point of junction of the pneumogastric with the communicating branch from the spinal accessory, so that probably the superior laryngeals contain few if any motor fibres from the eleventh nerve. The superior laryngeal gives off the external laryngeal, a long, delicate branch, which sends a few filaments to the inferior constrictor of the pharynx and is distributed to the crico-thyroid muscle and the mucous membrane of the ventricle of the larynx. The external laryngeal branch anastomoses with the inferior laryngeal nerve and with the sympathetic. The internal branch is distributed to the mucous membrane of the epiglottis, the base of the tongue, the arytenoepiglottidean fold and the mucous membrane of the larynx as far down as the true vocal chords. A branch from this nerve, in its course to the larynx, penetrates the arytenoid muscle, to which it sends a few filaments, but these are all sensory. This branch also supplies the crico-thyroid muscle. It anastomoses with the inferior laryngeal nerve. An important branch, described by Cyon and Ludwig, in the rabbit, under the name of the depressor nerve, arises by two roots, one from the superior laryngeal and the other from the trunk of the pneumogastric. It passes down the neck by the side of the sympathetic, and in the chest, it joins filaments from the thoracic sympathetic, to pass to the heart, between the aorta and the pulmonary artery. This nerve is not isolated in the human subject, but it is probable that analagous fibres exist in man in the trunk of the pneumogastric.

It is important from a physiological point of view to note that the superior laryngeal nerve is the nerve of sensibility of the upper part of the larynx, as well as of the supralaryngeal mucous membranes, and that it animates a single muscle of the larynx (the crico-thyroid) and the inferior constrictor of the pharynx.

The inferior, or recurrent laryngeal nerves present some slight differences in their anatomy upon the two sides. Upon the left side the nerve is the larger and is given off at the arch of the aorta. Passing beneath this vessel, it ascends in the groove between the trachea and the œsophagus. In its upward course it gives off certain filaments which join the cardiac branches, filaments to the muscular tissue and mucous membrane of the upper part of the œsophagus, filaments to the mucous membrane and the intercartilaginous muscular tissue of the trachea, one or two filaments to the inferior constrictor of the pharynx and a branch which joins the superior laryngeal. Its terminal branches penetrate the larynx, behind the posterior articulation of the thyroid with the cricoid cartilage, and are distributed to all of the intrinsic muscles of the larynx, except the crico-thyroids, which are supplied by the superior laryngeal. Upon the right side the nerve winds from before backward around the subclavian artery, and it has essentially the same course and distribution as upon the left side, except that it is smaller and has fewer filaments of distribution.

The important physiological point connected with the anatomy of the recurrent laryngeals is that they animate all of the intrinsic muscles of the larynx, except the crico-thyroid. Experiments have shown that these nerves contain a large number of motor filaments derived from the spinal accessory.

The cervical cardiac branches, two or three in number, arise from the pneumogastrics at different points in the cervical portion, and pass to the cardiac plexus, which is formed in great part of filaments from the sympathetic. The thoracic cardiac branches are given off from the pneumogastrics, below the origin of the inferior laryngeals, and join the cardiac plexus.

The anterior pulmonary branches are few and delicate as compared with the posterior branches. They are given off below the origin of the thoracic cardiac branches, send a few filaments to the trachea, and then form a plexus which surrounds the bronchial tubes and follows the bronchial tree to its terminations in the air-cells. The posterior pulmonary branches are larger and more abundant than the anterior. They communicate freely with sympathetic filaments from the upper three or four thoracic ganglia and then form the great posterior pulmonary plexus. From this plexus a few filaments go to the inferior and posterior portion of the trachea, a few pass to the muscular tissue and mucous membrane of the middle portion of the œsophagus, and a few are sent to the posterior and superior portion of the pericardium. The plexus then surrounds the bronchial tree and passes with its ramifications to the pulmonary tissue, like the corresponding filaments of the anterior branches. The pulmonary branches are distributed to the mucous membrane, and not to the walls of the blood-vessels.

The œsophageal branches take their origin from the pneumogastrics, above and below the pulmonary branches. These branches from the two sides join to form the œsophageal plexus, their filaments of distribution going to the muscular tissue and the mucous membrane of the lower third of the œsophagus.

