garded by some as an unicellular gland. It is found distributed throughout the epithelium of the intestinal tract, trachea, and bronchi. Owing to its shape it is commonly called a goblet cell.

Mucous cells are formed from cylindrical epithelial cells, the most of the cytoplasm of which is gradually converted into mucin. The process begins at the free surface of the cell (Fig. 1929, *A*), and progresses until the cytoplasm, excepting a small portion containing the nucleus, is changed. The latter becomes crowded to the

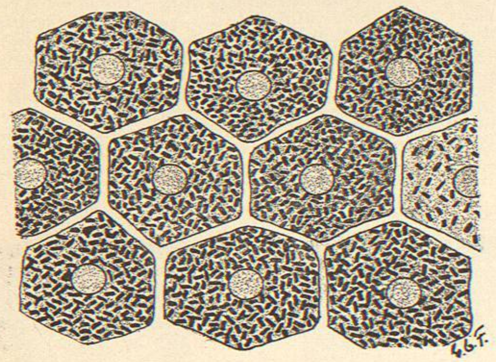


Fig. 1930.—Pigmented Epithelial Cells from the Retina.

base of the cell. The cell increases in volume (Fig. 1929, *B*), finally it ruptures at its free surface and its contents are discharged (Fig. 1929, *C*). The cell then collapses (Fig. 1929, *D*), and from its basal part which contains the unchanged cytoplasm and nucleus, a new cell is formed (Fig. 1929, *E*).

Pigmented Epithelium.—In some parts of the body there occurs an epithelium, the cytoplasm of which is more or less filled with granules of pigment. These granules may be spherical or rod-like in shape and of a color varying from light brown to black.

This type of epithelium forms one of the layers of the retina (Fig. 1930) and is also found in the deep layer of the epidermis of the colored races.

Glandular Epithelium.—This form of epithelium lines the alveoli or secreting portion of glands. The shape of the cells varies in different glands, in some being cylin-

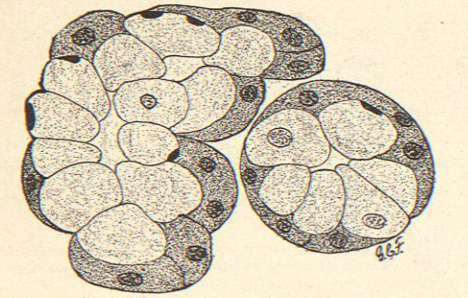


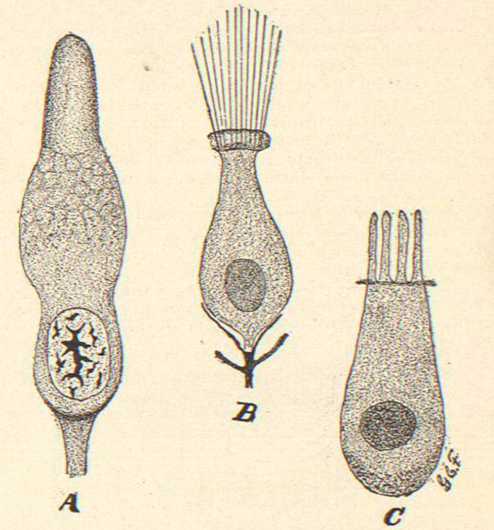
Fig. 1931.—Glandular Epithelium. Mucous acini from human submaxillary gland. The light central cells are the mucous cells; the dark cells form the crescents of Gianuzzi.

drical, in others polyhedral or irregular. In some glands two types of cells occur. Many of the mucous glands have an internal layer of cylindrical cells with a moderately clear cytoplasm, and between these and the membrana propria a second type, viz., granular cells (Fig. 1931). These granular cells form the crescents of Gianuzzi or demilunes of Heidenhain. The cardiac glands of the stomach also contain two types of cells, the internal or chief cells and the large granular peripheral cells—the acid cells.

