required to draw apart the bones, and as soon as the force is removed the bones spring back to their former position. By synchondroses the vertebræ are held together, the ribs connected with the sternum, etc.

Lastly, if the connected parts are easily movable one upon the other, we speak of the connection as a *joint* (Fig. 1).

The parts of the bones which enter into the joint, the *articular surfaces*, are covered with caps of smooth cartilage (Fig. 1, *d*). The bones themselves are bound together by *ligaments*, one of which forms a bag or capsule which completely encloses the joint. The capsule is lined by a delicate membrane, the *synovial membrane*, which secretes the synovial fluid. This membrane is also reflected over the surfaces of the bones enclosed within the capsules. The smooth articular surfaces facilitate the cohesion of the bones and weaken the force of any impact on them. The synovial fluid keeps the surfaces moist, and so allows of the free action of the joint.

The bones of the joint are kept in position by the ligaments, but also by atmospheric pressure and by adhesion consequent upon the close contact of the surfaces. Atmospheric pressure and adhesion alone are sufficient to counteract the weight of the parts connected with the joint, for when muscles and ligaments are cut away and only the synovial membrane left enclosing the joint, the bones still remain in position.

The amount of movement which a joint executes is often limited by special check-arrangements, *e.g.* at the elbow-joint by a strong ligament, and also by the projection of the ulnar behind the point of insertion of the humerus; in other places ligaments alone serve to restrict the movement. Thus in the thigh-joint, a very strong ligament connecting the pelvis and the thigh prevents the trunk from falling backwards when the body is in a standing position.

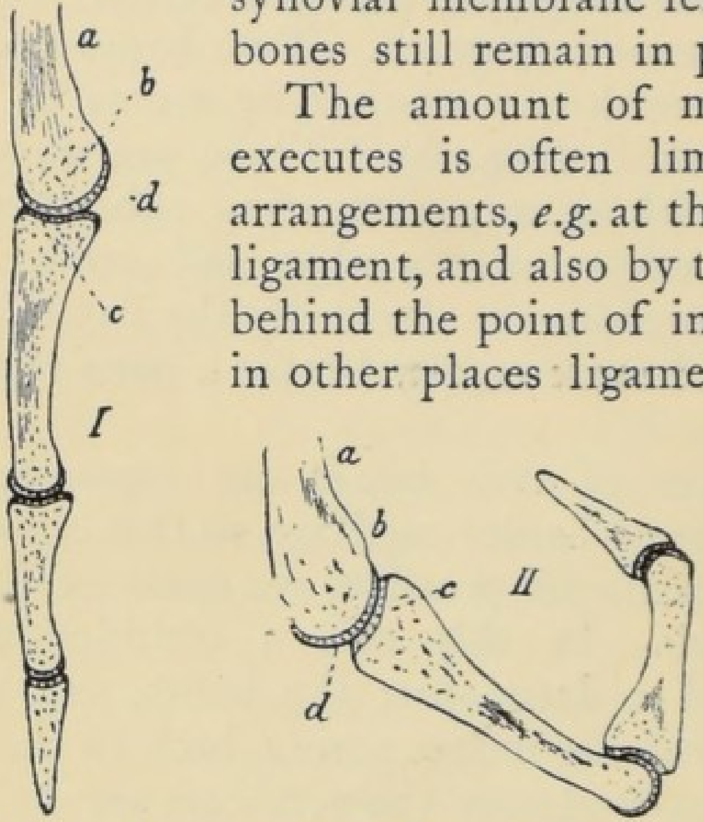

FIG. 1.—BONES OF THE MIDDLE FINGER. I., extended; II., flexed. *a*, metacarpal bone; *b*, *c*, articular surfaces; *d*, articular cartilage.

The movements possible to joints vary in extent and direction according to the form of the joint-surfaces. Specially important forms of articulation are *hinge joints*, in which the articular surfaces are cylindrical and the movement only in one direction and its opposite; *ball-and-socket* joints, with spherical articular surfaces admitting of movement in all directions.

Few joints are purely of the one form or the other, most being combinations of these simple forms, and so admitting of the different kinds of movement peculiar to these forms. In some cases the articular surfaces are quite irregular, but in the human body they are never flat.

(*c*) ***General Survey of the Skeleton.***—The principal part of the skeleton is the spinal column with the superimposed skull and the appended thorax : the bones of the limbs, together with those of the shoulder and pelvic girdles, make up the rest.

1. ***The Vertebral Column*** (Fig. 2).—The *vertebral column* consists of thirty-three bones, *the vertebræ*. These are grouped according to their position, thus : 7 Cervical ; 12 Thoracic or Dorsal ; 5 Lumbar ; 5 Sacral ; 4 Coccygeal.

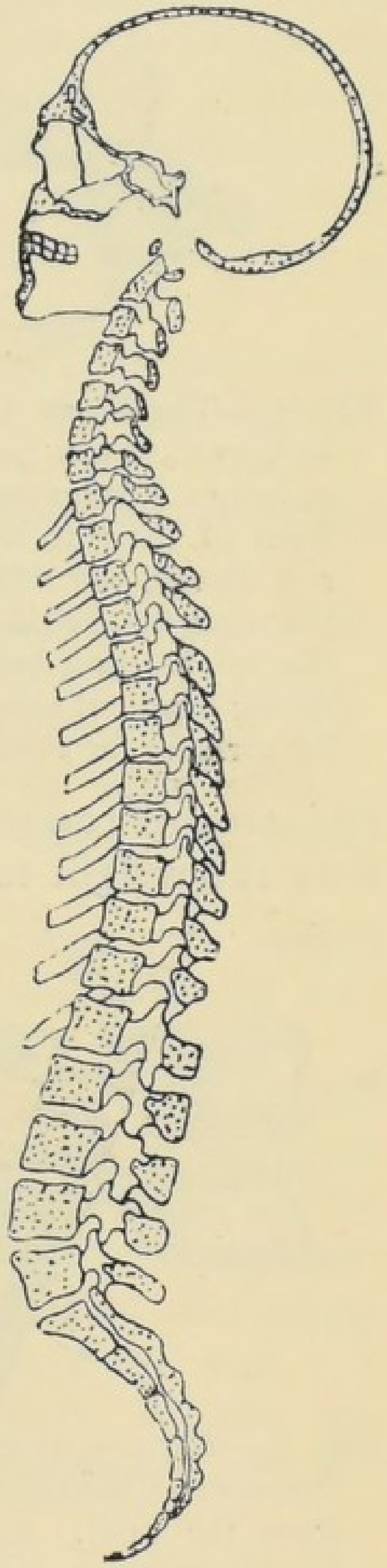

FIG. 2.—LONGITUDINAL SECTION THROUGH SKULL AND VERTEBRAL COLUMN.

The vertebræ of the first three regions are alike in general plan of structure. Each consists of a strong discoidal piece of bone, *the body* (Figs. 5, 9 *a*), to the back of which a ring of bone, the *neural arch*, is attached (Fig. 3, *c*). The neural arch bears three processes : the *spinous process* (Figs. 4 *c*, 5 and 9 *b*), which arises in the median line and projects backwards ; and two *transverse processes* (Figs. 3 *b*, 5 *c*, 9 *c*), which are borne laterally and serve for the attachment of muscles, except in the thoracic region, where they, together with the bodies of the vertebræ, bear the ribs. Smaller projections, two above and two below (Fig. 5, *d*, *e*), also arising laterally on the neural arch, fit into corresponding depressions on the arches of the adjoining vertebræ, and form a double row of inter-vertebral articulations.

The space within the neural arches of the vertebræ forms a channel, the *spinal canal*, in which runs the *spinal cord*, which tapers and ends about the level of the second lumbar vertebra. Both the bodies of the vertebræ and their neural arches become larger

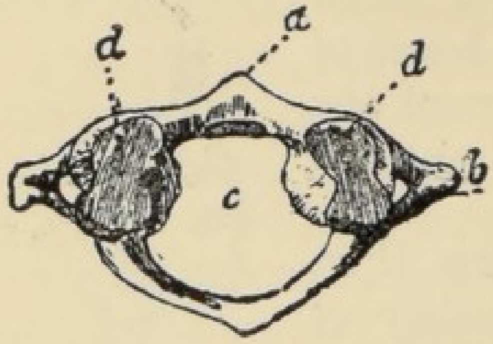

Fig. 3.—The First Cervical Vertebra, the Atlas (seen from above). *a*, body; *b*, transverse process; *c*, in front of the ring in which the letter *c* is placed, the odontoid process of the *axis* fits, behind is the space for the spinal cord, between the two a strong ligament stretches; *dd*, articular surfaces for skull.

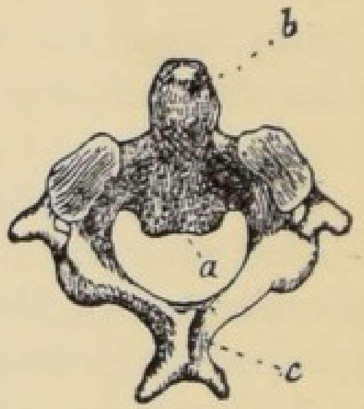

Fig. 4.—Second Cervical Vertebra, the Axis (seen from above). *a*, body; *b*, odontoid process; *c*, spinous process.

and stronger toward the lumbar part of the spinal column, for here the weight to be borne by them increases, and necessitates larger surfaces for the attachment of stronger muscles. The transverse processes are, as might be expected, especially strong in the twelve thoracic vertebræ.

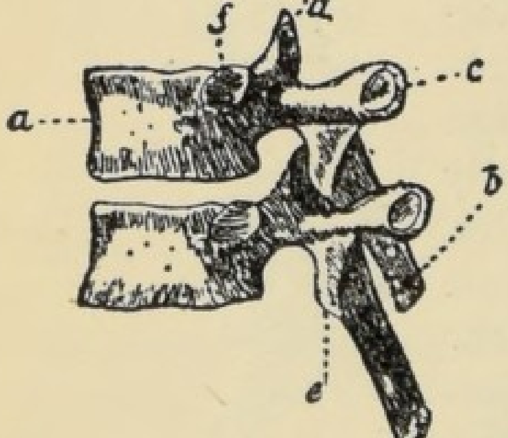

Fig. 5.—Fourth and Fifth Thoracic Vertebræ (seen from the side). *a*, body; *b*, spinous process; *c*, transverse process; *d*, upper, *e*, lower, intervertebral articular processes; *f*, articular surface for a rib.

The first cervical vertebra, the *atlas* (Fig. 3), differs in form from the type just described. It is a thin ring of bone bearing on its upper side two articular surfaces (Fig. 3, *d*), which unite it firmly with the base of the skull. The second cervical vertebra, the *axis* (Fig. 4), bears on its body a process, the *odontoid process* (Fig. 4, *b*) which fits into the front part of the ring of the atlas and serves as a pivot on which the atlas with the skull can be turned.

The joints between the atlas and axis are looser than those between the typical vertebra already described, and so allow sufficient play to the atlas, which, in the act of turning the head, moves with the skull. In nodding, the atlas remains still, and the head moves on the two smooth joints, which it makes with that bone. As in all movements of the vertebral column, so especially here, the spinal cord is protected from strains.

The sacral region of the vertebral column consists, in early life, of five vertebræ, which later become welded together into one bone, the *sacrum*.

The *coccyx* consists originally of four small bones, which also in later life may become joined to form one.

The vertebral column serves as a support to the trunk, and requires for this so high a degree of solidity as to preclude much mobility. Therefore the bodies of the individual vertebræ are connected together by tough, elastic discs of fibrous cartilage, the *intervertebral discs*, which only permit a slight lateral rotation.

The joints between the vertebræ, borne as already described on the small lateral processes, allow only very slight movements backwards and forwards.

The vertebral column presents in its course a sinuous curvature, forwards in the cervical and lumbar regions, and backwards in the dorsal and sacral regions (Fig. 2). Although the trunk is attached almost entirely to the front of the vertebral column, its weight, by reason of this curvature, is so distributed that part falls in front and part behind. Through the one part tending to balance the other, the muscles are to some extent relieved from the task of supporting the trunk.

2. ***The Skull.***—The skull (Fig. 6) comprises two groups of bones—those which form the *cranium* or brain-case, and those, the bones of the face, which partly serve as supports to the organs of the senses, and partly stand in some relation to the processes of speaking, breathing, eating.

The *cranium* is composed of eight large bones.

The *occipital* bone (Fig. 6, *c*) forms the hind wall of the skull, and, together with the *sphenoid* and parts of the *temporal* bones (Fig. 6, *d*), its base. In front of the sphenoid, in the middle line and immediately behind the nasal cavity, is placed the *ethmoid* bone, through whose numerous small openings the branches of the olfactory nerves enter the nasal cavity. On either side of the cranium, the temporal bones unite with the occipital bone. From each temporal bone an inwardly directed process arises which forms a bony support to the internal ear of that side; externally also a thin process runs forward and unites with a backwardly directed process of the *cheek-bone* (Fig. 6, *g*) to form a thin arch of bone, the *zygomatic arch*. Passing from the lower side of this arch to the lower jaw are the muscles which are concerned in mastication.

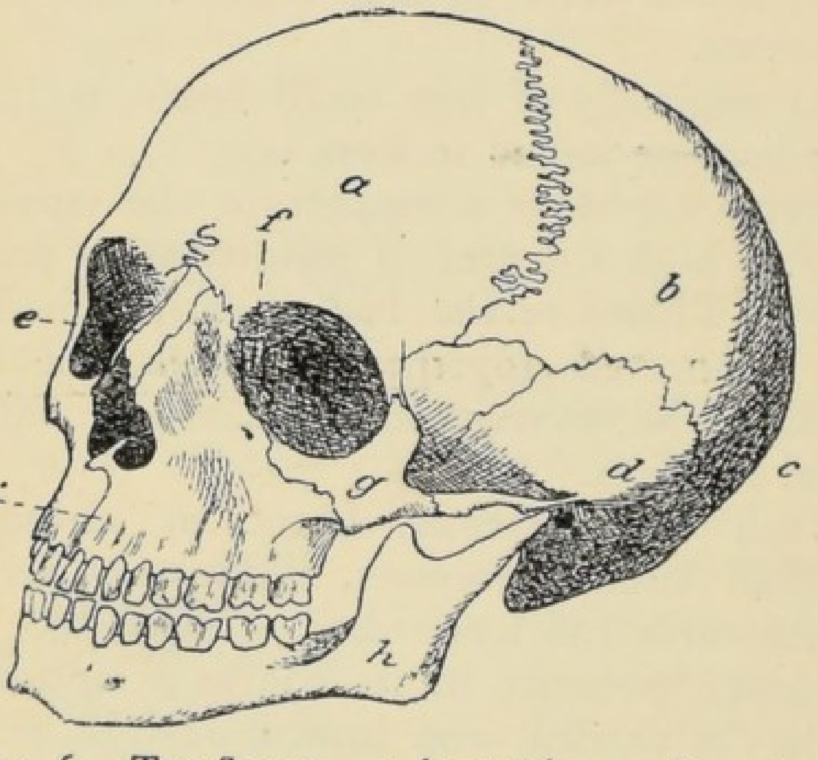

Fig. 6.—The Skull. *a*, frontal bone; *b*, parietal; *c*, occipital; *d*, temporal; *e*, nasal; *f*, lachrymal; *g*, cheek-bone; *h*, lower jaw; *i*, upper jaw.

The *frontal* bone closes the brain-case in front (Fig. 6, *a*), and the two almost regularly quadrilateral *parietal* bones (Fig. 6, *b*) close it above and at the sides.

The skull-cavity which these bones enclose is so completely filled by the brain, that the channels of the blood-vessels run in flat grooves on the inner surfaces of the bones.

In the occipital bone is an opening, the *occipital foramen*, through which the brain passes, to be continued in the spinal canal as the spinal cord.

The *frontal bone* is formed by the complete and seamless junction in the median line of two lateral bones. Traces of the medial suture are to be seen above the root of the nose.

The largest of all the bones of the face is the *upper jaw-bone* (Fig. 6, *i*), consisting of two symmetrical halves joined by a median suture. Its most massive part is that which bears the upper teeth. From this a plate, the bony basis of the hard palate, stretches horizontally backwards. A further flat piece turns upward from the lower edge to the orbit, and forms a great part of the face. This part bounds the front of the nasal cavity, and contains within itself two hollow spaces of considerable size, the lateral cavities of the nose.

The palatal part of the upper jaw-bone is continued backwards as the two *palatal* bones—two flat plates fitted at right angles to one another.

The bone called the *vomer* lies unsymmetrically in the middle line of the head. Its vertical ridge supplies the bony support to the septum of the nose.

Above the palate the nasal cavities contain discs of bone, thin as paper, and some of them rolled up, scroll-like, the *turbinal bones.*

The outer roof of the nose is formed by the two small thin *nasal bones* (Fig. 6, *e*). An elastic cartilage, an excellent pad in case of blows or falls, forms the continuation of these as far as the point of the nose.

The two cheek-bones (Fig. 6, *g*) are thin laminæ of bone. Their inner edges form the outer edges of the orbits. Of the four projections of the cheek-bones, two unite with the upper jaw, one with the frontal bone, and one, stretching backwards, assists in the formation of the zygomatic arch.

Two small, thin bones, the *lachrymal bones* (Fig. 6, *f*), are inserted on the inner side of each orbit.

The *lower jaw-bone* (Fig. 6, *h*) consists of two branches so firmly fused in the median line as to obliterate the suture. The two upper ends articulate with the temporal bones to form the jaw. The joints so formed execute rotatory and pushing movements downwards, laterally, and backwards and forwards. The edges of the lower and also of the upper jaw contain hollows, *alveoli*, into which the teeth are inserted.

Adults possess thirty-two teeth, similarly arranged, both as regards kind and number, in the two jaws. On either side of the middle line are two *incisors*, next to these on each side is a *canine* tooth, then two *bicuspids*, and three *molars*—

$$\frac{\overbrace{3+2}+1+4+1+\overbrace{2+3}}{\underbrace{3+2}+1+4+1+\underbrace{2+3}}$$

The part of the tooth inserted into the jaw is the *fang;* the free biting part, the *crown* (Fig. 7). Between the two is the *neck*. The incisors and canines (Fig. 7, I.) have a single fang, the molars (Fig. 7, II.) several fangs. In the former case the tooth is kept firm in its cavity by an enlargement of the neck ; in the latter this is effected by the divergence of the several fangs.

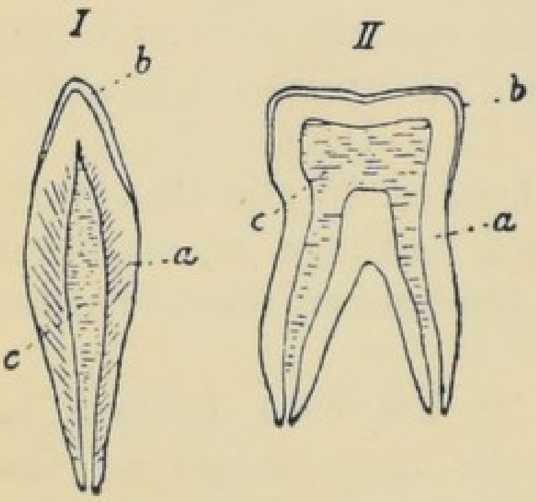

FIG. 7.—LONGITUDINAL SECTION THROUGH : I., A CANINE TOOTH ; II., A MOLAR. *a*, dentine ; *b*, enamel ; *c*, pulp-cavity.

A tooth consists chiefly of *dentine*, a hard bony substance, in which occur a great number of minute tubes running parallel to one another (Fig. 7, *a*).

The dentine of the fang is covered by bone, called the *cement ;* that of the crown by the denser, harder, and brilliantly white *enamel* (Fig. 7, *b*). The dentine of the neck and fangs encloses a space, the *pulp-cavity* (Fig. 7, *c*), which is filled with soft pulp, and in which run the blood-vessels and nerves of the tooth. From the cellular elements of the pulp, processes extend into the dentine tubules.

The incisors are somewhat shovel-shaped, their tops forming sharp edges ; the canines, except that they are more pointed, resemble the incisors in shape and in function. The bicuspids are pointed ; the hinder ones, as well as the molars, have broad uneven surfaces with protuberances, to facilitate chewing. The incisors and canines serve, by means of vertical movements of the lower jaw, to bite off the food, whilst the real work of mastication, the comminution of solid substances, is carried out by bicuspids and molars, aided by lateral and rotatory movements of the lower jaw.

Human beings are, as a rule, born without teeth ; during the first two years, the *temporary* or *milk* teeth, twenty in number, make their appearance. They consist of incisors, canines, and premolars. After the seventh year, the milk teeth fall out, and are replaced by permanent teeth, the molars being the last to make their appearance. Unlike the milk teeth, the permanent teeth are not replaced when lost.

With the exception of the lower jaw, all the bones of the skull are connected by sutures. The largest and most important of these are: the *coronal* suture, between the frontal and parietal bones ; the *sagittal* suture, which unites the two parietal bones ; and the *occipital* sutures, where the parietal bones join the occipital bone. In early life these skull-bones are separated by strips of cartilage, and it is only later that the bones are firmly united by the sutures. Those between the frontal and parietal bones are the last to be closed.

The measurements of the skull show considerable variations in different individuals, and especially in different races (Fig. 8, *a*, *b*). The illustrations are of extreme cases of the skull of a *brachycephalous* (short-headed) (Fig. 8, *a*), and of a *dolichocephalous* (long-headed) (Fig. 8, *b*) individual. Between these two extremes, skulls of all imaginable proportions occur.

3. ***The Thorax.***—The *ribs* are lateral appendages of

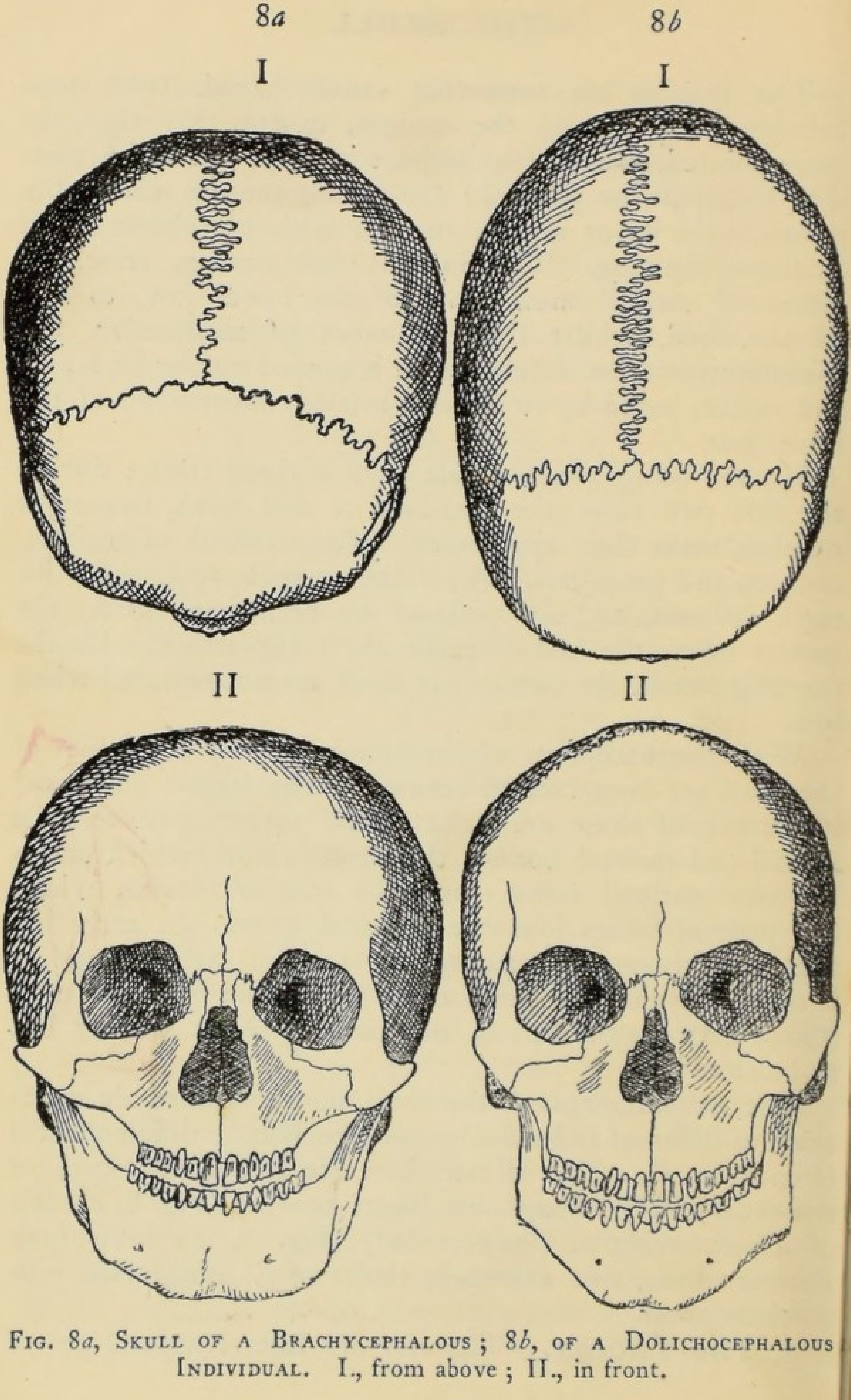

FIG. 8*a*, SKULL OF A BRACHYCEPHALOUS ; 8*b*, OF A DOLICHOCEPHALOUS INDIVIDUAL. I., from above ; II., in front.

the thoracic vertebræ. They are thin curved bones, which, starting from the vertebral column, form—together with a central narrow plate of bone, the *sternum*, or breast-bone—the framework of *the thorax*.

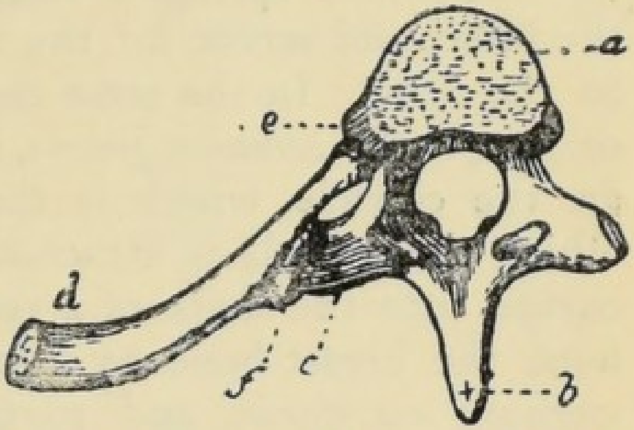

FIG. 9.—THORACIC VERTEBRA BEARING A RIB (seen from above). *a*, body ; *b*, spinous process ; *c*, transverse process ; *d*, part of a rib ; *e*, articulation of rib with the body ; *f*, with the transverse process of vertebra.

There are twelve pairs of ribs, of which the upper seven pairs are termed the true ribs, the rest the false ribs. Each rib makes with its vertebra two articulations—one with the body, the other with the transverse process (Fig. 9, *e*, *f*). At the other end each of the first ten ribs on either side terminates in a cartilage, which in the true ribs is attached to the breast-bone, in the false ribs to the cartilage of the preceding rib. The ends of the two last ribs are free, and bear no cartilage.

The *sternum* is a flat bone, originally consisting of a number of bony plates corresponding to the number of the ribs attached to it. All but two of the sutures connecting these bony plates disappear, so that the sternum comes to have only three divisions.

Ribs and breast-bone together form a whole, whose parts are incapable of separate movement. Apart from the protection afforded by the thorax to the organs sheltered within it, the principal task of the bony framework of the chest is to facilitate the movements connected with respiration.

4. ***The Limbs.***—The bones of the limbs are appended to the vertebral column through those of the shoulder and pelvic girdles.

The *pectoral*, or shoulder-girdle, consists of the *scapula*, or shoulder-blade, and the *clavicle*, or collar-bone.

The *scapula* is a thin triangular plate of bone lying at the back of the thorax. Its inner edge is quite smooth, its outer edge has three processes, one of which bears the articular surface for the shoulder-joint. From the outer surface of the shoulder-blade springs a ridge which rises above the rest of the bone, and serves for the attachment of muscles passing to the arm. In the same region, but arising on the inner surface, is the *acromion process*, serving as a point of attachment for the clavicle, which is the only bone of the thorax to which the scapula is attached. The *clavicle* is rod-shaped, curved into the shape of a very elongated S, and connected with the breast-bone by a stiff joint. It passes from the sternum outwards, and partakes with the scapula in the formation of the shoulder-joint.

The shoulder-blade and collar-bone together clasp between them the upper edge of the thorax as if in a pair of tongs. At their point of junction hangs the arm, which by this mode of attachment secures its peculiar mobility. The arm is not immediately attached to the skeleton of the trunk, but only indirectly connected with it through the breast-bone.

The arm (Fig. 10) is divided into three sections: the upper arm; the lower or forearm; the hand, including wrist, hand proper, and fingers.

The *humerus* (Fig. 10, *a*), the bone of the upper arm, is tubular, and thickened at both ends where the articulations occur. At the upper end, the articular surface is spherical; at the lower, there are two articular surfaces—a cylindrical inner surface for the ulna, and a spherical outer one for the radius.

In the lower arm are two elongated bones, the *radius* and the *ulna* (Fig. 10, *c*, *b*), which, in the middle, diverge somewhat from one another. Both bones taper, the former being thicker at the wrist, the latter towards the elbow. At the elbow the lower side of the ulna is prolonged beyond its articular surface into a process which, fitting into a depression on the lower side of the humerus, prevents the forearm from bending back at the elbow; this is also provided against by one of the ligaments of the joint, which stretches in front from the ulna to the humerus. This arrangement is one of the essential conditions for the firmness of the arm.

The hand itself consists of three groups of bones. The *carpals*, or wrist-bones (Fig. 10, *d*), form two transverse rows, each of four short thick bones; the *metacarpals* (Fig. 10, *e*), or bones of the hand, five in number; and the bones of the fingers, *phalanges* (Fig. 10, *f*), of which there are three in each finger and two in the thumb.

The arm has three great joints—shoulder, elbow, and wrist, differing from one another both in form and function. The *shoulder-joint* is a ball-and-socket joint, and, as such, allows the arm to move in various planes as well as round its own axis.

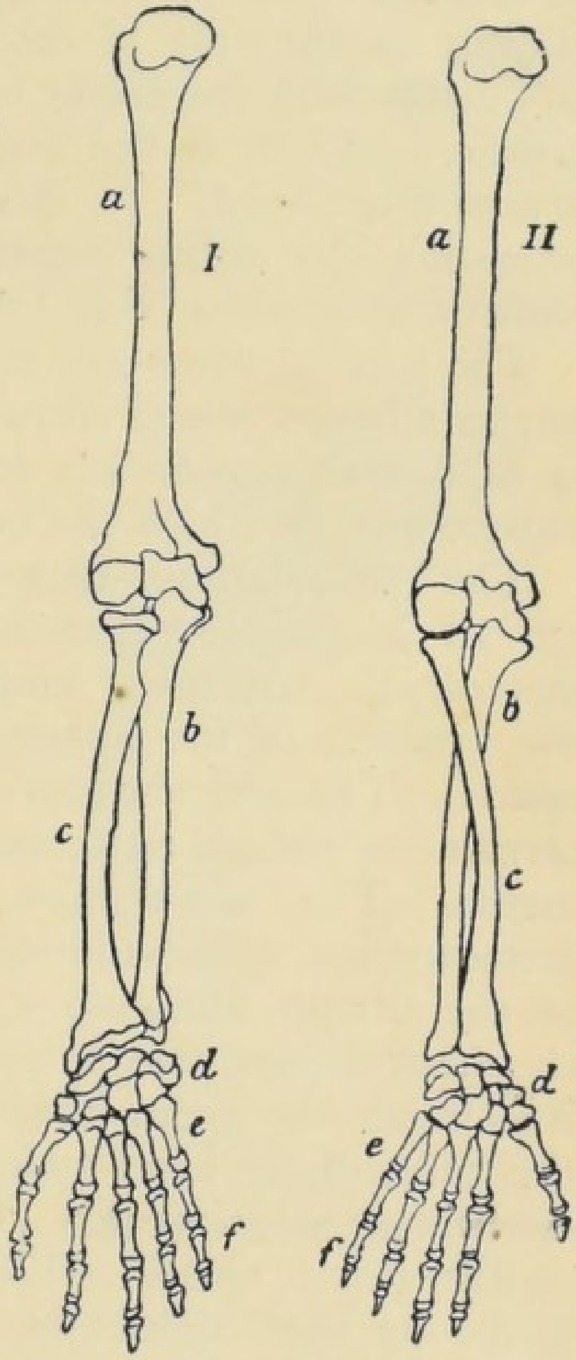

Fig. 10.—The Bones of the Right Arm: I., in Supination (palm upward); II., in Pronation (palm downward). *a*, humerus; *b*, ulna; *c*, radius; *d*, carpal bones; *e*, metacarpals; *f*, phalanges.

