fibres, taking their origin from all of the gray nodules of the medulla, pass to the parts of the encephalon situated above.

The uncrossed pyramidal tracts of the spinal cord (columns of Türck) pass to the encephalon, by direct fibres situated at the outer border of the anterior pyramids of the medulla.

The crossed pyramidal tracts of the cord decussate in the lower portion of the medulla and constitute the greatest part of the anterior pyramids.

Fibres from the anterior fundamental fasciculi, the anterior radicular zone and from the mixed lateral columns of the cord, probably pass to the gray matter of the medulla.

The direct cerebellar fasciculi of the cord are continuous with the funiculi graciles of the medulla.

The columns of Burdach are continuous with the restiform bodies of the medulla.

The columns of Goll pass to the medulla and are lost in the fasciculi graciles.

As far as the fibres of origin of the cranial nerves are concerned, it may be stated in general terms that a number of the motor roots arise from the gray matter of the floor of the fourth ventricle, the roots of the sensory nerves arising from gray matter in the posterior portions.

Uses of the Medulla Oblongata.

It is hardly necessary to discuss the action of the medulla oblongata as a conductor of sensory impressions and of motor stimulus to and from the brain. It is evident that there is conduction of this kind from the spinal cord to the ganglia of the encephalon, and this must take place through the medulla; a fact which is inevitable, from its anatomical relations, and which is demonstrated by its section in living animals. Nor is it necessary to dwell upon the general properties of the medulla, in which it resembles the spinal cord, at least as far as has been demonstrated by experiments upon living animals or upon animals just killed. It is difficult to expose this part in the higher classes of animals, but experiments show that it is sensitive on its posterior surface and insensible in front. The difficulty of observing the phenomena which follow its stimulation in living animals has rendered it impossible to determine the limits of its excitability and sensibility as exactly as has been done for the different portions of the cord.

It is also somewhat difficult to determine whether the action of the medulla itself, in its relations to motion and sensation, be crossed or direct. As regards conduction from the brain, the direction is sufficiently well shown by cases of cerebral disease, in which the paralysis, in simple lesions, is on the opposite side of the body.

The action of the medulla as a reflex nerve-centre depends upon its gray matter. When this gray substance is destroyed, certain important reflex phenomena are instantly abolished. From its connection with various of the cranial nerves, one would expect it to play an important part in the movements of the face, in deglutition, in the action of the heart and of various glands etc., important points which are fully considered in their appropriate place. The various reflex centres in the medulla have been located chiefly by a study of the relations of the gray matter to the deep fibres of origin of certain of the cranial nerves. The centre for the orbicularis oculi muscle is related to the origin of the large root of the fifth nerve and the origin of the facial; and the integrity of these two nerves is necessary to the reflex act of closure of the eyelids. The impression which produces the act of sneezing is conveyed to the medulla through the nasal branch of the fifth—possibly sometimes through the olfactory nerves—and excites certain of the expiratory muscles. Impressions conveyed to the medulla by certain sensory branches of the pneumogastrics give rise to the reflex acts of coughing. The reflex acts of swallowing and vomiting also depend upon centres in the medulla oblongata. There are centres, also, which influence the glycogenic action of the liver, the secretion of saliva and the secretion of sweat. The vaso-motor centres will be considered in connection with the physiology of the vaso-motor nerves. The centres connected with respiration are so important that they demand special description.

Respiratory Nerve-Centre.—In 1809, Legallois made a number of experiments upon rabbits, cats and other animals, in which he showed that respiration depends upon the medulla oblongata and not upon the brain; and he farther located the part which presides over the respiratory movements, at the site of origin of the pneumogastric nerves. Flourens, in his elaborate experiments upon the nerve-centres, extended the observations of Legallois, and limited the respiratory centre in the rabbit, between the upper border of the roots of the pneumogastrics and a plane situated about a quarter of an inch (6·4 mm.) below the lowest point of origin of these nerves; these limits, of course, varying with the size of the animal. Following these experiments, Longet has shown that the respiratory centre does not occupy the whole of the medulla included between the two planes first indicated by Flourens, but that it is confined to the gray matter of the lateral tracts, or the intermediary fasciculi. This was demonstrated by the fact that respiration persists in animals after division of the anterior pyramids and the restiform bodies. Subsequently, Flourens restricted the limits of the respiratory centre and fully confirmed the observations of Longet.

The portion of the medulla oblongata above indicated presides over the movements of respiration and is the true respiratory nerve-centre. Nearly all who have repeated the experiments of Flourens have found that the spinal cord may be divided below the medulla oblongata, and that all of the encephalic ganglia above may be removed, respiratory movements still persisting. It is a very common thing in vivisections to kill an animal by breaking up the medulla. When this is done there are no struggles and no manifestations of the distress of asphyxia. The respiratory muscles simply cease their action, and the animal loses instantly the sense of want of air. A striking contrast to this is presented when the trachea is tied or when all of the respiratory muscles are paralyzed without touching the medulla.