The microscopic appearance of gland cells varies with their state of activity. The resting cell is generally granular and dark in appearance, the granules staining intensely, and the volume of the cell is reduced. As the cell passes into the active state its granules cease to stain; small vacuoles appear in the cytoplasm, which becomes clearer; and the volume of the cell increases. After the cell has discharged its secretion the cytoplasm may become nearly clear and the cell returns to the resting state. In some glands (for example, the mammary gland) a portion of the external part of the cytoplasm is used up in the process of the formation of the secretion, the basal part with the nucleus remaining unaltered. From this portion the cell is reconstructed. In other glands the entire cytoplasm is used up and a new cell takes its place.

Many gland cells discharge their secretion not only from their free surfaces, but also from all sides. In such cases the cells are surrounded by a network of canaliculi, which take up the secretion and convey it to the lumen of the gland by a "duct."

Neuro-epithelium.—Neuro-epithelium is a highly differentiated type and occurs in the sense organs. The



A. *C.*

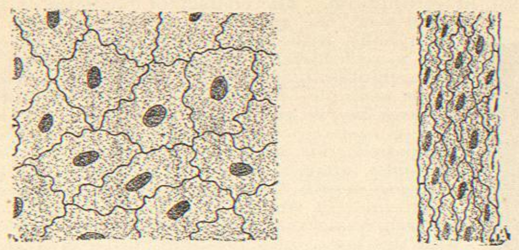
Fig. 1932.—Neuro-epithelium. *A*, Cone from the retina; *B*, hair cell from the crista acustica; *C*, hair cell from the organ of Corti of the cochlea.

rods and cones (Fig. 1932, *A*) of the retina; the hair cells of the organ of Corti of the cochlea (Fig. 1932, *C*); and the hair cells of the macula and crista acusticæ (Fig. 1932, *B*) are examples.

Neuro-epithelial cells consist of two portions: the basal, containing the nucleus, and which is in close contact with the nerve terminations; and the outer or perceptive portion, which usually terminates in the form of thick, hair-like processes.

Mesothelium and Endothelium.—These two types of cells, on account of their characteristics, are now classified by many as simple epithelium. If we trace them back to their origin in the blastoderm it is found that they are both derived from the mesoderm or middle layer, but from different cells. Mesothelium, which lines the cavities of the peritoneum, pleura, and pericardium, is derived from the cells which line the original body cavity—the cœlom. At the suggestion of Minot the term mesothelium has been applied to them.

Cells of a similar type form the capillaries, and line the interior of blood and lymph vessels, synovial spaces, bursæ, tendon sheaths, and the anterior chamber of the



A. *B.*

Fig. 1933.—*A*, Mesothelium Covering the Surface of a Serous Membrane; *B*, endothelium lining a blood-vessel.

eye. These are differentiated mesochymal cells (Minot) and the term endothelium is alone applied to them.

Mesothelial cells (Fig. 1933, *A*) are thin, flat cells, the cytoplasm of which is slightly granular. Their nuclei may be either oval or spherical in shape and they project above the surface of the cytoplasm. The general shape of the cells is polyhedral with more or less wavy edges, and they are united by an exceedingly slight amount of intercellular substance.

Endothelial cells (Fig. 1933, *B*) are, as regards structure, like the mesothelial. Their shape is an irregular oblong one with markedly serrated edges.

These two types of cells are always laid down in a single layer.

George C. Freeborn.

EPULIS. See *Sarcoma.*

EQUILIBRIUM AND EQUILIBRATION.—The term equilibrium is used to indicate a state in which all the muscles of the body are under such nervous control that when called upon they can execute some co-ordinate movement or resist the force of gravity. Equilibrium is of great importance in animal life, as can be readily understood, and it is by no means a simple phenomenon. That the motor apparatus may act properly it is necessary that it should receive sensory impressions informing it of the position of the body at any moment, and every known sense appears to contribute the necessary information. A combination of these sensations constitutes the sense of equilibrium.

