CHAPTER VIII.

The Nervous System.

Animal and Vegetative Functions—Sensation, Motion, and Volition—The Structure of the Nervous System—The White and Gray Substances—The Brain—Its Convolutions—The Cerebellum—The Spinal Cord and its System of Nerves—The Anterior and Posterior Roots—The Sympathetic System of Nerves—The Properties of Nervous Tissue—Excitability of Nervous Tissues—The Functions of the Spinal Nerves and Cord—The Direction of the Fibres of the Cord—Reflex Activity, and its Uses—The Functions of the Medulla Oblongata and the Cranial Ganglia—The Reflex Action of the Brain.

1. Animal Functions.—The vital processes which we have been considering, in the three previous chapters, of digestion, circulation, and respiration—belong to the class of functions known as *vegetative* functions. That is, they are common to vegetables as well as animals. The plant has its circulatory fluid and channels, by which the nutriment is distributed to all its parts. It has, also, a curious apparatus in its foliage, by which it abstracts from the air those gaseous elements so necessary to its support; and thus it accomplishes vegetable respiration.

2. The animal, in addition to these vegetative functions, has another set of powers, by the use of which he becomes conscious of a world external to himself, and brings himself into active relations with it. These functions, among which are sensation, motion, and volition, not only distinguish the animal from the

plant, but, in proportion to their development, elevate one creature above another; and it is by virtue of his pre-eminent endowment, in these respects, that man holds his position at the head of the animal creation.

3. Among animals whose structure is very simple, the hydra or fresh-water polyp, being an example, no special organs are empowered to perform separate functions; but every part is endowed alike, so that if the animal be cut into pieces, each portion has all the properties of the entire original; and, if the circumstances be favorable, each of the pieces will soon become a complete hydra. As we approach man, in the scale of beings, we find that the organs multiply, and the functions become more complete. The function of motion, the instruments of which—the muscles and bones—have been considered in former chapters, and all the other animal functions of man, depend upon the set of organs known as the nervous system.

4. The Nervous System.—The nervous tissue is composed of a soft, pulpy substance, which, early in life, is almost fluid, but which gradually hardens with the growth of the body. When examined under the microscope, it is found to be composed of two distinct elements:—(1) the white substance, composing the larger proportion of the nervous organs of the body, which is formed of delicate filaments, about $\frac{1}{6000}$ of an inch in diameter, termed the nerve-fibres; and (2) the gray substance, composed of grayish-red, or ashen-colored cells, of various sizes.

5. The gray, cellular substance constitutes the larger portion of those important masses, which bear the name of *nervous centres* and *ganglia* (from *ganglion*, a knot), in which all the nerve-fibres unite. These white nerve-fibres are found combined together in long and dense cords, called *nerves* (from *neuron*, a cord), which serve to connect the nervous centres with each other, and to place them in communication with all the other parts of the body which have sensibility or power of motion. That part of the nervous system which is concerned in the animal functions, comprises the brain, the spinal cord,