The *elbow-joint*, between the humerus above and the radius and ulna below, is a hinge-joint, in which the lower arm extends itself and bends downward, swinging in one plane only through an angle of nearly 180°. The form of the joint and the check arrangements, the bony process and ligament, limit the movements of the lower arm, the former in *direction*, the latter in *extent*.

The articulation of the radius at the elbow is such that it is capable of a rotatory movement about its own axis, its concave extremity turning on the humerus, and its edge gliding on the side of the ulna. Thus the hand, which articulates with the radius only, is turned so that its palmar surface, upwards at the commencement of the movement, is now downward. In this movement from supination to pronation, the radius comes to lie across the ulna, which remains motionless (Fig. 10, I., II.).

The joint at the wrist, formed by the radius and carpals, acts as a hinge, which allows of flexor and extensor, as well as of lateral, movements of the hand, but not of rotatory movements, in which the radius moves with the hand.

The articulations between the joints of the fingers are all hinge-joints ; those between the fingers and the metacarpals are loose hinge-joints, allowing not only of the bending of the fingers, but also of their being spread apart. The articulations of the carpals with the metacarpals are almost rigid, and admit only of slight displacements. The articulation between the thumb and its metacarpal is a ball-and-socket joint, giving great mobility to the thumb, allowing it, for example, to be opposed to the other fingers, and so permitting the hand to grasp. It is as much the great mobility of the arm as the variety of the joints of the hand which makes the latter the wonderful instrument which it is.

The Pelvic Girdle.—The leg is attached to the pelvic girdle by the thigh-bone. The pelvis consists of the *innominate* or hip-bones, each of which has three parts—*ilium*, *ischium*, and *pubis*. It is a curved plate of bone of unusual size, not thick, but very strong.

At the back the sacrum is wedged in between the ilia, the dorsal parts of the hip-bones, and in front the ring is completed by the *symphysis pubis*. Thus the shape of the pelvis may be likened to that of a dish without a bottom, and with irregular sides. On the outer side of each hip-bone is a deep spherical depression, which, receiving the head of the thigh-bone, forms the hip-joint.

The arrangement of the bones of the leg corresponds with that of the arm-bones. Its three divisions are the thigh, the lower leg, and the foot.

The *femur*, or thigh-bone, is a strong, cylindrical bone, much thicker at the ends than in the middle. Its upper end bears, as a lateral process, the articulation for the hip-joint; its lower end, that for the knee-joint.

The large heads of such bones as the femur afford large

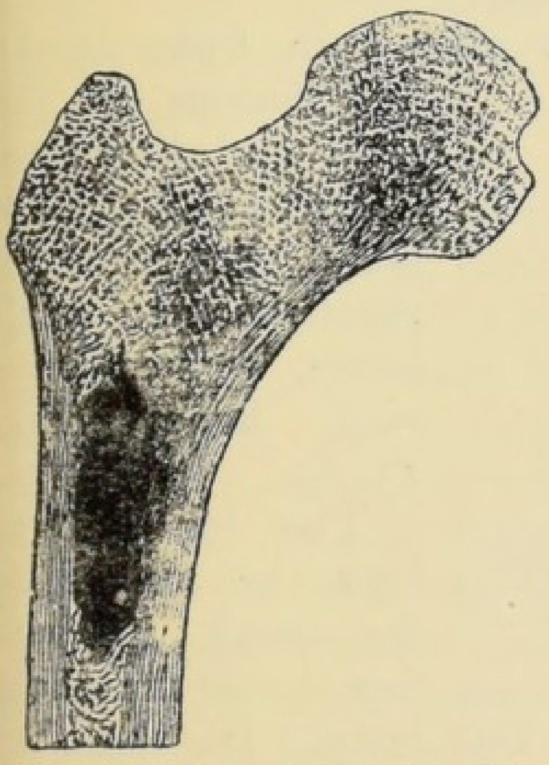

FIG. 11.—LONGITUDINAL SECTION THROUGH THE UPPER END OF THE FEMUR.

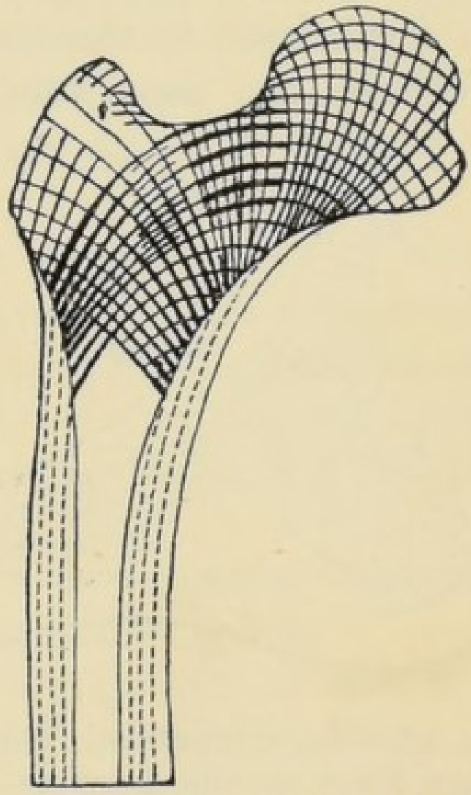

FIG. 12.—LONGITUDINAL SECTION THROUGH THE UPPER END OF THE FEMUR, SHOWING DIAGRAMMATICALLY THE ARRANGEMENT OF THE SHEETS OF BONE-SPICULES.

articular surfaces, and thus, the friction being distributed over these large surfaces, great power of movement of the joint is attained.

The lower leg, like the lower arm, consists of two bones—the stronger *tibia*, or shin-bone, and the *fibula*, or splint-bone, a smaller bone which lies along the outer side of the leg. At the upper end of the tibia, in the front of the knee-joint, is a small bone, the *patella*. It is nearly circular, flat on the inner side, slightly convex on the outer, and is embedded in the sinews and ligaments of the knee.

In the foot the seven *tarsal* bones (Fig. 13, *c*) are arranged in two rows; of the four of the hinder row, the bone of the heel (Fig. 13, *b*), with a process projecting far back, is the largest bone of the whole foot. The *metatarsal bones* (Fig. 13, *d*) are five in number, that to which the bones of the big toe are attached being the longest. The bones of the toes, the *phalanges* (Fig. 13, *e*), are similar in number and disposition to those of the hand.

Where the foot touches the ground in front, at the articulations of the great and little toe with the foot, are found with tolerable regularity two small bones, termed *sesamoid* bones (Fig. 13, *f*).

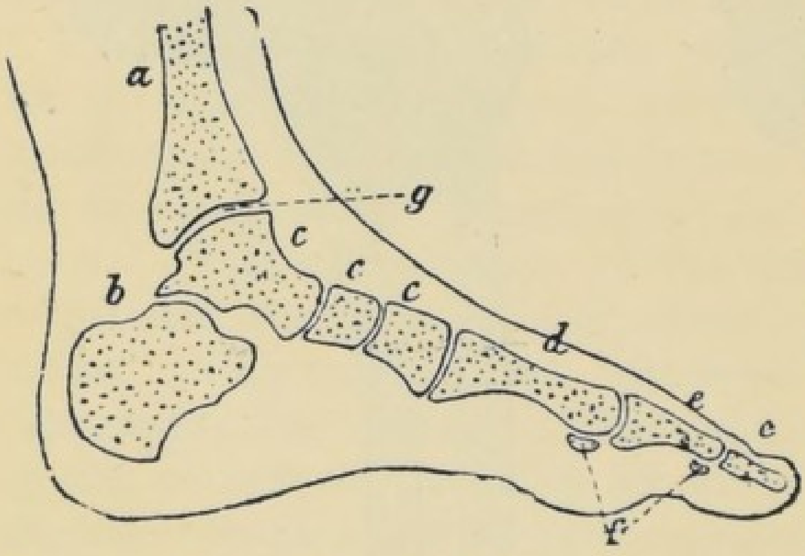

FIG. 13.—LONGITUDINAL SECTION THROUGH THE FOOT IN THE LINE OF THE BIG TOE. *a*, tibia; *b*, bone of the heel; *c*, tarsal; *d*, metatarsal; *e*, phalanges; *f*, sesamoid bones; *g*, ankle-joint.

The leg has to bear the weight of the trunk, and the foot that of the whole body. It is therefore not to be expected that their joints should admit of so complete and varied motion as those of the arm. The leg, however, has much greater solidity than the arm, and the pelvic girdle, firmly united with the vertebral column, a greater rigidity than the pectoral girdle.

The *hip-joint* is a ball-and-socket joint, in which, however, several strong ligaments prevent an equal degree of motion in all directions. The trunk does not bear immediately on the articulation, but its weight is in part transferred to the femur through the round ligament. This is a strong ligament passing from the head of the femur through the joint to the bottom of the cup, or *acetabulum*, of the pelvis.

The *knee-joint* is a hinge-joint in function, though its form is peculiar. The femur has two articular surfaces which meet in front and are continued a little way up the bone. The corresponding surfaces of the tibia are only slightly concave, but are deepened on their outer edges by rims of cartilage, the *semilunar* cartilage. The articular surfaces of the femur roll backwards and forwards on those of the tibia. The movement at the knee-joint is limited by the patella and by special ligaments. Between the latter and the patella are masses of fat, which serve as pads to the knee.

The bones of the foot form in a double sense an elastic spring, which acts in both the transverse and longitudinal directions. The foot, when suspended, is therefore shorter and narrower than when the weight of the body rests on it. On the upper side of this elastic arch is the flat ball-and-socket ankle-joint (Fig. 13, *g*).

The foot rests on the ground in three places—the heel, the ball of the great toe, and that of the little toe.

The same remarks apply to the joints of the foot as to those of the hand, except that the great toe is attached to the foot by a hinge-joint—not, like the thumb to the hand, by a ball-and-socket joint. It is therefore capable of no other movements than are the rest of the toes, and cannot be opposed to them so as to grasp an object. This absence of prehensible power and of general mobility such as is possessed by the hand, is associated with the greater degree of firmness required by the feet to enable them alone to support the weight of the body; in other words, it is associated with the upright position of man.

II. The Muscles

THE movements of the body are executed by muscles, which, according to their structure, are distinguished as smooth and striated.

A *striped* or *striated* muscle is so called because, when examined microscopically, its bundles of fibres, as well as the individual fibres, present a transversely banded appearance. A single fibre under sufficiently high magnification shows alternating bright and dim transverse discs, to which this banded or striped appearance is due. The ultimate elements of *smooth muscle*—muscle-cells—present, on the contrary, no such cross-marking. The muscles of the alimentary canal, iris, blood-vessels, etc., are smooth ; those of the skeleton in general are striated. In what follows the term "muscle" applies, unless it be otherwise expressly stated, only to striated muscle.

Every muscle is a red, fleshy mass, consisting of bundles of fine muscular fibres. Each bundle of fibres is surrounded by a sheet of connective tissue, which also binds the bundles together, forms a layer investing the whole muscle and enters at the two ends into the formation of the tendon. The *tendons* (Fig. 15, *f*) are very much firmer and tougher than the muscles themselves ; they connect the muscles with the bones or other attachments, and serve to effect the transference of force from the muscles to the parts moved.

The mass of the muscle is termed the belly ; the point where the tendon is fixed to the bone *toward* which motion is directed, is called the *origin*, and the opposite point at which the tendon is connected with the part moved, the *insertion*. Though generally the effect of the contraction of a muscle is to draw the insertion and the parts to which it is attached nearer the origin, yet there are some muscles which can work both ways. For example, the muscles of the jaw, as a rule, move the lower jaw ; but when the chin is supported, they can be made to raise the head.

In most muscles the fibres, running parallel to one another, give the appearance of longitudinal striation : for example, the flexor and extensor muscles of the arm

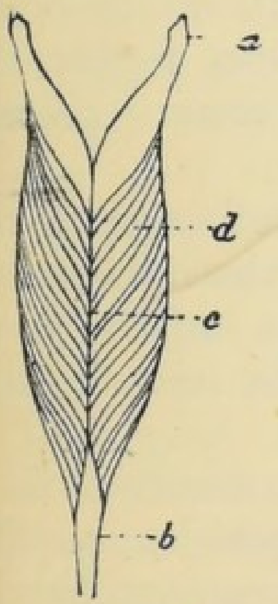

FIG. 14.—DIAGRAM OF THE MUSCLE OF THE CALF. *a*, upper, *b*, lower, *c*, middle part of the tendon ; *d*, bundles of muscle-fibres.

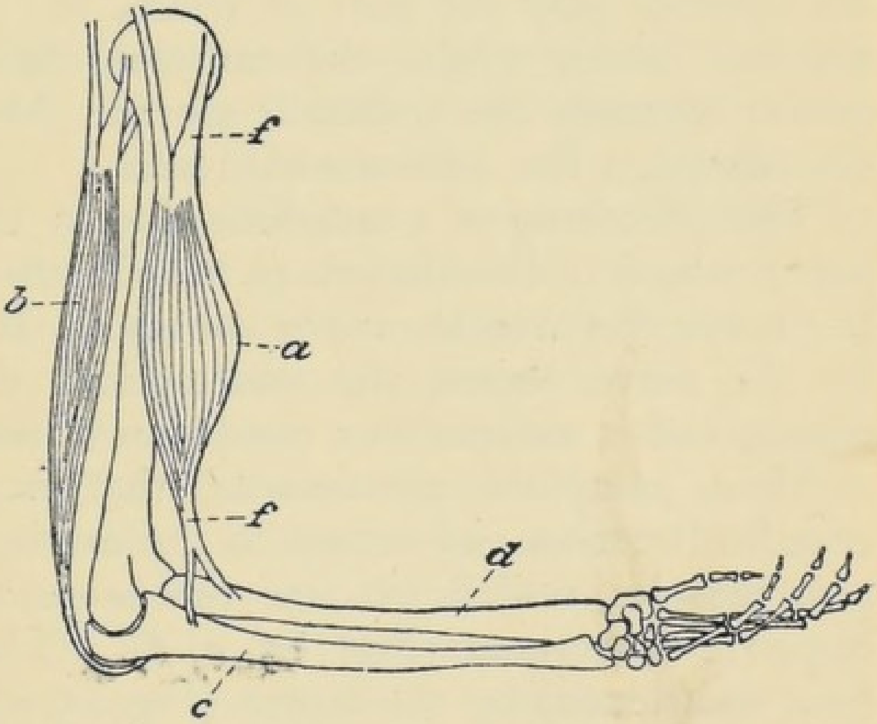

FIG. 15.—ARM, WITH FOREARM FLEXED. *a*, biceps ; *b*, triceps ; *c*, ulna ; *d*, radius ; *f*, tendons.

(Fig. 15, *a*, *b*). In such muscles the tendons occur only at the ends, and the muscle consists of a comparatively small number of long fibres. In another kind, a tendon runs through the muscle from origin to insertion, and the fibres are attached obliquely to it and to the outer sheath of connective tissue. Muscles of this kind (*e.g.* of the calf) contain a large number of short fibres (Fig. 14). Generally speaking, the former kind are adapted to the carriage of light weights over long distances ; the latter, to the lifting of heavy weights through a short distance: between these extremes various intermediate forms occur.

The activity of a muscle consists in contracting, and therefore shortening itself. As the muscle shortens, it thickens, its volume remaining practically unchanged. A muscle in extreme contraction may be about half its length when at rest. In the movement effected, the insertion and all fastened thereto approach the origin, which remains fixed. In muscular movements the bones on which the muscles are inserted play the part of levers, the joints of the bones are the fulcra, whilst the muscles themselves supply the power whereby the system is moved. Most bones represent one-armed, a few two-armed, levers.

The twitching of a muscle is due to the influence of the nerve which is distributed to it. Without the influence of the nerve the muscle cannot contract. If the impulse given by the nerve ceases, the contraction of the muscle also ceases, and it returns to a condition of rest.

Most complete movements, that is, movements in a certain direction and return to the original position, require two muscles, which execute the same movements, but in opposite directions (Fig. 15, *a*, *b*). Thus the forearm is bent up (flexed) by the biceps (Fig. 15, *a*), and extended by the triceps (Fig. 15, *b*); so too each finger is moved by its flexor and extensor muscles.

The strength of a muscle depends directly on the number of its fibres, *i.e.* on the size of the transverse section, but varies greatly in the different muscles of the body, as does the strength of the same muscle in different individuals. Exact measurements have shown that an arm muscle can lift, for every square centimetre of its transverse section, a weight of 6 to 7 kilogs., while in the muscle of the calf the same amount of muscle-tissue has a working power of over 8 kilogs. Frequently repeated and uninterruptedly continued movements of a muscle produce fatigue. This is removed by an increased flow of blood to the part when in a state of repose, more especially during sleep.

The movements executed by the human body are voluntary and involuntary. In the latter class are included *reflex* movements.

Voluntary movements depend for their performance on the action of the will. To this class belong the usual movements of the limbs, though those involved in walking have been rendered reflex by continued practice.

Involuntary movements, such as those of the heart, stomach, intestine, iris, etc., are effected quite independently of the will.

Speaking generally, the striated muscles are the means of voluntary movements, the unstriated of involuntary movements. But in the heart, the muscle, which differs in other respects from skeletal muscle, is striated, though its movements are involuntary. Again, the muscles concerned in respiration are only very slightly under the control of the will, and yet are of the ordinary striated kind.

The *reflex movements* do not result from an impulse initiated in the brain, but from a stimulus from without. This gives rise, generally through the medium of the sense-organs, to a nervous impulse. This impulse, reaching the spinal cord or the brain, sets up changes which result in other nervous impulses putting the muscles concerned in the movement in action. On hearing a loud report, we close our eyes; on stumbling, we stretch our arms forward; when we are startled, we involuntarily draw back. These reflex movements are usually effected before the knowledge of them reaches the consciousness, and, indeed, may be carried out without the knowledge of them or their cause ever reaching the consciousness.

There is yet another group of movements in which the will may exert some little influence. For instance, we may strengthen, or accelerate, or for a short time stop, the respiratory movements, though the operation of breathing usually takes place without any influence of the will.

Very few movements are single, that is to say, executed by a single muscle. Most are composite, so that several muscles and groups of muscles have a share in their execution. The proper co-ordination of the muscles necessary to the performance of a movement has to be learned by practice. This may be observed in young children, who, in grasping anything with the hand, do not close all the fingers at once, but one by one. Very frequently the separate parts of composite, frequently repeated movements acquire, through continued practice, the character of reflex movements, whose details are no longer watched over by our will and consciousness—as in writing, knitting, playing the piano, walking, etc. The impulse of the will, in these cases, has relation only to the whole act.

The number of muscles is very large. They may be grouped, for convenience, into skeletal muscles; muscles of the alimentary canal and other internal organs; and those of the sense-organs.

The *skeletal muscles* are described according to the parts of the body in which they occur.

The face-muscles spring from the bones of the face, and end on them, or sometimes in the skin of the face. They effect the play of the features, the movements of the eyelids, and participate in speech and mastication. They are, with the exception of the masticatory muscles, small and weak. They have, however, as in speaking, to execute with greatest accuracy a number of movements following one another with lightning rapidity.

Since the centre of gravity of the head lies some distance in front of its point of support on the vertebral column, muscular action is needed to maintain the head in its proper position. This action is carried out by the powerful muscles which, originating in the back, are inserted on the base of the skull. When the contraction of these muscles ceases, as in sleep, the head nods, or falls forward.

The muscles of the neck support and turn the head.

The muscles of the trunk are distinguished, according to their position, as dorsal, pectoral, or abdominal muscles. The first stretch between the single vertebræ, and from these to the ribs, and provide chiefly for the movements of the back, more particularly serving to keep the trunk, in the course of its various movements, in equilibrium. In an erect position, the services of these muscles are not required, for, as we have learned, the trunk is then in equilibrium, owing to the double curvature of the vertebral column. The outer layer of the pectoral muscles, which, starting from the sternum, clavicles, and scapulæ, pass to the upper arm, moves the whole arm.

Deeper layers of muscles invest the thorax, stretching from the sternum and from each dorsal vertebra to the ribs. In the act of breathing an important part is played by these muscles, and also by the *diaphragm* (Fig. 28). This partition, convex when viewed from above, separates the thorax from the abdomen. From its central tendinous part muscles radiate to the body-wall. By the contraction of its muscles the diaphragm is flattened, and consequently the cavity of the chest is increased (Fig. 25, *f*, *g*).

A broad, thin muscular layer closes the *abdominal cavity* in front and at the sides. By its contraction the abdomen is compressed.

The muscles of the arm are mostly in the form of elongated bundles. Those which move the lower arm originate on the upper arm; those which turn the hand or flex and extend the fingers, on the lower arm.

On the hand itself are only a few weak muscles for spreading the fingers apart, for special movements of the thumb, etc.

In the pelvis powerful masses of muscles have their origin, reaching to the thigh and knee, and serving to support the weight of the body in walking. In this they are also assisted by some of the muscles of the lower leg, while the rest of the latter effect the movements of the foot. The flexor and extensor muscles of the toes originate in the foot itself.

III. The Nervous System

(*a*) ***The Brain.***—The group of organs of which the nervous system consists are—the *brain*, the *spinal cord*, and the *nerves*, with their *nerve-endings*. The central nervous system, consisting of the brain and spinal cord, is the seat of consciousness, sensation, and will. It receives and gives out nervous impulses. The impulses which it receives result from stimulation of nerve-endings ; for instance, those of the organs of special sense, sight, etc. Such impulses, travelling *to* the brain (*afferent impulses*), frequently give rise to sensations. As a consequence of changes set up in its nervous substance by afferent impulses, or on the initiative of the will, *efferent impulses* proceed *from* the brain along other nerve-fibres (*efferent nerves*) to the muscles, which they set in movement, and to other structures, such as glands, whose secretions they control.

Because afferent impulses frequently give rise to sensations, the nerves along which they pass (*afferent nerves*) are sometimes called *sensory nerves ;* and because the principal effect of efferent impulses is to produce movement, the nerves conducting them are sometimes called *motor nerves.*

Afferent impulses may produce an effect, although they fail to give rise to a sensation. Failing to reach the threshold of consciousness, they may stir up the spinal cord or parts of the brain to activity ; the resulting movements in such cases are termed reflex actions.

The brain is enclosed in three membranes. The outermost, the *dura-mater*, is a tough membrane lying close against the inside of the skull, and sending several flattened folds between the different parts of the brain. The innermost membrane, the *pia-mater*, is soft and vascular, and forms a delicate investment to the brain itself, whose contours and depressions it faithfully follows. Between dura- and pia-mater is a third membrane, the *arachnoid*, consisting of loose connective tissue, in the spaces of which small quantities of fluid occur.

Viewed from the dorsal surface, the brain appears to consist of two main parts — a larger part in front, the *cerebrum* (Fig. 16, *g*), and a smaller part behind, the *cerebellum* (Fig. 16, *h*). The latter is about one-eighth the size of the whole brain, and occupies the occipital region of the cranial cavity.

Looked at from beneath and from the sides, it is seen that the spinal cord gradually increases in diameter to form the *medulla oblongata*, the connecting nervous link between brain and spinal cord (Fig. 16, *j*).

On the under side, the medulla is continued as the *pons* (Figs. 16 *k*, and 17 *f*), the greater part of whose substance divides anteriorly into two diverging arms — the *crura cerebri* (Fig. 16 *o*), which enter into the cerebral hemispheres; the

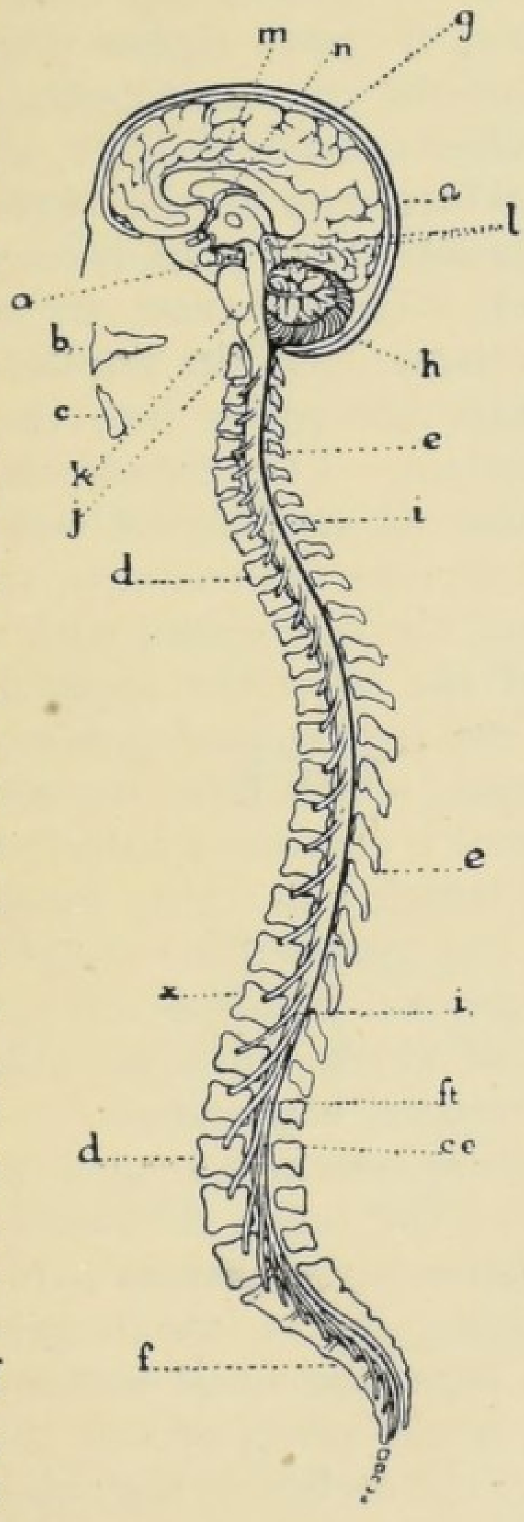

Fig. 16.—Longitudinal Median Section through the Skull and Vertebral Column, exposing the Brain and Spinal Cord. *a*, cranium; *b*, upper jaw; *c*, lower jaw; *d*, bodies of the vertebræ; *e*, spinous processes; *f*, sacrum; *g*, cerebrum; *h*, cerebellum; *i*, spinal cord; i_1, spinal cord passing at the level of first lumbar vertebra (x) into the filum terminale, *ft*; *ce*, cauda equina, consisting of the bundle of nerve-roots surrounding filum terminale; *j*, medulla oblongata; *k*, pons Varolii; *l*, anterior and posterior corpora quadrigemina; *m*, corpus callosum; *n*, fornix; *o*, one of the crura cerebri.

remainder of the fibres passing up from below terminate in two oval masses, the *optic thalami* (Fig. 17, *k*), situated in the inner sides of the crura and enclosing between them the deep slit-like *third ventricle* (Fig. 17, *d*).

The *cerebellum*, which rests on the upper side of the front part of the medulla and of the pons, is connected with them by two pairs, and with the crura by one pair of stout strands of nervous tissue. Of the former, the pair running backward on either side passes into the medulla on its upper and outer surface. The second pair, wrapping round it transversely, meet on the ventral surface of the pons. The third pair of nervous ties connects, through the upper surfaces of the crura, the cerebellum with the cerebrum.

In the region of the crura the upper dorsal side of the brain consists of the *corpora quadrigemina* (Fig. 16, *l*), two pairs of lobed masses, which form the roof of this part of the brain. This roof is continued anteriorly by a thin layer of nervous tissue, which, stretching forward as the *fornix* (Figs. 16 *n*, and 17 *c*), comes to be completely overlaid and enfolded by the cerebral hemispheres. Above the fornix a transverse mass of fibres, the *corpus callosum* (Fig. 16, *m*), connects the two cerebral hemispheres.

The central nervous system is a tube, the walls of which are, in the region of the brain, thickened very irregularly: in some places enormously, in others hardly at all. In the spinal cord the thickening is less irregular, but still considerable. In the latter the small *central canal* (Fig. 18, *f*), circular in section, is the cavity of this tube. The central canal comes close to the surface in the region of the medulla, where it forms a lozenge-shaped cavity, the *fourth ventricle*, covered above by a very thin layer of nervous tissue. The fourth ventricle is continued forward through the middle part of the brain by the *iter a tertiam ad quartum ventriculum*, which runs below the lobed corpora quadrigemini and passes anteriorly into the narrow, cleft-like space, the *third ventricle* (Fig. 17, *d*), lying between the optic thalami. The third ventricle gives off three clefts, *lateral ventricles*, on either side, which penetrate deep into the cerebral hemispheres. One of these clefts is seen on either side in Fig. 17, *e*.

The *cerebrum* is divided by a longitudinal furrow, the *median* fissure (Fig. 17, *g*), into two fairly symmetrical halves. This fissure cuts deep into the cerebrum from before, above, and behind. Each hemisphere also bears a number of deep fissures, one of which, the fissure of *Sylvius*, commencing on the ventral surface, running round and reaching nearly to the median fissure, marks out the hemisphere into two unequal halves.

Other fissures—of which the chief, named after the bones

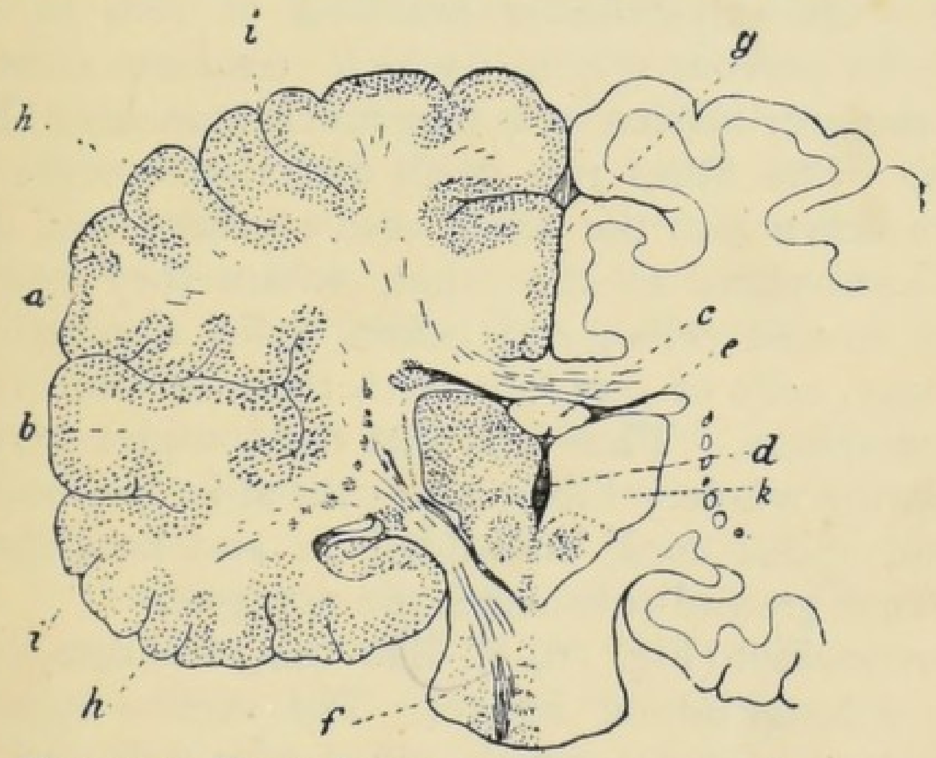

FIG. 17.—VERTICAL CROSS SECTION THROUGH THE BRAIN. *a*, cortex, grey matter of the cerebral hemisphere; *b*, white matter of the cerebral hemisphere; *c*, fornix; *d*, third ventricle; *e*, lateral ventricle; *f*, pons Varolii, cut obliquely and showing fibres running from it and forming the crura cerebri; *g*, median fissure; *h*, convolutions (gyri); *i*, fissures (sulci); *k*, optic thalamus.

covering them, are the *frontal*, *parietal*, *temporal*, and *occipital*—divide the surface of the cerebrum into as many lobes. In the temporal region of either side a part of the surface called the *island of Reil* is thrust deep into the brain.