Before discussing equilibrium and equilibration with regard to its nervous control or how it is maintained in the human body, it is necessary that we should have a clear idea of the position of the centre of gravity of the body and how the position of this centre may vary in different postures. It is mainly owing to the researches of the Weber brothers, Barellus, Harless, and Meyer, and more recently Braune and Fischer, that the position of the centre of gravity of the body has been determined.

In the *erect posture*, roughly speaking, the centre is situated between the pubes and buttocks, and is farther from the sole of the foot than from the crown of the head. A variation may be pointed out here, viz., that the position of this centre will vary according to a man's build. A man heavily built in his shoulders and arms will naturally have his centre of gravity higher than a man with narrow shoulders, light arms, but powerful legs and buttocks. Meyer's method for determining the centre of gravity in the antero-posterior plane was as follows:

A soldier standing at "attention" leaned forward so as to throw the weight of the body upon the front of his feet. A line plumb to this point would pass through his centre of gravity. The man then extended his limbs at the ankle-joint until he nearly lost his balance backward. A vertical line from his heels again passed through his centre of gravity which lay naturally where these two lines crossed one another. This was found to be in the region of the body of the second sacral vertebra.

Braune and Fischer's method was more complex and their experiments were performed upon the cadaver. For a full account of this I would refer the reader to their original articles. According to their method the centre of gravity for the whole body was about 4.5 cm. above a horizontal line joining the centres of the heads of the two femora, or on a level with the third sacral vertebra (upper border).

These observers have claimed that the centre of gravity of the body is found to fall in the same frontal plane as that in which all the axes of rotation of the joints lie. It can be readily understood from this that anatomical variations will very considerably alter this statement, this being particularly true of women in pregnancy or of abnormally stout men. In such persons, when in the erect position, the centre of gravity must lie well away from the plane containing these joints, the abdominal weight necessitating an arching of the spine, the shoulders being thrown back, bringing the centre posterior to the normal plane.

It has been pointed out by the Weber brothers, that the fact that the various centres of gravity of the body form a vertical line when the body is in an erect position, is sufficient to maintain the body in an erect position without any muscular effort. (According to Braune and Fischer the centre of gravity for the head was plumb above the atlanto-occipital joint.) According to them the centre of gravity plumbs behind the hip, in front of the knee and through the ankle-joint. Meyer claims that the centre plumbs in front of the ankle-joint. If this is so the calf muscles would have to act toward the support of the body. In bending forward or backward the centre of gravity will fall either forward or backward, as the case may be (see Fig. 1934).

In the most comfortable standing position the centre plumbs really in front of the ankle. When it falls farther forward than this, as for instance when it falls over the ball of the great toe as in the military position of "attention," there is a sensation of straining and this posture cannot be long supported. In fact there is no erect position of the body which can be maintained for many minutes without exhaustion, although it has been claimed that muscular action is not necessary to maintain the body in the erect position. It may be noted that we instinctively

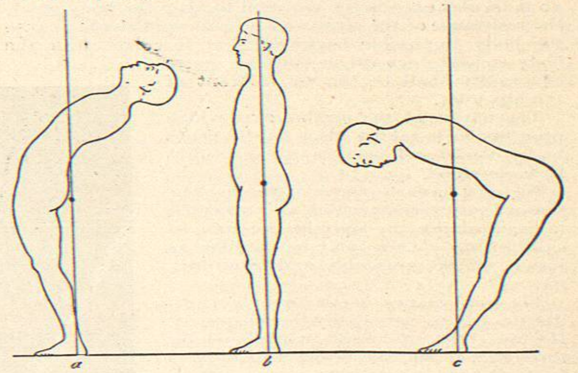


Fig. 1934.—The Position of the Centre of Gravity is Indicated by a Dot in Each of the Postures *a*, *b*, and *c*. In *a* and *c* it lies outside the body altogether.

and frequently change our position and so ease the various sets of muscles when standing for any length of time.