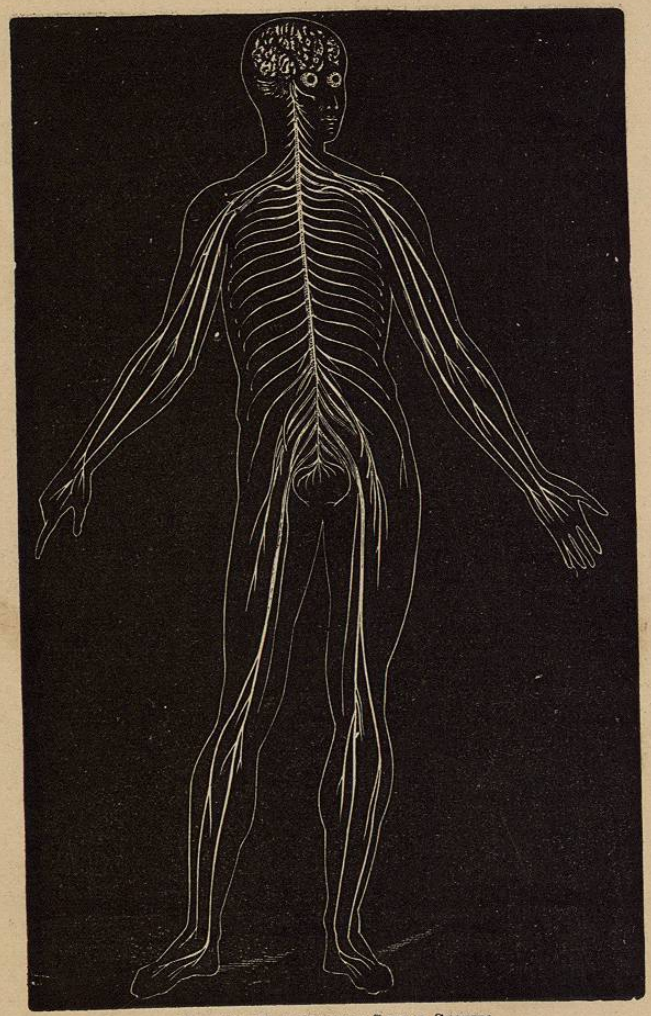

FIG. 29.—THE CEREBRO-SPINAL SYSTEM.

and the nerves which are derived therefrom; these, together, are called the *cerebro-spinal* system (Fig. 29); while that other set of organs, which presides over, and regulates the vegetative functions, is called the sympathetic system of nerves.

6. The Brain.—The brain is the great volume of nervous tissue that is lodged within the skull. It is the largest and most complex of the nervous centres, its weight in the adult being about fifty ounces, or one-fortieth of that of the whole body. The shape of the brain is oval, or egg-shaped, with one extremity larger than the other. The brain consists chiefly of two parts: the *cerebrum*, or brain proper, and the *cerebellum*, or "little brain." In addition to these, there are several smaller organs at the base, among which is the commencement or expansion of the spinal cord, termed the *medulla oblongata*, or oblong marrow.

7. The tissue of the brain is soft and easily altered in shape by pressure; it therefore requires to be placed in a well-protected position, such as is afforded by the skull, or *cranium*, which is strong without being cumbrous. In the course of an ordinary lifetime, this bony box sustains many blows, with little inconvenience; while, if they fell directly upon the brain, they would at once, and completely, disorganize that structure. Within the skull, the brain is enveloped by three membranes, which at once protect it from friction, and furnish it with a supply of nutrient vessels. The supply of blood sent to the brain is very liberal, amounting to one-fifth of all that the entire body possesses. The brain of man is heavier than that of any other animal, except the elephant and whale.

8. The Cerebrum.—The brain proper, or *cerebrum*, is the largest of the intracranial organs, and occupies the entire upper and front portion of the skull. It is almost completely bisected by a fissure, or cleft, running through it lengthwise, into two equal parts called *hemispheres*. The exterior of these hemispheres is gray in color, consisting chiefly of nerve-cells, arranged so as to form a layer of gray matter one-fifth of an inch in thickness, and is abundantly supplied with blood-vessels. The

interior of the brain, however, is composed almost wholly of white substance, or nerve-fibres.

9. The surface of the cerebrum is divided by a considerable number of winding and irregular furrows, about an inch deep, as shown in Fig. 30. Into these furrows the gray matter of

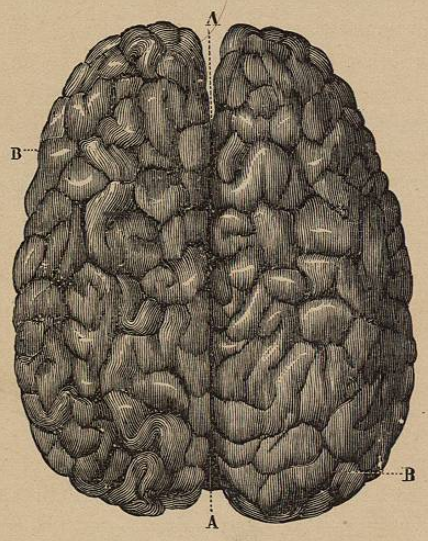

FIG. 30.—UPPER SURFACE OF THE CEREBRUM.
A, Longitudinal Fissure.
B, The Hemispheres.