The surface of the lobes shows a number of raised *convolutions*, or *gyri*, bounded by the fissures, or *sulci* (Fig. 17, *h*, *i*). The exact sizes and positions of the convolutions differ in different brains, and even in the opposite hemispheres of the same brain.

An incision into the mass of the brain shows it to consist of two different substances : on the surface a reddish-grey layer, the *grey matter*, or *cortex* (Fig. 17, *a*) ; and within, the *white matter* (Fig. 17, *b*), into which the former insensibly passes. The nervous part of the grey matter consists of cells, each of which bears a number of finely branching processes (*dendrites*), as well as one unbranching process, the *neurite* or *axis-cylinder process*. The white matter consists of fibres—the axis-cylinder processes of cells in different parts of the nervous system—which terminate either in the cells of the grey matter, or as fine, much-branching fibres near the cells. The fibres run in all directions—some through the brain down into the spinal cord ; others from the cells of one hemisphere to the other, where they end in fine branches around cells ; and others again connecting, in a similar way, cells of one lobe with those of another of the same hemisphere. Thus it is that the complex brain forms a dominating whole. Fibres and cells alike are, both in the brain and spinal cord, embedded in and nourished by a non-nervous ground substance, the *neuroglia*.

The *cerebellum* (Fig. 16, *h*), like the cerebrum, is deeply cleft by a longitudinal fissure. The surface appears striated, owing to fissures which run horizontally and nearly parallel with one another. In this part of the brain, as in the cerebrum, a number of lobes can be distinguished. The grey matter of the cerebellum penetrates more deeply than does that of the cerebrum, so that the tissue of the cerebellum presents, in a transverse section, the appearance of tree-like branching ; hence its old name, "the tree of life."

It is clear that the folding of the surface of cerebrum and cerebellum into convolutions and fissures greatly increases the superficial area of the cortex.

The brain governs the whole body and its activities ; it is the seat of all ideas of states and processes in and out of the body; it also occasions all voluntary movements of the body and its parts.

Those nerve-fibres whose function it is to transmit impulses to the muscles of the body cross over in their passage from brain to spinal cord: thus disease or injury to the cerebral hemisphere of one side results in paralysis of the other side of the body. Similarly, the fibres which convey impulses from the various parts of the body to the brain decussate, or cross over, in the spinal cord or medulla, to the opposite side of the cerebrum; so that injury to one hemisphere also entails loss of sensation on the opposite side of the body.

The foundation of intellectual activity is formed by the reception and working up in the brain of the nervous impulses transmitted by the nerves as the result of stimulation of the sense-organs. The sensations which reach the consciousness are called *concepts*. Concepts once acquired can be stored up by the brain. This faculty is called *memory*. If such concepts are recalled by the memory, the act is termed recollection.

The stimulation of a part of the body is the first link in that nervous chain of events whose last is sensation. Experience teaches us to refer back the sensation arising in the brain to the part of the body where the first link was forged. Thus, after the amputation of a limb, the subject thinks that he feels acute pain in the missing part. For the connections of the severed nerves still exist with the brain, the stimulation of the cut ends of the nerves still gives rise to afferent impulses, which, arriving at the brain, call forth the sensation of pain; and experience, localizing as heretofore, plays the sufferer false. Similarly, when the elbow is struck or dipped in very cold water, pain is felt in the three outer fingers.

Interruption of the nerve-tracks leads to loss of sensation and power of movement. The severance of the optic nerve produces blindness; the brain receives no information of the images produced in the eye. If the spinal cord be severed below the thoracic region, paralysis and loss of sensation in the legs subvene; the brain has lost all control over these parts, for the nervous road is broken up, and passage either way barred.

Little is known of the processes going on in the brain during its various activities. Nor have we any complete knowledge of the way in which the cerebral activities are localized in the different parts of the brain, and how far the place of a diseased or destroyed part can be taken by another. We know, however, that certain areas of the cerebral hemispheres are closely associated with the movement of certain parts of the body, that certain regions of the brain are specially associated with the working up of special sensations, and that nervous impulses, before giving rise to sensations, are worked up gradually in special regions; but how the physical train of events conjures up the psychical, is still an enigma.

The weight of the brain varies within wide limits on either side of an average of 1300 grams, about $\frac{1}{36}$ of the weight of the body. The smallest known brain, that of a German woman, weighed 820 grams. The largest, that of a French workman, 2222 grams. The size of the brain does not appear to have any ascertainable relation to race, occupation, or intellectual capacity. One of the largest brains on record was that of an idiot. The brains of great scholars and other famous men which have been examined show, on the whole, weights slightly above or below the average.

The brain is never in a state of complete repose. Even in deep sleep it is busy, though consciousness is at rest. In the waking state it is continually occupied with the reception and working up of sensations and concepts, even if this activity does not always fully reach the consciousness. The activity of the brain during sleep takes place without the proper, or, at all events, the full, co-operation of the consciousness and the intellect: this is called dreaming. The want of supervision on the part of the arranging and sifting intellect explains the often irregular and confused, sometimes unmeaning, grouping of ideas. Frequently, in dreams, the activity of the brain calls forth that of the body; the sleeper moves or speaks—the latter usually without coherence. It was believed till recently that dreams only take place at the moment of awakening, or at times when sleep is less deep, and last only a short time. The belief is now gaining ground that even deepest sleep is never dreamless, and that dreams may present every gradation of coherence.

(*b*) **The Spinal Cord.**—The central nervous system passes out of the skull by the *occipital foramen*. That part of it which lies in the spinal canal is called the spinal cord (Fig. 16).

The *spinal cord* is a fusiform column of soft nervous tissue. It is thicker in its cervical and lumbar regions than in its dorsal region, and thins away again at its extremity to form the *filum terminale*. At the point where it leaves the skull it has a diameter of about 11 mms., and nowhere entirely fills the spinal canal. At each vertebra it gives off a pair of spinal nerves, which pass out from the spinal canal through spaces between the neural arches. At the lower end the pairs of nerves before passing out of the canal, run down it for some distance, forming a bundle of fibres, the *cauda equina*.

Deep fissures occur in the median line of the cord, one in front, the *anterior fissure*, another at the back, the *posterior fissure* (Figs. 18, 19). At the bottom of each of these fissures is a narrow bridge of nervous tissue surrounding the *central canal* (Fig. 18, *f*).

Like the brain, the spinal cord consists of grey and white matter, though, unlike the arrangement of these substances in the brain, the white matter lies at the surface of the cord, the grey at the interior (Fig. 18, *a*, *b*). As in the brain, the nervous elements of the white and grey matter are embedded in a supporting non-nervous groundwork of neuroglia.

The white matter consists of groups of fibres running for the most part longitudinally; the grey, of cells with branches similar to those of the brain-cells and of fine much-branching fibres. In a cross-section of the spinal cord (Fig. 18) the grey matter is seen to be disposed in two more or less crescent-shaped masses placed back to back, and connected by a strand which, together with a small quantity of white matter on its ventral surface, separates the *anterior* and *posterior fissures.*

The membranes of the cord are similar to those of the brain. Lining the vertebræ, to the inner surfaces of which

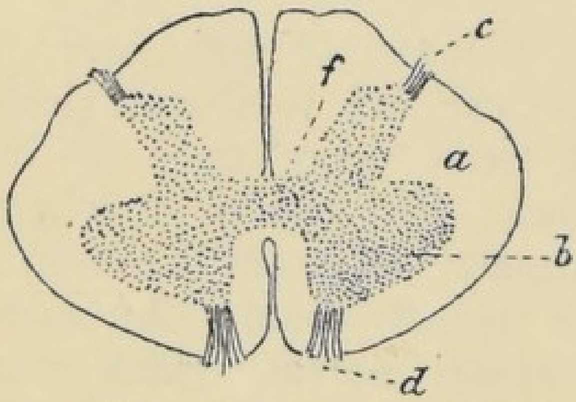

FIG. 18.—TRANSVERSE SECTION THROUGH THE SPINAL CORD IN THE CERVICAL REGION. *a*, white matter; *b*, grey matter; *c*, posterior root of a spinal nerve; *d*, anterior root; *f*, central canal.

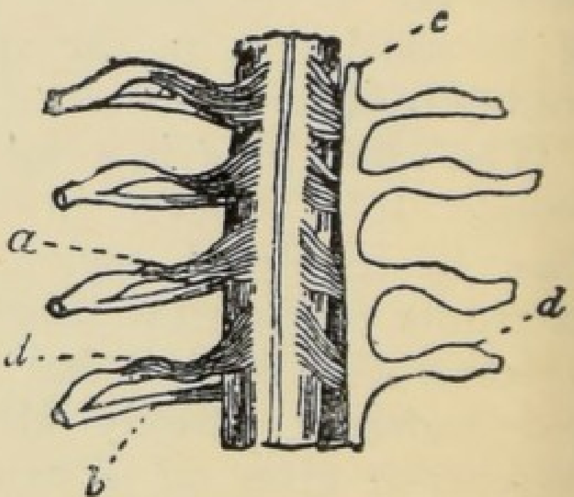

FIG. 19.—PART OF THE SPINAL CORD (seen from behind). *a*, posterior root of a spinal nerve; *b*, anterior root; *c*, dura-mater covering spinal column; *d*, ganglion of the posterior root.

it forms a periosteum, and continuous with that lining the skull, is the dura-mater; closely investing the cord itself, and supplying it with blood-vessels, is the pia-mater; and between the two is the space occupied by the diffuse arachnoid and by a watery fluid.

Each spinal nerve is connected with the cord by two branches, called the *anterior* and *posterior roots.* These roots spring to the surface of the cord opposite the horns of the crescent-shaped grey matter, from which in part they arise (Fig. 18, *c*, *d*). Just before the point within the spinal canal at which the roots unite to form the nerve-trunk, the posterior of these bears a swelling, the *posterior root-ganglion* (Fig. 19, *d*).

The spinal cord is the connection between the brain and the majority of the nerves of the trunk and limbs, and therefore contains nerve-fibres for the production of all movements of these parts and those concerned in the transmission of afferent impulses, sensory as well as other.

(*c*) **The Nerves.**—The nerves are white cords of various thicknesses, not consisting, however, of single threads, but composed of many very thin elongated nerve-fibres.

Each nerve-fibre is a thread of extreme thinness, consisting of a central strand of protoplasm, the *axis-cylinder process*, which is nothing but the branch of the nerve-cell in which the fibre arises. Surrounding this essential part of the nerve is a fatty substance which is called the *medulla*, and, bounding this, a delicate sheath, the *neurilemma*. Some nerves are not medullated, that is, are devoid of the intermediate fatty layer. The nerve-fibres are bound into bundles by connective tissue, which also forms a sheath for the whole nerve. Along the course of the nerve, branches, consisting of bundles of its fibres, pass out to supply various parts. In other cases, branches originally separate may come for a time to be included in the same sheath, and thus form a *plexus*.

Nerves may be distinguished, according to their function, as *sensory*, *motor*, *secretory*, *trophic*, and *tonic*. The nature and the functions of the first two kinds of nerves we have already considered.

Secretory nerves stand in the same relation to glands as motor nerves to muscles ; they conduct efferent impulses, which incite the organ to activity ; only the activity consists, in their case, in the manufacture of special secretions, such as saliva.

Trophic nerves are concerned with the control of the growth and well-being of the parts of the body to which they are distributed. They seem, by controlling the nutrition of the part, to have much to do in maintaining the legions of cells of which the body consists, in a state of unity.

Tonic nerves are such as regulate the activity of the organ to which they are supplied. Thus the heart is provided with two sets of nerve-fibres, *augmentor* and *inhibitory;* the former carry impulses which increase the rate of the heart's beat, the latter carry impulses which slacken the rhythm. Many other organs of the body appear to be supplied with such antagonistic fibres, which may be likened to rein and spur, the one or other of which the brain, the rider, may apply according to need.

Having regard to their origin, nerves may be classed as *cerebral*, *spinal*, and *sympathetic*.

There are twelve pairs of *cerebral nerves*, all originating within the skull ; with the exception of two pairs (tenth and eleventh) their course is confined to the head. The cerebral nerves are mostly connected with the organs of special sense, and with the mechanism of speech.

The *spinal nerves*, of which there are thirty-one pairs, are distributed to the trunk and extremities. They contain efferent and afferent fibres. The former leave the cord by the anterior root, and originate in the cells of the anterior horn of grey matter ; the latter leave by the posterior root, and many of them are processes, not of the cells of the posterior horn, but of the posterior root-ganglion. Entering the cord by the posterior root, they run up for some distance, and gradually pass into the grey matter.

The principal part of the *sympathetic nervous system* is a double cord, *the sympathetic chain*, descending in front of the vertebral column, and bearing in its course a number of paired ganglia. In the dorsal and lumbar regions a pair of ganglia occurs opposite each vertebra, in the cervical region, only opposite some vertebræ. Each ganglion receives a branch from a spinal nerve, and, from the chain, branches are given off to the various organs of the thorax and abdomen. Above, the sympathetic makes connections with some of the cranial nerves. Among its functions are the carriage of impulses regulating the contraction of the muscles of the intestine, and those (tonic impulses) which normally maintain the small blood-vessels in a state of slight contraction, and those affecting the movement of the iris. The sympathetic system receives its fibres from the central nervous system, of which its ganglia are but offshoots. Within its ganglia many of the nerve-fibres lose their medullary sheaths, and so leave as non-medullated fibres.

(*d*) ***Sense-Organs.***—The connection of the brain with the outer world is established by means of the sense-organs. The agents, such as light, heat, sound, pressure, or chemical substances, which excite the sense-organs to nervous activity, are termed stimuli. The nerve connected with an organ of special sense can give rise in the brain to sensations of one kind only ; thus the optic nerve only gives rise to sensations of sight. Stimuli of kinds other than those to which the sense-organ is attuned may give rise to the sensation peculiar to the organ in question. The recipient of a blow on the eye "sees stars ;" the pressure stimulates the optic nerve, which transmits the stimulus in the only way open to it, as a visual impulse.

The essential parts of every sense-organ are: first, the nerve with its endings ; and secondly, epithelium cells, which are often highly specialized in form and arrangement, and with which the nerve-endings are in intimate relation. The specialized epithelial cells, with the nerve-endings, receive the stimulus, and, in consequence of it, transmit a nervous impulse to the central nervous system.

The effects of stimulation are often enhanced by contrast and by repetition ; thus water taken after acid foods tastes sweet, but bitter if it follows sweet things. A cellar of constant temperature seems cold in summer, warm in winter ; tepid water seems cold to the fingers after warm, and warm after cold water. The effects of repetition are well known in the case of smell : by sniffing, an odour before doubtful is readily recognized.

1. ***Of Sight.***—The eye lies in the *orbit* (Fig. 20), a conical

space, bounded on its outer edge by the nasal, frontal, cheek-bones, and upper jaw ; inside by the sphenoid, ethmoid, and lachrymal bones. This setting of the eye, especially the outer edge, affords effectual protection against a blow. The interior of the cavity is lined with a fatty substance, in which the eyeball is embedded. The eye is protected externally by two folds of skin, the eyelids, of which the upper is the larger and more mobile. Thin plates of cartilage embedded in the folds extend the skin of the eyelids. At the outer edge of each eyelid is a set of more or less bristly hairs, the eye-

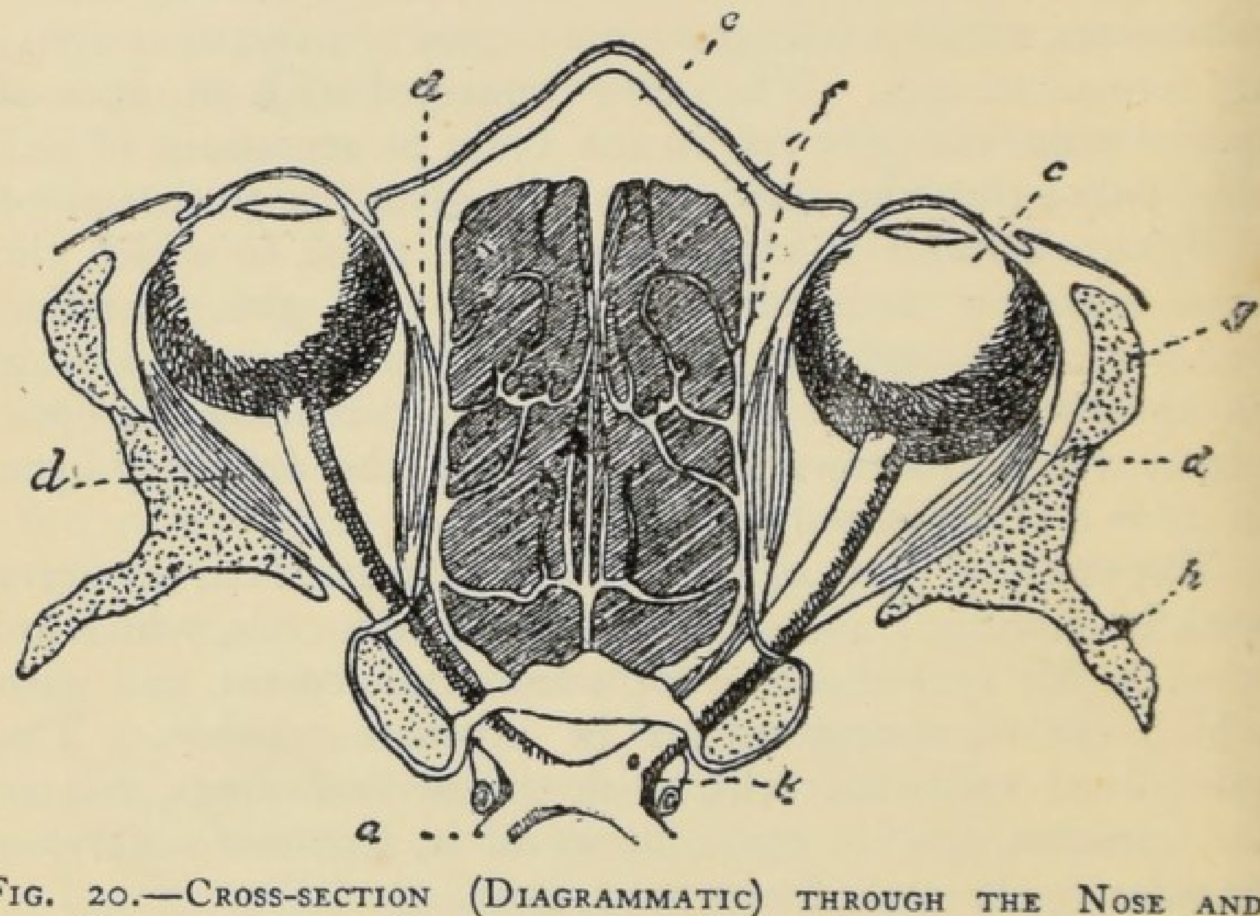

FIG. 20.—CROSS-SECTION (DIAGRAMMATIC) THROUGH THE NOSE AND ORBITS, AT THE LEVEL OF THE OPTIC NERVES. *a*, optic tract ; *b*, optic chiasma, from which the two optic nerves run to the eyes ; *c*, eye-ball ; *d*, muscles (external and internal recti) of the eye ; *e*, nose ; *f*, turbinal bone ; *g*, cheek-bone ; *h*, process of cheek-bone entering into the formation of the zygomatic arch.

lashes, which are lubricated by fluid secreted by glands situated within the eyelids. Internally, the eyelids are lined with a mucous membrane. The eyelids close the eyes in sleep, form a protection against shock, and, by movements repeated at short intervals, get rid of the dust settling on the eye. On the upper wall of the orbit are placed the *lachrymal glands*, several groups of thin lobed glands, the largest about 2·2 cms. long and 1·4 cm. broad. They secrete "tears," which consist chiefly of water and a little salt. Their primary function is to continuously wash and keep warm the front of the eye, and so render it possible for the eyelids to keep the eye clean. The water which runs off, together with the dust, collects in the inner corner of the eye, where it is conducted through a minute opening into a narrow channel, the *lachrymal duct*, and thence into the nose. Tears come into the eyes by any irritation of the eye, such as contact of foreign bodies with the cornea, very cold air, strong light, and sometimes over-fatigue.

The eye is moved in its socket by six muscles, only two of which are shown in Fig. 20 (*d*). Four muscles of the eye pass in straight lines from the back of the orbit to the eye, to which they are attached—one above, one below, and one on either side. They are named respectively the *superior*, *inferior*, *exterior*, and *interior rectus muscles*. The remaining two, the *superior and inferior oblique muscles*, are attached to the eyeball laterally, from above and below. By the co-operation of these muscles, the eye is capable of movement in various directions. They do not admit of a rotation of the eye. Though the directions in which the eye can be moved are many, its mobility is limited, since every muscle acts as a check on its opposite antagonistic muscle.

The movements of the two eyes are so co-ordinated that both always direct the sight to the same point. Disturbances and irregularities in this co-ordination are known as squinting.

The movements of the muscles of the eye are directed by three pairs of cranial nerves, the third, fourth, and sixth. The mucous membrane of the eyelids passes as a transparent colourless layer, the *conjunctiva* (Fig. 21, *a*), over the anterior surface of the eyeball.

The central space of the eyeball is enclosed by two, and at the back by three coats.

The outer layer, called the *sclerotic* (Figs. 21 *b*, 23 *b*), is a bluish-white, very strong and tough membrane, from ½ mm. to 1½ mm. in thickness. Its anterior surface, the *cornea*, is somewhat more convex than the rest, and has the form and transparency of a watch-glass (Figs. 21 *c*, 23 *c*). Somewhat below, a little to the inner, nasal, side of the centre of the posterior wall (Fig. 22, *l*), the optic nerve passes through the sclerotic coat.

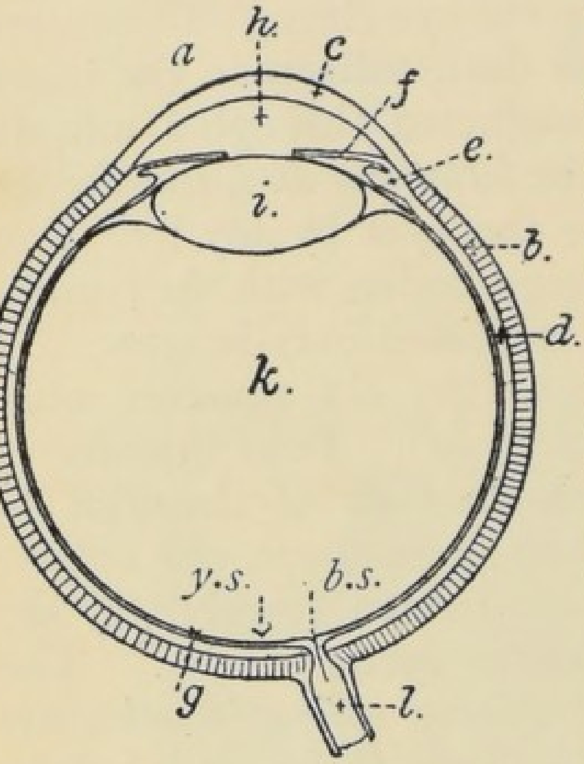

FIG. 21.—DIAGRAMMATIC SECTION THROUGH THE EYE. *a*, conjunctiva; *b*, sclerotic coat; *c*, cornea; *d*, choroid; *e*, ciliary body; *f*, iris; *g*, retina; *h*, anterior chamber of the eye; *i*, crystalline lens; *k*, posterior chamber, containing the vitreous humour; *l*, optic nerve; *bs*, blind spot; *ys*, yellow spot.

The second layer investing the eyeball is the black pigmented *choroid* (Fig. 21, *d*), a very thin and vascular membrane, which is also pierced posteriorly by the optic nerve. It lies close against the sclerotic, and is attached to the rim of the cornea, over which, however, it does not pass. Instead, it is disposed vertically to form the iris (Figs. 21, 23 *f*).

The *iris* is stouter than the choroid, and its colour, brown, grey, or blue, gives the colour to the eye. It is pierced in the middle by a circular aperture, the *pupil*, the size of which is modified by the contraction of the smooth muscles of the iris. The area of the pupil is diminished by the contraction of the circular muscles, and increased by the contraction of the radiating muscle of the iris. Near its attached edge, on its internal surface, the iris bears a number of folds, the *ciliary processes* (Figs. 21, 23 *e*). The ciliary processes form a ring, to which the *suspensory ligament* (Fig. 23, *m*) of the lens is attached. From the line of junction of sclerotic and cornea arise muscle-fibres which stretch inward and backward into the choroid in the region of the ciliary processes, so that at their bases a ring-shaped fold, conveniently called the *ciliary body*, is formed.

A delicate pinkish layer of nervous tissue, the *retina* (Fig. 21, *g*), lines the inner surface of the choroid, stretching almost as far forward as the ring of the ciliary processes. It is in direct connection behind with the optic nerve, of which its innermost layer is a cup-like expansion. On the retina two points are specially noteworthy—the *yellow* spot and the *blind spot* (Fig. 21, *bs*, *ys*). The former is a slight depression round the point at which the *visual axis*, a line passing through the middle points of the cornea and the pupil, meets the retina. The blind spot is the point where the optic nerve enters the eyeball. Light falling on the blind spot gives rise to no visual sensations ; whereas when, as is the case in normal vision, the eye is so directed that the image of the object looked at falls on the yellow spot, vision is most distinct.

The cavity of the eyeball is marked out by the iris into two unequal spaces : the one in front, the *anterior chamber* of the eye (Figs. 21, 23 *h*), lies between the cornea and the iris, and is filled with a watery fluid, the *aqueous humour*. The large *posterior chamber* (Figs. 21, 23 *k*) is occupied by the jelly-like transparent *vitreous humour*. Behind the iris and between the two chambers is the *crystalline lens* (Figs. 21, 23 *i*). The lens is an elastic body which, though composed of a number of concentric layers, possesses a high degree of transparency. Its form is that of a biconvex lens, the anterior surface of which is flatter than the posterior, and whose edge is circular. The lens is enclosed in a strong yet thin membrane which, projecting beyond its edge, forms the suspensory ligament. This ligament, in which the lens is slung, is fixed to the bases of the ciliary processes. In the quiescent state of the eye, the suspensory ligament, being tightly attached to the edge and to the anterior surface of the lens, maintains the curvature of that surface.

Each eye is connected with the brain by an *optic nerve* (Figs. 20 *a*, 21 *l*), the second of the cranial nerves.

The optic nerves originate in the brain, and, emerging, appear passing round the under surfaces of the crura cerebri. Arrived at the middle line, they cross one another at the *optic chiasma* (Fig. 20, *b*), so that the optic nerve of the left eye goes to the right side of the brain, and that of the right eye to the left side.

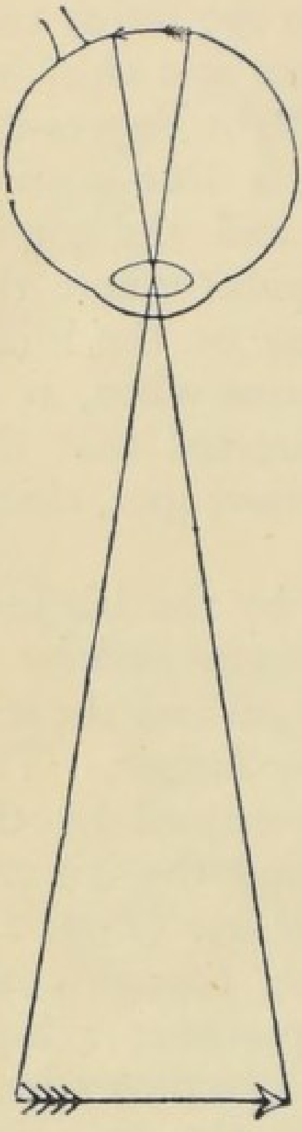

Fig. 22.—Diagram showing the Production of a Retinal Image.

The nutrition of the interior of the eye is carried on by the blood-vessels of the choroid and of the retina. The lens and the vitreous humour contain no blood-vessels.

The bony framework of the eye, the eyelids, and the lachrymal apparatus furnish a series of arrangements for the external protection of the eye.

The sclerotic serves for the insertion of the eye-muscles and for the protection of the interior parts of the eye, while the cornea allows of the access of light to the eye.

The iris regulates the quantity of light penetrating into the eye ; it moves by the agency of its muscles in such a manner that an increase in the amount of light entering the eye causes a narrowing of the pupil, a decrease a dilation.

Like other movements executed by unstriped muscle, those of the iris are slow, a considerable contraction requiring over half a second.

The cornea, the aqueous humour, the vitreous humour, and especially the lens, refract the entering rays of light so that an actual, though inverted and reduced, picture of the object looked at appears upon the retina. This picture is termed the *retinal image* (Fig. 22).

Images which come to a focus in front of or behind the retina give rise only to indistinct vision.

If the eye and its parts were rigid, the range of sight would be very limited. As a matter of fact, however, clear vision extends to almost any distance.

The changes which take place in the eye when directed to near or distant objects are termed *accommoda-tion.* The eye at rest is, owing to the flatness of the anterior surface of the lens, accommodated to distant vision. In this state, parallel rays of light — those proceeding from a great distance—are brought to a focus on the retina, whilst near objects, if seen at all, produce but blurred images, since the rays of light proceeding from them tend to come to a focus, not on the retina, but behind it. When the sight is directed to such near

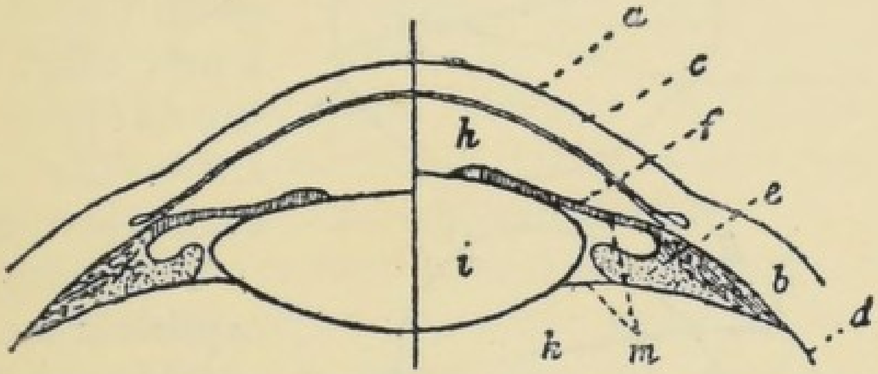

FIG. 23.—DIAGRAMMATIC SECTION THROUGH THE ANTERIOR PART OF THE EYE. The left side of the figure shows accommodation for far, the right for near, vision. Lettering as in Fig. 21. *m*, suspensory ligament.

objects, they in turn become distinct, to the exclusion or dimming of the distant ones. The changes in accommodation, whereby this readjustment of the eye is brought about, have, as a result, the increased curvature of the anterior surface of the lens. In this condition the lens exerts a greater refraction on the rays of light passing through it, so that their focus is brought forward to coincide with the surface of the retina.