The relations of the respiratory centre have already been fully considered in connection with the physiology of respiration. Under normal conditions, the centres on the two sides probably operate through the pneumogastric nerves and the respiratory movements on the two sides are synchronous. That there is a respiratory centre on either side, is shown by the experiment of dividing the medulla longitudinally in the median line, the respiratory movements afterward continuing with regularity. If, now, the pneumogastric be divided on one side, the respiratory movements on that side become slower and are no longer synchronous with the movements on the opposite side. This shows that while the respiratory centres on the two sides normally act together, being undoubtedly connected with each other by commissural fibres, each one has independent connections with the pneumogastric on the corresponding side of the body.

Cardiac Centres.—There can be scarcely any doubt with regard to the existence of cardiac centres in the medulla—perhaps an inhibitory centre and an acceleratory centre—but the situation of these centres has not been exactly determined. The influence of the nerves and nerve-centres over the movements of the heart has been fully considered in connection with the physiology of the circulation.

Vital Point (*so called*).—Since it has been definitely ascertained that destruction of a restricted portion of the gray substance of the medulla produces instantaneous and permanent arrest of the respiratory movements, Flourens and others have called this centre the vital knot, destruction of which is immediately followed by death. With the existing knowledge of the properties and uses of the different tissues and organs of which the body is composed, it is almost unnecessary to present any arguments to show the unphilosophical character of such a proposition. One can hardly imagine such a thing as instantaneous death of the entire organism; and still less can it be assumed that any restricted portion of the nervous system is the one, essential vital point. Probably, a very powerful electric discharge passed through the entire cerebro-spinal axis produces the nearest approach to instantaneous death; but even then it is by no means certain that some parts do not for a time retain their physiological properties. In apparent death, the nerves and the heart may be shown to retain their characteristic properties; the muscles will contract under stimulus, and will appropriate oxygen and give off carbon dioxide, or respire; the glands may be made to secrete, etc.; and no one can assume that under these conditions, the entire organism is dead. There seems to be no such thing as death, except as the various tissues and organs which go to make up the entire body become so altered as to lose their physiological properties beyond the possibility of restoration; and this never occurs for all parts of the organism in an instant. A person drowned may be to all appearances dead, and would certainly die without measures for restoration; yet in such instances, restoration may be accomplished, the period of apparent death being simply a blank, as far as the recollection of the individual is concerned. It is as utterly impossible to determine the exact instant when the vital principle, or whatever it may be called, leaves the body in death, as to indicate the time when the organism becomes a living

being. Death is nothing more than a permanent destruction of so-called vital physiological properties; and this occurs successively, and at different times, for different tissues and organs.

When it is seen that frogs will live for weeks, and sometimes for months, after destruction of the medulla oblongata, and that in mammals, by keeping up artificial respiration, many of the most important physiological acts, such as the movements of the heart, may be prolonged for hours after decapitation, one can understand the physiological absurdity of the proposition that there is any such thing as a vital point, in the medulla or in any part of the nervous system.

There is little to be said concerning certain ganglia and other parts of the brain that have not yet been considered. The olfactory ganglia preside over olfaction and will be treated of fully in connection with the special senses. The pineal gland and the pituary body, in their structure, present a certain resemblance to the ductless glands, and their anatomy has been considered in another chapter. Passing over the purely theoretical views of the older writers, who had very indefinite ideas of the action of any of the encephalic ganglia, it can only be said that the uses of the pineal gland and pituitary body in the economy are entirely unknown. The same remark applies to the corpus callosum, the septum lucidum, the ventricles, hippocampi and various other parts that are necessarily described in anatomical works. It is useless to discuss the early or even the recent speculations with regard to the uses of these parts, which are entirely unsupported by experimental or pathological facts and which have not advanced positive knowledge.

Rolling and Turning Movements following Injury of Certain Parts of the Encephalon.

The remarkable movements of rolling and turning, produced by section or injury of certain of the commissural fibres of the encephalon, are not very important in their bearing upon the uses of the brain, and they are rather to be classed among the curiosities of experimental physiology. These movements follow unilateral lesions and are dependent, to a certain extent, upon a consequent inequality in the power of the muscles on one side, without actual paralysis. Vulpian has enumerated the following parts, injury of which, upon one side, in living animals, may determine movements of rotation:

"1. Cerebral hemispheres;

"2. Corpora striata;

"3. Optic thalami (Flourens, Longet, Schiff);

"4. Cerebral peduncles (Longet);

"5. Pons Varolii;

"6. Tubercula quadrigemina, or bigemina (Flourens);

"7. Peduncles of the cerebellum, especially the middle, and the lateral portions of the cerebellum (Magendie);

"8. Olivary bodies, restiform bodies (Magendie);

"9. External part of the anterior pyramids (Magendie);

"10. Portion of the medulla from which the facial nerve arises (Brown-Séquard);

"11. Optic nerves;

"12. Semicircular canals (Flourens); auditory nerve (Brown-Séquard)."