The abdominal branches are quite different in their distribution upon the two sides.

Upon the left side the nerve, which is here anterior to the cardiac opening of the stomach, immediately after its passage by the side of the œsophagus into the abdomen, divides into a number of branches, which are distributed to the muscular walls and the mucous membrane of the stomach. As the branches pass from the lesser curvature, they take a downward direction and go to the liver, and with another branch running between the folds of the gastro-hepatic omentum, they follow the course of the portal vein in the hepatic substance. The branches of this nerve anastomose with the nerve of the right side and with the sympathetic.

The right pneumogastric, situated posteriorly, at the œsophageal opening of the diaphragm, sends a few filaments to the muscular coat and the mucous membrane of the stomach, passes backward and is distributed to the liver, spleen, kidneys, suprarenal capsules and finally to the whole of the small intestine (Kollmann). The anatomical researches by Kollmann (1860) have been fully confirmed by physiological experiments. Before the nerves pass to the intestines, there is a free anastomosis and interchange of filaments between the right and the left pneumogastric.

General Properties of the Roots of Origin of the Pneumogastrics.—The sensibility of the pneumogastrics in the neck, while it is dull as compared

with the properties of other sensory nerves, is nevertheless distinct. It is impossible, however, to expose the roots of the nerves in living animals, before they have received communicating motor filaments, without such mutilation as would interfere with accurate observations; but in animals just killed, if the roots be exposed and divided, so as to avoid reflex movements, and if care be taken to avoid stimulation of motor filaments from adjacent nerves, it is found that the application of electricity to the peripheral end of the root, from its origin to the ganglion, gives rise to no movements. It may therefore be assumed that the true filaments of origin of the pneumogastrics are exclusively sensory or at least that they have no motor properties.

Properties and Uses of the Auricular Nerves.—There is very little to be said with regard to the auricular nerves after a description of their anatomy. They are sometimes described with the facial and sometimes with the pneumogastric. They contain filaments from the facial, the pneumogastric and the glosso-pharyngeal. The sensory filaments of these nerves give sensibility to the upper part of the external auditory meatus and the membrana tympani.

Properties and Uses of the Pharyngeal Nerves.—The pharyngeal branches of the pneumogastric are mixed nerves, their motor filaments being derived from the spinal accessory; and their direct action upon the muscles of deglutition belongs to the physiological history of the last-named nerve. As already stated in treating of the spinal accessory, the filaments of communication that go to the pharyngeal branches of the pneumogastric are distributed to the pharyngeal muscles.

It is impossible to divide all of the pharyngeal filaments in living animals and observe directly how far the general sensibility of the pharynx and the reflex phenomena of deglutition are influenced by this section. As far as one can judge from the distribution of the filaments to the mucous membrane, it would seem that they combine with the pharyngeal filaments of the fifth, and possibly with sensory filaments from the glosso-pharyngeal, in giving general sensibility to these parts.

In the experiments of Waller and Prevost, upon the reflex phenomena of deglutition, it is shown that the action of the pharyngeal muscles can not be excited by stimulation of the mucous membrane of the supralaryngeal region and the pharynx, after section of the fifth and of the superior laryngeal branches of the pneumogastrics. This would seem to show that the pharyngeal branches of the pneumogastrics are of little importance in these reflex phenomena.

Properties and Uses of the Superior Laryngeal Nerves.—The stimulation of these nerves produces intense pain and contraction of the crico-thyroids; but it has been shown by experiment that the arytenoid muscles, through which the nerves pass, receive no motor filaments. The influence of the nerves upon the muscles resolves itself into the action of the crico-thyroids, which has been treated of fully under the head of phonation. When these muscles are paralyzed, the voice becomes hoarse. The filaments to the inferior muscles of the pharynx are few and comparatively unimportant. The

superior laryngeals do not receive their motor filaments from the spinal accessory.

The sensory filaments of the superior laryngeals have important uses connected with the protection of the air-passages from the entrance of foreign matters, particularly in deglutition, and they are also concerned in the reflex action of the constrictors of the pharynx. When both superior laryngeals have been divided in living animals, liquids often pass in small quantity into the larynx, owing to the absence of the reflex closure of the glottis when foreign matters are brought in contact with its superior surface and the occasional occurrence of inspiration during deglutition.