the surface is extended, and, in this manner, its quantity is vastly increased. When it is stated that the gray matter is the true source of nervous power, it becomes evident that this arrangement has an important bearing on the mental capacity of the individual. And it is noticed that in children, before the mind is brought into vigorous use, these markings or furrows on the surface are comparatively shallow and indistinct; the same fact is true of the brain in the less civilized races of mankind and in the lower animals. It is also noticeable that, among

animals, those are the most capable of being educated which have the best development of the cerebrum.

10. The Cerebellum.—The "little brain" is placed beneath the posterior part of the cerebrum, and, like the latter, is divided into hemispheres. Like it, also, the surface of the cerebellum is composed of gray matter, and its interior is chiefly white matter. It is subdivided by many parallel ridges, which, sending down gray matter deeply into the white, central portion, gives the latter a somewhat branched appearance. This peculiar appearance has been called the *arbor vitæ*, or the "tree of life," from the fact that when a section of the organ is made, it bears some resemblance to the trunk and branches of a tree (Fig. 31, F).

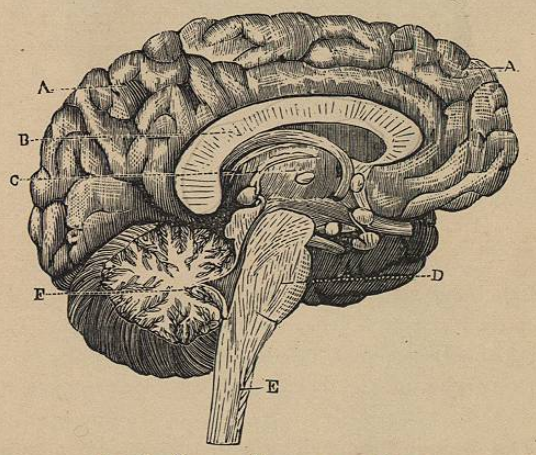

FIG. 31.—VERTICAL SECTION OF THE BRAIN.

A, Left Hemisphere of Cerebrum.
B, Corpus Callosum.
C, Optic Thalamus.
D, The Pons Varolii.
E, Upper Extremity of the Spinal Cord.
F, The Arbor Vitæ.

In size, this cerebellum, or "little brain," is less than one-eighth of the cerebrum.

11. From the under surface of the cerebrum, and from the front margin of the cerebellum, fibres collect together to form

the *medulla oblongata* (Fig. 32, M *a*), which, on issuing from the skull, enters the spinal column, and then becomes known as the spinal cord. From the base of the brain and from the

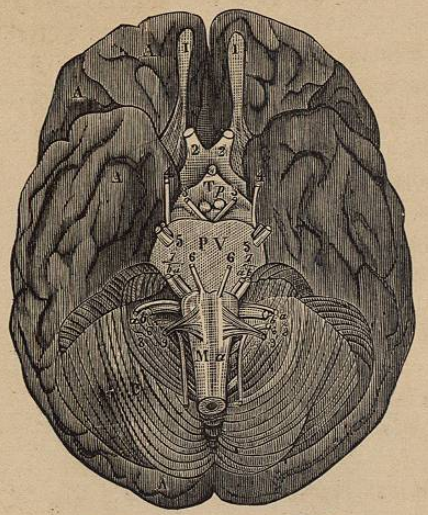

FIG. 32.—THE BASE OF THE BRAIN.
The numbers refer to the pairs of nerves.

sides of the medulla originate, also, the *cranial nerves*, of which there are twelve pairs. These nerves are round cords of glistening white appearance, and, like the arteries, generally lie remote from the surface of the body, and are well protected from injury.