Walking and Running.—In these modes of progression there are certain forces which have to be so balanced that the speed of progression is neither diminished nor increased, and also that during locomotion the body shall remain erect. Three forces may be considered: first, the weight of the body to be supported; second, atmospheric resistance, which naturally varies with the speed of progression and the size of the surface presented to the air; and thirdly, the friction of the ground on which locomotion is performed. Against these forces we have the

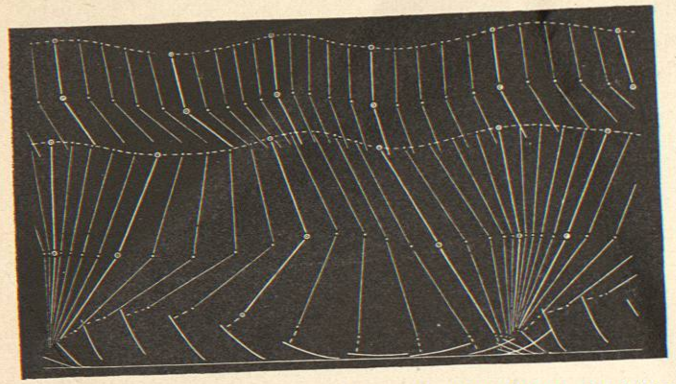


FIG. 1935.—Diagram showing a Man's Movements when Walking. Read from left to right. (From a chronophotograph, after Marey.)

muscular force of the body, which, by altering its position, raises the centre of gravity by shortening the legs and so gives it naturally a forward impetus.

During locomotion the centre of gravity constantly and rhythmically changes its position as the body changes its shape. The centre of gravity is moved not only on a horizontal plane forward through the median sagittal plane of the body, but also from side to side. This side-to-side movement is naturally due to the fact that a different leg is supporting the weight of the body every moment.

Figs. 1935 and 1936 give Marey's chronophotographs of a man's movements when walking and running. In these it can be seen that the plumb from the centre of gravity falls through different portions of the leg and ankle at different stages of progression. Should the body progress forward in a perfectly erect position and no muscular exercise be required to keep the body erect, the resistance of the air would be quite sufficient to cause the body to tumble backward, but to correct this the body is bent forward so that the centre of gravity shall be thrown in front of the hip-joint.

The nature of the ground over which progression is taking place hardly needs to be considered here, as it can readily be understood.

We now have to consider the various sensory impressions which are concerned in maintaining the body in the state of equilibrium. These may be classified as visual, tactile, muscular, and labyrinthine.

The importance of the eye in equilibrium can be very easily demonstrated. If one tries to walk while looking through a prism, the position of objects is so distorted that improper co-ordination of the various muscles results; where under normal conditions, knowing the position of objects to be determined by the sense of sight, we would have perfect co-ordination. Again, when we look at rapidly moving objects, wrong ideas of equilibrium are commonly formed through the visual sense, and there may be a strong tendency for the body to move itself in one direction or another. These phenomena may primarily be due to, we might say, deceiving educated senses, for the reason that people born blind are not troubled with inco-ordination of the muscles and neither are people from whom the eyes have been removed.

The tactile sense also plays an important part in the sense of equilibrium. The contact of the soles of the feet with the ground or of various parts of our body with surrounding objects conveys to us considerable knowledge with regard to the position of the body. We see a remarkable example of the value of this sense in the disease known as "locomotor ataxia" in which the muscular power of the lower limbs is not impaired, but sensory impressions are profoundly altered. The inco-ordination in this disease results from the false tactile impressions and not from any disease of the muscles, which retain their original strength. We can see this same phenomenon in persons who have had the soles of their feet frozen. Here their tactile impressions are not received by the sensory end organs, consequently do not reach the higher centres, and so inco-ordination will result. Attention has been called to a peculiar tactile phenomenon in the fact that air waves exert an influence upon the tympanic membrane (?), and so we are capable of appreciating the presence and to some extent the character of near objects (irrespective of sound). Whether this involves the nerves of common sensibility or those distributed to the internal ear is disputed.

