After division of pneumogastrics in the neck, if the peripheral ends be stimulated there is no effect upon the liver; but if the stimulus be applied to the central ends, the glycogenic processes become exaggerated, and sugar makes its appearance in the blood and in the urine. Bernard made a number of experiments illustrating this point, upon dogs and rabbits. The current employed was generally feeble, and it was continued for five or ten minutes, two or three times in an hour. In some instances the stimulation was kept up for thirty minutes. From these experiments, it is assumed that the physiological production of glycogen by the liver is reflex and is due to an impression conveyed to the nerve-centres through the pneumogastrics. The inhalation of irritating vapors and of anæsthetics produces an increased glycogenic action in the liver.

The effects of irritating the floor of the fourth ventricle, by which temporary diabetes is produced, have been considered in connection with the glycogenic action of the liver. This effect is not due to a direct transmission of the irritation to the liver through the pneumogastrics, for the phenomena are observed in animals upon which this operation has been performed after section of both pneumogastrics in the neck. It is probable, indeed, that the impression is conveyed to the liver through the sympathetic system; for it has been shown that animals do not become diabetic after irritation of the floor of the fourth ventricle when the branches of the sympathetic going to the solar plexus have been divided. The operation, however, of dividing the sympathetic nerves in this situation is so serious, that it may interfere with the experiment in some other way than by the direct influence of the nerves upon the liver.

Influence of the Pneumogastrics upon the Stomach and Intestines.—Little or nothing is known with regard to the action of the pneumogastrics on the spleen, kidneys and suprarenal capsules. The influence of these nerves upon the stomach and intestine will be considered under the following heads:

1. The effects of Faradization of the nerves.
2. The effects of section of the nerves upon the movements of the stomach in digestion.
3. The influence of the nerves upon the small intestine.

Effects of Faradization.—The stomach contracts under stimulation of the pneumogastrics in the neck, not instantly, but after the lapse of five or six seconds (Longet). Longet explained some of the contradictory results obtained by other observers by the fact that these contractions are very marked during stomach-digestion, while they are wanting "when the stomach is entirely empty, retracted on itself and in a measure in repose." Stimulation of the splanchnic nerves, while it produces movements of the intestines, does not affect the stomach. Judging from the tardy contraction of the stomach and the analogy between the action of the pneumogastrics upon this organ and the action of the sympathetic nerves upon the non-striated muscular tissue, Longet assumed that the motor action of the pneumogastrics is due, not to the proper filaments of these nerves, but to filaments derived from the sympathetic.

Effects of Section of the Pneumogastrics upon the Movements of the Stomach.—If the pneumogastrics be divided in the neck in a dog in full digestion, in which a gastric fistula has been established so that the interior of the organ can be explored, the following phenomena are observed:

In the first place, before division of the nerves, the mucous membrane of the stomach is turgid, its reaction is intensely acid, and if the finger be introduced through the fistula, it will be firmly grasped by the contractions of the muscular walls. When the pneumogastrics are divided, the contractions of the muscular walls instantly cease, the mucous membrane becomes pale, the secretion of gastric juice is apparently arrested and the sensibility of the organ is abolished (Bernard).

Notwithstanding the apparent arrest of the movements of the stomach in digestion, by section of the pneumogastrics, it has been shown that substances may be very slowly passed to the pylorus, and that the movements, although they are greatly diminished in activity, are not entirely abolished. This fact has been established by the experiments of Schiff, who attributed the movements occurring after section of the nerves to local irritation of the intramuscular terminal nervous filaments.

The influence of the pneumogastrics upon the general processes of digestion, the sensations of hunger and thirst and upon absorption from the alimentary canal have already been considered in connection with the physiology of digestion and absorption.

Influence of the Pneumogastrics upon the Small Intestine.—Physiologists have given but little attention to the influence of the pneumagastrics upon the intestinal canal, for the reason that the distribution of the abdominal branches to the small intestine, notwithstanding the researches of Kollmann, in 1860, does not appear to have been generally recognized. The right, or posterior abdominal branch was formerly supposed to be lost in the semilunar ganglion and the solar plexus, after sending a few filaments to the stomach; but since it has been shown that this nerve is supplied to the whole of the small intestine, its physiology, in connection with intestinal secretion, has assumed considerable importance.

The experiments of Wood have shown that the pneumogastrics influence intestinal as well as gastric secretion. After section of the nerves in the cervical region, the most powerful cathartics (croton-oil, calomel, podophyllin, jalap, arsenic etc.), fail to produce purgation, even in doses sufficient to cause death. The articles used were either given by the mouth, just before dividing the nerves, or were injected under the skin.

Although the observations of Wood are not entirely new, they are by far the most extended and satisfactory, and were made with a knowledge of the fact of the distribution of the nerves to the small intestine. Brodie failed to produce purging in dogs, when both pneumogastrics had been divided in the neck, after the administration of arsenic by the mouth and after injecting it under the skin. Reid made five experiments, and in all but one, it is stated that diarrhœa existed after division of the nerves. In twenty experiments by Wood, there was no purgation after division of the nerves, in one

there was free purgation, and in one there was "some slight muco-fæcal discharge." From these, Wood concluded that while section of the cervical pneumogastrics, in the great majority of instances, arrests gastro-intestinal secretion and prevents the action of purgatives upon the intestinal canal, a few exceptional cases occur in which these effects are not observed.

