"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.

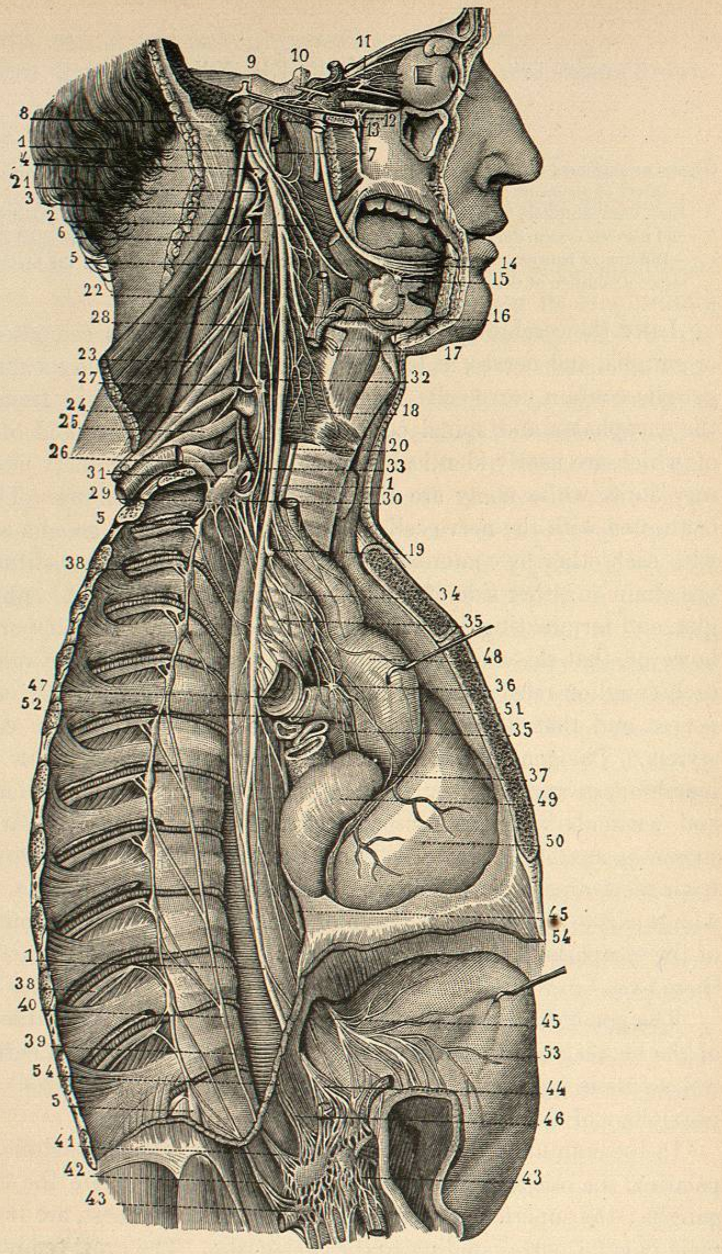

Fig. 233.—*Cervical and thoracic portion of the sympathetic* (Sappey).

1, 1, 1, right pneumogastric ; 2, glosso-pharyngeal ; 3, spinal accessory ; 4, sublingual ; 5, 5, 5, *chain of ganglia of the sympathetic* ; 6, *superior cervical ganglion* ; 7, *branches to the carotid* ; 8, nerve of Jacobson ; 9, *filaments from the facial, to the spheno-palatine and to the otic ganglion* ; 10, motor oculi externus ; 11, *ophthalmic ganglion* ; 12, *spheno-palatine ganglion* ; 13, *otic ganglion* ; 14, lingual branch of the fifth nerve ; 15, *submaxillary ganglion* ; 16, 17, superior laryngeal nerve ; 18, external laryngeal nerve ; 19, 20, recurrent laryngeal nerve ; 21, 22, 23, anterior branches of the upper four cervical nerves ; 24, anterior branches of the fifth and sixth cervical nerves ; 25, 26, anterior branches of the seventh and eighth cervical and the first dorsal nerves ; 27, *middle cervical ganglion* ; 28, *cord connecting the two ganglia* ; 29, *inferior cervical ganglion* ; 30, 31, *filaments connecting this with the middle ganglion* ; 32, *superior cardiac nerve* ; 33, *middle cardiac nerve* ; 34, *inferior cardiac nerve* : 35, 35, *cardiac plexus* ; 36, *ganglion of the cardiac plexus* ; 37, *nerve following the right coronary artery* : 38, 38, intercostal nerves ; 39, 40, 41, *great splanchnic nerve* ; 42, *lesser splanchnic nerve* ; 43, 43, *solar plexus* ; 44, left pneumogastric ; 45, right pneumogastric ; 46, phrenic nerve ; 47, right bronchus ; 48, aorta ; 49, right auricle ; 50, right ventricle ; 51, 52, pulmonary artery ; 53, stomach ; 54, diaphragm.