The muscular sense, whether our bodies are moving or not, is another active factor in determining the condition with regard to the tension and position of our muscles. That the various skeletal muscles are acting reflexly more or less all the time is shown by the fact that from a person with the eyes closed, standing in an erect position and having a writing point attached to the head, a graphic record may be obtained showing a peculiar swaying motion of the body. Evidently different groups of muscles are successively contracting. A peculiar sensation which has been experienced by almost every one is that of going up-stairs in the dark, miscalculating the number of stairs, and taking an extra step at the top of the stairs. The sense of loss of equilibrium is at once experienced. A patient with failure of tactile or muscular sense, as in the above-mentioned disease, locomotor ataxia, is unable to stand with the eyes closed. Here we see the importance of the combined loss of the visual, tactile, and muscular sense.

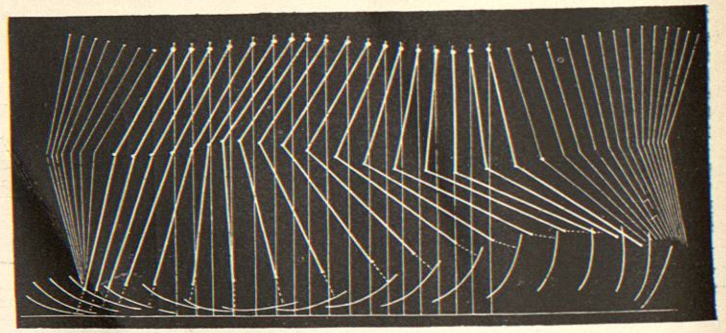


FIG. 1936.—Diagram of the Movements of a Man's Leg in Running. Read from right to left. (From a chronophotograph, after Marey.)

A normal combination of all these senses gives us our idea of position. Should the impressions arising from any of them clash with our conscious perception formed through the other senses, a disturbance of equilibrium results and the usual result of this disturbance is the sensation of nausea or dizziness. An example of this clash-

ing with the resulting dizziness is seen in people on the top of a high building. The tactile organs of the soles of the feet and the muscular sense organs of the limbs are originating perceptions which indicate that one is standing on the solid earth. Yet the eyes at the same time originate perceptions that indicate that the solid earth is far below.

FIG. 1937.—Diagrammatic Horizontal Section through the Head to Illustrate the Planes Occupied by the Semicircular Canals. S, Superior; *H*, horizontal; *P*, posterior. (After Waller.)

We see from the above that the sense of equilibrium is served by various special senses. However, we have good reason for believing that there is one special sense organ which determines the position and direction of the movements of the head, and consequently of the whole body. This organ consists of the system of semicircular canals in the internal ear (anterior, posterior, and external).

Various experiments performed on birds show that a motor disturbance invariably follows division of any of these canals. The animal shortly after operation, whenever it is disturbed, undergoes peculiar forced movements with rolling of the eyes. When at rest the animal does not maintain its perfect erect position, its legs spreading farther apart than normal and its body coming closer to the ground. The effect of this operation varies, of course, very considerably, it depending altogether on the number of the canals cut. Some observers have claimed that it is the activity of the hair cells on the *cristæ acusticæ* of the ampullæ of the semicircular canals, which are irritated by the increased or diminished pressure of the endolymph in them, which gives rise to a nervous impulse and so originates various ideas of position.

The anatomical position and relationships of these canals in the human being have been very extensively studied by Crum Brown, who pointed out that the three canals of each side lay in the three dimensions of space and that the canals of each side are almost at right angles to one another (see Fig. 1937). Any movement of the