12. The Spinal Cord.—The spinal cord, or "marrow," is a cylindrical mass of soft nervous tissue, which occupies a chamber, or tunnel, fashioned for it in the spinal column (Fig. 33). It is composed of the same substances as the brain; but the arrangement is exactly reversed, the white matter encompassing or surrounding the gray matter instead of being encompassed by it. The amount of the white substance is also greatly in excess of the other material. A vertical fissure partly separates the

cord into two lateral halves, and each half is composed of two separate bundles of fibres, which are named the anterior and posterior columns.

13. These columns have entirely different uses, and each of them unites with a different portion of the nerves which have their origin in the spinal cord. The importance of this part of the nervous system is apparent from the extreme care taken to protect it from external injury. For, while a very slight disturbance of its structure suffices to disarm it of its power, yet so staunch is its bony enclosure, that only by very severe injuries is it put in peril.

14. The Spinal Nerves.—The spinal nerves, thirty-one pairs in number, spring from each side of the cord by two roots, an anterior and a posterior root. The posterior root is distinguished by possessing a ganglion of gray matter, and by a somewhat larger size. The successive points of departure, or the offshooting of these nerves, occur at short and nearly regular intervals along the course of the spinal cord. Soon after leaving these points, the anterior and posterior roots unite to form the trunk of a nerve, which is distributed, by means of branches, to the various

FIG. 33.
A, Cerebrum.
B, Cerebellum.
D, D, Spinal Cord.

organs of that part of the body which this nerve is designed to serve. The spinal nerves supply chiefly the muscles of the trunk and limbs and the external surface of the body.

15. The tissue composing the nerves is entirely of the white variety, or, in other words, the nerve-fibres; the same as we have observed forming a part of the brain. But the nerves, instead of being soft and pulpy, as in the case of the brain, are dense in structure, being hardened and strengthened by means of a fibrous tissue which surrounds each of these delicate fibres, and binds them together in glistening, silvery bundles. Delicate and minutely fine as are these nerve-fibres, with their extremities often only a hair's breadth distant from each other, the impression which any one of them communicates is perfectly distinct, and is referred to the exact point whence it came. This may be illustrated in a simple manner, thus: if two fingers be pressed closely together, and the point of a pin be carried lightly across from one to the other, the eyes may be closed, and yet we can easily note the precise instant when the pin passes from one finger to the other.

16. The Sympathetic System.—The *sympathetic system* of nerves remains to be described. It consists of a double chain of ganglia, situated on each side of the spinal column, and extending through the cavities of the trunk, and along the neck into the head. From these, numerous small nerves are derived, which connect the ganglia together, send out branches to the cranial and spinal nerves, and form networks in the vicinity of the stomach and other large organs. Branches also ascend into the head, and supply the muscles of the eye and ear, and other organs of sense.

17. The Properties of Nervous Tissue.—We have seen that in all parts of this system, there are only two forms of nervous tissue; namely, the gray substance and the white substance, so called from their difference of color as seen by the naked eye; or the nerve-cell, and the nerve-fibre, so called from their microscopic appearance. Now these two tissues are not

commonly mingled together, but either form separate organs, or distinct parts of the same organs. This leads us to the conclusion that their respective uses are distinct. And this proves to be the simple fact; wherever we find the gray substance, we must look upon it as performing an active part in the system, that is, it originates nervous impulses; the white matter, on the contrary, is a passive agent, and serves merely as a conductor of nervous influences. Accordingly, the nervous centres, composed so largely of the gray cells, are the great centres of power, and the white fibres are simply the instruments by which the former communicate with the near and distant regions of the body under their control.

18. The Functions of the Nerves.—The nerves are the instruments of the two grand functions of the nervous system, Sensation and Motion. If a nerve that has been exposed be divided, and the inner end, or that still in connection with the nerve-centres, be irritated, sensation is produced, but no movement takes place. But if the outer end, or that still connected with the limb, be irritated, then no pain is felt, but muscular contractions are produced. Thus we prove that there are two distinct sets of fibres in the nerves; one of which, the *sensory* fibres, conduct toward the brain, and another, the *motor* fibres, conduct to the muscles. The former may be said to begin in the skin and other organs, and end in the brain; while the latter begin in the nervous centres and end in the muscles.