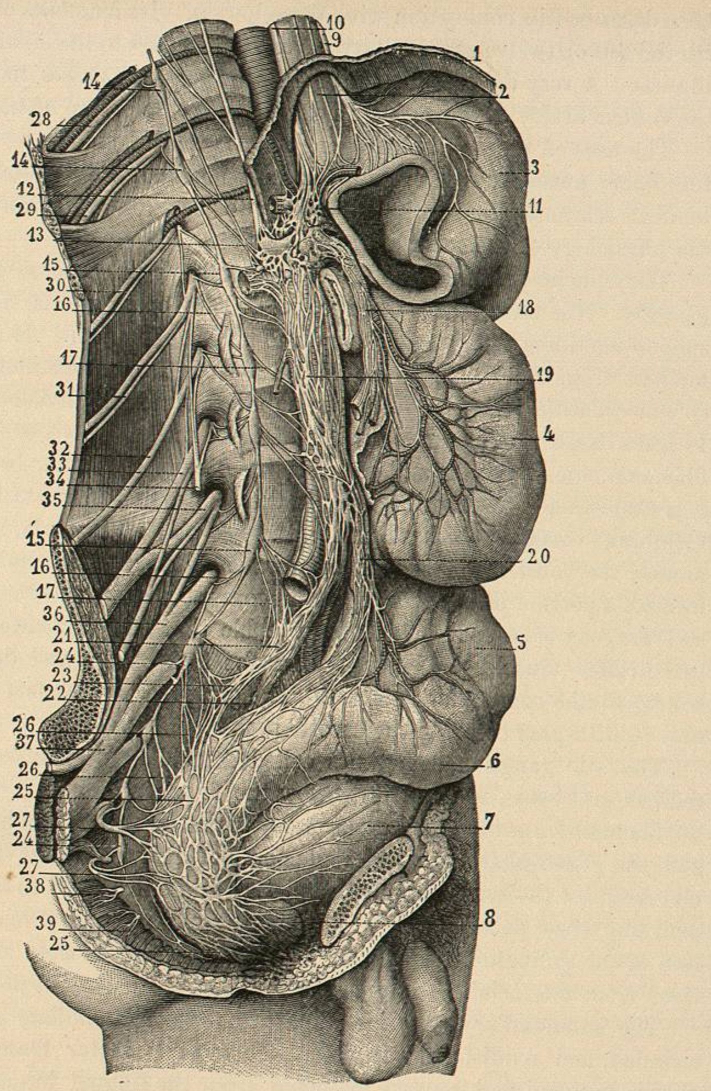

Fig. 234.—*Lumbar and sacral portions of the sympathetic* (Sappey).

1, section of the diaphragm ; 2, lower end of the œsophagus ; 3, left half of the stomach ; 4, small intestine ; 5, sigmoid flexure of the colon ; 6, rectum ; 7, bladder ; 8, prostate ; 9, lower end of the left pneumogastric ; 10, lower end of the right pneumogastric ; 11, *solar plexus* ; 12, *lower end of the great splanchnic nerve* ; 13, *lower end of the lesser splanchnic nerve* ; 14, 14, *last two thoracic ganglia* ; 15, 15, *the four lumbar ganglia* ; 16, 16, 17, 17, *branches from the lumbar ganglia* ; 18, *superior mesenteric plexus* ; 19, 21, 22, 23, *aortic lumbar plexus* ; 20, *inferior mesenteric plexus* ; 24, 24, *sacral portion of the sympathetic* ; 25, 25, 26, 26, 27, 27, *hypogastric plexus* ; 28, 29, 30, tenth, eleventh and twelfth dorsal nerves ; 31, 32, 33, 34, 35, 36, 37, 38, 39, lumbar and sacral nerves.