To the parts above enumerated, Vulpian added the upper part of the cervical portion of the spinal cord.

The movements which follow unilateral injury of the parts mentioned above are of two kinds; viz., rolling of the entire body on its longitudinal axis, and turning, always in one direction, in a small circle, called by the French the movement of *manége.* A capital point to determine in these phenomena is whether the movements be due to paralysis or enfeeblement of certain muscles upon one side of the body, to a direct or reflex irritation of the parts of the nervous system involved or to both of these causes combined. The experiments of Brown-Séquard and others show that the movements may be due to irritation alone, for they occur when parts of the encephalon and the upper portions of the cord are simply pricked, without section of fibres. When there is extensive division of fibres, it is probable that the effects of the enfeeblement of certain muscles are added to the phenomena produced by simple irritation. The most satisfactory explanation of these movements is the one proposed by Brown-Séquard, who attributed them to a more or less convulsive action of muscles on one side of the body, produced by irritation of the nerve-centres. He regarded the rolling as simply an exaggeration of the turning movements, and places both in the same category.

It is not necessary to enter into an extended discussion of the above experiments. In some of them, the movements have been observed toward the side operated upon, and in others, toward the sound side. These differences probably depend upon the fact that in certain experiments, the fibres are involved before their decussation, and in others, after they have crossed in the median line. In some instances, the movements may be due to a reflex action, from stimulation of afferent fibres, and in others, the action of the irritation may be direct. Judging from the fact that most of the encephalic commissural fibres are apparently insensible and inexcitable under direct stimulation, it is probable that the action generally is reflex.

CHAPTER XX.

SYMPATHETIC NERVOUS SYSTEM—SLEEP.

General arrangement of the sympathetic system—General properties of the sympathetic ganglia and nerves—Direct experiments on the sympathetic—Vaso-motor centres and nerves—Reflex vaso-motor phenomena—Vaso-inhibitory nerves—Trophic centres and nerves (so-called)—Sleep—Condition of the brain and nervous system during sleep—Anæsthesia and sleep produced by pressure upon the carotid arteries—Differences between natural sleep and stupor or coma—Regeneration of the brain-substance during sleep—Condition of the organism during sleep.

LIKE the cerebro-spinal system, the sympathetic is composed of centres, or ganglia, and nerves, at least as far as can be seen from its anatomy. The ganglia contain nerve-cells, most of which differ but little from the cells of the encephalon and spinal cord. The nerves are composed of fibres, some of which are nearly identical in structure with the ordinary motor and sensory fibres, while many are the so-called gelatinous fibres. The fibres are connected with the nerve-cells in the ganglia, and the ganglia are connected with each other by commissural fibres. These ganglia constitute a continuous chain on either side of the body, beginning above, by the ophthalmic ganglia, and terminating below in the ganglion impar. It is important to note, however, that the chain of sympathetic ganglia is not independent, but that each ganglion receives motor and sensory filaments from the cerebro-spinal nerves, and that filaments pass from the sympathetic to the cerebro-spinal system. The general distribution of the sympathetic filaments is to mucous membranes—and possibly to integument—to non-striated muscular fibres, and particularly to the muscular coat of the arteries. As far as has been shown by anatomical investigations, there are no fibres derived exclusively from the sympathetic which are distributed to striated muscles, except those which pass to the muscular tissue of the heart. Near the terminal filaments of the sympathetic, in most of the parts to which these fibres are distributed, there exist large numbers of ganglionic cells.

The general arrangement of the sympathetic ganglia and the distribution of the nerves may be stated very briefly; but a knowledge of certain anatomical points is indispensable as an introduction to an intelligent study of the physiology of this system.

In the cranium, are the four cranial ganglia; the ophthalmic, the spheno-palatine, the otic and the submaxillary. In the neck, are the three cervical ganglia; the superior, middle and inferior. In the chest, are the twelve thoracic ganglia, corresponding to the twelve ribs. The great semilunar ganglia, the largest of all and sometimes called the abdominal brain, are in the abdomen, by the side of the cœliac axis. In the lumbar region, in front of the spinal column, are the four lumbar ganglia. In front of the sacrum, are the four or five sacral, or pelvic ganglia; and finally, in front of the coccyx, is a small, single ganglion, the last of the sympathetic chain, called the ganglion impar. Thus, the sympathetic cord, as it is sometimes called, consists of twenty-eight to thirty ganglia on either side, terminating below in a single ganglion.