The change in curvature of the lens is effected by the contraction of the ciliary muscles to which (Fig. 23, *m*) the suspensory ligament of the lens is attached. By their contraction the ciliary muscles draw the ligament forward, and, in so doing, slacken it so that it ceases to control the shape of the lens. The lens, released from this control, bulges forward by virtue of its elasticity (Fig. 23). Thus its anterior curvature becomes greater; with that its refractive power is increased, and accommodation for near vision effected.

When the effort of accommodation is relaxed, the ciliary muscles also relax; the ligament falls back to its original position, resumes its tension on the lens, drawing it taut and causing it to return to its more flattened form. Automatically then, the eye becomes adjusted for far vision, in which condition it rests till a new effort of accommodation produces anew the series of events just described.

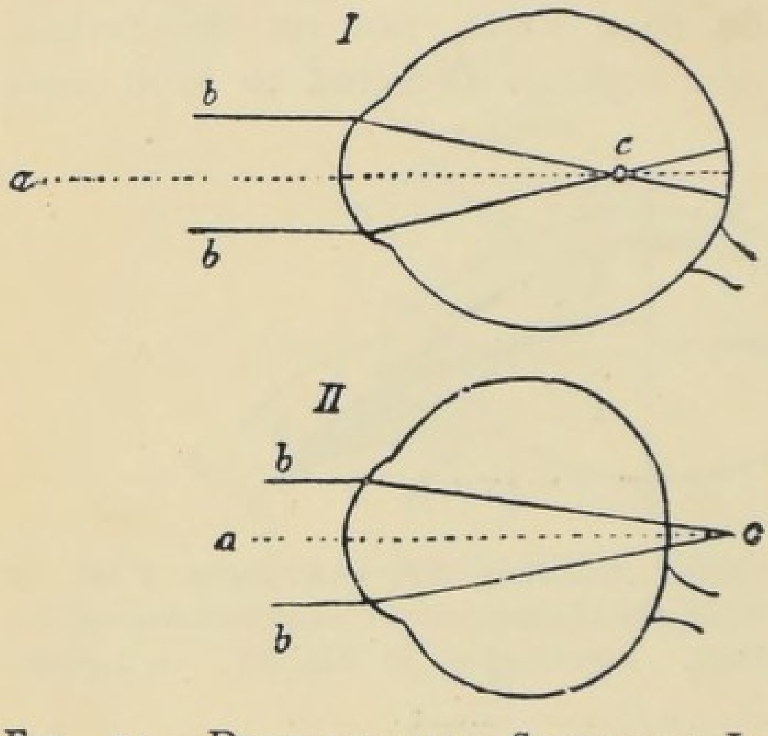

FIG. 24.—DIAGRAMMATIC SECTIONS: I., THROUGH SHORT-SIGHTED; II., THROUGH FAR-SIGHTED EYE. *a*, visual axis; *b*, rays of light; *c*, focus of light-rays.

The normal eye is capable of seeing clearly anything between an infinite distance and one of 15 cms. from the eye. From the fifteenth year, as a rule, in consequence of the induration of the lens, the faculty of accommodation for near objects decreases.

The two most frequent defects in the eye, short-sightedness and long-sightedness, are connected with accommodation. In short-sightedness the images of distant objects do not fall upon, but somewhat in front of, the retina; in long-sightedness the images of near objects would only be focussed behind the retina. In either case the effect is due to one of two causes: too short a front-to-back diameter of the eyeball, or inability of the lens to assume the requisite degree of convexity, makes the eye far-sighted; while too great a diameter of the eyeball, or inability of the lens to flatten itself sufficiently, causes short-sightedness (Fig. 24). A short-sighted eye should be aided by concave glasses, a far-sighted one by convex glasses. The former throw the images further back on the retina; the latter bring the images forward to the retina.

Each of the two eyes furnishes a picture of the image looked at, but we actually see it single, the images of the two eyes giving rise to one fused, visual image. It is the images of the point directly looked at, falling on the yellow spots and on a small area of the retina surrounding them, which are united.

If one retina could, without being in any way turned round, be laid on the other, any two points of contact might be called *identical points*. Images falling on identical points of the eyes are seen singly, while images whose parts fall on points not identical, appear double. In any case, however, the experience that images of this sort are caused by one and the same object has some share in their union. For squinting people, in whose eyes the images of things looked at cannot fall on identical points, see objects singly.

The two images of an object supplied by the two eyes are, however, not identical, the right eye seeing rather more of the right, the left eye of the left side. Their union, therefore, shows more of an object than either eye could see singly, and this fuller view creates the impression of solidity (*stereoscopic sight*), while in seeing with one eye all objects appear like flat surfaces in one plane. Therefore, too, all judgments of distance are very uncertain when objects are seen with one eye only. If one eye be closed, it is very difficult to strike a match or to touch with the point of the finger a small object held anywhere within arm's length.

The retinal images lying outside the small areas surrounding and including the yellow spots are not united to form a single, fused, visual image, and should therefore be seen as double images. This, in fact, takes place; but experience, especially that gained by the sense of touch, has taught us from early childhood that such objects, seen double, exist singly, and so we become accustomed at a very early age to disregard one of the images. This is rendered still easier by the fact that the attention is directed to the exact point looked at. Only of this does the image fall on the yellow spot, not that of the other points. Images falling on points of the eye other than the yellow spot also lack detail of shape and colour.

The eye informs us as to the shape, colour, size, and distance of objects.

The form of the retinal image determines the concept of shape, though the consciousness takes into consideration the stereoscopic proportions imported into the appearance by the union of the two retinal images.

The sensation of colour is connected with the more delicate structure of the retina. Rays of certain wave-lengths falling thereon give rise to the various colour-sensations. White is the sensation produced by the collective impact of the rays which individually produce the colour-sensations of red, orange, yellow, green, blue, indigo, and violet (the spectral colours). Black is the absence of light-sensation.

Total or partial absence of sensitiveness to colour is called *colour-blindness;* it is in most cases connected with a specially acute sensitiveness towards brightness, so that the defect is partially remedied. The human eye is not sensitive towards all rays, those lying beyond the red at one end and the violet at the other end of the spectrum are invisible to it.

The apparent size of an object depends on the size of the retinal image, and this again on the *visual angle.* By visual angle is meant the angle formed by two imaginary lines drawn from the focus of the lens to the furthest limits of an object. All objects seen within the same visual angle appear of the same size. Experience, comparison with objects of known size, observation of distances, inform us of their actual size. At too small a visual angle, objects either too minute or too far off are no longer distinguishable. This is the case when the visual angle is less than about 1°. Artificial aids can enlarge it. In the case of minute objects this is done by the microscope; in that of distant objects by the telescope.

Impressions of size, amongst other phenomena, assist the judgment in estimating the distance of an object. An important influence is exercised by the degree of accommodation; for the effort in accommodating the eye is the greater the nearer the object.

The estimation of length and distance is an activity of the muscular sense; while we let our eye pass over the length to be estimated, the amount of muscular exertion necessary gives the notion of the magnitude in question.

The duration of a light-stimulus need only be very short to produce a sensation of light; thus the electric spark, lasting not quite $\frac{1}{1000000}$ of a second, gives the sensation of a flash of light.

Very strong impressions of light, and therefore impressions of great brightness, produce peculiar contrast effects, called *after-images*. A glance at the sun produces the appearance of an image of the sun, lasting about a minute and continually changing its colour. A long and steady gaze at the bright sky through a window produces an after-image, in which the dark window-frame appears light, and the bright sky dark.

To the phenomenon of after-images are due many optical effects and illusions. Thus a stick, whose end is glowing, gives, when rapidly flourished, the appearance of lines of light; telegraph-wires seen from the window of a rapidly moving train appear to rise up and down in wave-like motion; the kinematoscope owes its effect also to after-images. Another optical illusion consists in the fact that light objects on a dark ground look larger, dark objects on a light ground look smaller than they really are. A material striped or checked in equal proportions of black and white looks light.

Vision is exposed to many illusions, especially when the attention is relaxed or the nervous system fatigued. When the clouds are passing quickly along the sky, the moon appears to move while the clouds are still. On looking down from a bridge into running water, one often feels—especially if any objects are floating on the water—as if the bridge were moving rapidly. After steadily watching the water of a cascade, the rocks over which it leaps appear to rise and recede.

In other ways also the eye—especially in the case of strong contrasts—is subject to many kinds of illusions respecting shape, direction, colour, and size.

2. ***Hearing.***—The organ of hearing consists of three parts, called respectively the outer, the middle, and the inner ear.

The outer ear consists of the "ear," or *concha*, and the

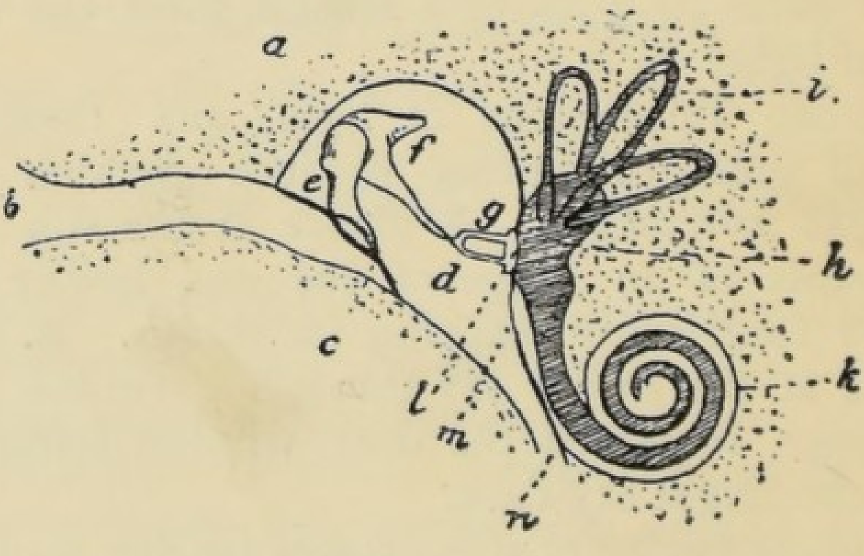

FIG. 25.—THE EAR (DIAGRAMMATIC). *a*, temporal bone; *b*, external auditory canal; *c*, tympanic membrane; *d*, middle ear; *e*, malleus (hammer) bone; *f*, incus (anvil); *g*, stapes (stirrup); *h*, vestibule; *i*, semicircular canals; *k*, cochlea; *l*, fenestra ovalis; *m*, fenestra rotunda; *n*, Eustachian tube.

external auditory canal. The concha is a thin, irregularly curved cartilage covered with skin. It serves as an elastic cup for the reception of sound. The external auditory canal (Fig. 25, *b*) is a tube about 2·5 cms. long and 5·1 mms. wide, situated within the temporal bone. On its outer side its walls are formed by cartilage continuous with that of the "ear," further inward by bone covered with membrane.

The *tympanic membrane* (Fig. 25, *c*), which closes the inner end of the external auditory canal, is a somewhat tense, almost circular membrane, attached at its edges to the bony wall. It stands obliquely to the axis of the canal, sloping downwards and backwards.

The *tympanic cavity*, or middle ear (Fig. 25, *d*), is an irregular hollow space in the temporal bone. From it a narrow funnel-shaped tube, the *Eustachian tube* (Fig. 25, *n*), runs forwards, inwards, and downwards, to open into the pharynx, thus admitting of the entrance of air from the mouth to the cavity of the middle ear.

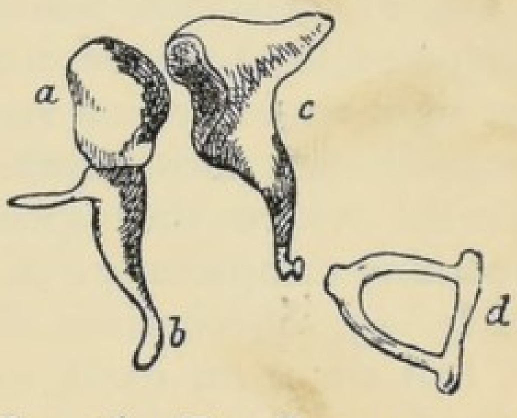

FIG. 26.—THE BONES OF THE EAR. *a*, malleus; *b*, process of the malleus, which attaches it to the tympanic membrane; *c*, incus; *d*, stapes.

Stretching across the tympanic cavity are the three small bones of the ear (Fig. 25, *e*, *f*, *g*, and Fig. 26), the *malleus*, *incus*, and *stapes*. The hammer (or malleus, Figs. 25 *c*, 26 *a*, *b*) is attached vertically to the tympanic membrane by a long, slender, handle-like process, and fixed by another process to the bony wall of the middle ear. The head of the malleus has a cartilaginous surface, to which the thicker part of the incus, or anvil (Figs. 25 *f*, 26 *c*), is articulated. The other, thin end of the incus articulates with a stirrup-shaped bone, the stapes (Figs. 25 *g*, 26 *d*). The face of the stapes rests against an oval membrane, the *fenestra ovalis* (Fig. 25, *l*), which closes an opening in the bony wall of the middle ear.

The *internal ear* (Fig. 25, *h*, *i*, *k*) consists of a membranous sac of very complicated shape and structure, lying, for the most part loosely, in a cavity of the temporal bone. This bony cavity, to the walls of which the membranous bag is here and there attached, contains a fluid, the *perilymph*, and is completely closed, except at two places, where openings in the bone would put it in free communication with the middle ear, were it not for the fact that over each a membrane stretches: of these membrane-covered spaces, one, against which the stapes rests, is oval, the *fenestra ovalis* (Fig. 25, *l*), the other, the *fenestra rotunda* (Fig. 25, *m*), is round. The sac of the inner ear consists of the *membranous labyrinth* and the *cochlea*. The former is an irregular compartment, the *vestibule* (Fig. 25, *h*), bearing the *semicircular canals* (Fig. 25, *i*), which branch from it laterally, and which are disposed in the three dimensions of space—two vertically, at right angles to one another, and one horizontally. The semicircular canals form three swellings, *ampullæ*, at the points where they spring from the vestibule. The remaining compartment of the membranous bag, the cochlea (Fig. 25, *k*), consists of a tapering tube coiled two and a half times on itself, so that it comes to have somewhat the shape of a snail's shell. It is about 3 mms. in diameter where it leaves the vestibule, but narrows down to a blind point. The cochlea is attached on its outer side to the bony wall of the cavity in which it lies, and is also attached on its inner side to a spiral ledge of bone, the *lamina spiralis*, jutting out into the cavity, which is thus divided throughout almost its whole length into an upper and lower chamber. The chambers are separated throughout their length by the cochlea, except at the apex of the spiral, to which the cochlea does not quite reach. The upper of these two chambers is continuous with that of the bony labyrinth, or cavity in which the membranous labyrinth lies. The lower is closed below by the fenestra rotunda (Fig. 25, *m*). Both, in common with the bony labyrinth, contain perilymph.

The ears are supplied by the *auditory nerves*, the eighth pair of cranial nerves. The auditory nerve of either side passes through a canal in the temporal bone, and divides into branches, which pass to the membranous labyrinth and to the cochlea. In the former, the nerve-fibres make connections with patches of auditory epithelium, whose cells bear hair-like processes—*auditory hairs.* The *auditory epithelium* occurs in patches on the inner surface of the ampullæ and of the vestibule. The rest of these surfaces is covered by a layer of cubical-celled epithelium. The *cochlear branch* of the auditory nerve passes through the lamina spiralis to the lower wall of the cochlea, all along which, here also in connection with auditory epithelial cells, it is distributed. These auditory hair-bearing cells of the cochlea constitute the *organ of Corti.* They pass gradually into the cubical epithelium, with which the rest of the cochlea is lined.

The nerve, with its ending in the auditory epithelium cells, is the only sensitive part ; all the other parts of the ear, in contact with one another and capable of vibration, serve to conduct or strengthen the sound, producing vibrations.

The sound-waves reaching the ear through the air are caught up by the concha and led into the external auditory canal. There they strike the elastic membrane of the tympanum, and produce in it regular vibrations. The malleus, fixed to this membrane and therefore swinging with it, sets the incus and stapes in motion. The vibrations of the latter communicate themselves to the tense membrane of the fenestra ovalis, which in turn sets up waves in the perilymph contained in the bony cavity of the internal ear. These, breaking on the various parts of the membranous bag, arrive ultimately at the fenestra rotunda, against whose yielding surface they spend themselves. But on their way these vibrations have communicated themselves across the thin membranes of labyrinth and cochlea to the fluid, *endolymph*, which these cavities contain. The vibration of this endolymph stimulates the auditory epithelium of the organ of Corti to set up in the fibres of the auditory nerve impulses which give rise in the brain to the sensation of *sound*.

The bones of the head are capable of conducting sound without employing the conducting apparatus of the ear. Thus the ticking of a watch held between the teeth may be very distinctly heard, though inaudible when held near the ear.

Sensations of sound are either musical notes or noises. Notes result from regular, periodic vibrations of the sound-producing body; noises from irregular, non-periodic vibrations. In a note, the ear perceives the loudness, the pitch, and the *timbre*. The first depends on the amplitude of the vibrations of the sounding body; the second, on the number of vibrations per unit of time; the last, on the number and strength of the accompanying over-tones.

Sensitiveness to the pitch of sound is limited in compass: the deepest tones which can be heard by the human ear are of from sixteen to twenty vibrations per second; the highest, those of about forty thousand vibrations per second; so that the ear has a range of about eleven octaves. The upper limit varies in different individuals; some, for instance, being unable to hear the cry of a bat. The highest notes used in music have about 4800 vibrations per second. The capacity for perceiving high notes can be greatly improved by practice, and also that for perceiving intervals or differences in the pitch of various sounds.

When several notes strike the ear at the same time, their combined sounds are felt either as agreeable (consonance) or as disagreeable (dissonance).

By timbre is understood the specific qualities of the notes produced by different bodies, and so the sensations by means of which we distinguish, for instance, the sounds of the violin, the flute, and the human voice from one another. The perception of timbre, too, requires practice. Under ordinary circumstances, the human ear is best practised in perceiving the timbre of the human voice.

The ear gives us a notion, though often but an uncertain one, of the direction from which a sound comes. Quite as uncertain, because dependent also on outside influences, especially on the loudness of the sound, is the determination of the distance from which a sound comes. For both these reasons the hearing with both ears is important, while for the mere act of hearing the co-operation of both ears is not required.

As the optic nerve can only call forth sensations of light, so the auditory fibres of the eighth nerve can only occasion those of sound. A blow on the ear produces sound-impressions by shock to the auditory nerve. In diseases of the different parts of the ear, all sorts of irregular sound-sensations are produced, as buzzing, ringing in the ears, etc.

As it does with visual images, so the brain refers sound-sensations to the spot outside the body where that which gives rise to the stimulus is situated; but this is only the case when the sound is conducted through the tympanic membrane. If it comes through the bones of the head, the sound seems to proceed from within the head itself.

It remains to mention that the semicircular canals are connected with the preservation of the equilibrium of the body.

3. ***Smell.***—As the ear is an organ accessory to the hearing apparatus, so is the nose to that of smell; the true organ of smell being an *olfactory epithelium*, with its nervous connections, within the nasal cavity.

The root of the nose is formed by the two *nasal bones*, which reach halfway along the whole length of the nose. The rest of the outer wall is formed of several plates of cartilage, which give it the necessary solidity and elasticity. Within the nostrils are the *nasal cavities* (Fig. 20, *e*), large, irregular, and bounded by all the bones of the face except the cheek-bone and lower jaw. The nasal cavities are separated by a median septum, which is formed behind by the vomer and the ethmoid bones, and in front by cartilage. Opening from the outer side of each nasal chamber is a lateral cavity enclosed by the upper jaw-bone. The roof of the mouth forms the floor of the nasal cavities, which open behind into the pharynx. The whole inner surface of each nasal cavity, to which the many folds and convolutions of the three turbinal bones (Fig. 20, *f*) impart a considerable extent, is lined with a mucous membrane. In the lower part of each nasal cavity, extending as far as the first turbinal bone, the mucous membrane is lined by ciliated cells, and is not concerned with smell. In the upper part this layer is replaced by the olfactory epithelium, consisting of two kinds of cells—*rod-cells* and *cylinder-cells*.

The *olfactory nerves*, the first pair of cranial nerves, dividing into many branches, pass through the holes of the cribriform plate of the ethmoid bone, and distribute themselves to the rod-cells of the olfactory epithelium.

None but gaseous bodies can be smelt; solid or fluid bodies, filling the nostrils, produce no olfactory sensations. Gases, moreover, are only smelt when they pass through the nose. When we breathe through the mouth, the sensation of smell immediately ceases, even though the nasal cavities be at the time filled with the odorous gas. Conversely, inhalations repeated in quick succession (sniffling) intensify the sensation. Of course, with any obstruction of the nasal passages, such as occurs in a "cold," the sensations of smell cease. Odorous substances take effect even when diluted to an extraordinary degree. Thus the nose can detect the two-millionth of a milligram of musk. The strength of the sensation depends partly on the quantity of the gas itself, partly on the size of the receptive surface. The extraordinarily acute sense of smell possessed by some animals is, at least in part, explained by the very large surface covered by their olfactory membranes.

It is quite unknown on what property of the odorous substances the sensation of smell depends, and also what are the detailed processes in the act of smelling.

The olfactory organ may be regarded as a sentinel placed at the entrance to the body, though the information which it gives of the nature of the entering gases is very imperfect.

Many poisonous gases, *e.g.* coal-gas which has passed through the soil and so left behind its odoriferous constituents, and also carbon dioxide, though poisonous, are quite without smell. On the other hand, some strong-smelling gases are innocuous. However, numerous dusty particles and many bacteria, intercepted by the moist mucous membrane of the nose, are hindered from passing with the inhaled air to the lungs.

4. ***Taste.***—The organs of the sensation of taste are located in the *mucous membrane* of the tongue and palate.

The main mass of the tongue is muscular. Its muscle-fibres run in the most various directions, so that it possesses an extraordinary mobility. The muscle-fibres have their origin on the *hyoid bone* and lower jaw, and are inserted below the mucous membrane of the tongue itself.

The mucous membrane is smooth on the under side, but roughened on the upper side by various prominences, the *papillæ*. In these are placed special groups of cells, the organs of taste, to which run the nerves of taste, the ninth and sensory part of the fifth cranial nerves.

From the bottom of the mouth springs a fold of its mucous membrane, which is attached to the median line of the tongue on its lower surface, and which prevents the tongue from being drawn too far back or turned completely over.

A necessary condition for tasting is that the substance to be tasted should be a liquid, or soluble in the saliva, and so be brought closely in contact with the taste-organs. Solid bodies which are not dissolved in the saliva do not taste.

Taste-sensations, like those of smell, are of little value in determining whether the substances which call them forth are injurious or no.

It is worth noting that our language has no words at all to accurately designate olfactory sensations, and only four for taste-sensations—"sweet," "sour," "bitter," and "salt." Smell- and taste-sensations often co-operate, and are also often mistaken for one another. Besides this, all sorts of tactile sensations, produced by contact of the substance with the tongue, also play their part. In any case, taste is the most inaccurate of all our senses. Very strong taste-sensations remain active for some time after the removal of the substance which gave rise to them ; or, as it is commonly said, certain substances "leave a taste in the mouth."

The taste-organs are somewhat sluggish in responding to stimuli, a substance put in the mouth takes at least two seconds before calling forth the sensation of taste.

5. **Touch.**—*Touch*, in the common sense of the word, is but one of a number of sensations, some definite, others obscure, which collectively make up the *tactile sense.*

By "general feeling" is understood an indefinite sensation of the state of the body as a whole. Local disturbances of this feeling are called pain, discomfort, etc., which feelings may be called forth by the stimulation of the ending of any sensory nerve of the body. Among these feelings may be classed hunger and thirst, which are associated with the stomach, mouth, and gullet. The muscles, as well as the skin, are well endowed with sensory nerves, and it is by their afferent impulses that muscular sensations and those of muscular fatigue are evoked.

Muscular sense is the name given to the judgments resulting from muscular sensations which enable us to estimate the weight of an object lifted, to gauge rapidly the amount of effort required for the performance of a certain act. Its development is of the highest importance alike to the athlete and the craftsman.

Temperature-sensations.—Sensations of temperature are caused by the stimulation of the skin covering the outside of the body only. A piece of hot food "burns" only on the tongue, not in the gullet or stomach ; in these organs it gives rise to the sensation of pain. In the same way, heat in the interior of the body conveys no temperature-sensation. The different parts of the skin are not equally sensitive to heat ; the most sensitive parts are the face and the tips of the fingers. These can feel differences of temperature as slight as 0·2° C. The sensation of heat is also caused, as in exercise, by an increase of blood running in the blood-vessels of the skin, or of cold by the withdrawal of the blood from the skin to other parts of the body. These sensations do not indicate a change of temperature in the blood, but that the supply of heat by the blood to the skin is augmented or reduced. In the chills of fever the temperature is actually above normal. A temperature over 47° C. produces pain, as does one under − 10° C. if not too long continued. A longer duration of so low a temperature causes the loss of all sensation.

Touch.—The totality of sensations produced by contact and pressure is called touch, whether the will has any share in them or not. The tactile sense is most highly developed in the tip of the tongue, in the finger-tips, and in the lips ; least in the skin of the back. The points of a pair of compasses simultaneously placed on the skin can be felt as two distinct impressions—on the tongue-tip, at 1·1 mm. apart ; on the middle finger, at 2·2 mms. ; on the back, at 30 to 40 mms. When the points are placed closer together, the impression of the two points is felt as a single sensation.

By feeling in the strict sense—that is, the passing of the tactile organs over the body to be examined—we convince ourselves of the shape of an object, the character of its surface, and, in conjunction with muscular and temperature sense, of its size and temperature. The sense of touch is capable of high development, as in the blind.

Certain forms of tactile sensation have sometimes been designated as special senses. Thus the capability of the skin, not only of feeling heat and pressure in themselves, but of indicating the place where this happens, is called the local sense, or sense of space. By sense of pressure we understand the sensitiveness of the skin to the degree of weight resting on any given spot. This is not to be confounded with the muscular sense, which is generally, however, called in as an aid to the judgment, the object being to this end lifted up and down.

IV. Metabolism

The activities of the body are accompanied by destruction of its substance. New supplies have to make good this loss, and also to provide for growth. The raw material whence these supplies are derived is called the food. The conversion of this raw material into substances which can be taken up by the living cells is termed the process of nutrition. Nutrition, in its widest sense, includes the digestive processes which go on in the alimentary canal; the distribution of the products of digestion by the blood; the further work of distribution carried on by means of the lymphatic system, whereby the requisite substances are brought to the individual cells; and finally the absorption of the substances by the cells, and their subsequent building-up by the living substance (protoplasm) into fresh protoplasm. The destruction above referred to is the outcome of respiration, and consists ultimately in the decomposition of protoplasm. This decomposition is associated with the presence of oxygen in the cells, brought thither from the lungs by the blood and lymph streams. The products of this decomposition leave the cells by the same streams, and ultimately pass out from the body in expired air, in urine, and in small part in perspiration. The complete and complicated series of changes, whereby new protoplasm is constructed from the raw materials, and whereby this living substance is decomposed, is conveniently termed *metabolism*.

The process of digestion is mainly one of solution. The solid constituents of the food-substances are acted on by various juices—salivary, gastric, pancreatic, and other. As the result of this action, certain of these substances are chemically changed and rendered soluble. The unchanged part of the food is voided, the dissolved parts absorbed.

(*a*) ***The Circulation of the Blood.*** 1. ***The Blood.***—The blood is a deep-red fluid, slightly heavier than water (sp. gr. 1·06). It consists of a liquid, the *plasma*, in which are suspended a vast number of minute living particles, the *blood-corpuscles*.

At death, or on removal from the body, the blood coagulates, and then consists of a solid cake or clot, and of a pale straw-coloured fluid, the *serum*. In the process of coagulation a proteid (a nitrogen-containing substance), *fibrinogen*, dissolved in the plasma, becomes converted into a solid body, *fibrin*. Fibrin consists of stringy threads, which, settling down, carry with them the blood-corpuscles. These, with the fibrin filaments, form the clot. The plasma consists of water holding a large number of substances, proteids, salts, etc., in solution. The serum is the plasma deprived of its fibrinogen.

The minute particles suspended in the plasma of the blood are the red corpuscles and white blood-cells, or *leucocytes*. The red blood-corpuscles are biconcave discs of 0·008 mm. diameter, and 0·002 mm. thickness. So numerous are the red corpuscles that a cubic millimetre of blood contains about five millions. They are soft and elastic, so that they can on occasion be drawn out, pass through passages narrower than themselves, and subsequently regain their shape.

The red corpuscles act as intermediaries between the air and the cells of the body, or rather the lymph surrounding those cells. To the lymph they carry the oxygen which they take up on their passage through the capillaries of the lungs. It is to a complex fluid substance, the *hæmoglobin*, held in its spongy matrix that the red corpuscle owes its power as an oxygen-carrier. The hæmoglobin holds the oxygen in loose chemical combination, parting readily with it in the presence of bodies having a stronger affinity for oxygen.

The colour of the blood depends on the amount of oxygen held by the hæmoglobin. When little or none is contained in the red corpuscles, the blood is dark red, *venous;* when they are charged with hæmoglobin, the blood becomes bright red, *arterial.*

The white blood-cells are somewhat smaller and much less numerous than the red corpuscles. Their outline is irregular and variable; their consistency jelly-like, though denser in the central part (the nucleus). Like all other living cells, animal or vegetable, they consist of the complex substance protoplasm, which has been well called "the physical basis of life." The leucocyte moves by thrusting out arm-like processes, into which the semi-fluid remainder of its body flows. Hence the irregularity and variability of its shape. Such movements, which are also characteristic of certain single-celled animals, *amœbæ*, are termed amœboid movements. In a greater degree even than the red corpuscles, the white cells can wriggle through very narrow passages; for instance, they pass, upon occasion, between the cells of the capillary wall into the surrounding spaces. It is known that leucocytes are not all of the same pattern, and believed that those of different forms are associated with the performance of different functions. Leucocytes play a part in effecting the conversion of fibrinogen to fibrin in the clotting of blood, though this is done at the expense of their lives. Other forms of leucocytes, *phagocytes*, play in all probability an important part in destroying bacteria which have gained access to the body, and thus in safeguarding the health. Both red and white corpuscles are continually wearing out, passing out of circulation, and being replaced by newly minted corpuscles. The red corpuscles are manufactured chiefly in the red marrow of the long bones; the white cells, in the lymphatic glands. Both forms—like, indeed, all other cells—arise by the division of pre-existing cells. The later stages of the disintegration of the red corpuscles are effected in the spleen and liver.

2. ***The Heart.***—The *heart* is a muscular pump, whose incessant strokes, called beats, keep the blood continually circulating. Its shape is roughly that of an inverted cone of about 15 cms. in height, 11 cms. in breadth, and 9 cms. in depth from front to back. It lies near the middle of the thorax, with the apex to the left and with its longitudinal axis inclined forward. A delicate membrane, the *pericardium*, encloses the heart in a double layer—one closely investing it, the other loosely. Between the two is the pericardial fluid. The muscular tissue which forms the walls of the heart consists of prismatic striated cells, connected together by short arms and by a cementing substance. A longitudinal septum, stretching from front to back, divides the heart-cavity into two. Each of these halves is again divided by a transverse partition, and the four chambers thus formed are called the right and left *ventricles* (below) (Fig. 27, *a*, *b*), and the right and left *auricles* (above) (Fig. 27, *c*, *d*).