Cranial Ganglia.—The ophthalmic, lenticular, or ciliary ganglion is situated deeply in the orbit, is of a reddish color and about the size of a pin's-head. It receives a motor branch from the third pair and sensory filaments from the nasal branch of the ophthalmic division of the fifth. It is also connected with the cavernous plexus and with Meckel's ganglion. Its so-called motor and sensory roots from the third and the fifth pair have already

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been described in connection with these nerves. Its filaments of distribution are the ten or twelve short ciliary nerves, which pass to the ciliary muscle and the iris. A very delicate filament from this ganglion passes to the eye, with the central artery of the retina, in the canal in the centre of the optic nerve.

The uses of the ophthalmic ganglion are related mainly to the action of the ciliary muscle and iris; and it is only necessary here to indicate its anatomical relations, leaving its physiology to be taken up in connection with the physiology of the sense of sight.

The spheno-palatine, or Meckel's ganglion, is the largest of the cranial ganglia. It is triangular in shape, reddish in color, and is situated in the spheno-maxillary fossa, near the spheno-palatine foramen. It receives a motor root from the facial, by the Vidian nerve. Its sensory roots are the two spheno-palatine branches from the superior maxillary division of the fifth. It has a large number of branches of distribution. Two or three delicate filaments enter the orbit and go to its periosteum. Its other branches, which it is unnecessary to describe fully in detail, are distributed to the gums, the membrane covering the hard palate, the soft palate, the uvula, the roof of the mouth, the tonsils, the mucous membrane of the nose, the middle auditory meatus, a portion of the pharyngeal mucous membrane, and the levator palati and azygos uvulæ muscles. It is probable that the filaments sent to these two striated muscles are derived from the facial nerve and do not properly belong to the sympathetic system. The ganglion also sends a short branch, of a reddish-gray color, to the carotid plexus.

The otic ganglion, sometimes called Arnold's ganglion, is a small, oval, reddish-gray mass, situated just below the foramen ovale. It receives a motor filament from the facial and sensory filaments from branches of the fifth and the glosso-pharyngeal. Its filaments of distribution go to the mucous membrane of the tympanic cavity and Eustachian tube and to the tensor tympani and tensor palati muscles. Reasoning from the general mode of distribution of the sympathetic filaments, those going to the striated muscles are derived from the facial. It also sends branches to the carotid plexus.

The submaxillary ganglion, situated on the submaxillary gland, is small, rounded, and reddish-gray in color. It receives motor filaments from the chorda tympani and sensory filaments from the lingual branch of the fifth. Its filaments of distribution go to Wharton's duct, to the mucous membrane of the mouth and to the submaxillary gland.

Cervical Ganglia.—The three cervical ganglia are situated opposite the third, fifth and seventh cervical vertebræ respectively. The middle ganglion is sometimes wanting, and the inferior ganglion is occasionally fused with the first thoracic ganglion. These ganglia are connected together by the so-called sympathetic cord. They have a number of filaments of communication above, with the cranial and the cervical nerves of the cerebro-spinal system. Branches from the superior ganglion go to the internal carotid, to form the carotid and the cavernous plexus, following the vessels as they branch to their distribution. Branches from this ganglion pass to the cranial ganglia. There are also branches which unite with filaments from the pneumogastric and the glosso-pharyngeal to form the pharyngeal plexus, and branches which form a plexus on the external carotid, the vertebral and the thyroid arteries, following the ramifications of these vessels.

From the cervical portion of the sympathetic the three cardiac nerves arise and pass to the heart, entering into the formation of the cardiac plexus. The superior cardiac nerve arises from the superior ganglion; the middle nerve, the largest of the three, arises from the middle ganglion or from the sympathetic cord, when this ganglion is wanting; and the inferior nerve arises from the inferior cervical ganglion or the first thoracic. These nerves present frequent communications with various of the adjacent cerebro-spinal nerves, penetrate the thorax, and form the deep and superficial cardiac plexuses and the posterior and the anterior coronary plexuses. In these various plexuses, there are found ganglioform enlargements; and upon the surface and in the substance of the heart, are collections of nerve-cells connected with the fibres.