19. We have already spoken of the two roots of the spinal nerves, called, from their points of origin in the spinal cord, the anterior and posterior roots. These have been separately cut and irritated in the living animal, and it has been found that the posterior root contains only sensory fibres, while the anterior root has only motor fibres. So that the nerves of a limb may be injured in such a way that it will retain power of motion and yet lose sensation; or the reverse condition, feeling without motion, may exist. Between these two sorts of fibres no difference of structure can be found; and where they have joined

to form a nerve it is impossible to distinguish one sort from the other. The rate of motion of a message, to or from the brain along a nerve, has been measured by experiment upon the lower animals, and estimated in the case of man at about two hundred feet per second. As compared with that of electricity, this is a very slow rate, but, in respect to the size of the human body, it is practically instantaneous.

20. The Functions of the Spinal Cord.—As the anterior and posterior roots of the spinal nerves have separate functions, so the anterior and posterior columns of the cord are distinct in function. The former are concerned in the production of motion, the latter in sensation.

21. When the spinal cord of an animal has been cut, in experiment, it may be irritated in a manner similar to that alluded to when considering the nerves. If, then, the upper cut surface be excited, it is found that pain, referable to the parts below the cut, is produced; but when the lower cut surface is irritated, no feeling is manifested. So we conclude that in respect to sensation, the spinal cord is not its true centre, but that it is merely a conductor, and is therefore the great sensory nerve of the body. When the lower surface of the cut is irritated, the muscles of the parts below the section are violently contracted. Hence, we conclude that, in respect to the movements ordered by the will, the spinal cord is not their source; but that it acts only as a conductor, and is, accordingly, the great motor nerve of the body.

22. Direction of the Fibres of the Cord.—If one lateral half of the spinal cord be cut or injured, a very singular fact is observed. All voluntary power over the muscles of the corresponding half of the body is lost, but the sensibility of that side remains undiminished. This result shows that the motor fibres of the cord pursue a direct course, while its sensory fibres are bent from their course. The direction of the anterior or motor columns of the cord is downward from the brain. In the cord itself, the course of the motor fibres is for the most part a

direct one; but in the medulla oblongata, or upper extremity of the cord, and therefore early in their career, these fibres cross from side to side in a mass.

23. From this double interlacing of fibres results a cross action between the original and terminal extremity of all nerve-fibres which pass through the medulla; namely, those of all the spinal nerves. Consequently, if the right hand be hurt, the left side of the brain feels the pain; and if the left foot move, it is the right hemisphere which dictates its movement.

24. The Reflex Action of the Cord.—We have already considered the cord as the great motor and sensory nerve of the body, but it has another and extremely important use. By virtue of the gray matter, which occupies its central portion, it plays the part of an independent nerve centre. The spinal cord not only conducts some impressions to the brain, but it also arrests others; and, as it is expressed, "reflects" them into movements by its own power. This mode of nervous activity is denominated the *Reflex Action* of the cord. A familiar example of this power of the cord is found in the violent movements which agitate a fowl after its head has been cut off. The cold-blooded animals also exhibit reflex movements in an astonishing degree. A decapitated centipede will run rapidly forward, and will seemingly strive to overturn, or else climb over obstacles placed in its way.

25. The Uses of the Reflex Action.—The reflex activity of the cord is exhibited in the healthy body in many ways, but since it is never accompanied with sensation, we do not readily recognize it in our own bodies. Reflex movements are best studied in the cases of other persons, when the conditions enable us to distinguish between acts that are consciously, and those that are unconsciously performed. For example, if the foot of a person sound asleep be tickled or pinched, it will be quickly withdrawn from the irritation. Again, when a substance like melted sealing-wax, or a heated coin, falls upon the hand, the limb is snatched away at once, even before the feeling of pain