A shallow groove on the outer surface denotes the position of the septum; a deeper grove running round the heart transversely marks the limit between the auricles and the ventricles. The septum completely separates the right and left halves from one another; but openings, one in each of the transverse partitions, put the right and left auricles in communication with the corresponding ventricles. Other openings, those leading into veins or arteries, occur in the walls of all four chambers.

The auricles, when empty, are somewhat smaller than the ventricles; but being more extensible, have about the same capacity.

The wall of the left ventricle is considerably thicker than that of the right, the work done by it being greater. Similarly and for the same reason, the wall of the right ventricle is thicker than that of either auricle. The muscle lining the chambers is not smooth, but forms projecting networks and columns of fibres.

The openings between the upper and lower chambers of

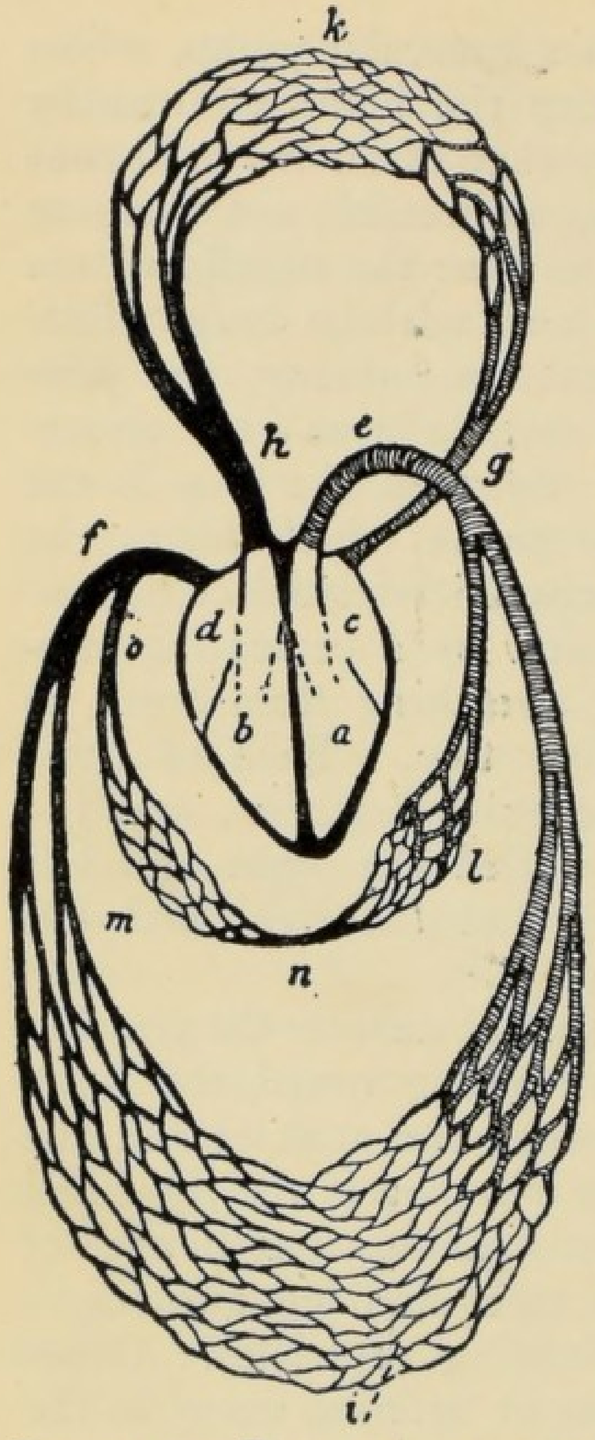

FIG. 27. — DIAGRAM SHOWING THE COURSE OF THE CIRCULATION OF THE BLOOD. *a*, left ventricle; *b*, right ventricle; *c*, left auricle; *d*, right auricle; *e*, aorta; *f*, venæ cavæ; *g*, pulmonary veins; *h*, pulmonary artery; *i*, capillaries in the systemic circulation; *k*, capillaries of the lung; *l*, arterial branches supplying intestine, etc.; *m*, capillaries of the liver; *n*, portal vein; *o*, hepatic vein.

either side are guarded by *valves*, consisting of triangular folds of tough membrane attached by their bases to the walls of the transverse septa. The valve on the right side, the *tricuspid*, consists of three, that on the left, the *mitral*, of two such flaps. From the apices of these triangular folds, which hang downwards into the ventricles, cords pass to stout columns of muscles, the *papillary muscles*, jutting out from the walls. When the ventricles are filled with blood, the flaps float up, and, meeting, completely close the openings about which they are set. Contraction of the ventricles only confirms this closure by driving the edges of the folds closer together; their ascent into the auricles is prevented by their tendinous cords, which, by the contraction of the papillary muscles, are rendered tense enough to resist the upward pressure of the blood in the contracting ventricles. Thus in this state the ventricles only communicate with the vessels opening into them.

The vessels which lead from the ventricles, the *pulmonary artery* from the right, the *aorta* from the left, are stout tubes, also provided, near their origin, with valves, the *semi-lunar valves*.

Each semi-lunar valve consists of three membranous folds. Each fold forms a pouch, which is open on the side away from the ventricle, and whose wall meets that of the other two folds. These valves offer no obstruction to the passage of blood from the ventricle ; but blood tending to pass back fills the pouches and drives their edges hard up against one another. Hence the valves automatically and effectually prevent the reflux of blood to the ventricle.

Though the septum completely cuts off the right from the left side of the heart, yet in a roundabout way all its chambers are connected. Thus the *aorta* leads from the left ventricle to nearly all parts of the body, and ultimately communicates with great veins, the *venæ cavæ*, which open into the right auricle. Again, from the right ventricle the *pulmonary artery* runs to the lungs, there branches into small arteries and capillary networks, ramifies and connects with veins which are gathered up into the four *pulmonary veins* opening into the left auricle. So, to arrive at its point of departure, blood has to make two circular tours—one through the body generally, the *systemic* circulation ; the other through the lungs, the *pulmonary circulation*.

The complete beat of the heart consists of the following phases. First the two auricles filled with blood, as well as the bases of the great vessels opening into them, contract, and so drive the blood into the empty and relaxed ventricles ; and then the auricles themselves relax. Thus filled, the ventricles contract, so that the blood is driven into the aorta and pulmonary arteries. Thereupon the ventricles relax, and the auricles, filled in the mean time with blood, once again contract and pass it on to the ventricles ; and so the cardiac cycle continues unceasingly.

The frequency of the beats of the heart varies. In the new-born child there are about 130 beats per minute : the rate diminishes up to the thirtieth year to about 72, and rises again somewhat in old age.

The amount of blood pumped from the heart in one beat is from 150 to 190 c.cms.

The work done by the whole heart in 24 hours is reckoned at about 75,000 kilogrammetres, equal to the work done in raising 75,000 kilogs. one metre—about a quarter of the average work done by a workman in 8 hours. This work is one of the sources of warmth for the body, as the whole of it is converted into heat by the friction of the blood against the sides of the vessels.

The movements of the heart are accelerated by muscular activity, by heat, by various emotions, and by painful sensations.

3. ***The Blood-vessels.***—The tubes in which the blood flows are called *blood-vessels;* they are of two kinds: one, the *arteries*, the walls of which are stout, elastic, and well provided with muscle; the other, the *veins*, whose walls are thin, collapsable, and possessed of but little muscular tissue. The arteries (Fig. 27, *e*, *h*) in their courses branch continually, becoming thinner-walled and smaller, and ultimately pass into the *capillaries*, which are tubes of extreme minuteness, little wider, indeed, than the red corpuscles, and whose walls consist of nothing but a film made up of a single layer of flat cells (Fig. 27, *i*, *k*). The capillaries, running as a branching network through the tissues, are gathered up into veins, which, uniting with their fellows, form the great veins of the body (Fig. 27, *f*). Arteries and veins are but the conducting apparatus, the capillaries are part of the distributing apparatus. In addition to the above differences between arteries and veins, the latter often possess valves, disposed at intervals along their course, pointing away from the capillaries, and so impeding the reflux of blood.

The heart itself is supplied with blood by the two *coronary arteries*, which spring from the aorta just beyond its semi-lunar valve. The *coronary vein*, which gathers up the blood from the capillaries supplied by these arteries, opens into the right auricle.

In addition to this comparatively small vessel, eight others originate or end in the heart.

From the left ventricle starts the *aorta* (Fig. 27, *e*), passing in a great curve backward and downward in front of the vertebral column, and at its curvature giving off the vessels for the head, neck, and arms. On its downward course it gives off branches to the organs of the thorax and abdomen, and, dividing, passes to the legs.

From the right ventricle springs the *pulmonary artery* (Fig. 27, *h*), which soon divides into two branches, one for each lung.

The two venæ cavæ (Fig. 27, *f*) open into the back of the right auricle. Of these, the *superior vena cava* receives blood from the head, neck, and arms; and the *inferior* from the rest of the body.

Lastly, four vessels, the *pulmonary veins*, bring the blood from the lungs to the left auricle, two coming from the right, and two from the left lung.

The blood of the abdominal viscera takes a peculiar course (Fig. 27, *l*, *n*, *m*). It comes from the descending branch of the aorta. From the capillaries of the stomach, intestine, and spleen, it first collects in a stout vessel, the *portal vein* (Fig. 27, *n*), which enters the liver, and there again resolves itself into a capillary network. The liver also receives arterial blood direct from the aorta by the *hepatic artery*. The hepatic vein collects all the blood brought to the liver, and carries it to the inferior vena cava. This course taken by the blood from the abdominal viscera through a second set of capillaries is sometimes referred to as the *portal circulation*.

The circulation is regulated to suit the local and general needs of the body by the central nervous system. This regulation is twofold, the nervous system acting both on the central organ of circulation, the heart, and on the peripheral organs, the small blood-vessels. The former control has already been referred to (p. 28). That of the small blood-vessels is by nervous impulses travelling along the nerves which supply their muscular coats, and which keep the muscle-cells, and so the vessel, in a constant state of contraction—*tonic contraction.*

This condition of tonic contraction, or tone, may be increased by an emphasis or cessation of the nervous impulses—*vaso-motor impulses.*

When the tonic impulses—*constrictor impulses*—increase, the constriction of the blood-vessels also increases, and the resistance to the flow of blood through the region supplied by these vessels becomes greater. Less blood therefore flows in this region, and more in the other regions of the body. When the impulses to a certain set of small blood-vessels cease or fall off, or are replaced by *dilator* impulses, the vessels dilate, and, in consequence, more blood flows through them.

The blood flows in jerks through the arteries ; in the veins its flow is steady. Three mechanical factors co-operate in causing this behaviour—the intermittency of the heart's beat, the elasticity of the artery walls, and the great resistance to the flow offered by the small arteries. If the artery walls were rigid, at each heart-beat, a quantity of blood equal to that thrust into the vessels would pass into the capillaries from the minute arteries like the shot from a gun ; or, if the resistance proved too great, the gun—the heart—would burst. But being elastic, the artery walls stretch at each beat, and so accommodate the blood injected. Their elasticity has a limit ; stretched to their utmost, they recoil with sufficient force to overcome the peripheral resistance, and so they drive blood in a steady stream through the capillaries and on into the veins. At each heart-beat a fresh stretching causes the limit of elasticity to be again reached, and so on ; thus *between* each beat is a wave of recoil along the length of the arterial system. This constitutes the pulse.

The force of the heart-beat being spent in overcoming the peripheral resistance, it is no longer available for driving the blood through the veins. This is effected by gravity in such veins as run downward; by muscular movements in general, the valves preventing any reflux; and by the movements connected with respiration. At each inspiration the cavity of the thorax is increased, and therefore the pressure in it is diminished. This decrease of pressure affects the blood-vessels, but specially the veins, owing to their thinner walls. They dilate, the pressure within them is reduced, and blood, like all other fluids, flows to the region of lower pressure, that is, toward the thoracic region, and so back to the heart.

Except for the hair, nails, outermost layer of the skin, etc., which are bloodless, all parts of the body are supplied with capillaries. Where greatest activity is habitually displayed, for example, in muscle and in glands, the capillary network is richest.

The velocity of the blood is highest where it leaves the heart. It falls off in the small arteries, and becomes extremely slow—little more than 1 mm. per second—in the capillaries. In the veins the flow quickens again, and increases towards the heart; and though it is never so great as that of the blood leaving the heart, the same quantity of blood enters the auricles as leaves the ventricles in a given time, for the rate of flow is determined by the sectional area of the channel:—if the orifice of a garden-hose be partly closed, the water squirts much further.

The united sectional area of the capillaries arising from a small artery is much greater than that of the artery or of the vein into which the capillaries are gathered up. Hence the flow is slowest in the capillaries. For the same reason, the sectional area of the venæ cavæ at the heart being greater than that of the aorta, the rate of flow is slower in the former. It has been estimated that a corpuscle takes about twenty-three seconds to pass over the whole course of circulation.

4. ***The Lymph.***—The *lymph* is the intermediary between the blood of the capillaries and the cells of the body. The cells, bathed by this fluid, which resembles in

composition blood diluted and devoid of red corpuscles, take up from it the substances which they require for their growth and activity. These substances—oxygen, proteid substances, carbo-hydrates, etc.—pass to the lymph through the walls of the capillaries. The lymph-spaces surrounding the cells connect with one another, and with fine tubes not unlike capillaries, the *lymphatic capillaries*, which, uniting with similar vessels, open into the lymphatic vessels.

The *lymphatic vessels* often follow the same courses as the veins, which they resemble in the thinness of their walls and in the possession of valves pointing away from the capillaries.

The lymphatics of the legs and of the abdomen open into a wider vessel, the *receptaculum chyli*, which lies in front of the lumbar vertebræ, and which is continued upward through the thorax as the narrower *thoracic duct*. The thoracic duct, after receiving branches from the thorax, the left side of the head, and left arm, opens by an entrance guarded by a valve into the junction of the veins of the neck (*jugular*) and arm (*subclavian*), and so its contents pass into the superior vena cava. On the right side a similar smaller vessel discharges its lymph, received from the lymphatics of that side, into the right jugular vein. Into the *receptaculum chyli* there flows, during digestion, a fluid, *chyle*, which contains especially the fatty products of digestion. The movements of the lymph are attributable to the same causes as those of the veins. On their courses the lymphatic vessels often bear nodules of wide-meshed connective tissue, *the lymphatic glands*, into which they send fine branches. In the meshes of the glands great numbers of young and actively dividing leucocytes occur. These afford fresh supplies of white blood-cells.

The total quantity of lymph in the body is greater than that of the blood. Like the latter, it clots on removal from the body.

(*b*) ***Respiration.***—The living cells take up nutrient substances from the lymph, change and incorporate them,

—build them up into living protoplasm. They also take up oxygen, and, as a consequence, decomposition-changes are set up in the cells, resulting in the release of energy and the formation of oxidized substances, carbon dioxide, water, etc. The absorption of oxygen by the cells, and the consequent decomposition of their substance, is termed *respiration.* Breathing is but the tool of respiration, the movements of the lungs and of the blood serving only to bring the oxygen of the air to the cells of the body. The air reaches the lungs after passing through the mouth or nose, the pharynx, and the trachea.

The *trachea*, or wind-pipe (Figs. 29 *a*, 30 *f*), is a stout open tube about 12 cms. in length and 20 mms. in width from right to left, 12–15 mms. from back to front. Its walls contain much elastic tissue, strengthened by a series of 18–20 C-shaped loops of cartilage, of which the open parts are behind. Internally the trachea is lined by a mucous membrane. Small particles of dust, etc., entering the trachea tend to stick on the viscid mucus which its membrane secretes, and are swept upward by the unceasing movement of the minute protoplasmic processes, the cilia, which project from the epithelial cells lining the free surface of the mucous membrane. The walls of the trachea, though rigid enough to keep it open, are sufficiently elastic to allow of its dilatation on strong pressure being exerted from within, as in coughing ; and of its stretching a little, as in speaking or during certain movements of the head.

The *lungs* (Fig. 28, *d*) consist of two almost equal, bluntly conical halves, which enclose the heart between them, and together with it fill the whole cavity of the thorax. They are pale red in colour, very soft and light, and extremely elastic. Each lung is enclosed in a tight-fitting membranous sac. At the root of each, that is, at the point of entry of the branch from the trachea into the lungs, this membrane passes over, as the *pleura*, to form the lining of the chest-wall. Within, the lungs show a spongy structure and a great abundance of blood-vessels. In spite of their large size, the weight of the lungs is not over 1·25 kilog. The lungs follow the curvature of the chest-wall so closely that no space, and so no air, exists between the pleural membrane of the lung and that of the chest-wall. The lower surface of the lungs is concave and lies closely against the diaphragm ; the inner surface turned towards the heart is also concave. Each branch of the trachea divides, as it enters the lungs, into two or three tubes. These again divide and subdivide till their finest ramifications have a diameter of about 0·2 or 0·3 mm. The larger branches are provided with cartilaginous loops. In the smaller, the loops are replaced by plates of cartilage, and in the still smaller they disappear altogether. Finally, the walls of the tubes consist of little more than a single layer of flat cells, and the tubes end each in a minute swelling, the *infundibulum*. Externally, an infundibulum resembles a minute bunch of grapes. Viewed on its inner side, it is seen that partitions of the wall project some distance into the cavity, which is thus subdivided into a number of chambers, the *alveoli*, all, however, opening into the common chamber. Over the walls of the alveoli close networks of capillaries run.

The whole lung consists of infundibuli, tubes leading therefrom, blood-vessels and nerves running to and from them, and connective tissue binding all together. It has been estimated that the number of the infundibuli is from 1600 to 1800 millions ; their walls, if opened out flat, would cover an area of from 120 to 140 square metres, or, to put it in another way, those of thirty-six lungs would cover about an acre. The interior of the lungs has thus a very big superficial area, over which the air is brought very close to the blood, being only separated from it by the filmy walls of the infundibuli and of the capillaries across which gaseous exchange takes place with the utmost readiness.

Breathing consists of the alternate and opposite processes of *inspiration* and *expiration*. In the former, air passes into the lungs; in the latter, it passes out. The air in the infundibuli is only indirectly affected by these processes, which admit and expel air from the trachea and upper branches of the bronchi. It is by diffusion between this air and that of the infundibuli that fresh oxygen comes to the alveoli, and the carbon dioxide, which has passed from the blood into the alveoli, is got rid of.

In inspiration, the depth and breadth of the thorax, and hence its capacity, are increased. Increase in depth is due to the muscular contraction and consequent flattening of the diaphragm. Increase in breadth from side to side and from back to front is effected by muscles, the *external intercostals*, stretching from each rib downwards and forwards to the next below, and whose contraction hauls up the ribs and attached sternum, which is in consequence thrust forwards.

Now, we have seen that the surface of the lungs is close against that of the thorax, hence the elastic lung follows the movement of the chest-wall; for to resist it would be to resist the pressure of the atmosphere acting on its walls from within.

The cavity of the lungs increases then step by step with that of the thorax, and air rushes in. If the chest-wall be punctured, so that air enters between the layers of the pleura, the lung collapses and inspiration ceases. The movement of the inspiratory muscles has now for its only effect the drawing of air into the chest-cavity, and that of expiration its expulsion.

Expiration is, in ordinary breathing, due to the relaxation of the muscles of inspiration. These relaxing, the chest-cavity returns to its former dimensions, constraining the lungs to do likewise, and air is expelled from them.

In both inspiration and expiration the movements of the lungs themselves are passive. In laboured breathing many other muscles come into play, till, indeed, if the difficulties of obtaining fresh air are much increased, as in poisoning by certain gases, every muscle of the body may take part convulsively.

In drawing a deep breath, about 3500 c.mms. of air pass into the lungs. In even the deepest expiration they are not quite emptied, about 1600 to 1500 c.mms. of air always remaining in them. The sum of these numbers, about 5000 c.mms., gives the cubic contents of the lungs. In quiet breathing a volume of air equal to about a quarter of the contents of the lungs passes in and out. The number of respirations is about 14 to 17 per minute. The respiratory movements take place, as a rule, without the co-operation of the subject, but are not so involuntary but that a person can cease breathing for a short time, or breathe faster or slower. Heavy muscular exertion and emotional excitement accelerate the respiratory movements.

In the cavities of the mouth and nose the air is warmed and partially cleaned from dust, which adheres to their moist surfaces.

The blood flowing through the capillaries which run in the walls of the alveoli of the lungs, has just previously made the circuit of the body, and has returned through the right auricle as dark-red venous blood, devoid of oxygen, but rich in carbon dioxide. Passing into the right ventricle, it is carried to the lungs by the pulmonary artery. Flowing through the capillaries of the lungs, its carbon dioxide is given up, and the hæmoglobin of the red corpuscles takes up oxygen, so that this blood, when it passes by the pulmonary veins to the left auricle, is bright-red arterial blood, prepared again to carry on the work of oxygen-distribution and carbon dioxide-collection.

The extent of this gaseous exchange between blood and air is best gauged by comparing the compositions of ordinary and of expired air. Atmospheric air consists, in 10,000 parts by volume, apart from a very variable quantity of aqueous vapour, of—

7901	parts	nitrogen	per 10,000.
2095	,,	oxygen	,,
4	,,	carbonic acid	,,

Expired air is warmer than inspired air, and is saturated with aqueous vapour. Its composition is—

7942	parts	nitrogen	per 10,000.
1620	"	oxygen	"
438	"	carbonic acid	"

Of the oxygen contained in the inspired air, the lungs retain one-fifth and give off a rather less quantity of carbon dioxide. In the course of a day a total quantity of from 700 to 750 grams (= nearly 2½ ozs.) of oxygen gets into the body, while 850 to 900 grams of carbon dioxide, which has a specific gravity greater than oxygen, leave it. The amount of water given off by the body in repose varies considerably on either side of 2700 grams per day, of which some 300 grams (about half a pint) are given off from the lungs.

The rate of breathing is subject to continual fluctuations. The time of day and the season of the year, weather, occupation, state of mind, the emotions, all exercise either an accelerating or a restraining influence on it. Muscular effort, more especially, enormously increases the output of carbon dioxide, doubling or even trebling it.

The quantity of carbon dioxide breathed out provides a means of roughly estimating the expenditure of energy by the body, both in muscular work and in the vital activities (growth, etc.). It is thus computed that the energy daily required by the body to carry on its work is about double that expended by a labourer in an eight-hours' day.

After what has been said of the *rôle* of oxygen in the body, it is perhaps needless to add that it is one of the elements essential to the life of all animals.

(*c*) ***Nutrition.***—The term "nutrition" is here used to indicate only the *constructive* changes whereby new material is prepared, new grist brought to the mill of life.

This new material is the food; but before it can be utilized, it has to be subjected to the action of the secretions of the alimentary canal, and of the glands which open into the canal. The *alimentary canal* is a tube of variable width and shape, passing through the head, neck, and trunk. It serves for the reception, digestion, and absorption of food. The successive parts of the alimentary canal are the mouth - cavity, œsophagus, stomach, and intestines (Fig. 28).

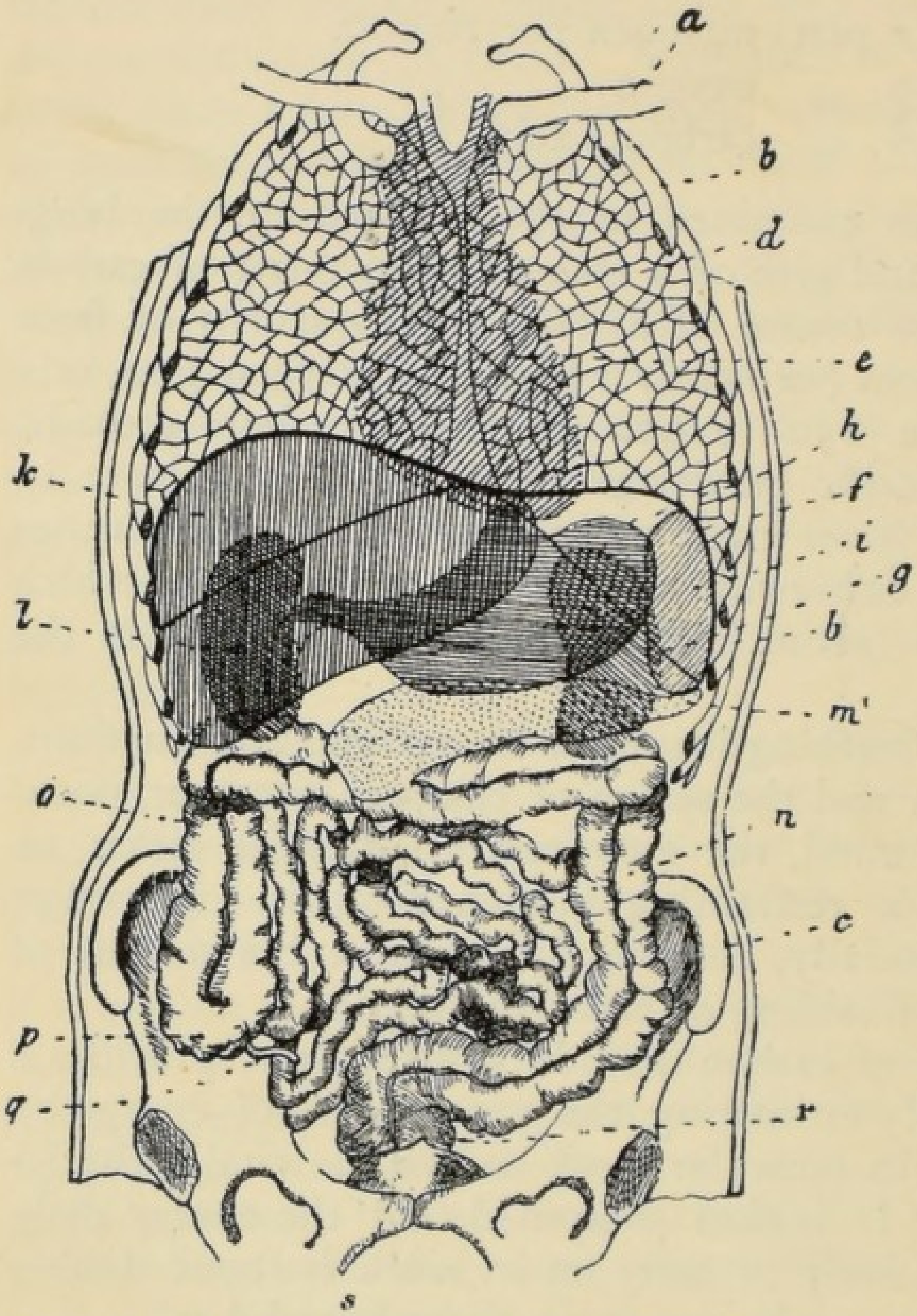

Fig. 28.—Diagrammatic View of the Principal Organs of the Thorax and Abdomen. *a*, clavicle ; *b*, ribs ; *c*, pelvis, *d*, lungs ; *e*, heart ; *f*, position of the diaphragm in extreme expiration ; *g*, ditto in extreme inspiration ; *h*, stomach ; *i*, spleen ; *k*, liver ; *l*, kidney ; *m*, pancreas ; *n*, small intestine ; *o*, large intestine ; *p*, cæcum ; *q*, vermiform appendix ; *r*, rectum ; *s*, bladder.

The *mouth-cavity* is a hollow space between the palate and the lower jaw, containing the tongue and lined with a mucous membrane. The mucous membrane begins at the edge of the lips, and, as the gums, covers the two free edges of the jaws, and also lines the inner side of the cheeks and the palate, behind which it hangs down as the *velum* or *soft palate* (Fig. 30, *e*). The central part of the soft palate, the *uvula*, is a conically rounded fold of skin hanging vertically. From each of its lateral edges two folds of skin, the *pillars of the fauces*, descend on either side. The two front pillars adjoin the edges of the tongue; the two hinder ones, the back of the pharynx. Between the two, embedded in the foundation of the posterior fauces, lie two glands of the size of hazel-nuts, the *tonsils*.

In breathing through the nose the velum lays itself close against the back of the tongue, so making a free passage between nasal cavities and pharynx. In breathing through the mouth and in swallowing, the lower edge of the velum is pressed tightly against the back of the pharynx, and so closes the entrance to the nasal cavity.

The food in the mouth is crushed and torn by the teeth and moistened by the saliva. But beside being mechanically changed, the soluble substances are dissolved and the starchy bodies chemically acted upon by the saliva.

The *saliva* is manufactured by three pairs of glands, the *salivary glands*. One pair lying below the ears is termed the *parotid*; another, under the tongue, the *sub-lingual*; and a third, on the inner side of the lower jaw, the *sub-maxillary*. The salivary glands open into the mouth by ducts, and, when stimulated by the presence of food in the mouth or in other ways—as, for example, the thought of food, making "the mouth water"—they discharge the watery, slightly alkaline saliva into the mouth. The saliva contains a substance, *ptyalin*, which is capable of converting starch into sugar.

The food, more or less finely divided and moistened, is rolled into balls by the sides of the mouth and tongue, and, poised on the tip of the latter, is carried backwards into the pharynx, the muscular-walled cavity behind the velum (Fig. 30). Thence it is passed on to the œsophagus which opens from the pharynx behind, and in front of which lies the trachea.

The *œsophagus* (Fig. 30, *g*) is a straight, extensible tube, passing somewhat obliquely to the left downwards, and perforating the diaphragm not far from the vertebral column.

Its sides, which in repose are folded, are lined with mucous membrane resting on layers of connective and muscular tissue. The muscle of the œsophagus is partly striated and partly unstriated, and is arranged in two layers, one disposed circularly, the other longitudinally. Where the œsophagus passes below into the stomach, the circular layer of muscle is more plentiful and forms a weak *sphincter muscle*, which, whilst digestion is going on in the stomach, constricts the opening.

All the abdominal viscera with their glands are enclosed in a membrane, the *peritoneum*, which, beside covering them, lines the whole cavity of the abdomen and pelvis, and fits itself in many folds between the separate parts.

The *stomach* is a pear-shaped sac, about 35 cms. in length, lying across the left half of the body, immediately under the diaphragm ; the wider end to the left, the narrower to the right, but still somewhat to the left of the median line. The opening of the stomach into the intestine is called the *pylorus*. Here, as at the entrance from the œsophagus, the circular muscle is thickened to form a sphincter. The cubic capacity of the stomach varies within wide limits from 2·5 to 5·5 litres.

The details of structure of the different parts of the alimentary canal vary, but, in all, its walls are vascular, and consist of a layer of connective tissue outside, intermediate layers of unstriped muscle, and an inner coat of mucous membrane, made up of a layer of epithelial cells lining the internal surface of the canal and resting on connective tissue.

The glands with which the mucous membrane is generally beset, and which in different parts receive different names, consist of epithelial cells lining tubular depressions in the mucous coat. The glandular epithelium, though continuous with that lining the rest of that coat, differs from the latter in form and function. The various secretions poured into the alimentary canal by the glands in the walls are manufactured from the blood richly supplied to them. The salivary gland is of a similar nature to those simple glands, but is compound, that is to say, much-branched.

It shows a further difference in that the ends of the branches are swollen not unlike the infundibuli of the lungs. The epithelium of the salivary alveoli, however, instead of becoming thin and plate-like, consists of large more or less cylindrical cells; that lining the conducting part consists of more cubical cells. It is by the activity of these larger, more or less cylindrical, cells that the saliva is produced.

The mucous membrane of the empty stomach is thrown into folds, the *rugæ;* when the stomach is distended the rugæ disappear. The mucous membrane of the small intestine bears permanent folds, which are beset with finger-like processes. These finger-like folds, the *villi*, are richly supplied with blood-vessels, and in them the *lacteals*, which communicate with the lymphatic vessels running to the receptaculum chyli, have their origin.