Thoracic Ganglia.—The thoracic ganglia are situated in the chest, beneath the pleura, and rest on the heads of the ribs. They are usually twelve in number, but occasionally two are fused into one. They are connected together by the sympathetic cord. They each communicate by two filaments with the cerebro-spinal nerves. One of these is white, like the spinal nerves, and probably passes to the sympathetic, and the other, of a grayish color, is thought to contain the true sympathetic filaments. From the upper six ganglia filaments pass to the aorta and its branches. The branches which form the posterior pulmonary plexus arise from the third and fourth ganglia. The great splanchnic nerve arises mainly from the seventh, eighth and ninth ganglia, receiving a few filaments from the upper six ganglia. This is a large, white, rounded cord, which penetrates the diaphragm and passes to the semilunar ganglion, sending a few filaments to the renal plexus and the suprarenal capsules. The lesser splanchnic nerve arises from the tenth and eleventh ganglia, passes into the abdomen and joins the cœliac plexus. The renal splanchnic nerve arises from the last thoracic ganglion and passes to the renal plexus. The three splanchnic nerves present frequent anastomoses with each other.

Ganglia in the Abdominal and the Pelvic Cavity.—The semilunar ganglia on the two sides send off radiating branches to form the solar plexus. They are situated by the side of the cœliac axis and near the suprarenal capsules. These are the largest of the sympathetic ganglia. From these arise plexuses distributed to various parts in the abdomen, as follows: The phrenic plexus follows the phrenic artery and its branches to the diaphragm. The cœliac plexus subdivides into the gastric, hepatic and splenic plexuses, which are distributed to organs, as their names indicate. From the solar plexus different plexuses are given off, which pass to the kidneys, the suprarenal capsules, the testes in the male and the ovaries in the female, the intestines (by the superior and inferior mesenteric plexuses), the upper part of the rectum, the abdominal aorta and the vena cava. The filaments follow the distribution of the blood-vessels in the solid viscera.

The lumbar ganglia, four in number, are situated in the lumbar region, upon the bodies of the vertebræ. They are connected with the ganglia above and below and with each other by the sympathetic cord, receiving, like the other ganglia, filaments from the spinal nerves. Their branches of distribution form the aortic lumbar plexus and the hypogastric plexus and follow the course of the blood-vessels.

The four or five sacral ganglia and the ganglion impar are situated by the inner side of the sacral foramina and in front of the coccyx. These are connected with the ganglia above and with each other, and they receive filaments from the sacral nerves, there being generally two branches of communication for each ganglion. The filaments of distribution go to all of the pelvic viscera and blood-vessels. The inferior hypogastric, or pelvic plexus is a continuation of the hypogastric plexus above, and receives a few filaments from the sacral ganglia. The uterine nerves go to the uterus and the Fallopian tubes. In the substance of the uterus the nerves are connected with small collections of ganglionic cells. The sympathetic filaments are prolonged into the upper and lower extremities, following the course of the blood-vessels and terminating in their muscular coat.

The filaments of the sympathetic, at or near their terminations, are connected with ganglionic cells, not only in the heart and the uterus, but in the blood-vessels, lymphatics, the coccygeal gland, the submucous and the muscular layer of the entire alimentary canal, the salivary glands, pancreas, excretory ducts of the liver and pancreas, the larynx, trachea, pulmonary tissue, bladder, ureters, the entire generative apparatus, suprarenal capsules, thymus, lachrymal canals, ciliary muscle and the iris. In these situations nerve-cells have been demonstrated by various observers, and it is probable that they exist everywhere in connection with the terminal filaments of this system of nerves.

General Properties of the Sympathetic Ganglia and Nerves.—The sympathetic ganglia and nerves possess a dull sensibility, which is particularly marked in the ganglia. That the nerves contain afferent fibres, is shown by certain reflex phenomena.