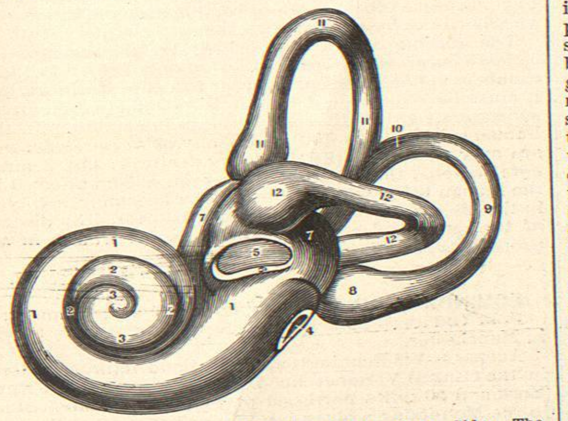


FIG. 1938.—Left Bony Labyrinth, Viewed from Outer Side. The figure represents the appearance produced by removing the petrous bone down to the denser layer immediately surrounding the labyrinth. 1, 2, 3, The first and second turns of the cochlea, and the cupola; 4, fenestra rotunda; 5, foot-plate of the stapes; 7, the vestibule; 8, 11, 12, the ampullæ of the semicircular canals; 9, 11, 12, semicircular canals.

head will constantly produce an increase of pressure in the ampulla of a canal of one side, with a corresponding decrease of pressure in the same canal on the opposite side, and this by exciting the hair cells in them originates the sense of movement. This assumption can be considerably strengthened by experiments on man. A person with the eyes bandaged, tactile and muscular sense eliminated, supported on a rotating table, can determine very correctly in what direction and through how great an angle he may be rotated. It will be found in the same experiment that after being rotated for a few moments and then the table brought to a standstill, the person will experience the sensation of rotation in the opposite direction. Patients with some disease of the internal ear are very

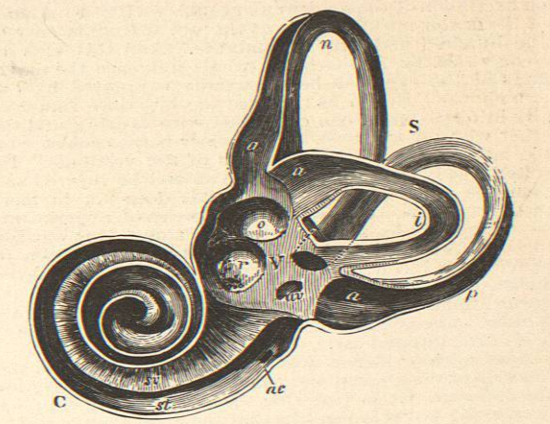


FIG. 1939.—Interior View of Left Bony Labyrinth After Removal of the Superior and External Walls. *n, p, i*, The superior, posterior, and horizontal semicircular canals; *a, a, a*, ampullæ; *av*, opening of the aqueduct of the vestibule; *V*, vestibule; *ac*, opening of the aqueduct of the cochlea; *sv*, scala vestibuli; *st*, scala tympani; *o*, fenestra ovalis; *r*, fenestra rotunda.

seldom subject to dizziness caused by rapid rotation or the motion of a swing. James has pointed this out in deaf-mutes who are subject to this and to another well-known peculiarity. Should a deaf-mute dive into deep water when bathing, the pressure of the water surrounding the body is nearly equal and so eliminates localized pressure; the mute may then, instead of swimming to the surface of the water, continue his progress toward the bottom—in short, he cannot distinguish whether he is going up or down. In support of this fact it may be mentioned that in birds and fishes whose environment is such that muscular and tactile sense can contribute little to the sense of equilibrium, the semicircular canals are very greatly developed. We find also that in cases of disease of the semicircular canals in which the pressure in them is considerably altered we have well-marked symptoms of vertigo and inco-ordination. Disease of the cochlea does not produce this. According to Lee, section of these canals in fish produces no forced movement, but section of the nerves supplying the ampullæ invariably gives rise to forced movements. This observer also found that when a fish is placed in different positions, there is an opposite movement of the dorsal fin and of the optic axes determined by the semicircular canal in whose plane the movement is made. Lee places great importance upon the presence of otoliths in the vestibular sacs of the nerve terminals and the *cristæ acusticæ*. These bodies form large masses in the ears of fishes and they undoubtedly exert considerable pressure on the hair cells.