The small intestine (Fig. 28, *n*) is about 34 cms. in diameter, and 4 to 5 metres in length. It is attached to the vertebral column by a strong fold of the peritoneum, the *mesentery*. In the depressions between the villi, tube-like infoldings (*glands of Lieberkühn*) of the mucous membrane occur.

The *small intestine* opens into the *cæcum* (Fig. 28, *p*) at right angles to the direction of the latter, making with it a sort of T-joint. One limb of the T is short and blind, and bears a tail-like process, the *vermiform appendix* (Fig. 28, *q*). The other, the cœcum, forms the first part of the tube of the large intestine. At the junction of the small intestine with the cœcum, the *ileo-cæcal valve*, a two-lipped fold of the mucous membrane of the large intestine, hinders the passage of substances back into the small intestine. Like the small intestine, the large bears tubular glands which secrete mucus, but which have little or no importance in the process of digestion. The terminal portion of the large intestine is the *rectum* (Fig. 28, *r*), between it and the first part of the cœcum are the ascending colon, the transverse and the descending colon.

Besides the numerous glands situated in the walls of the intestine, there are two large glands lying outside the intestine which open into it—the liver and the pancreas.

The *liver* (Fig. 28, *k*) is a massive gland, of a brown colour and of considerable size, lying to the right of the stomach, immediately under the diaphragm. It is held fast in its place by several folds of the peritoneum and by special ligaments. Its outer surface is convex and lies close against the wall of the abdomen. Its inner surface is slightly concave and, with its anterior upper surface, fits round the intestinal end of the stomach. The greatest thickness, on the right side, is 10 cms. It tapers down in front and below to a sharp edge, which forms the boundary between its inner and outer surfaces. Its weight varies within wide limits on either side an average of 1·5 kilog.

The structure of the liver, though not at first sight evident, is, indeed, fundamentally that of a compound gland. Its duct, the *bile-duct*, opening into the small intestine a short distance from its commencement, discharges during digestion a viscid green secretion, the *bile*. At other times the bile flows through a branch from the bile-duct into the *gall-bladder*. This is a pear-shaped membranous receptacle, about 8 to 10 cms. in length, situated close to the inner surface of the liver.

The quantity of bile secreted by the liver is very variable ; it may be as great as 2400 grs. in 24 hours, but averages 500 to 600 grs.

The other large gland, the *pancreas* (Fig. 28, *m*), is a thin, flat, elongated body, 20 to 25 cms. in length, 4·5 cms. in height, resembling a salivary gland in structure. It lies close to the small intestine, partly across the abdomen, below the stomach. Its secretion, the *pancreatic juice*, flows through the pancreatic duct, which opens into the small intestine near the entrance of the bile-duct.

Digestion in the Stomach and Small Intestine. —During the short time the food remains in the mouth, the ptyalin of the saliva is able to exert but little action on its starchy constituents. On the arrival of the food in the stomach this action is altogether checked, for ptyalin cannot effect the conversion of starch to sugar in an acid medium, and the gastric juice contains 0·2 per cent. of hydrochloric acid. In its course through stomach and small intestine the food is, however, subject to the action of other *enzymes* or *unorganized ferments*, the active principles of the various secretions. These ferments are all alike in existing in minute quantities, and in being able to do a large amount of work ; they differ, however, in the substances which they attack. Enzymes are widely distributed both among animals and among plants ; especially common among the latter are diastatic ferments, which are in their effects quite similar to ptyalin, the enzyme of saliva.

The enzyme of the gastric juice, *pepsin*, has the power to act on proteid substances, such as the white of egg (albumen), fibrin, etc. These it converts into soluble bodies called *peptones* and *albuminoses*. The action of the gastric juice is aided by the powerful movements of the muscular walls of the stomach. After a certain time, from two to four hours, the contents of the stomach are discharged into the small intestine, and there brought in contact with the bile and pancreatic juice. The former has little digestive activity, but by its alkalinity it assists the pancreatic juice in neutralizing the acid from the stomach, and so is of service in enabling the proteid-changing, *proteolytic* ferment, *trypsin*, of the latter, which can only act in an alkaline medium, to continue the work of proteid digestion.

In addition to this ferment, the pancreatic juice also contains a starch-changing, *amylolytic*, ferment, similar to that of saliva, which completes the work begun by ptyalin. Both bile and pancreatic juice act on fats, the former breaking them up, emulsifying them into fine particles ; the latter to some extent decomposing them. The glands of the small intestine also produce ferment-containing secretions, but they are of minor importance.

Whilst these digestive changes have been going on, absorption of the products has already begun. The sugar and peptone pass mainly by the portal vein, the finely divided fat passes as the chyle through the lacteals of the villi, into the lymphatic system. The work of absorption is continued in the large intestine, water especially being taken up, so that the unutilized part of the food becomes harder. In the large intestine, too, it is subject to decompositions by various micro-organisms which habitually live therein, and so it comes to assume the condition of fœces, in which state it is voided.

Man's whole structure, and especially that of the teeth, stomach, and intestines, disposes him to seek his food from the animal and vegetable kingdoms. For sustaining the body the following five substances are required, none of which can be dispensed with for a long period without serious disturbances of health :—

Water, of which the daily requirement is 2700 to 2800 grams ; the greater part of this amount is contained in the food.

Proteids (containing the elements carbon, oxygen, hydrogen, nitrogen, with a little sulphur and phosphorus) are present in animal and vegetable food-stuffs.

Fats.

Carbo-hydrates, which are, like fats, composed of carbon, oxygen, and hydrogen, though in different proportions.

Salts of various kinds.

The amount required at any given time, especially of proteids, fats, and carbo-hydrates, varies according to circumstances. Thus, *e.g.*, an adult requires in twenty-four hours—

	During repose.	Working moderately.	Working hard.
Proteids	70·87 grams	130 grams	155·92 grams
Fats	28·35 „	84 „	90·87 „
Carbo-hydrates ..	340·20 „	404 „	567·50 „

There is no food-stuff, except milk, which contains all these materials in the proportions required by the body. Food-stuffs, therefore, must be mixed. Of the great variety of food-stuffs we may enumerate the most important.

Meat contains water, salts, proteids, gelatin, and fat.

Milk : water, salts, proteids, fat, carbo-hydrates, sugar.

Egg : Proteids, fat, water.

Grain : proteids and starch, with little water.

Peas and beans : the same.

Potatoes : poor in proteid, but rich in starch and water.

Fruit : sugar, salts, organic acids, and much water.

Vegetables (green parts of plants) are also poor in proteids, but contain starch, sugar, and salts.

Besides food, stimulants are of assistance to digestion, the most important being common salt, less so spices, etc.

Of drink, water is by far the most important. Milk is a food. Tea, coffee, alcoholic liquors are stimulants, or merely means of enjoyment.

V. The Excretion of Waste Substances

In addition to the lungs, which are the organ of excretion of the greater part of the carbon dioxide and of a variable quantity of water, the kidneys and the skin are concerned in the process of excretion. By the former the waste substances of proteid metabolism are removed from the body, and by both water and various salts are got rid of.

(*a*) **The Kidneys.**—*The kidneys* (Fig. 28, *l*) are two red-brown, bean-shaped glands, 12 cms. long, 6 cms. broad, and 4 cms. thick. They are placed on either side of and close to the vertebral column, halfway up the abdomen.

Their substance is made up of a great number of narrow tubes, embedded in a small quantity of connective tissue. These tubules have, in their origin toward the outer part (cortex), an irregular looped course, but in the deeper tissues run parallel with one another. They open into one another, and finally discharge their contents into a cavity, the pelvis of the kidney, which occurs at its incurved portion, and which opens outward into the ureter.

The *ureters*, one from each kidney, convey the excretion (urine) to the bladder (Fig. 28, *s*), in which it is temporarily stored. The tubules of the kidney are richly supplied with blood-vessels, and are lined internally in some parts with flat, in others with large cubical or irregular epithelial cells. The regions in which these latter occur are the secretory parts of the tubules. It is by the activity of these cells that the most characteristic nitrogenous constituent of the urine, *urea*, as well as some other substances, are excreted.

The cortical end of each tubule terminates in an enlargement, the *glomerulus*, the cells of which are flat and plate-like. The glomerulus may be likened to a minute bladder, the bottom of which is punched in so that the cavity is almost obliterated, and a cup-like hollow space is formed surrounded by the two layers of the membrane. Into the cup-like space a tangle of blood-capillaries passes. Through the thin wall of the glomerulus water and salts pass from the blood to the tubules: though here, no more than in any other gland, the passage is no mere physical filtration or diffusion, but an active secretory process, that is, one dependent on the vital activity of the living protoplasm contained in the plate-like cells of the glomeruli.

(*b*) **The Skin.**—The *skin* is primarily an organ of protection and a means of regulating the relations between the body and the external world. In it, as we have learned, reside the organs of the sense of touch. In addition to these functions, the skin plays the part of an excretory organ, and in so doing assists in the control of the temperature of the body. The skin forms a connected envelope over the entire body: modified to form mucous membranes, it also lines the walls of the tubes, alimentary canal, trachea, etc., which open to the exterior.

The skin lining the surface of the body consists of two intimately connected layers, of which the outer is called the *epidermis*, or *cuticle;* the inner, the *dermis*, or true skin. The outer layers of the epidermis consist of hard, flat, scale-like, dead cells. Its innermost layers, *Malpighian* layers, consist of living, actively dividing cells. The change from within outward is gradual, for the inner cells, pushed further outward by younger, later-formed cells, change almost imperceptibly into the outer scale-like plates, which are being continually removed at the surface.

The epidermis rests on a vascular layer of variable thickness, the dermis, which is thrown up into ridges or papillæ, into some of which blood-vessels, and into others of which nerves with their nerve-endings project.

The dermis consists of a loose connective tissue, containing elastic fibres, and in its lower parts often much fatty tissue ; the latter is a useful auxiliary in the protection of the underlying parts.

In special regions the skin bears hairs and nails, which, like the epidermis, are produced by the active division of cells of the Malpighian layer.

The hairs consist of a hollow tube of hard dry cells surrounding a shaft of looser cells. They arise from pits, the *hair-follicles*, at the bottom of which are small papillæ, whose cells form the hair. Pigments of various colours occurring in the shaft of the hair give to it its colour ; when partially replaced by air, greyness is produced ; when the pigment wholly disappears, the hair becomes white.

The secretory organs of the skin are the *sweat glands*, and to a lesser degree the *sebaceous glands*. The former are coiled tubes lying in the dermis, and lined by secretory epithelium. They are connected with the exterior by tubular, sinuously running passages in the epidermis, which open on the exterior as the pores of the skin. Their secretion, perspiration, always being formed, is a watery fluid containing small quantities of common salt and of various organic bodies. Special glands, the *sebaceous glands*, open into the hair-follicles, into which they pour a fatty secretion.

The quantity of sweat produced varies inversely with the amount of urine excreted. Any causes tending to dilate the blood-vessels of the skin—nervous states, *e.g.* blushing, hot weather, etc.—bring about an increase in perspiration, and so indirectly a decrease in the amount of urine.

The skin allows, though but slowly, the entrance of some substances, as water, and solutions of salts into the blood ; a process of which advantage is taken in medicinal baths.

VI. The Temperature of the Body

The temperature of the blood of man, as of warm-blooded animals in general, is, within very narrow limits, constant. But there exist, owing to differing thicknesses of the skin, considerable differences of temperature between one part of the body and another. The lowest temperature is registered when the thermometer is put on the sole of the foot (32·3° C.); the highest when placed in the arm-pit (37° C.). Any considerable variation of the temperature of the blood is a dangerous symptom, and indicative of disease. There must therefore, in health, be a balance struck between the gain of heat to the body and the loss of heat from the body. As in all such cases, the nervous system is arbitrator. By keeping a hand on both these processes, it maintains the temperature constant.

The sources of heat to the body are physical and chemical. The energy by which all the work of the body is done is resolved into heat: these constitute the physical sources. The chemical sources lie, as may be inferred from what has been already said, in the oxidation processes due to the interaction between oxygen and the living substances of the cells. Thus, when a muscle contracts, chemical decompositions occur, and the energy resulting makes its appearance sooner or later as heat. But in response to the needs of the body, the central nervous system can stir up similar activities in the liver and other "heat-centres," so that more heat is produced than would have been the case had the organs been merely concerned in their routine work. In face of an emergency, reserves of heat may be called out.

In addition, the skin may be fortified against too great a loss of heat. Vaso-motor nerves supply its blood-vessels, which therefore dilate or contract according to the impulses sent out from the central nervous system. Contraction of the blood-vessels of the skin entails diminished excretion of sweat, reduced evaporation, and consequently curtailed loss of heat.

Of the amount of heat which at any given time is contained in the body, about one-third is used in raising the temperature of foods and drinks and of the air entering the lungs.

We have now traced the processes of nutrition and of excretion, which represent, the one the receipts, the other the working expenses, of the body. When the quantities of food assimilated, and of waste excreted, each calculated in terms of weight of carbon, oxygen, hydrogen, and nitrogen, are equal, the equilibrium of the body is maintained; it neither loses nor gains weight. When the constructive processes are in excess of the destructive, weight is gained. This weight results from an actual increase, a growth of living substance, or from a more or less temporary storage of the excess. The storage may take the form of fat, which can be laid down in almost any cell of the body, but especially in the connective-tissue cells; or again, a form of starch, *glycogen*, may be deposited in the liver and elsewhere, and doled out subsequently to meet the general demand for carbo-hydrate material. Under what form, other than by being incorporated in the living tissue, the excess of proteid is stored, we do not know. It is noteworthy that an excess of proteid given in the food leads at once to a rapid increase in metabolism, and a rise of nitrogenous substances in the excreta. When the loss of substance outweighs the gain, the body wastes. The temporarily stored substances are the first to disappear, later the tissues themselves become impoverished.

In youth, the business of life is carried on at a profit; in middle age, the body remains, generally speaking, in equilibrium, just making both ends meet; in old age, life's business is carried on at a continually increasing loss.

VII. The Larynx

The *larynx* (Fig. 29), the organ of voice, forms the upper end of the trachea. Covered in front by the skin of the neck, it is suspended from the hyoid bone (Fig. 29, *f*), and embedded between the muscles of the neck. Following on the uppermost C-shaped cartilage of the trachea is a complete loop of cartilage, the *cricoid* (Fig. 29, *b*). It is somewhat like a signet-ring in shape, being about twice as high on one side (the back) as on the other.

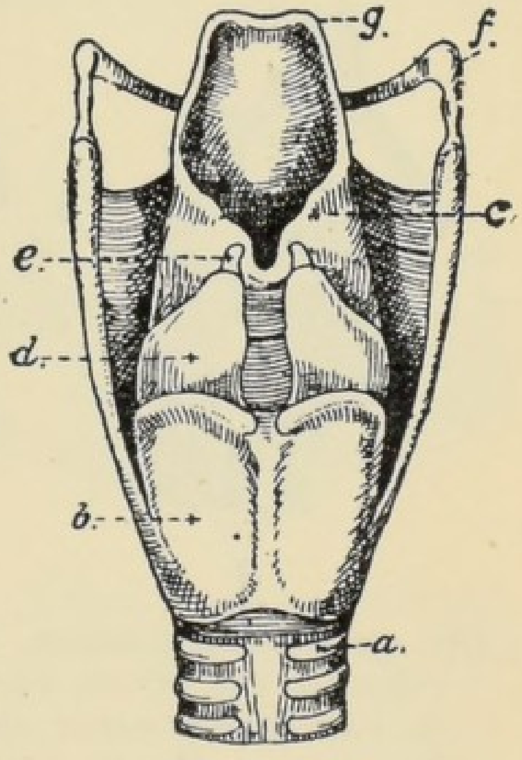

Fig. 29.—The Larynx (seen from behind). *a*, trachea ; *b*, cricoid cartilage ; *c*, thyroid cartilage ; *d*, arytenoid cartilage ; *e*, Santorini's cartilage ; *f*, hyoid bone ; *g*, epiglottis.

Situated above the cricoid cartilage, forming the hard "lump" in the throat, is a wedge-shaped cartilage, the *thyroid* (Fig. 29, *c*). The apex of the wedge is directed forwards, and lies in the median line ; its free edges send out processes above and below. The lower processes articulate with the cricoid, on which, in consequence, the thyroid is movable ; the upper processes are attached to the hyoid bone.

Articulating with the cricoid cartilage at the back are the two *arytenoid* cartilages (Fig. 29, *d*). Each arytenoid is somewhat like a three-sided pyramid in shape, and so disposed that the apex is upwards, and that one surface is plane with the back of the larynx, the other two jut out wedge-wise into its cavity.

The apex of each arytenoid bears a small cartilage, called *Santorini's cartilage* (Fig. 29, *e*).

In the middle of the upper edge of the thyroid rises a long narrow tongue of thin elastic cartilage, the *epiglottis* (Figs. 29 *g*, 30 *h*). In repose it stands nearly vertically upright; but by means of special muscles it can be turned over backwards, so as to close the larynx when food or drink is passing to the œsophagus.

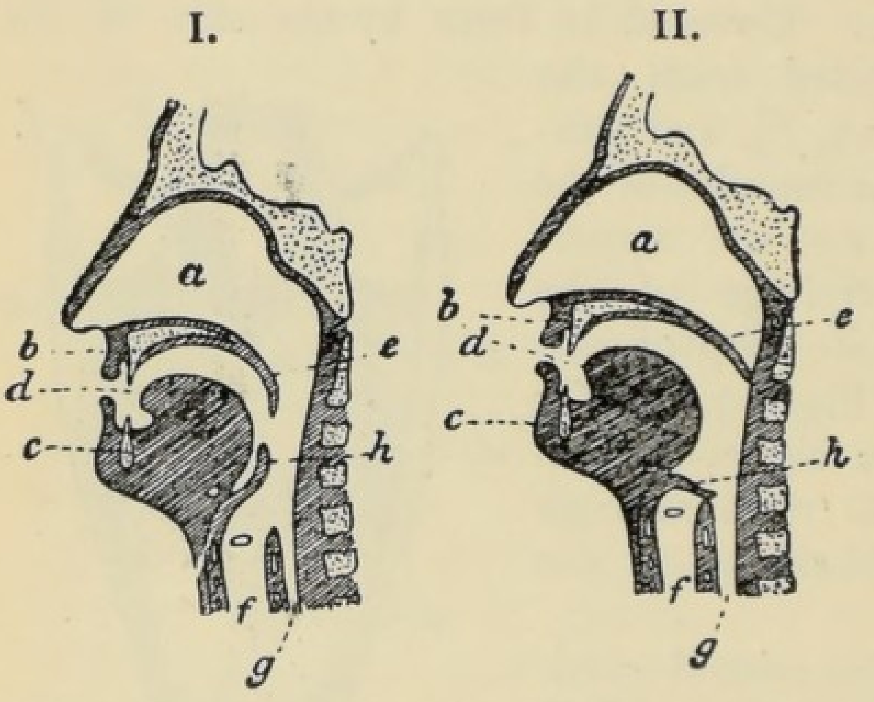

Fig. 30.—Diagrammatic Vertical Section through the Head, showing the Position of the Mouth-parts and Larynx: I., in Breathing; II., in Swallowing. *a*, nasal cavity; *b*, upper jaw; *c*, lower jaw; *d*, tongue; *e*, soft palate and uvula; *f*, larynx leading to trachea; *g*, œsophagus; *h*, epiglottis.

The cartilages of the larynx are fastened to each other, and to the hyoid bone, by ligaments and muscles.

The movements of most importance for the production of the voice are those of the thyroid and arytenoid cartilages. The former can be made to incline forwards on its pivots on the upper edge of the cricoid cartilage, and then flatten itself laterally; each of the arytenoids can be caused, by the contraction of appropriate muscles, to slightly revolve round a vertical axis on the hinder edge of the thyroid cartilage, in such a manner that the inwardly projecting edge of one approaches that of the other.

Two pairs of folds of the mucous membrane, with which it is lined, stretch across the larynx. They originate on the inner side of the thyroid cartilage, near the median line, one pair about halfway up, the other slightly higher. The former folds, stiffened by elastic fibres, pass backward, diverging from one another to the arytenoid cartilages. These are called the *vocal cords* (Fig. 31, *a*). The other pair, the so-called *false vocal cords* (Fig. 31, *b*), are attached also to the arytenoid cartilages, a little above and to the side of the vocal cords. The space between the edges of the vocal cords is called the *glottis* (Fig. 31, *c*). In breathing, the glottis is wide open (Fig. 31, I., *e*).

By contraction of the various muscles stretching between

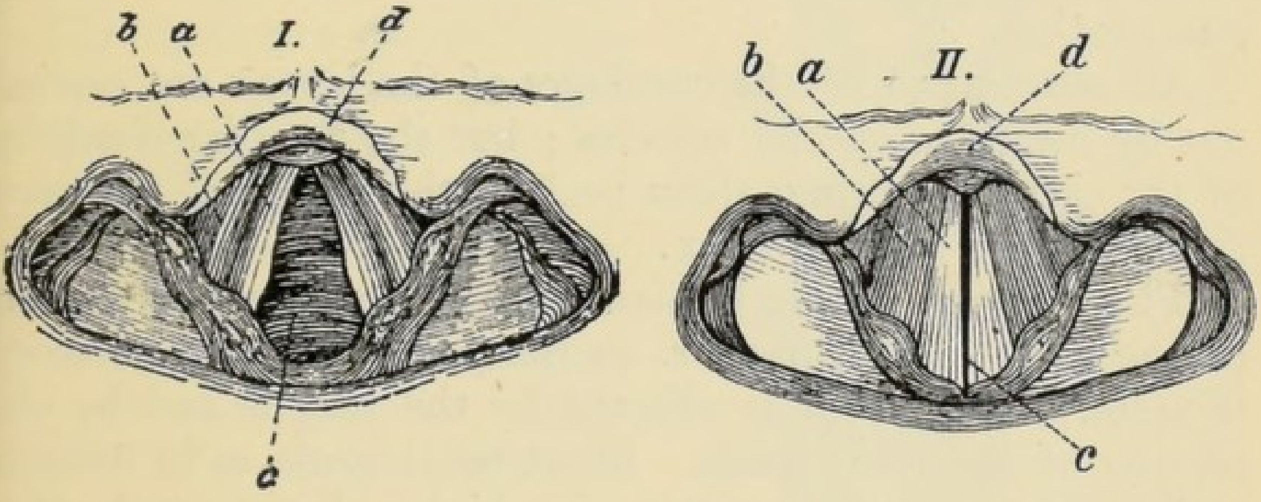

FIG. 31.—LARYNX (viewed from above): I., IN BREATHING (glottis open); II., IN SPEAKING (glottis narrowed). *a*, vocal cords; *b*, false vocal cords; *c*, glottis; *d*, epiglottis.

the cartilages, these, and hence also the vocal cords, are moved, approximated, or separated. This occurs normally in voice-production, abnormally by the irritant effect of various gases, such as chlorine, coal-gas, etc., on the mucous membrane of the larynx. Such gases effect a spasmodic closure of the glottis, and so are hindered from reaching the lungs.

The vocal cords are the essential organs for the production of the voice. The false vocal cords have no share in it. The vocal cords are, by the contraction of the special muscles attached between the cartilages, subject to three forms of movement: (1) by the rotation of the arytenoid cartilages on their longitudinal axes, the edges of the vocal cords are brought together, and the glottis narrowed (cf. Fig. 31, I., II.); (2) by the inclination of the thyroid forward the cords are stretched from front to back; (3) by decreased convexity of the thyroid, *i.e.* by the widening of the angle of the wedge made by its sides, the vocal cords are pulled right and left. At the same time as any of these movements are occurring, the air, through the increased activity of the respiratory muscles, is pressed with greater force through the wind-pipe, and sets the tense cords vibrating. These vibrations produce the sound. Its production can only take place when the cords have approached to within a distance of 2 mms. of one another.

All movements of the cartilages of the larynx are carried out by means of special muscles; but the peculiar elasticity of the cartilages brings them back to their original positions as soon as the muscles relax.

The loudness of the human voice depends on the tension of the air in the lungs, *i.e.* on the power of the respiratory muscles. The pitch is affected by the length and by the tension of the vocal cords. Short vocal cords, as in women and children, produce notes of a higher, longer cords of a lower, pitch. The tension of the vocal cords is determined by the degree of movement—in this case rotations of the thyroid and arytenoid cartilages. In the timbre, lastly, the individual peculiarities in the construction of larynx, mouth, and pharynx find their expression.

The superiority of the human voice over every other instrument consists in the fact that within its own limits it renders possible every conceivable gradation of loudness and pitch, and possesses a great power of expression by means of changes in the timbre. The compass of the human voice in general is not quite three octaves: it reaches from the D of the deep bass to the B flat of the upper soprano. An individual voice rarely has a compass, for singing, of two octaves, though in speech the compass is often as much as three octaves. A few notes, say from C flat to E, are common to all voices, but distinguished in each case by the timbre. The most important use of the voice is in speaking.

Articulate sounds are composed of vowels and consonants, but the limits between these two groups are not very clearly defined.

The vowels are *a*, *e*, *i*, *o*, *u*, and are simple sounds of the larynx which owe their particular timbre to the fact that, for each, a particular position of the mouth, lips, etc., is required (Fig. 32).

The consonants are sounds caused exclusively or partially by the friction of the air passing out under peculiar conditions. They are grouped as—

(*a*) *Labials*,
(*b*) *Dentals*,
(*c*) *Palatals*,

according as one or other of the parts suggested by these names is principally concerned in their formation.

Within each of these groups we distinguish further—

1. *Explosives*, in the production of which the air passes out suddenly through the barrier formed by lips, teeth, or palate.

2. *Fricatives*, if it passes out gradually.

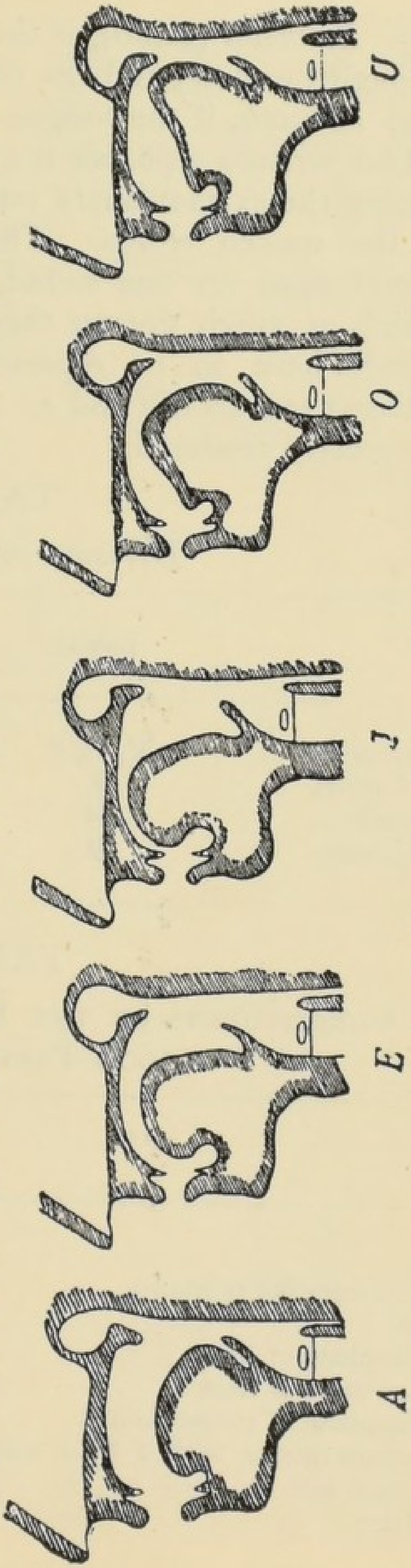

Fig. 32.—Diagram of the Position of the Mouth-parts in the Articulation of the five Vowels, a, e, i, o, u.

3. *Resonants* (*nasals*), if the air partly or wholly passes out through the nose, and the voice is heard at the same time.

4. *Vibrants*, if the tongue vibrates rapidly.

Our written alphabet is a very imperfect means of representing the extraordinary number and variety of the sounds of the spoken words. Though in some cases there are several signs for one sound, yet in general the number of sounds is much greater than that of letters, so that several sounds have to be represented by one sign—as *e.g.* the different sounds of *l* and *o*. Some composite sounds are also incorrectly rendered.

TABLE I.

Division of Consonants.

	Labial.	Dental.	Palatal.
Explosives ..	V, B, P	D, T	G, K
Fricatives ..	F	Z, S, SH, L, TH	CH (guttural)
Nasals ..	M	N	NG (as in *sing*)
Vibrants ..	R	Lingual R	Palatal R

TABLE II.

Constituents of the Bones of a Man of 25 in 1000 Parts by Weight.

	Thigh-bone.	Occipital bone.
	Per 1000 parts.	Per 1000 parts.
Cartilage-like substance	284·1	251·8
Fat	12·9	11·3
Phosphate of lime	565·8	490·8
Carbonate of lime	70·1	67·2
Phosphate of magnesium.. ..	10·9	11·8
Sodium nitrate with a little common salt	6·2	7·6
Water	50·0	160·0

TABLE III.

CONSTITUENTS OF SOME FOOD-STUFFS (1000 PARTS BY WEIGHT).

	Beef.	Fowl.	Fish (carp).	Hen's eggs.	Wheat meal.	Rye bread.	Peas.	Potatoes.	Cauli-flower.	Apples without seeds, which = 2·19 per 1000.
Proteids ..	206·72	197·29	151·64	134·40	127·07	90·05	233·57	13·23		3·91
Cellulose ..	—	—	—	—	3·32	48·08	41·52	64·43		15·20
Starch ..	—	—	—	—	678·29	399·42 (Starch and Sugar)	527·21	175·30	73·58 (Proteids to Colouring matter and organic acids)	—
Sugar ..	—	—	—	—	45·64		—	—		79·64
Colouring matter and organic acids	—	—	—	—	—	—	—	—		74·08
Fat ..	28·69	14·23	28·37	116·37	12·24	—	19·50	1·56	—	—
Salts ..	30·66	26·29	34·58	14·25	8·63	14·76	40·65	19·84	7·55	3·65
Water ..	733·92	762·19	785·41	735·04	124·81	447·67	136·74	727·64	918·87	821·33

THE LAWS OF HEALTH

THE LAWS OF HEALTH

I. Necessaries of Life

It is the object of hygiene to examine the external circumstances under which man lives in order to ascertain the most favourable conditions for his bodily welfare. To this end it seeks also to discover the causes of disease, and to point out the way to prevent or cure it.

Man's well-being is determined by many complicated circumstances, one dependent on another, though the exact relationships between them it is not always easy to unravel. As absolutely necessary for the permanent well-being of man, we may enumerate—

1. Pure air.
2. Certain conditions of temperature and atmospheric pressure.
3. Sunlight.
4. Water, of sufficient quantity and purity.
5. A soil free from noxious influences.
6. Food enough, and of the right sort.
7. The means of rendering harmless the waste products of our bodies, our households, and our industries.

(*a*) ***The Air.***—For the composition of air, see p. 74. We take oxygen from the air, and we give back to it carbon dioxide. The nitrogen contained in the air is directly important to us only as a diluent of the oxygen, the latter in a pure state acting as a poison.

Fresh supplies of oxygen can only be dispensed with as long as the small reserve stored up in the blood is unconsumed. This takes place so quickly that lack of oxygen causes almost instant death. A more condensed form of oxygen, ozone, occurs in very small quantities in the atmosphere. It is a powerful disinfectant.

Carbon dioxide in large quantities is poisonous. Its accumulation in the atmosphere is prevented by the green parts of plants. These, in the presence of sunlight, decompose it, give off the oxygen, and unite the carbon with the hydrogen and oxygen to form starch or sugar.