Stimulation of the sympathetic produces muscular movements, but these are confined generally to non-striated muscular fibres, to which these nerves are largely distributed. The muscular movements do not immediately follow stimulation of the nerves, but there is a long, latent period. The muscular contraction, also, persists for a time and the subsequent relaxation is slow. The induced current applied to the splanchnic nerves does not produce movements of the intestines, but these movements are excited by the constant current (Legros and Onimus). The properties of the vaso-motor nerves will be considered separately.

The sympathetic ganglia are connected with the motor and sensory divisions of the cerebro-spinal system. Some of the ganglia and nerve-plexuses are directly dependent for their action upon the cerebro-spinal system, while others are capable, at least for a time, of independent action. Among the latter, are the ganglia of the heart, the intestinal plexuses, the plexuses of the uterus and Fallopian tubes, of the ureters and of the blood-vessels.

Direct Experiments on the Sympathetic.—The experiments of Pourfour du Petit (1712–1725) were the first to give any positive information regarding the action of the sympathetic system; and these observations may be taken as the starting-point of a definite knowledge of the physiology of the sympathetic, although they showed only the influence of the cervical portion upon the eye. In 1816, Dupuy removed the superior cervical ganglia in horses, with the effect of producing injection of the conjunctiva, increase of temperature in the ear and an abundant secretion of sweat upon one side of the head and neck. These experiments showed that the sympathetic has an important influence upon nutrition, calorification and secretion. In 1851, Bernard divided the sympathetic in the neck on one side in rabbits, and noted on the corresponding side of the head and the ear, increased vascularity and an elevation in temperature of 7° to 11° Fahr. (4° to 6° C.). This condition of increased heat and vascularity continues for several months after division of the nerve. In 1852, Brown-Séquard repeated these experiments and attributed the elevation of temperature directly to an increase in the supply of blood to the parts affected. He made an important advance in the history of the sympathetic, by demonstrating that its section paralyzed the muscular coat of the arteries, and farther, that Faradization of the nerve in the neck caused the vessels to contract. This was the discovery of the vaso-motor nerves, and it belongs without question to Brown-Séquard, who published his observations in August, 1852. A few months later in the same year, Bernard made analogous experiments and presented the same explanation of the phenomena observed.

The important points developed by the first experiments of Bernard and of Brown-Séquard were that the sympathetic system influences the general process of nutrition, and that many of its filaments are distributed to the muscular coat of the blood-vessels. Before these experiments, it had been shown that filaments from this system influenced the contractions of the muscular coats of the alimentary canal.

When the sympathetic is divided in the neck, the local increase in temperature is always attended with a very great increase in the supply of blood to the side of the head corresponding to the section. The increased temperature is due to a local exaggeration of the nutritive processes, apparently dependent directly upon the hyperæmia. There are many instances in pathology, of local increase in temperature attending increased supply of blood to restricted parts. In an experiment by Bidder, after excising about half an inch (12·7 mm.) of the cervical sympathetic in a half-grown rabbit, the ear on that side, in the course of about two weeks, became distinctly longer and broader than the other.

It is easy to observe the effects of dividing the sympathetic in the neck, but analogous phenomena have been noted in other parts. Among the most striking of these experiments are those reported by Samuel, who described an intense hyperæmia of the mucous membrane of the stomach and intestines, following extirpation of the cœliac plexus. By comparative experiments it was shown that this did not result from the peritonitis produced by the operation.

As regards secretion, the influence of the sympathetic is very marked. When the sympathetic filaments distributed to a gland are divided, the supply of blood is much increased and an abundant flow of the secretion follows (Bernard). Peyrani has shown that the sympathetic has an influence upon the secretion of urine. When the nerves in the neck are stimulated, the quantity of urine and of urea is increased, and this increase is greater with the induced than with the constant current. When the sympathetic is divided, the quantity of urine and of urea sinks to the minimum.

Moreau published in 1870 a series of observations on the influence of the sympathetic nerves upon the secretion of liquid by the intestinal canal, which are important as affording a possible explanation of the sudden occurrence of watery diarrhœa. In these experiments, the abdomen was opened in a fasting animal, and three loops of intestine, each loop four to eight inches (100 to 200 mm.) long, were isolated by ligatures. All of the nerves passing to the middle loop were divided, taking care to avoid the blood-vessels. The intestine was then replaced, and the wound in the abdomen was closed with sutures. The next day the animal was killed. The two loops with the nerves intact were found empty, as is normal in fasting animals, and the mucous membrane was dry; but the loop with the nerves divided was found filled with a clear, alkaline liquid, colorless or slightly opaline, which precipitated a few flocculi of organic matter on boiling.