Aside from the protection of the air-passages, the superior laryngeal is one of the sensory nerves through which the reflex acts in deglutition operate. There are certain parts which depend for their sensibility entirely upon this nerve; viz., the mucous membrane of the epiglottis, of the aryteno-epiglottidean fold and of the larynx as far down as the true vocal chords. When an impression is made upon these parts, as when they are touched with a piece of meat, regular and natural movements of deglutition ensue.

If the superior laryngeal nerves be divided and a stimulus be applied to their central ends, movements of deglutition are observed, and there is also arrest of the action of the diaphragm. From these experiments, it would seem that the impression which gives rise to the movements of deglutition aids in protecting the air-passages from the entrance of foreign matters, by temporarily arresting the inspiratory act.

Properties and Uses of the Inferior, or Recurrent Laryngeal Nerves.—The anatomical distribution of these nerves shows that their most important action is connected with the muscles of the larynx. The few filaments which are given off in the neck, to join the cardiac branches, are probably not very important. It is proper to note, however, that the inferior laryngeal nerves supply the muscular tissue and mucous membrane of the upper part of the œsophagus and trachea, and one or two branches are sent to the inferior constrictor of the pharynx. The action of these filaments is sufficiently evident.

The inferior laryngeals contain chiefly motor filaments, as is evident from their distribution as well as from the effects of direct stimulation. All who have experimented upon these nerves have noted little or no evidence of pain when they are irritated or divided.

One of the most important uses of the recurrents relates to the production of vocal sounds. In connection with the physiology of the internal, or communicating branch from the spinal accessory to the pneumogastric, it has been shown that this branch of the spinal accessory is the true nerve of phonation. Before the uses of the spinal accessory were fully understood, the experiments upon the inferior laryngeals led to the opinion that these were the nerves of phonation, as loss of voice follows their division in living animals. It is true that these nerves contain the filaments which preside over the vocal movements of the larynx; but it is also the fact that these vocal filaments are derived exclusively from the spinal accessory, and that the

recurrents contain as well motor filaments which preside over movements of the larynx not concerned in the production of vocal sounds.

The muscles of the larynx concerned in phonation are the crico-thyroids, animated by the superior laryngeals, and the arytenoid, the lateral crico-arytenoids and the thyro-arytenoids, animated by the inferior laryngeals. The posterior crico-arytenoids are respiratory muscles, and these are not affected by extirpation of the spinal accessories, but the glottis is still capable of dilatation, so that inspiration is not impeded. If, however, the spinal accessories be extirpated and the larynx be then exposed in a living animal, the glottis still remains dilated, but will not close when irritated. If the inferior laryngeals be then divided, the glottis is mechanically closed with the inspiratory act, and the animals often die of suffocation. In view of the varied sources from which the pneumogastrics receive their motor filaments, it is easy to understand how certain of these may preside over the vocal movements, and others, from a different source, may animate the respiratory movements.

The impediment to the entrance of air into the lungs is a sufficient explanation of the increase in the number of the respiratory acts after division of both recurrents. The acceleration of respiration is much greater in young than in adult animals. This does not apply to very young animals, in which section of the recurrents produces almost instant death.

Feeble stimulation of the central ends of the inferior laryngeals, after their division, produces rhythmical movements of deglutition, generally coincident with arrest of the action of the diaphragm. These phenomena are generally observed in rabbits, but they are not constant. The reflex action of these nerves in deglutition probably is dependent upon the communicating filaments which they send to the superior laryngeal nerves.

Properties and Uses of the Cardiac Nerves.—The chief uses of the cardiac branches relate to the influence of the pneumogastrics on the action of the heart. This has already been considered in connection with the physiology of the circulation. The effect of dividing the pneumogastrics in the neck is to remove the heart from the influence of its inhibitory nerves; but at the same time, the operation profoundly affects the respiratory movements, and this latter effect must be eliminated as far as possible in studying the influence of the pneumogastrics on the circulation. The same remark applies to the experiment of Faradization of the pneumogastrics in the neck. The cardiac branches are operated upon with difficulty, and most experiments have been made upon the cervical portion of the pneumogastric itself.