The semicircular canals are not entirely necessary for the preservation of equilibrium, yet the muscular, tactile, visual, and other senses supplying their quota of information regarding the position of the body may, no doubt, to a considerable extent, take the place of the semicircular canals when these are destroyed by either operation or disease.

The first suggestion of the importance of the semicircular canals in maintaining the body equilibrium may be traced to the two important researches by Purkinje in

1820, and another by Flourens in 1828. Against the usually accepted theory that the semicircular canals are the organs for determining the spatial relations of the head, Cyon contends that the semicircular canals only assist indirectly in this function. He maintains that really our knowledge of the position of the bodies in space depends more upon the nerve impulses coming from the contracted ocular muscles, pointing out that the oculomotor centres are in close relationship with the centres receiving the stimuli from the semicircular canals. Consequently on excitation of the semicircular canals oscillatory spasms of the ocular muscles occur at the rate of from twenty to one hundred and fifty per minute. And this view of Cyon's that the semicircular canals influence the movement of the eyes has been partially supported by Lee (see above). Ewald has divided the labyrinth functionally into two parts, one concerned with hearing and the other with muscle tone. The former is the cochlea, and the latter the semicircular canals of the vestibule. He states that if the labyrinth of an animal be injured and then the animal killed, rigor mortis does not in most cases occur. Sewall carried out a series of experiments on young sharks and skates and claimed that cutting through the canal on one side produced no alteration in equilibrium. But should the utricle be injured and the otoliths be removed the fishes usually dived and swam toward the injured side. Ewald claims that the saccule is more concerned in the equilibrium than any other portion of the internal ear.

Anatomical evidence clearly points to the fact that the function of the semicircular canals and that of the cochlea are different. It is true that the eighth nerve supplies them both; but it is also true that the eighth nerve really consists of two divisions, a vestibular and a cochlear portion, which, although running together in the human subject (in the horse they are separate and distinct nerves), on entering the internal auditory meatus they separate and are distributed as named.

The question may now be asked, In what part of the brain are these impressions from the semicircular canals and other senses received and elaborated into the sense of equilibrium? We have seen above that nearly all the special senses are concerned in maintaining equilibrium and that the semicircular canals are of primary importance.

The cerebellum has long been regarded as the nervous centre for equilibrium and co-ordination of muscles. Certainly pathological evidence points to the fact that the cerebellum is concerned in this function, giddiness being a well-marked symptom of cerebellar disease, although it is not so well marked as in labyrinthine or eighth-nerve lesions.

Should a large portion of the cerebellum be destroyed, we have well-marked inco-ordination phenomena, and here, although sensation may remain good, the inco-ordination must be ascribed to a loss of impulses which regulate body movements without being on their way or in the cerebellum elaborated to conscious sensations.

Experimental work on the cerebellum seems to point to the fact that the organ "functions" as a whole, not in "areas" as the cerebrum, because it is so largely concerned in the innervation of the muscular system of the whole body, and this fact led Flourens and Bouillard, early observers, to express the opinion that the cerebellum was the organ of "equilibrium." The cerebellum, according to Lussana and Carpenter, receives impressions originating in the sense organs of muscles, joints, ligaments, and tendons, and it also is intimately connected with the vestibular nerve, consequently destruction of one side of the cerebellum greatly lowers the muscular tone of that side. Removal of one-half of the cerebellum gives well-marked symptoms of inco-ordination and partial loss of equilibrium. Complete removal of the organ does not give such marked symptoms, but profound lassitude is marked, following execution of movements which should be ordinarily quite unfatiguing. In unilateral ablation the animal usually lies on the side from which the portion of the cerebellum is being removed and with the trunk often curved concavely to the same side. The four limbs are usually extended, the one on the operated side more than the other. There is conjugate deviation of the eyeballs to the opposite side. As a rule, the animal cannot stand and has a great tendency to fall to the injured side. Should it try to move, it will move around in the long axis of its body toward the injured side. In a few days, the majority of these symptoms disappear. However, entire disappearance of the symptoms has not been obtained.