It would be interesting to determine whether the pneumogastrics influence the intestinal secretions through their own fibres or through filaments received from the sympathetic system; but there are no experimental facts sufficiently definite to admit of a positive answer to this question. If the action take place through the sympathetic system, as in the case of the stomach, the filaments of communication join the pneumogastrics high up in the neck.

The cranial nerves that have been considered in this chapter are the third, fourth, fifth, sixth, seventh, tenth, eleventh and twelfth. The anatomical and physiological history of the olfactory (first), optic (second), auditory (eighth), gustatory (branch of the seventh and a part of the ninth) and of the general sensory nerves, as far as they are concerned in the sense of touch, belongs properly to the chapters on the special senses.

CHAPTER XVIII.

THE SPINAL CORD.

General arrangement of the cerebro-spinal axis—Membranes of the encephalon and spinal cord—Cephalo-rachidian fluid—Physiological anatomy of the spinal cord—Columns of the Cord—Direction of the nerve-fibres in the cord—General properties of the spinal cord—Motor paths in the cord—Sensory paths in the cord—Relations of the posterior white columns of the cord to muscular co-ordination—Nerve-centres in the spinal cord—Reflex action of the spinal cord—Exaggeration of reflex excitability by decapitation, poisoning with strychnine etc.—Reflex phenomena observed in the human subject.

THE nervous matter contained in the cavity of the cranium and in the spinal canal, exclusive of the roots of the cranial and spinal nerves, is known as the cerebro-spinal axis. This portion of the nervous system is composed of white and gray matter. The fibres of the white matter act solely as conductors. The gray matter constitutes a chain of ganglia, which act as nerve-centres, receiving impressions and generating the so-called nerve-force. Certain parts of the gray matter also serve as conductors.

The cerebro-spinal axis is enveloped in membranes, which are for its protection and for the support of its nutrient vessels. It is surrounded to a certain extent with liquid, and it presents cavities, as the ventricles of the brain and the central canal of the cord, which contain liquid. The gray matter is distinct from the white, even to the naked eye. In the spinal cord the white substance is external and the gray is internal. The surface of the brain presents an external layer of gray matter, the white substance being

internal. In the white substance of the brain, also, are collections of gray matter. The white matter of the cerebro-spinal axis is composed largely of fibres. The gray substance is composed chiefly of cells.

The encephalon is contained in the cranial cavity and consists of the cerebrum, cerebellum, pons Varolii and medulla oblongata. In the human subject and in many of the higher animals, its surface is marked by convolutions, by which the extent of its gray substance is much increased. The cerebrum, the cerebellum and most of the encephalic ganglia are connected with the white substance of the encephalon and with the spinal cord. All of the cerebro-spinal nerves are connected with the encephalon and the cord. The cerebro-spinal axis acts as a conductor, and its different collections of gray matter, or ganglia, receive impressions conveyed by the sensory conducting fibres, and generate motor impulses which are transmitted to the proper organs by the motor fibres.

Membranes of the Encephalon and Spinal Cord.—The membranes of the brain and spinal cord are the dura mater, the arachnoid and the pia mater.

The dura mater of the encephalon is a dense membrane, in two layers, composed chiefly of ordinary fibrous tissue, which lines the cranial cavity and is adherent to the bones. In certain situations its two layers are separated and form what are known as the venous sinuses. The dura mater also sends off folds or processes of its internal layer. One of these passes into the longitudinal fissure and is called the falx cerebri; another lies between the cerebrum and the cerebellum and is called the tentorium; another is situated between the lateral halves of the cerebellum and is called the falx cerebelli. The dura mater is closely attached to the bone at the border of the foramen magnum. From this point it passes into the spinal canal and forms a loose covering for the cord. In the spinal canal, this membrane is not adherent to the bones, which have, like most other bones in the body, a special periosteum. At the foramina of exit of the cranial and the spinal nerves, the dura mater sends out processes which envelop the nerves, with the fibrous sheaths of which they soon become continuous.

The arachnoid is a delicate membrane, resembling the serous membranes, with the exception that it presents but one layer. Its inner surface is covered with a layer of tesselated endothelium. There is a considerable quantity of liquid between the arachnoid and the pia mater, surrounding the cerebro-spinal axis, in what is called the subarachnoid space. This is called the cerebro-spinal, or cephalo-rachidian fluid. The arachnoid does not follow the convolutions and fissures of the encephalon or the fissures of the cord, but it simply covers their surfaces. Magendie described a longitudinal, incomplete, cribriform, fibrous septum in the cord, passing from the inner layer of the arachnoid to the pia mater. A similar arrangement is found in certain situations at the base of the skull.

The pia mater of the encephalon is a delicate, fibrous structure, very vascular, seeming to present, indeed, only a skeleton net-work of fibres for the support of the vessels going to the nervous substance. This membrane covers the surface of the encephalon immediately, follows the sulci and fis-