Faradization of the pneumogastrics in the neck arrests the action of the heart in diastole (the brothers Weber, 1846). This is a direct action and is due to the excitation of the inhibitory fibres, which are derived from the spinal accessory nerves. The phenomena following stimulation of these nerves have already been described in connection with the physiology of the circulation and the properties and uses of the spinal accessories.

Depressor Nerve.—While this nerve, which has been described in the rabbit (Cyon and Ludwig, 1867), is not isolated in the human subject, it is probable that fibres, the action of which is analogous to the action observed

in animals in which the nerve is anatomically distinct, exist in the trunk of the pneumogastric. The action of the depressor nerves, which is reflex, has already been described in connection with the physiology of the circulation.

Properties and Uses of the Pulmonary Nerves.—The trachea, bronchia and the pulmonary structure are supplied with motor and sensory filaments by branches of the pneumogastrics. The recurrent laryngeals supply the upper part, and the pulmonary branches, the lower part of the trachea, the lungs themselves being supplied by the pulmonary branches alone. The sensibility of the mucous membrane of the trachea and bronchia is due to the pneumogastrics, for these parts are insensible to irritation when the nerves have been divided in the neck. Longet has shown that while an animal coughed and showed signs of pain when the mucous membrane of the respiratory passages was irritated, after division of the pneumogastrics there was no evidence of sensibility, even when the tracheal mucous membrane was treated with strong acid or cauterized. He also saw the muscular fibres of the small bronchial tubes contract when an electric stimulus was applied to the branches of the pneumogastrics.

Effects of Division of the Pneumogastrics upon Respiration.—Section of both pneumogastrics in the neck, in mammals and birds, is usually followed by death, in two to five days. In very young animals, death may occur almost instantly from paralysis of the respiratory movements of the glottis. It has been found by all experimenters that animals survived and presented no very distinct abnormal phenomena after section of one nerve. According to Longet, animals operated upon in this way present hoarseness of the voice and a slight increase in the number of respiratory acts. Some observers have found the corresponding lung partly emphysematous and partly engorged with blood, and others have not noted any change in the pulmonary structure.

When both nerves are divided in full-grown dogs, the effect upon the respiratory movements is very marked. For a few seconds the number of respiratory acts may be increased; but so soon as the animal becomes tranquil, the number is very much diminished and the movements change their character. The inspiratory acts become unusually profound and are attended with excessive dilatation of the thorax. The animal generally is quiet and indisposed to move. Under these conditions the number of respirations may fall from sixteen or eighteen to four per minute.

In most animals that die from section of both pneumogastrics, the lungs are found engorged with blood, and, as it were, carnified, so that they sink in water. This condition is not the result of inflammation of the pulmonary parenchyma, although this was the view formerly entertained and is even now held by some physiologists. Bernard found that the pulmonary lesion did not exist in birds, although section of both nerves was fatal. It had previously been ascertained that in some animals death takes place with no alteration of the lungs. When the entrance of the secretions into the air passages was prevented by the introduction of a canula into the trachea, the solidification of the lungs was nevertheless observed. Without detailing all of the

experiments upon which the explanation offered by Bernard is based, it is sufficient to state that he observed a traumatic emphysema as a consequence of the excessively labored and profound inspirations. Indeed, this can be actually seen when the pleura is exposed in living animals. As a result of this excessive distention of the air-cells, the pulmonary capillaries are ruptured in different parts, the blood becomes coagulated and the lungs are finally solidified. This can not occur in birds, because the lungs are fixed, and their relations are such that they are not exposed to excessive distention in inspiration.

The pneumogastrics sometimes reunite after division. The following observation (Flint, 1874) illustrates this fact, which has frequently been noted: Both pneumogastrics were divided in the neck in a medium-sized dog. The pulse was immediately increased from one hundred and twenty to two hundred and forty in the minute, and the number of respirations fell from twenty-four to four or six. In ten days the pulse and respirations had become normal. The dog was then killed by section of the medulla oblongata, and the reunion of the divided ends of the nerves was found to be nearly complete.