Although an enormous mass of work has been done on the cerebellum, very little definite knowledge has been obtained. It appears that this organ is concerned in a particular class of phenomena, rather than in a particular sense. It is more intimately concerned in receiving impulses from the various senses, more especially of those concerned with equilibrium and muscular sense. Through it habitual posture is supported and it is immediately associated with the movements depending principally on the lower cerebral sense, that is, walking and running, and not with those elaborated with the highest technical movement.

From the foregoing description we can see that the sense of equilibrium is one of the most complex phenomena in the body. As already mentioned, it is made up from impressions derived from nearly all the special senses. Experimental evidence clearly points to the fact that the semicircular canals are of primary importance, that they transmit their impulses to the cerebellum through the vestibular nerve, and the cerebellum in turn, acting through the vermis, may react upon the cerebellospinal and vestibulo-spinal efferent system and so through these contribute a factor to the normal tonus of the spinal, cranial, and motor cells.

In conclusion it may be mentioned that although we have seen that the semicircular canals and vestibule are primarily concerned in equilibrium, yet pathological cases have been found in which a slowly progressive affection of the internal ear ultimately left these structures transformed into a bony mass in which no trace of the original soft structures remained. And in these cases there was no perceptible disturbance of equilibrium, nystagmus, or giddiness. We must therefore admit that these organs are not indispensable for equilibrium, but that some other organ or combination of organs can vicariously carry on their function.

The question may also be asked, Are the semicircular canals concerned in hearing? Certainly injury to these canals in animals does not appear to cause deafness, but it must be remembered that it is extremely difficult to substantiate any of the special senses in animals. In the human subject it is doubtful if any of these structures are ever affected without causing deafness; but it must here be noted that these structures are seldom affected in the human being without the cochlea becoming involved in the disease, so that deafness may be caused by disease of the semicircular canals, which disease would, in all probability, also involve the cochlea.

Allen M. Cleghorn.

EQUINOX SPRING.—Bennington County, Vermont.

Post-Office.—Manchester. Equinox and other hotels in Manchester.

Access.—Viâ Bennington and Rutland Railroad, a link in the Central Vermont line between Montreal and New York and 50 miles northeast of Saratoga. Manchester-in-the-Mountains, a charming village in the southwestern part of Vermont, is situated on a plateau about 200 feet above the Battenkill River, and 1,000 feet above tide-water, in a valley between the Green and Taconic ranges. For nearly half a century it has been one of the principal resorts of New England, famed alike for its beautiful scenery, fine drives, healthful, invigorating air, pure water, and numerous brooks, alive with trout. The place has been properly termed a model village, the main street being bordered by wide lawns, overarched by century-old elms and maples. Shaded by these trees are marble side-walks, and back of them the cottages in

their setting of emerald, the entire absence of fences on the street giving the effect of a park. The village contains a beautiful new library building, charming drives in all directions, a strictly first-class hotel (the Equinox) and other desirable features too numerous to mention here. In the immediate vicinity is an unending variety of natural attractions. Away off on Mount Equinox, 1,500 feet above the village and 2,500 feet above the level of the sea and far from any habitation, is located the spring which supplies the Equinox mineral water. An analysis of this water in 1892 by Messrs. Chandler and Pellew, of New York, showed the following ingredients:

One United States Gallon Contains: Sodium bicarbonate, gr. 0.55; sodium chloride, gr. .48; potassium sulphate, gr. .08; calcium sulphate, gr. .15; calcium bicarbonate, gr. 1.98; magnesium bicarbonate, gr. .73; iron oxide and alumina, gr. .01; silica, gr. .18; organic and volatile matter, trace. Total solids, gr. 4.16.

This water has become well known for its purity and softness. It is widely used in the hotels, clubs, and private residences of many of our large cities as a drinking-water. It is very lightly mineralized, as shown by the analysis, yet it is recommended by numerous medical men as being useful in the treatment of gout, rheumatism, dyspepsia, and diseased conditions generally which are traceable to the uric-acid diathesis. *James K. Crook.*

END OF VOLUME III.