The carbon dioxide contained in the air of insufficiently-ventilated rooms often reaches twice or three times the normal quantity. In cellars, where fermentations due to the activity of micro-organisms are going on, it may rise to 5 or 10 per cent. In such quantities it becomes a very real source of danger.

The amount of aqueous vapour which the air can contain depends on the temperature. The following are the maximum quantities which air at the temperatures mentioned can hold per 1000 litres (= 1,000,000 c.cs.)—

At $-20°$ C.	1·06 grams,	or $\frac{1}{1225}$	of the total weight.	
$0°$ C.	4·89 „	„ $\frac{1}{265}$	„	„
$+15°$ C.	12·81 „	„ $\frac{1}{100}$	„	„
$+100°$ C.	591·92 „	or nearly half the weight.		

The water contained in the air only attains its maximum out of doors when there is rain, snow, fog, or dew; at other times the quantity is considerably less.

In houses the air is often extraordinarily dry, especially if artificial heat is used. Very dry air is harmless to the lungs, if it only be pure; but an excess of dryness in one's dwelling is not desirable, as it seriously increases the danger of dust-formation. Too much dampness is not in the long run favourable to health, not only because, being a better conductor of heat than dry air, it tends to produce a too-rapid cooling of the body, but also because it favours the multiplication of micro-organisms.

Air often contains various injurious substances. Those of more accidental or local kinds, gases, such as sulphuric acid, sulphur dioxide, carbon monoxide, coal-gas, are too often the waste products of factories. More important are solid bodies, floating in the air in extremely minute particles, and settling as dust. Of them common salt alone, which, as spray from the sea and from salt-pans, is found in the air in considerable quantities, has a salutary effect. All others are injurious; they produce a mechanical irritation of the respiratory passages, or act as direct poisons. Dust is one of our worst enemies, and when accessible, as in our dwellings, cannot be combated too energetically. The dust-impurities in the air are partly lifeless bodies, partly living beings. These latter in themselves, but more especially on account of the disease-producing effect of some of them, are of the greatest interest to us.

Of such micro-organisms, some affect our life very nearly, some only very remotely. Some, belonging to a lowly group of fungi, set up decompositions in various substances, and are responsible for much spoiling of food. Others, still more potent, belong to another fungoid group, the fission-fungi (bacteria).

Many bacteria are harmless, and not a few beneficial, or even perhaps in an indirect way essential, to man; but many, like those of the first-mentioned group, produce decomposition in meat, milk, etc.; many also are, by reason of their rapid growth within the body and the consequent harmful processes they set up therein, the causes of disease. Among the diseases due to the growth of, and decompositions set up by, bacteria in the body are tuberculosis, typhus, cholera, leprosy, influenza, pneumonia, diphtheria, anthrax, etc. The immediate causes of scarlet fever, measles, small-pox, and other infectious diseases are at present unknown.

In the case of most of those diseases it must be assumed they are generally transmitted through the air. Germs exciting disease have not, up till the present time, been obtained and cultivated from the open air; but the bacteria of anthrax, pneumonia, and tuberculosis have been obtained from the air of rooms.

The purity of the air can only be secured in large communities by insisting on spacious and cleanly streets, many open spaces, and also on the right kind of chimneys.

The most important agents in the purification of the air are rain, wind, and snow. By these agents the micro-organisms are carried to the soil, sea, or to rivers. In these situations sunlight, the universal disinfectant, is a powerful agent for their destruction.

(*b*) ***Atmospheric Pressure and Heat.***—The pressure of the air and the variations thereof, so far as they can be observed by us, are without influence on our health. On the other hand, people who ascend quickly and with violent exertions to places of high altitude, where the atmosphere is rarefied, are attacked by so-called mountain-sickness (weakness, difficulty in breathing, vertigo, faintness, nausea).

In a balloon, in which those ascending rise without exertion, they may feel quite well so long as a height of 4500 metres is not exceeded.

Temperature within the limits known in our climate has no appreciable effect on health. Its variation, moreover, entails no inconvenience as long as the air does not contain too much moisture. In the latter case a rise in the temperature may easily become injurious, especially if the person is forced to exert himself violently, and may lead to heat-apoplexy, commonly called sunstroke.

The sum-total of meteorological conditions, heat, moisture, etc., has, as mortality statistics only too clearly show, a great effect on the general health. Man is forced by the great daily variations of temperature all over the earth, to protect himself from their ill effects by artificial means. These are clothing and dwellings. With these aids man can live in all climates, and remain permanently even in the coldest regions of our earth.

1. ***Clothing.***—The materials of our clothing are in themselves bad conductors of heat (linen, cotton, wool, silk). By the manner in which they are woven into fabrics,

a greater or less quantity of air is entangled between the threads, and so the power of conducting heat is still further lessened. In a dry state, the various kinds of fabrics, if they enclose equal quantities of air, are nearly of equal value in this respect. It is otherwise when they are moistened by rain or perspiration, for wet considerably increases the heat-conductive power of a fabric; and while all materials composed of vegetable fibres allow the fluid they have absorbed to evaporate quickly, causing a great loss of heat to the body, wool only gives off the moisture very slowly by evaporation.

The clothes in contact with the body have the further task of taking up the various excretions of the skin, and so assist in keeping it clean. The present fashion of using vegetable fibres for under-clothing, but of making the upper clothing of woollen stuffs, is much to be recommended for healthy people. For those who perspire easily and have sensitive nerves, it is advisable to use for under-clothing hygienic materials (jaeger wool, celluloid, etc.); and the same is true of less sensitive persons in making extraordinary exertions (long marches, military service, etc.). Materials which allow no air to pass through, such as mackintoshes, are injurious if worn for a long time, as they check perspiration. The air contained within the clothes is, as a rule, remarkably dry. If, however, the person is perspiring copiously, this air soon attains a high degree of moisture. The clothing thereby becomes a better conductor of heat, and renders the evaporation from the skin more difficult.

Besides loss of heat by conduction, the body parts with an appreciable quantity of heat by radiation. This, like the absorption of heat, has very little to do with the material of the clothes, but very much with their colour. Black stuffs absorb twice, blue almost twice, yellow and red one and a half times as much warmth as white ones. By night the bed undertakes the work of the clothing. Here, too, it is mainly the air enclosed within the bed-clothes which keeps the body warm. Both insufficient and too-warm clothes and beds occasion diseases, mostly so-called colds. An especial error is that of making the clothes too tight. No article of clothing ought to impede the breathing or the circulation of the blood or constrict the stomach. Transient or permanent disturbances of health and even deformations are the results. Corns and other troubles on the feet are to be ascribed to badly fitting, and especially tight shoes.

Clothes which have been worn, sheets which have been slept in by others, should never be used without being thoroughly washed or otherwise disinfected in order to destroy any disease-germs which may lurk in them.

2. ***Dwellings: Artificial Heating.***—The dwellings in which man passes a great part of his life exercise an essential and often undervalued influence on his health. Hygienic considerations ought to have the first place in determining the position, size, and structure of houses. A dwelling-house should be built on a healthy, that is to say, uncontaminated spot, and of materials permeable to air; and, if possible, on a porous soil. No substances liable to decomposition should be used for filling up the space between the floors. Newly built houses should not be occupied before they have completely dried. Any one who has the choice should select a house in a sunny situation. Most dwellings and rooms, even those of well-to-do people, are too small. The minimum space for a dwelling-house is 10 cubic metres per head. The dwellings of the poor are often so overcrowded as to occasion serious danger to the health of their inmates. But even in the richer classes the use made of the rooms is not always guided by considerations of health. The largest and sunniest rooms should be used as living and sleeping rooms; the smaller and worse situated rooms are well enough for less-used "drawing-rooms."

The furniture of rooms should be such as to facilitate the ready and frequent removal of dust. The universally used wall-papers are bad dust-traps. For sick-rooms, at all events, painted walls which can easily be washed are to be recommended.

The most scrupulous cleanliness in the dwelling is a requirement which, after what has already been said, hardly needs to be dwelt upon. Continued stay within doors weakens the body. Damp houses favour colds and diseases of the lungs; bad drainage arrangements often give rise to typhus.

The heating of rooms is effected in this country chiefly by open fire-places, abroad more often by stoves. Open fires, though cheerful enough, are extravagant. They ventilate well, but do comparatively little towards warming the house. Tiled stoves, which part slowly with their heat, are convenient and economical. The giving off by stoves of the deadly poisonous gas, carbon monoxide, should always be prevented by choosing such as have their heat-regulating appliances connected with the stove-doors, and not as valves in the stove-pipe.

Large buildings have of late years been provided with a central heating apparatus, in which the heating is effected by air, steam, or hot water; but such arrangements, unless provision is made at the same time for admission of dust-free and sufficiently moist air, are to be condemned.

Of great importance to human well-being is the removal of air whose oxygen has been used in respiration or in the processes of burning (oxidation), and the supplying of fresh pure air. Ventilation is best carried out by making use of the difference of temperature produced by artificial heat—even an open window ventilates to a great degree; but still better is the effect of a ventilation-shaft, such as the chimney of a fire-place, through which the heated air rises continually. The openings for ventilation must be large enough, and should be two in number, one placed high for the summer, and a lower one for winter. If a special ventilation-shaft is used, the current of the air is often quickened by a flame in the vicinity of the ventilation-opening.

(*c*) ***Light.***—Sunlight is necessary for the preservation of health. Even diffused daylight, and still more direct sunlight, destroys micro-organisms. Sunlight also has a direct influence on health, and we cannot be mistaken in ascribing the fresher appearance and better health of dwellers in the country to the effect of sunlight as well as to their being constantly in the fresh air. This is confirmed by the experience of travellers in the Arctic regions. While the extraordinary cold (as low as $-63°$ C.) of some places in Siberia can be endured without injury, because the sun shines there every day in winter, if only for a short time, serious derangements of health are apt to set in in the polar regions, with a less degree of cold, soon after the beginning of the winter's continuous night. In particular, the skin becomes pale and greenish-yellow, as in advanced chlorosis or anæmia, and added to this are nervous disturbances, sleeplessness, irritability, and depression. It is in the highest degree probable also that the quality of light—colour, for instance—influences the mental as well as the bodily state.

Defective conditions of light have an unfavourable effect on the eyes, too much light being as injurious as too little. Thus, walking on snow on which the sun is shining is apt to cause so-called snow-blindness, whose symptoms are temporary loss of sight, and a painful irritation of the eyes. Of more frequent occurrence are injuries to the eyes from straining them with insufficient light. This forces us to bring the objects looked at very near to the eyes, and therefore unduly strains the accommodation apparatus. A frequent repetition of this engenders short-sightedness.

In the evening artificial light takes the place of sunlight. Good artificial lights conform to the following requirements :—

1. Supply a sufficient and uniform brightness.
2. Produce little heat.
3. Give off as few noxious gases as possible.

These three requirements are best fulfilled by the electric light, if properly shaded with ruby glass.

The usual method of gas-lighting is convenient, but not to be recommended for small dwellings ; it produces great heat, and supplies many noxious substances to the air. The latter defect is reduced by the use of various forms of incandescent gas-light. Petroleum gives an excellent light, and, if of sufficiently high flash-point, its use in scrupulously made lamps is without danger. Petroleum in burning contaminates the air less than gas ; and, next to electric light, contaminates the air least of all the artificial illuminants in common use. Candles give little light, and, though they also give little heat, yet they supply to the air seven times as great a quantity of noxious products of incompleted combustion as good petroleum-light.

Finally, the supply of light should be taken into consideration in laying out streets and houses. The width of the street should be at least equal to the height of the highest houses ; the houses themselves should not be too high, and should, if possible, stand apart from one another. Streets should not run due E. and W., as the various rooms in them in that case do not get their due proportion of sunlight. As many open spaces as possible should be preserved as public parks within and near the town.

(*d*) ***Water.***—Water is almost as important a factor in our lives as air. About 70 per cent. of our bodies consists of water ; our most important foods contain it in quantities varying from 0 to 75 or more per cent.

The body excretes daily about 2700 grams of water. This quantity is replaced by that contained in the food and drink. The former source provides, or should provide, by far the greater amount. Excessive drinking, even of drinks harmless in themselves, is a widespread and bad habit.

The drinking-water which comes from natural springs is generally free from impurities, that from artificial wells is not infrequently contaminated, and may even contain germs of typhus, cholera, etc. : water from such sources must therefore be used with great caution. Water from rivers with populous towns on their banks, and also that stored in cisterns, demands still greater precautions before use.

All natural water which passes any distance through the soil contains various earthy substances in a suspended and dissolved condition. Among its dissolved constituents are carbonates of lime and magnesia, salts of ammonia, and organic matter : of the suspended substances, the more important, as bearing on health, are micro-organisms. Of the contained salts, some are insignificant so far as health is concerned. Ammonia, compounds of nitric and of nitrous acids, never act as poisons in the quantities in which they occur ; they are, however, useful danger-signals, since they show that the water has passed spots where organic matters were in process of decomposition, and that they may therefore be associated with less innocuous substances. Salts of lime and magnesia in water are not injurious to health, but they impart to it a hardness which has many disadvantages. Apart from incrustations which it forms in pipes, boilers, and cooking-vessels, hard water is a poor cooking agent, failing to soften meat and vegetables cooked therein. It is also unsuitable for washing or bathing purposes, as the fatty acids of soap form with these salts of lime and magnesia insoluble compounds, and are thus prevented from exerting their cleansing action. The hardness due to carbonate of lime is readily removed by boiling ; but hardness due to sulphates of magnesia, etc., only yields to chemical treatment. The organic substances contained in water do not necessarily cause direct injury, but their presence is to be regarded with suspicion, inasmuch as they form a nidus for the growth of bacteria.

Vast numbers of very different kinds of living organisms find their way into water. Besides bacteria, harmless and disease-producing spores of other fungi, algæ (lowly green plants), minute unicellular animals (infusoria), small crustacea and worms, as well as the eggs of these and other forms, may all occur. The greater number of these forms of life are quite harmless to man ; but of some of the bacteria, such as the typhus and the comma-shaped cholera bacilli, as well as the micro-organisms causing malaria, which are occasionally found in water, are among the worst enemies of the health of man. Parasites of various kinds also often find their way into our bodies by means of drinking-water. The knowledge of these facts should not be a source of alarm to the timid, but of help to everybody. It supplies the reason why a constant provision of pure water is so essential to the health of the community. This provision is in cities made the more important and the more difficult by the fact that the ground in the neighbourhood of inhabited places, having been occupied for centuries, is so fouled as to be altogether unsuitable as a collecting-ground for water intended for human consumption.

The best form of water supply for a town is that brought by means of aqueducts from springs arising in a higher level of the country. Almost as good, but more difficult to get at and bring to the spot, is sub-soil water from places where the soil has not been fouled. Only as a last resource should the supply be obtained from river water.

Water from doubtful sources should always be filtered. By this process, matters in suspension, including micro-organisms, are removed. It is of the greatest importance that the filter be frequently cleaned; otherwise the remedy, by harbouring the micro-organisms, provokes disease. Still more important, the way the filter works should be understood by the purchaser, that he may use it intelligently, for in some of the best filters parts should be cleaned and parts let alone.

From an hygienic point of view the water supply ought to fulfil the following conditions:—

1. It must be pure, in which case the water is colourless; though water which is colourless is not necessarily pure.

[The following numbers give the maximum amounts of the respective substances which may be tolerated in 1 litre of water:—

Sediment, 0·5 gram.

Nitric acid (in combination), 5 mgrs.

Organic substances, 5 cgrs.
Chlorine (in combination), 2·5 cgrs.
Sulphuric acid (in combination), 3 cgrs.

There should not even be traces of ammonia or nitrous acid, and the number of bacteria should not exceed 250 per centimetre; of disease-producing germs there should, of course, be none.]

2. The water supply should be sufficient, *i.e.* about 80 litres per head per day.

3. It should be cheap.

4. It should have the pressure necessary to reach the top floors of houses.

5. It must be brought through pipes not liable to impart to it any hurtful elements: therefore neither through leaden nor through iron pipes.

6. It should be constant, so that storage in cisterns is avoided.

(*e*) ***Soil.***—The soil on which we live has its influence on our well-being. The degree of porosity and capacity for becoming foul are qualities of the sub-soil which have an important bearing on health. The less porous the sub-soil, the more water accumulates above it, and, becoming stagnant, proves a source of danger.

Very impervious soils favour the formation of swamps. Swampy regions are the home of intermittent fevers and malaria. In England and America a decrease in this last-mentioned disease has been observed after the draining of extensive areas of swamp-land.

Of great importance, too, is the level of the sub-soil water. In damp strata, which also contain organic matters, a particularly abundant development of bacteria takes place. Bacteria are not found in the sub-soil water itself to any extent worth mentioning, but if its level sinks, the stratum just left by the water may become, whilst still damp, a focus for the rapid development of bacteria, among which disease-producing germs may occur. Thus is explained the deleterious influence which fluctuations in the level of the sub-soil water may exercise on the general health. In damp soils are found the bacteria of malaria, tetanus ("lock-jaw"), typhus, and perhaps also of cholera. These may get into our bodies from the soil in various ways with drinking-water or along with particles of earth adhering to the food; or by the drying up and flying away as dust of the upper layers of the soil.

The air contained in the soil may also pollute that of our houses by passing up, especially in winter, into the heated rooms. Such air often contains ammonia, sulphuric acid gas, and carbon dioxide, but these substances are probably never contained in it in such quantities as to do harm. Sewer and coal gas may, perhaps, spread disease by passing through contaminated soil, and carrying disease-germs thence to the atmosphere, though the most recent experiments seem to show that such gases carry very few bacteria. Air itself, passing up from the soil, is free from germs.

By suitable precautions most of the dangers just enumerated may be effectually combated.

In the first place, the great quantity of decomposable waste products of men, animals, and plants ought to be given over to the soil at a distance from human dwellings, in order to be decomposed as quickly as possible, so that the fouling of the soil on which we live may, as far as possible, be avoided. So treated, these waste products become a prey to various kinds of bacteria, which break them up into harmless substances. Extensive applications of this method of sewage treatment are now becoming common in this country.

A good system of sewers is essential for the carriage of all refuse of the house and of the streets to the places in which the scavengering bacteria are allowed to have full destructive play.

The paving of streets and courtyards also prevents organic matter from penetrating in any quantity into the soil. It also allows the sub-soil of towns to free itself from former contaminations. Thus it has been observed that in many towns, after the introduction of such improvements in drainage, the mortality from typhus has been appreciably lessened. For example, at Munich, in 1858, of 100,000 inhabitants 333 died of typhus. After the town had in the following year been supplied with sewers and with wholesome drinking-water brought from mountain springs, this number has considerably diminished, so that now there are scarcely three per 100,000 yearly deaths from typhus.

(*f*) ***Food.*** 1. ***General Considerations.***—Our food is composed of various materials, each of which is to be looked on as a mixture of simple food-stuffs. The simple food-stuffs are (besides water and air) proteids, fat, carbo-hydrates (starch, sugar, etc.), water, and salts.

For nutrition man requires daily—

About	700–750	grams of	oxygen ($\frac{1}{2}$ c.m.).
,,	2700–2800	,,	water ($2\frac{3}{4}$ litres).
,,	30	,,	salts.
,,	70–150	,,	proteids
,,	30–90	,,	fats.
,,	340–570	,,	carbo-hydrates (see also p. 82).

At the same time he excretes, beside 2700 grams of water, 850 grams of carbon dioxide, and the waste products of proteid metabolism about 40 grams per day in urine.

Part of the food assimilated—more especially water, salts, a part of the fat, and the proteids—serves to build the body during growth, and replaces the matter consumed in the various vital processes. Another part—especially the carbo-hydrates and the greater part of the fat and proteids—supplies, in conjunction with the oxygen of the air, the energy necessary to the carrying on of the vital processes, 100 grams of fat supplying as much energy as 210 grams of albumen (a form of proteid), or 240 grams of carbo-hydrates. No sharp distinction is, however, to be drawn between the two possibilities just mentioned, since substances which are built up into the living protoplasm are also being continually broken down, and so contribute to the stock of available energy.

No one of the food-stuffs can alone sustain the body. It is true that in our food the food-stuffs are usually found already mixed in the proportions required by the body. But if we tried to live on one kind of food only, we should have, in order to get a sufficient quantity of every food-stuff, to take a considerable surplus of all the others; the stomach would be seriously overloaded, and the cost of living needlessly increased. For example, we require about 540 grams of meat daily to supply the needful amount of proteids; if we wished to supply also the necessary quantity of carbo-hydrate material from this source, we should have to eat 2600 grams daily—a quantity with which the digestive organs of human beings are not capable of dealing. Dogs, on the other hand, can subsist on a purely proteid diet, *i.e.* on meat only. In the same way, if we wish to supply the necessary proteids by a vegetable diet, which is rich in carbo-hydrates, we have to consume an excessive quantity of vegetable food. Milk alone contains the nutritive elements in proportions fitted to sustain the body and facilitate growth. Even in this case, an adult, to obtain a sufficiency of all the food-stuffs, would be obliged to take over 4 litres of milk daily.

It is therefore advisable to have a mixed diet, using both animal and vegetable substances. Those who wish to avoid the use of meat (vegetarians), can find sufficient compensation in eggs, milk, and cheese. Strict vegetarianism, which rejects the use of all animal substances, or would even limit us to the fruits of trees, is scarcely possible in our climate; but only for external reasons. In the tropics, where dates, bananas, bread-fruit, etc., flourish, these fruits are the only food of millions of hard-working people.

In the choice of diet, the manner of life must be taken into consideration. In a sedentary life if the stomach is overloaded with a great quantity of vegetable food, digestion only takes place with difficulty. When work is principally mental, a diet richer in proteids and more easily digested is more necessary than when the work is mainly physical. Also, in the former case, a greater variety of food is advisable, if for no other reason, because monotony in diet is apt to cause repugnance towards the frequently repeated dishes.

Cooking renders food more digestible, admits of a greater variety of dishes, and often destroys injurious substances or organisms associated with the raw food-materials. To further increase the variety and to stimulate the stomach—often, perhaps, unadvisably—condiments are added to food.

2. ***Animal Food.*** — *Meat* consists chiefly of flesh (muscular tissue) and of fat. Muscle contains about 73 per cent. of water, 20 per cent. proteids, and 8 per cent. of fats, salts, and organic substances termed extractives. Boiled meat has parted with most of its salts and extractives to the *broth*, but still contains its proteids. It has suffered no appreciable loss as a nutritive agent. Meat-broth, like meat-extract, is only a stimulant, with little nutritive value. Roast meat contains nearly all its nutritive elements, as does meat prepared in other ways—pickled, smoked, or tinned.

Somewhat less in value than the meat are the glandular parts of animals (kidneys, liver, etc.). Fish is nearly equal in nutritive value to the flesh of mammals and of birds. Horseflesh is only inferior when coming from old and overdriven animals. It must be remembered, with respect to these various meats, that, besides the nutritive value, another factor, the *digestibility*, is of equal importance, and that this varies very much with the nature of the meat and with the mode of preparation.

The eating of meat is not without danger to health. Thus pork sometimes contains small worms, *trichinæ*, which, if they get into the human body in large numbers, may occasion serious illness or even death. Beef and pork also contain now and then the larvæ of tapeworms, which develop in the human intestine to the mature animal. In both cases thorough cooking kills the parasites. If only on account of this danger, the eating of raw meat is not advisable. Animals killed for the market are often tubercular, *i.e.* contain the bacteria which give rise to consumption and allied diseases. Only rigorous official inspection, not only of meat, but of the animals to be slaughtered, can safeguard the community from the risks of contracting tuberculosis through the medium of the meat consumed. Public slaughter-houses, such as are in vogue on the Continent, facilitate the putting into practice of such preventive measures.

Lastly, poisoning, properly so called, may arise from the consumption of tainted meat, badly sealed or improperly selected "tinned meat," sausages, fish, milk, or cheese. In these the effects of bacterial or other vital activity have begun, and have resulted in the production of poisonous alkaloids, termed *ptomaines*.

Eggs.—By far the most important from our point of view, and the only ones here considered, are hen's eggs. Of their contents, the "white" constitutes two-thirds; the yolk one-third. The white of a hen's egg consists of 87 per cent. of water, and 13 per cent. of albumen and of another proteid called globulin. The yolk contains 50 per cent. of water, 25 per cent. albumen, 25 per cent. fat. An egg contains on an average about 8 grams of albumen, and 4 grams of fat, and has the same nutritive value as 40 grams of fat meat, or 180 grams of milk. Soft-boiled eggs are digestible; hard-boiled eggs are, on the contrary, very indigestible. The indigestible nature of the hard-boiled egg is due to the fact that prolonged boiling has produced a lump of proteid which stubbornly resists the penetration of the gastric juice.

Caviare, consisting of the salted eggs of the sturgeon and similar fishes, is very nutritious; but, on account of its high price, it can only be regarded as a luxury.

Milk.—Besides cows' milk, which is in such general use, that of goats and mares is occasionally employed as an article of diet. The milk of these animals has much the same nutritive value as that of cows. Cows' milk contains 3 to 4 per cent. of proteids, 3 to 6 per cent. fat, 4 to 8 per cent. milk-sugar and salts in varying quantities up to 7 per cent., water making up the rest. It may therefore, in case of necessity, be used as sole food, even by adults. Milk is richer in summer than in winter. Evening milk contains twice as much cream as morning milk ; the milk drawn last is richer than that drawn first, and milk of cows in the country is richer than that coming from town dairies.

After long standing, especially in a warm place, milk becomes sour. In this state it may quite well be taken, in not too great quantities. The skim-milk remaining after the cream has been removed from the surface of milk which has been allowed to stand for a time, is an excellent cheap food, always providing that the necessary fat, which has been withdrawn from it by skimming, be supplied in some other way.

By shaking or beating the cream which collects on the surface of milk, butter is obtained. A litre of milk yields about 30 grams of butter.

Cheeses, of the kinds in general use in this country, are made by causing the milk to curdle by the addition of a rennet ferment. The curd consists of a proteid, casein, and of fat. Others, cream-cheeses, are made from the cream only. Cheese contains 22 to 32 per cent. of proteids, and 40 to 60 per cent. of fat, and therefore is two to three times as rich in nutritive material as meat, though by no means of two or three times the nutritive value of the latter. For, as we have already observed, the nutritive value of a food is to be measured, not only by the quantity of its contained food-stuffs, but also by the readiness with which they are digested.

Milk has its dangers. Through milk, such diseases of animals as tuberculosis and foot-and-mouth disease may be transmitted to man.

By accidental contamination of milk, typhus, cholera, and scarlet fever are occasionally spread. More grave, because more frequent, is infantile diarrhœa, a disease which is, in most cases, avoidable by the exercise of a little care.

All dangers arising from milk may be guarded against by cleanliness, by keeping it cool, and by only using it boiled. For feeding infants, sterilized milk, *i.e.* milk in which all bacteria germs have been destroyed by boiling for a sufficient time, is to be urgently recommended.

The present police regulations concerning milk are directed towards preventing adulteration, *i.e.* preventing the public from pecuniary loss. The law prohibits the sale of milk from cows suffering from anthrax, rabies, or foot-and-mouth disease.

Animal Fats.—Of these are used butter and clarified butter, suet, lard, goose grease, and, in special cases, cod-liver oil. They are about equal in nutritive value. The margarine of trade is somewhat less nutritious; it consists mostly of animal fats, to which a butter taste has been imparted by impregnation with milk. It is cheap, and not to be condemned if its manufacture be carried on in a cleanly manner.

Diseases, such as tuberculosis, have sometimes been transmitted through butter. The process of clarifying butter by boiling destroys all disease-germs.

3. **Vegetable Food.**—Vegetable foods also contain proteids, usually associated with large quantities of carbohydrates, such as starch, sugar, and cellulose, and with some fat; in general, the same salts are present as are contained in animal food.

(1) *Cereals.*—The seeds of a number of grasses, as wheat, barley, rye, maize, rice, all serve as human food. From these is prepared flour, which contains 67 per cent. of starch, 12 per cent. proteids, 2 per cent. fat, 2 per cent. salts, 3 per cent. vegetable fibres, and 14 per cent. water. The most important food made of flour is bread, for the preparation of which the flour is worked up into dough, with about three-quarters of its own quantity of water, some yeast

or leaven, and the necessary salt. When sufficiently heated, the dough ferments—a process which gives rise to a great quantity of carbon dioxide, which makes the dough rise, and renders it porous. The fermented mass is then baked at a temperature of about 200° C., which kills all organisms which may happen to be in it.

The more bran is mixed with the flour, the browner, the richer in proteids, and therefore the more nutritious it is. This gain, however, is counterbalanced by the fact that it is less assimilable than ordinary bread.

Of bread of the finest flour, only about one-twenty-fifth remains undigested ; in coarse brown bread, the amount of undigested matter rises to one-fifth of the quantity of bread eaten. Brown bread, however, may profitably be used in cases of sluggish digestion, as it stimulates the alimentary canal to more rapid movement.

Flour not carefully selected may contain a poison, *ergot*, as well as the poisonous seed of the corn-cockle.

(2) *Legumes.*—Under this term are included the seeds of beans, peas, and lentils. They contain, on an average, 57 per cent. of starch and cellulose, 23 per cent. proteids, 2 per cent. fat, 2 per cent. salts, 2 per cent. woody fibres, and 14 per cent. water. They are therefore more nutritious than cereals ; *e.g.* 1 kilog. of peas contains 230 grams, the same quantity of grain only 120 grams, of proteids. They, however, in order to form a completely nourishing food, need the addition of some fat.

(3) *Potatoes.*—The importance of the potato as a food lies in the fact of its flourishing on almost every soil, and generally yielding good crops. Potatoes consist of more than 75 per cent. of water, 1 per cent. proteids, 21 per cent. starch, 1 to 4 per cent. woody fibres, and a variable quantity of salts. Potatoes are the cheapest form in which we can get the starch necessary for nutrition. They cannot alone sustain the body, but require the addition of fat and some food rich in proteid, as milk, meat, butter, or cheese.

(4) *Vegetables and Fruit.*—The "roots" in general use,

turnips, carrots, etc., are deficient in proteids, 1 per cent., and contain only small quantities of starch and sugar (2 to 6 per cent.), though richer in salts, 4 to 7 per cent. They stand low in the list of foods arranged according to nutritive value, but are wholesome additions to the table. Green vegetables stand still lower, but are even more welcome, on account of their wholesomeness, and because they are the pleasantest and most convenient vehicles for the conveyance of salts, and especially of organic salts, and acids needed by the body. The want of them is the cause of scurvy, which formerly caused great ravages among sailors, in armies on campaign, and in times of scarcity among the peasantry. The nutritive value of fruit depends on the amount of sugar contained in it, which may be as high as 10 per cent. Nuts, almonds, chestnuts, and other proteid- and fat-containing seeds, have a more considerable nutritive value. Mushrooms scarcely deserve their reputation, except as delicacies. They contain 90 per cent. of water, and only about 2 per cent. of proteids.

(5) *Vegetable Fats.*—In the vegetable kingdom, fat is usually found in the form of oil, which is stored up as a reserve substance in many seeds—poppy-seed, rape-seed, olives, nuts, etc. Vegetable fats are quite equal to animal in nutritive value.

4. ***Luxuries and Stimulants.***—Among these must be counted, in the first place, vinegar, and secondly, aromatic substances, such as are contained in pepper, cloves, nutmeg, mustard, onions, and hosts of other plants. The nutritive value of these substances is often nil, and generally little; but, nevertheless, they are important accessories to the food. Not only do they give flavours to otherwise tasteless foods, but also, by stimulating the mucous membrane of the intestine, serve to increase the amount of its secretions. The much-used luxuries coffee, tea, and cocoa, by means of the alkaloids caffein, thein, and theobromin contained in them, act as stimulants; coffee having a marked effect on the heart's action. So far as they are intended to take the

place of alcoholic beverages, there is something to be said for them ; but where, as among the poorer classes, they are gaining a footing as a convenient form of food, and begin to be taken to excess, they are to be condemned. The excessive use of strong coffee has even worse consequences than that of alcohol ; though the far wider-spread ravages caused by excess of the latter make it one of the worst enemies to the health of mankind.