The relations of the pneumogastrics to the respiratory nervous centre have been fully considered in connection with the physiology of respiration.

Effects of Faradization of the Pneumogastrics upon Respiration.—Faradization of the pneumogastrics in the neck, if the current be sufficiently powerful, arrests respiration. This arrest may be produced at any time with reference to the respiratory act, either in expiration or inspiration, although it is more readily effected in expiration. During the passage of the current the general movements of the animal are also arrested. Although respiration may always be arrested in this way, quite a powerful current is required. During the passage of a very feeble current, the respirations are accelerated. They are then retarded as the current is made stronger, until they finally cease (Bert).

The following are the phenomena, observed by Bert, during the passage of a powerful Faradic current:

"If an excitation be employed sufficiently powerful to arrest respiration in inspiration, all respiratory movements may be made to cease at the very moment when the excitation is applied (inspiration, half-inspiration, expiration), either by operating upon the pneumogastric, or operating upon the laryngeal. . . .

"Any feeble excitation of centripetal nerves increases the number of the respiratory movements; any powerful excitation diminishes them. A powerful excitation of the pneumogastrics, of the superior laryngeal, of the nasal branch of the infraörbital, may arrest them completely; if the excitation be sufficiently energetic, the arrest takes place at the very moment it is applied. Finally, sudden death of the animal may follow a too powerful impression thus transmitted to the respiratory centre: all this being true for certain mammalia, birds and reptiles."

The above expresses the most important experimental facts at present known with regard to the influence of stimulation of the pneumogastrics

upon respiration. The pulmonary branches themselves are so deeply situated that they have not as yet been made the subject of direct experiment, with any positive and satisfactory results.

Properties and Uses of the Œsophageal Nerves.—The muscular walls and the mucous membrane of the œsophagus are supplied entirely by branches from the pneumogastrics. The upper portion is supplied by filaments from the inferior laryngeal branches, the middle portion, by filaments from the posterior pulmonary branches, and the inferior portion receives the œsophageal branches. These branches are both sensory and motor; but probably the motor filaments largely predominate, for the mucous membrane, although it is sensible to the extremes of heat and cold, the feeling of distention, and a burning sensation upon the application of strong irritants, is by no means acutely sensitive.

That the movements of the œsophagus are animated by branches from the pneumogastrics, has been clearly shown by experiments. In the first place, except in animals in which the anatomical distribution of the nerves is different from the arrangement in the human subject, the entire œsophagus is paralyzed by dividing the nerves in the neck. When the pneumogastrics are divided in the cervical region in dogs, if the animals attempt to swallow a considerable quantity of food, the upper part of the œsophagus is found enormously distended. Bernard noted in a dog in which a gastric fistula had been established, that articles of food given to the animal did not pass into the stomach, although he made great efforts to swallow. An instant after the attempt, the matters were regurgitated, mixed with mucus, but of course did not come from the stomach.

Direct experiments upon the roots of the pneumogastrics have shown that these nerves influence the movements of the œsophagus, and that the motor filaments involved do not come from the spinal accessory; but it is not known from what nerves these motor filaments are derived.

Properties and Uses of the Abdominal Nerves.—In view of the extensive distribution of the terminal branches of the pneumogastrics to the abdominal organs, it is evident that the action of these nerves must be very important, particularly since it has been shown that the right nerve is distributed to the whole of the small intestine.

Influence of the Pneumogastrics upon the Liver.—There is very little known with regard to the influence of the pneumogastrics upon the secretion of bile; and the most important experiments upon the innervation of the liver relate to the production of glycogen. If both pneumogastrics be divided in the neck, and if the animal be killed at a time varying between a few hours and one or two days after, the liver contains no sugar, under the conditions in which it is generally found; viz., a certain time after death. From experiments of this kind, Bernard concluded that the glycogenic processes are suspended when the nerves are divided. The experiments, however, made by irritating the pneumogastrics, were more satisfactory, as in these he looked for sugar in the blood and in the urine and did not confine his examinations for sugar to the substance of the liver.