Vaso-Motor Centres and Nerves.—The principal or dominating vaso-motor centres are situated in the medulla oblongata, one on either side, about one-tenth of an inch (2·5 mm.) from the median line. Each centre, in the rabbit, is about one-eighth of an inch (3 mm.) long and about one-sixteenth of an inch (1·5 mm.) wide. Its lower border is about one-fifth of an inch (5 mm.) above the calamus scriptorius. Each side of the body has its special vaso-motor centre, and very few if any of the vaso-motor fibres decussate. The situation of the vaso-motor centres in the medulla has been determined by successive removal of the nerve-centres above. If the central end of a large cerebro-spinal nerve be stimulated in an animal poisoned with curare, the vaso-motor nerves produce contraction of the blood-vessels, by reflex action, and there is a rise in the blood-pressure. The action is not interfered with by removal of the encephalic ganglia from above downward, until the part of the medulla containing the vaso-motor centres is reached. When these centres are removed, the reflex vaso-motor action is permanently arrested.

Subordinate vaso-motor centres exist in the spinal cord. When the vaso-motor centre in the medulla is destroyed, there is a fall in the blood-pressure; but if the circulation be continued, after a time the blood-vessels regain their "tone" and the pressure may then be affected by reflex action. It is probable that these spinal centres exist throughout the dorsal region and in the upper part of the lumbar region of the cord.

All the vaso-motor nerves are derived from the medulla oblongata and the spinal cord. Some of the vaso-motor fibres to the head pass in the trunks of the motor cranial nerves, but most of them come from the anterior roots of some of the spinal nerves and pass to the head by the filaments of distribution of the cervical sympathetic. The vaso-motor fibres pass in the lateral columns of the cord, and from the cord, in the anterior roots of the spinal nerves, in the dog, as far down as the second pair of lumbar nerves. These fibres are medullated but are of small size. They pass to the blood-vessels either through branches from the sympathetic ganglia or through the ordinary cerebro-spinal nerves. They are therefore not confined to branches of the sympathetic, as Bernard has shown by the following experiment: He divided the fourth, fifth, sixth, seventh and eighth pairs of lumbar nerves on one side in a dog, at the spinal column, and paralyzed motion and sensation in the leg of that side, but the temperature of the two sides remained the same. He afterward exposed and divided the sciatic nerve on that side, and then noted decided increase in temperature. This experiment, which is only one of a large number, shows that the ordinary mixed nerves contain vaso-motor fibres, which are entirely independent of the nerves of motion and sensation, a fact which is now well known to physiologists and has frequently been illustrated in cases of disease in the human subject.

The vaso-motor nerves are capable of influencing local circulations, probably through distinct centres for different parts. Direct stimulation of the principal vaso-motor centre (10 to 12 or more single induction shocks per second for strong currents or 20 to 25 for moderate currents) increases the blood-pressure to the maximum.

The contractile coats of the veins and lymphatics probably are influenced by vaso-motor nerves, but there is little known of the mechanism of this action.

Reflex Vaso-Motor Phenomena.—The most important physiological acts connected with the vaso-motor nerves are reflex. It is evident from experiments on the inferior animals and observations on the human subject that there are afferent as well as efferent nerves. The reflex acts connected with secretion have already been considered; but there are other phenomena that demand a brief description.

As regards animal heat, the phenomena of which are intimately connected with the supply of blood to the parts, it is important to note the observations of Brown-Séquard and Lombard, who found that pinching of the skin on one side was attended with a diminution in the temperature in the corresponding member of the opposite side, and that sometimes, when the irritation was applied to the upper extremities, changes were produced in the temperature of the lower limbs. Tholozan and Brown-Séquard found, also, that lowering the temperature of one hand produced a considerable depression in the heat of the other hand, without any notable diminution in the general heat of the body. Brown-Séquard showed that by immersing one foot in water at 41° Fahr. (5° C.) the temperature of the other foot was diminished by about 7° Fahr. (4° C.) in the course of eight minutes.