Tobacco.—The leaves of the tobacco plant are very generally used for smoking, chewing, and snuffing. Their active principle, nicotin, is an acute poison, but the body, in many cases, soon accustoms itself to considerable quantities of it without appreciable injury ; though here also excess is frequently attended by harmful results.

Alcoholic Stimulants.—The effect of alcoholic drinks depends primarily on the amount of alcohol contained in them. Taken in moderation, they produce agreeable sensations, in consequence of which they are often used immoderately. Excessive indulgence in alcoholic drinks leads to serious disease ; worse, the children of inebriates show many signs of degeneration, and of disease. Intemperance is one of the most fertile sources of nervous disease and of crime ; in view of this and of its increase, its effects cannot be insisted upon too strongly. Children ought on no account to touch alcoholic stimulants of any sort. Alcohol perceptibly retards the digestion, and though it has some nutritive value, its evil effects, already insisted upon, deprive it of all claim to be considered as a food.

The various sorts of brandy contain 30 to 70 per cent. of alcohol, whilst bad brandy and whisky also contain the deleterious fusel oil. The abuse of brandy ruins the system in a terrible manner. Catarrh of the stomach, affections of the liver and kidneys, degeneration of the brain and other nervous affections (delirium tremens), are frequent consequences of it.

Absinth contains an ethereal oil, and thereby has a peculiarly deleterious influence on the nervous system.

Wine made of grapes and not adulterated by the addition of deleterious substances is, used in moderation, an agreeable beverage. The percentage of alcohol is 7 to 15 per cent., and the danger therefore considerably less than is the case with "spirits." Yet even with wine, habitual excess leads to severe bodily sufferings. The heavy wines of the South are mostly fortified by the addition of spirits of wine, and therefore have a similar effect to brandy.

Beer contains little alcohol (2 to 9 per cent.), and, besides hops, 4 to 8 per cent. of malt-sugar and dextrin, 0·5 per cent of albumen, salts, and carbonic acid. Good beer has therefore a certain nutritive value. Taken in excess, it injures the organs of circulation by the great quantity of liquid poured into the stomach, occasions hypertrophy and fatty degeneration of the circulatory apparatus, and so leads to apoplexy. Added to this is the destruction wrought by the alcohol contained in the beer—disturbances of the digestion, affections of the kidneys, etc. Beer is often adulterated, other and injurious bitter substances being substituted for hops. It is also injurious when containing yeast, or even acid-forming bacteria, which speedily give rise to catarrh of the stomach.

(*g*) ***The Disposal of Waste Products.***—The waste products of the human body and household are partly directly injurious or poisonous, and partly indirectly so in supplying an excellent nidus for the growth of micro-organisms of all sorts. The necessity for their removal or destruction is obvious. Analyzed according to composition, waste products per head per annum come to 100 kilogs., sweepings, kitchen refuse, etc.; 460 kilogs. solid and liquid excreta of the human body; and up to 36,000 litres of water used.

By proper ventilation the gaseous waste products are led into the open air, where they are at once rendered innocuous by dilution and carried away by the constant motion of the atmosphere.

The disposal of the solid and liquid waste is more difficult. In many villages all waste products are collected on the dunghill, carted into the fields, and there rendered innocuous by admixture with the soil. In towns this simple process is not practicable. Better arrangements for disposal of sewage immediately improve the general health. In most large towns there is a regular system in use for carting away sweepings to places set apart for their reception. Yet the rubbish-heaps which in the neighbourhood of large towns are sometimes allowed to grow to a gigantic size are a source of serious difficulty. Attempts to dispose of the rubbish by burning have not hitherto produced very satisfactory results.

Human excreta are best taken out of a town by a good sewage system which also carries off the rain-water. The contents of the sewers may only be emptied unhesitatingly into a river when the amount of water in the river is many times greater than the amount of the sewage. In this case the river cleanses itself. The solid matters are deposited on its bed, and the bacteria destroyed by the agency of sunlight, so that the river water in a comparatively short time regains its former purity. If, however, the contents of the sewers are not quickly diluted by the river water, a state of putridity sets in, which is highly injurious to the health of the dwellers on the river-banks. In this last case the contents of the sewers ought to be purified before being discharged into the river. This is best done by filtration through the soil (filter-beds). When these cannot be constructed, the sewage must be purified in large tanks by the addition of substances acting on it mechanically and chemically.

When excreta cannot be removed by means of sewers, recourse must be had to the old system of cartage. This method is cheaper than sewers, but it is much less efficacious than a sewage system in keeping the houses free from bad smells. It is necessary that the walls of the cesspools required by this system should be as impervious as possible, so that fouling of the sub-soil may be avoided. The cask system is also to be recommended if rightly carried out. The excreta are collected in movable casks, which can be hermetically sealed and carried off. The contents of pits or casks can be quite deodorized by strewing in earth or peat-dust.

Mistakes or carelessness in the treatment of waste products favour the rise and spread of infectious diseases, especially typhus and cholera.

The burial of the dead requires especial care. The official inspection of the corpse has been introduced in order to prevent the burial of those only apparently dead, to discover crimes, and to gain an insight into the causes of death. After this, the corpse is, as a rule, placed in the mortuary, or otherwise isolated, to avoid any possible danger of infection. It is afterwards buried in a wooden coffin in a cemetery, in a grave 2 metres deep. As a rule, everything but the bones disappears in the course of nine years. The soil in the vicinity of burying-grounds is not likely to be contaminated so far as to endanger health, as the earth is quite capable of destroying the organic matter of the corpses, the number of which is comparatively small, the yearly death-rate being only about 25 per 1000. These give to the soil about 300 kilogs. of decomposable organic matter, while the same 1000 persons in any year supply, in their excreta, nearly 30,000 kilogs. of decomposable substances. Moreover, most disease-producing microbes are destroyed by the soil in a comparatively short period—within the first year—and are, in all except a few doubtful cases, long extinct when the grave is opened again. They cannot get out of the soil, and do not pass into water. That cemeteries are not otherwise prejudicial to health is clear from the fact that grave-diggers are a long-lived race, despite the fact that they breathe the air of graveyards, drink water from their soil, and dig up the soil itself.

In recent times a movement has been started in favour of cremation. This reduces the corpse to ashes in a very short time ; it is therefore most effectual from an hygienic point of view. It is, however, still very costly, and the process is too slow to deal with large numbers of corpses with the speed necessary in the case of epidemics. Yet the question of space alone will ultimately necessitate the extensive introduction of cremation in large towns.

II. Hygienic Rules for Special Circumstances.

(*a*) ***Schools.***—Education being compulsory, it follows that it is the duty of the State or the community to see that teachers and scholars suffer no injury to health from their stay in the school buildings. For this purpose the schoolrooms must be of sufficient size, well lighted, warmed, and ventilated. The seats must not be so constructed as to occasion or favour wrong attitudes of the body. Intervals and change of work should be adopted in order to prevent fatigue, and the pursuit of all sorts of physical exercises encouraged. But even though these conditions be observed, the work of the school will be vain, unless the elementary principles of hygiene are made part of the home training.

One great danger of schools is the spread of infectious diseases (measles, scarlet fever, diphtheria). A child attacked by one of these must be kept away from school till all danger of infection is over—in measles, for four weeks ; diphtheria, two ; scarlet fever, six weeks. For the same reason the brothers and sisters of the patient should also be kept at home, unless the patient has been isolated in time. If any such disease appears as an epidemic, the school must be closed at once, and the buildings thoroughly disinfected.

In the case of weakly children, all kinds of "school diseases" appear in consequence of long sitting in vitiated air, and of the effort of learning. Digestive troubles, headache, and bleeding of the nose, short-sightedness, and curvature of the spine, are among the troubles so engendered.

It is coming to be generally recognized that such weaklings must be subjected to special school discipline, and not to the ordinary *régime*, which, whilst excellent for the common run of healthy children, is little short of brutal to the fragile.

(*b*) **Trades.**—Unfavourable circumstances under which men pursue their callings, as well as the callings themselves, may have a prejudicial influence on health. In large workshops and factories the Legislature has begun to take measures for the health of the workers, by issuing regulations as to the size and nature of the work-rooms, and by attempting to neutralize, as far as possible, the dangers arising from the work. It is also attempted to protect women and children against unscrupulous exploitation; continuous and manifest overwork is prohibited, proper intervals and rest on Sundays are enforced.

The conditions of labour are especially bad in many *small trades* and *home industries*, where necessity compels terribly long hours of work, and over which the State has less power of exercising vigilance.

Apart from legislation, there are various other provisions for the well-being of the workers. "People's kitchens" and eating-houses provide good and cheap food, and many things have been done by various associations in the way of providing healthy dwellings, baths, wash-houses, etc.; but the greater part of the work necessary in this department is yet to do.

This is not the place to discuss the question as to whether the care of the sick poor, and of those suffering from accidents, is best carried on in hospitals, which owe their existence to philanthropy, or whether it should be, as in Germany for instance, undertaken by the State.

1. ***Poisoning in Dangerous Trades.***—Chemical lead-poisoning occurs among the workers in lead, silver, and zinc mines, also among painters, glaziers, compositors, and gas-fitters. Scrupulous cleanliness and avoidance of eating in the workshops with unwashed hands, are some protection.

Mercurial poisoning is rife among workers in quicksilver-mines, as well as in all trades which have to do with quicksilver. As the mischief is done by the inhalation of mercurial vapours, large and well-ventilated workshops, short hours of work, and strict medical supervision, can protect the workers in some degree against serious injury to health.

Chronic phosphorus-poisoning, which shows itself in the decay of the jaw-bone, arises in the manufacture of phosphorous matches, which ought to be entirely prohibited. No workers with defective teeth ought to be employed at all in this trade.

Arsenical poisoning occurs in the arsenic-mines, and in the manufacture of arsenical dyes and coloured paper made therewith.

Injuries from irritant and poisonous gases occur in the manufacture of soda, from sulphuric acid gas, in gasworks ; from ammonia ; in bleaching works, from chlorine and sulphurous acid gas. Such gases ought at once to be conducted away from the places where they are produced.

In such trades as pottery-manufacture, which, as it has been carried on in this country till quite recently, has been a fearful source of disease to the workers, it has been necessary for the State to interfere and show the employers that it is possible to substitute, for the deleterious articles obstinately employed, quite harmless material.

In all the dangerous trades, the health of the workers is protected, as far as possible, by precise legislative enactments. The carrying out of these, and all other hygienic rules, is supervised by special inspectors.

2. ***Injuries from Dust.***—The most frequent of all injuries is that caused by the inhalation of dust. Dust-formation is inseparable from the carrying on of most industries. Continued inhalation of dust occasions catarrh of the bronchial tubes and chronic inflammation of the lungs, which are thus prepared for the bacilli of tuberculosis.

Especially endangered are all workmen who are forced to breathe stone-dust, as masons and stone-cutters, porcelain-workers, cutlers, jewellers, glaziers, and colliers. With all these, particles of stone, glass, iron, or coal are deposited in the lungs in considerable quantities.

Legislation has not yet done nearly enough to provide against these dangers. Such industries as cuttling and glass-cutting, in which, as they are now carried on, but few workers live to the age of forty, have no claim to protection or consideration. For the rest, the dangers from dust may be, to a certain extent, diminished by various arrangements.

The production of dust may, in some cases, be prevented by wetting the material.

The deposited dust may be got rid of by frequent washing.

Good ventilation, supported, if necessary, by powerful exhausters, removes dust from workshops.

If the dust can neither be avoided nor removed, the workmen might, in time, be induced to wear respirators.

Work which produces dust should not be always committed to the same set of men.

Workmen ascertained to be suffering from tuberculosis ought—in order to prevent infection—never to be admitted to such works.

(*c*) ***The Neighbourhood of Factories.***—Many industries not only injure the workers engaged in them, but pollute the neighbourhood. Tanneries, soap-works, and glue-works, develop bad smells ; the waste water from sugar-refineries and breweries produces evil results, through the wholesale development of bacteria. Rag and leather works have sometimes even occasioned infectious disease among the neighbouring population. Many other industries are nuisances on account of the noise and smoke. It is only fair that, when such works are being opened for the first time, their location at a distance from inhabited places should be insisted on, and that already existing works should be subjected to certain restrictions in the interests of the people living near. For example, it should be required that factories purify their waste water before discharging it into the public water-ways.

(*d*) ***Infection.***—Various measures have been taken by the State to prevent the spread of disease. Schools are closed on the outbreak of an epidemic, and fairs, festivals, and other occasions for the assembling of large numbers of people, prohibited. For travellers coming from infected districts, quarantine has been resorted to. It has, however, proved useless, in the state of traffic at the present day, and has therefore recently been replaced, in most countries, by a careful medical inspection of those coming from the infected region, and by isolation of such as are suspected of suffering from the disease.

The spread of small-pox is combated by vaccination. It is certain that besides the cessation of the continuous wars of former ages, and the improvement in public cleanliness, nothing has so greatly contributed to the almost total disappearance of the small-pox as the practice of vaccination introduced at the beginning of this century by Jenner. In the last century, on an average, 10 per cent. of all children died of small-pox.

In countries such as France and Germany, where vaccination and revaccination are compulsory, small-pox is almost an unknown disease; the few cases which do arise in these countries are usually imported from others. Between the years 1886 and 1892 there were, in the whole German empire, 891 cases of death from small-pox, of which 833 occurred in the frontier districts and in sea-ports. If, however, vaccination is to have a lasting effect, it must be repeated at suitable intervals. It is to be deplored that in our country compulsion has been reduced by recent legislation almost to a mere formula.

For individual cases, on the outbreak of an infectious disease (diphtheria, scarlet fever, measles, small-pox, whooping-cough, typhus, cholera, etc.), the following rules should be observed, in order to prevent its spread :—

1. The patient must be isolated, either in hospital or at home.

2. The rooms in which the patient lived before the disease declared itself must be thoroughly disinfected.

3. All excreta of the patient, which may contain the infectious matter, must be disinfected, as well as his linen ; the fouling of the room with such matters must be avoided. In this connection it must be noted that, in diphtheria, the infectious substance is principally spread by means of the mucus from the pharynx ; in measles and whooping-cough, by the sputum ; also that the dissemination of these diseases is increased by the fact that the infectious matters are present in the sputum before these diseases have positively declared themselves. In typhus and cholera the bacilli make their appearance in discharges from the bowels and in the vomit ; in pulmonary tuberculosis, in the sputum.

4. After recovery, both patient and nurse must be *thoroughly* cleansed and disinfected.

5. When infectious diseases are prevalent, careful attention must be paid even to slight indispositions not recognizable as diphtheria, etc., as the early stages are often especially dangerous in spreading the infection.

As disinfection is such an important matter, the most general rules connected with it may be given. Its object is to destroy the infectious matter—generally bacteria. It is best to burn valueless objects. Things not liable to be seriously injured by steam — blankets, feather-beds, mattresses—are heated for half an hour or an hour by means of a current of steam at 100° C. Superheated steam does not disinfect so well as a current of steam. Leathern articles are spoilt by steam. Most large towns possess the necessary apparatus for steam disinfection. Linen can be disinfected by boiling for half an hour. Objects of metal, glass, etc., are exposed to dry heat of 140° to 160° C. for a longer period.

The desired end may also be attained by chemical disinfectants. Fumigations with brimstone, chlorine, and bromine, though much in use, are not very trustworthy; but milk of lime is very effectual, on account of its cheapness and its easy applicability to the disinfection of large masses of material. It is used in the proportion of one part of slaked lime to 4 litres of water: a bulk equal to that of the fluid to be disinfected being added to the latter. Chloride of lime is a stronger disinfectant than lime; it is used as a powder, or a liquid mixture of one part chloride of lime to four parts water; less of this solution is required than of the milk of lime. A very effective disinfectant is pure carbolic acid, of which a solution containing 5 per cent. of carbolic is added to the liquid to be disinfected. Crude carbolic acid, on the other hand, is only efficacious when the substances contained in it, which are insoluble in water, have been made soluble by the addition of a little sulphuric acid or potash solution. Corrosive sublimate (mercuric chloride), lastly, is effectual in a solution of 1 to 1000 or 2000, but some common salt must be added to the solution, otherwise insoluble compounds of albumen may be formed in the liquid to be disinfected.

All these disinfectants must be used of the proper strength, and allowed to act for some time, if they are to be successful. Therefore the whole mass must not be thrown away immediately after being sprinkled over with the disinfectant. Many objects which will not stand any of these methods may be well washed with soap. Wall-papers may be rubbed down with bread-crumbs, which carry with them all dust and dirt, and which should be afterwards burnt.

III. Care of the Body

(*a*) ***The Skin.***—The skin forms a protective covering to the body, and excretes water and some waste matters through the pores. It is, moreover, as we have learned, an important agent for the regulation of the temperature of the body. The skin performs its work most effectually when the accumulation of the fatty substances excreted, as well as of the dead scales of the scarf-skin and any other dirt, is prevented by scrupulous cleanliness.

By the process of "hardening," that is, by gradually accustoming the skin to the stimulus of cold, it may be made capable of enduring unavoidable changes of temperature. The best means to this end are baths. When possible, a tepid or cold bath should be taken daily.

Warm baths, not over 35° C., should be followed by cold sponging, or a douche. It is hurtful to remain too long in a bath.

A gradual and uniform cooling usually does no harm, even if it reaches almost the point of freezing; but great fluctuations of temperature, especially if the cold only affects one part, while other parts are exposed to warming influences, are specially apt to derange the temperature-regulating activity of the skin. Such rapid chills drive the blood back from the skin to the internal organs. If the subject has a weak place anywhere—whether a mucous membrane subject to catarrh, or a small tuberculous or easily inflamed part in the lungs, a nerve altered by neuralgia, a decayed tooth, or a tonsil subject to inflammation—such a back-rush of the blood is almost certain to produce, at such spots incapable of resistance, an intensification of the disease process, a "chill" or catarrh, pneumonia, neuralgia, rheumatism, toothache, inflamed throat, etc.

The skin protects itself against excessive dryness by the fatty matters which it secretes. If these are not secreted in sufficient quantities, and the skin becomes dry and hard, it can be rendered supple by rubbing with pure fats (pure oil, pure vaseline, etc.).

The best means of preserving the hair is cleanliness. The scalp should be kept clean by frequent washings with lukewarm soap and water, and if the natural lubricant is thus removed, its place should be supplied by pure oil. If, however, the hair is once lost and the hair-follicles dead, all remedies, and especially the much-vaunted quack nostrums, are useless.

The nails may be injured by cutting them too close; those of the foot also by tight boots and shoes.

A moderate padding of fat forms a very desirable reserve fund against times of such diseases—fevers, derangements of digestive organs—as prevent the acquisition of sufficient nourishment, and should therefore be aimed at by means of suitable diet. All efforts, however, should be used to combat excessive accumulation of fat.

(*b*) ***The Motor Apparatus.***—A strong and well-developed skeleton is of importance, in the first place, because the marrow of the bones is one of the sources of the red and white blood-corpuscles; moreover, unexercised bones are, as a rule, weak and easily broken. Ligaments and muscles not used for a long time waste and become weak. Strong and healthy muscles are of special importance, because they play a prominent part in the metabolism of the body. Muscular activity also accelerates the circulation and so promotes well-being.

If, however, the motor organs are to be rightly developed, they must be used from the earliest years rightly, and in all directions.

Bodily exercises, games, gymnastics, dancing, fencing, riding, swimming, rowing, mountain-climbing, skating, cycling, are therefore of the highest importance to health. They should be practised from youth up, and especially if a man's profession forces him to lead a sedentary life, or if it does not exercise the body uniformly should bodily exercises be continued.

In some trades, some groups of muscles are over-excited, while others remain almost unused. Gymnastics are the best remedy for defects so caused. By regular exercise the whole body gains strength and confidence. Courage and self-reliance are increased. Exercise in the open air is to be preferred to that taken within doors.

Excess of exercise, from which the professional athlete often suffers, ought to be avoided. By it some groups of muscles become developed at the expense of the rest of the body, and the body, as a whole, becomes less capable of work or resistance. The straining of the heart may also lead to lasting injury. When muscles are left tense too long, as in continued standing, they become tired, and strains on the bones and ligaments are caused. This, when the body is still growing, may entail evil consequences, such as the gradual lengthening of the ligaments, and the irregular growth of the bones. Different kinds of curvatures often result from over-strain of the bones and ligaments.

(*c*) ***The Respiratory Organs.***—For the respiratory organs to have the necessary capacity and mobility, the thorax and respiratory muscles must be well developed. Therefore tight clothes, which compress the thorax, should not be tolerated ; and no position which impedes breathing should be allowed to become natural. The development of the thorax and its muscles is effected by general exercise. It may also be pursued systematically by suitable exercises in breathing, singing, and speaking.

In order to protect the lungs from dust, from too-dry and from too-cold air, we should breathe through the nose, in whose passages the air is freed from dust, warmed and charged with aqueous vapour.

Over-exertion sometimes causes a rush of blood to the lungs, which under some circumstances may be dangerous.

(*d*) ***The Organs of Speech.***—The larynx is often affected by inflammation of the mucous membrane, which shows itself in hoarseness. With people, in particular, who in the course of their profession are forced to exert their throats greatly (singers, teachers, preachers), the constant irritation of the mucous membrane and over-strain of the muscles often leads to chronic disease. To keep the larynx healthy, we should avoid over-strain, give it complete rest on the first appearance of hoarseness, protect it from cold, dust, or damp air, and, above all, accustom it gradually to its work, and harden the throat.

(*e*) ***The Circulatory Organs.***—Proper feeding and breathing, healthy organs to prepare the blood, metabolism rendered active by muscular exercise and healthy conditions of light and air, keep the blood and circulatory organs in health. Exercise in the open air and simple food are the best means to this end. Excessive bodily exertion increases the activity of the heart, and leads to hypertrophy of the cardiac muscle. Besides this, the extreme tension of the blood-vessels causes their chronic inflammation and subsequent weakening, and so leads to diseases of the heart, kidney, or, in the case when the weakened blood-vessels are those of the brain, to apoplexy. Abuse of alcohol and over-eating are further sources of heart-disease. In this case deposits of fat are very apt to form between the fibres of the heart-muscle, and the unduly increased quantity of blood can only be removed by abnormal activity on the part of that muscle. If the kidneys are permanently forced, by too great a consumption of liquids, to do an excessive amount of work, or if they have to deal with too many irritant substances, kidney-disease arises, which might have been avoided by exercise and a little care.

(*f*) ***The Digestive Organs.***—Food should be taken at regular times, in moderate quantities, and of a kind suited to the manner of life. Tainted or doubtful food should be avoided. Food should never be too hot nor too cold, and plenty of time should be allowed for meals, as good mastication is of the highest importance for digestion, especially for that of starchy foods, for which an intimate mixture with the saliva is indispensable. Other substances as well are thereby made more accessible to the influence of the gastric and intestinal juices ; while defective mastication may cause diseases of the stomach and intestine. Violent exercise soon after eating should be avoided, as it retards digestion. Not much drink should be taken with meals, or soon after them, as the digestive juices are thus unnecessarily diluted. No drinks favour digestion, alcohol retards it ; some drinks, such as coffee, quickly remove the feeling of fatigue which affects many people after meals.

Good teeth are of far greater moment than is commonly supposed to the health of the digestive organs, and therefore of the whole body. The teeth may be preserved by keeping them clean. After every meal, or, if this is impossible, at least morning and evening, the teeth should be cleaned with a soft brush and harmless tooth-powder, in order to remove the remains of food as well as the bacteria lodged in the teeth. Particles of food wedged in between the teeth should be got rid of with a bit of wood or a quill, never with any metal instrument. One should avoid a rapid alternation between hot and cold food, as this is apt to crack the enamel of the teeth. If a tooth begins to decay, it should be stopped by the dentist, as a good stopping may preserve a tooth for years. In decaying teeth no projecting points should be allowed to remain ; they scratch the skin of the tongue or cheek, and may cause serious illness.

If a tooth is decayed past remedy, it should be extracted. If those remaining are not sufficient for chewing, artificial teeth should be adopted. Those who have no teeth left, and cannot wear artificial teeth, should only eat soft or very finely chopped food, as otherwise the food cannot be properly utilized, the body becomes ill-nourished, and the stomach often diseased.

It is advisable that the teeth should be examined at fixed periods by a dentist.

The stomach is one of the most used and most abused organs of the body, and therefore is very often diseased. Like every organ which works hard, it needs due intervals of rest. Many persons, however, think that they must be continually eating trifles. With such people the stomach is never empty before it is called upon to receive a fresh supply of food. Deprived of intervals of repose, it becomes diseased through over-work. Food that is too warm or too cold is hurtful, so is overloading of the stomach. Too copious drinking at or after meals, and excess in alcoholic drinks, are frequent causes of chronic stomach complaints.

Slight derangements of the stomach are most speedily relieved by doing what should be done with any diseased organ—letting it rest, either by putting the sufferer on a strict diet or allowing him to fast for a while.

Catarrh of the bowels arises, in children especially, from feeding with already partly decomposed milk; in adults, from tainted food, or drink in course of fermentation and also from insufficient mastication.

Inflammation of the cœcum is caused by solid bodies—apple-pips, cherry-stones, etc.—getting lodged in the vermiform appendix. All seeds should therefore, as far as possible, be removed from fruits before they are eaten.

(*g*) ***The Sense-Organs and the Brain.***—The *eyes.* Cleanliness prevents various inflammatory affections of the lids, the conjunctiva, and of the cornea.

The prevention of short-sightedness is a very important task. One of its most frequent causes is bad light, which forces the things looked at to be brought very near the eye. The right kind of light must be provided, both in the school and in the home. The places in which work is done should be sufficiently lighted, and the light should fall from the left side on to the object looked at. Care must also be taken that children do not acquire a bad habit of bringing their eyes too near to the books they are reading, or on which they are writing—30 cms. is the right distance. Small print should be avoided ; small and close writing should not be allowed. Exertion of the eyes should be interrupted by frequent intervals during which the eyes are allowed to rest. This is best done by a few minutes in the open air, as then the eyes look at distant objects, and thus rest the accommodation apparatus. The habit of regular play in the open air is also good for the eyes. Any one inclined to short-sightedness should avoid everything likely to increase the pressure of blood towards the head, *e.g.* any articles of clothing, such as tight collars, which impede the circulation, excess in eating and drinking, and bending the head forward when working. In such cases it is well to read or write at a sloping desk.

Short-sighted people need spectacles with concave glasses ; as a rule they need only be used to see objects at a distance. The choice of the glasses must be left entirely to the medical adviser. If too weak, the glasses are useless ; if too strong, they increase short-sightedness.

With the progress of short-sightedness, weakness of vision is commonly connected ; if the former can be prevented, the eye is protected against the weakness otherwise produced by it. This latter may also arise if the retina is often fatigued by too bright a light. Brilliant illumination, and rapid alternations of light and darkness, should therefore be avoided ; it is not well to read in strong sunlight, nor, as is well known, to look at the sun itself.

Far-sightedness also requires spectacles, in order to enable objects near at hand to be seen ; for this purpose the glasses must be convex. With increasing age the crystalline lens loses more and more its power of curvature, so that, from a certain age—as a rule, from the forty-fifth year—the power of seeing near objects diminishes with the loss of the power of accommodation ; the eye comes to be soon fatigued in the dusk or in artificial light. This alteration in the eye through age also necessitates the use of convex glasses for seeing near objects.

Cleanliness assists the preservation of the *hearing*, as very often the formation of plugs of dried wax in the external auditory canal is the cause of deafness. The wax is best removed by syringing with water, and not by means of rigid instruments, as these are apt to injure the tympanic membrane.

Excessive strain on the hearing may also cause deafness. Musicians, smiths, and others who are constantly exposed to loud noises, very frequently suffer from this affliction.

Even though the sense of *smell* fulfils its office of warning us against injurious substances but imperfectly, yet we should let ourselves be restrained by its warning from the use of tainted food and drink, from remaining in vitiated air, and from similar dangers. The long-continued effect of strong odours blunts the sense of smell, as do frequent inflammations of the mucous membrane of the nose, which, indeed, may in time quite destroy the sense. In very obstinate colds, medical aid should be sought. Generally "hardening" protects against too frequent catarrhs of the nose.

Frequent repetition of the same taste, very hot food, but especially any strong stimulus, as of pungent spices, so blunt the sense of *taste* that a constant heightening of the flavour is needed to produce the desired effect at all.

Those who, for want of bodily exertion, have to eat without any great appetite, should see that they have easily digested food and a varied diet, but should not tempt their appetites with highly spiced dishes.

The delicacy of the *tactile* sense and of those senses allied to it can, by practice, be developed to a high degree. Any one who needs a specially delicate touch should avoid everything likely to harden the skin and injure the sensitiveness of the nerves. Hard work, too great extremes of heat and cold, the effect of injurious chemicals, all tend to reduce the delicacy of the tactile sense.

The *brain*, the seat of intellect and will, which receives all the impressions of the senses and, with the spinal cord, occasions movements, may, like other organs, suffer from over-exertion. Especial care ought to be taken to inure it gradually to an increased activity, and to secure, in children, the right proportion between work and rest. In many cases it is quite sufficient to change the kind of intellectual activity, but the alternation of bodily and intellectual work has a still better effect.

Sufficient sleep is indispensable to persons engaged in hard brain-work. Children and weakly, especially anæmic, adults require more sleep, but for adults in general, seven to eight hours are sufficient. The need of sleep is less with bodily than with mental work. Besides over-exertion, the brain may be injured by violent emotions, troubles, or passion, over-strong impressions of the senses, abuse of spirits or other stimulants, shocks, and extreme degrees of temperature. Especially during the years of growth, such injurious influences may have the worst consequences. Children should therefore be guarded with the most anxious care against all such evils. At the first symptoms of brain- and nerve-exhaustion (neurasthesia), it is time to change the mode of life. Only by so doing can the spread of this disease, the commonest of our day, be checked.

If a family show an hereditary tendency to any serious nervous affection, hysteria, epilepsy, or other mental disturbances, care must be taken, in the education of the children, to keep them from all violent excitement, and to restrain the development of mental activity, whilst encouraging, as far as possible, a strong and healthy physical development.

APPENDIX

THE METRIC SYSTEM

Measure.

1 kilometre = 10 hectometres.
1 hectometre = 10 decametres.
1 decametre = 10 metres (m.).
1 metre = 10 decimetres.
1 decimetre = 10 centimetres (cm.).
1 centimetre = 10 millimetres (mm.).

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1 metre = 39·37 inches.
1 centimetre = 0·3937 = about $\frac{2}{5}$ inch.
1 millimetre = 0·03937 = about $\frac{1}{25}$ inch.

Weight.

1 kilogram = 10 hectograms.
1 hectogram = 10 decagrams.
1 decagram = 10 grams (g.).
1 gram = 10 decigrams.
1 decigram = 10 centigrams (cg.)
1 centigram = 10 milligrams (mg.).

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1 gram = the weight of 1 cc. of water at 4° C. = 13·54 grains
1 litre = 1000 cubic centimetres (cc.) = about 1·76 pints

Temperature Table.

	Centigrade (C.).	Fahrenheit (F.).
Boiling point ..	100° ..	212°
Freezing point ..	0° ..	32°

To convert degrees Centigrade to degrees Fahrenheit—

Degrees C. $\times \frac{180}{100} + 32$
Degrees F. $- 32 \times \frac{100}{180}$

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LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.