surface of the soft palate are larger and here form a continuous layer. The glands of the tongue are situated beneath the mucous membrane, mainly on the posterior third of the dorsum; but a few are found at the edges and the tip, and there is a gland of considerable size on either side of the frenum, near the tip. All of these are small, racemose glands, similar in structure to those which have been called the true salivary glands. In addition to these structures, the mucous membrane of the tongue is provided with simple and compound follicular glands, which extend over its entire surface, but are most abundant at the posterior portion, behind the circumvallate papillæ. The most important of the glands of the tongue will be described in connection with the physiology of gustation.

In the pharynx and the posterior portion of the buccal cavity, are the pharyngeal glands and the tonsils. In the pharynx, particularly the upper portion, racemose glands, like those found in the mouth, exist in large numbers. The mucous membrane is provided, also, with simple and compound mucous follicles. The tonsils, situated on either side of the fauces between the pillars of the soft palate, consist of an aggregation of compound follicular glands. The number of glands entering into the composition of each tonsil is ten to twenty.

The secretion from the glands and follicles above enumerated can not be obtained, in the human subject, unmixed with the fluids from the true salivary glands. It has been collected in small quantity, however, from the inferior animals, after ligature of all the salivary ducts. This secretion is simply a grayish, viscid mucus, containing a number of leucocytes and desquamated epithelial scales. It is this which gives the turbid and opaline character to the mixed saliva, as the secretions of the salivary glands are all perfectly transparent. The fluid from these glands in the mouth is mixed with the salivary secretions; and that from the posterior part of the tongue, the tonsils, and the pharyngeal glands passes down to the stomach with the alimentary bolus. This secretion, consequently, forms a constant and essential part of the mixed saliva.

Mixed Saliva.—Although the study of the distinct secretions discharged into the mouth possesses considerable physiological importance, it is only the fluid resulting from a union of them all, which can properly be considered in connection with the general process of insalivation. In man it is necessary that the cavity of the mouth should be continually moistened, if for nothing else, to keep the parts in a proper condition for phonation. A little reflection will make it apparent that the flow, from some of the glands at least, is constant, and that from time to time a certain quantity of saliva is swallowed. The discharge of the fluid into the mouth, though diminished, is not arrested during sleep. In the review of the different kinds of saliva, it has been seen that the flow from none of the glands is absolutely intermittent; unless it be so occasionally from the parotid, the secreting action of which is most powerfully influenced by the act of mastication and the impression of sapid substances.

Upon the introduction of food the quantity of saliva is greatly increased; and the influence of the sight, odor, and occasionally even the thought of

agreeable articles has already been mentioned. The experiments of Frerichs on dogs with gastric fistulæ, and the observations of Gardner on a patient with a wound in the œsophagus, have demonstrated that the flow of saliva may be excited by the stimulus of food introduced directly into the stomach without passing through the mouth.

Quantity of Saliva.—It is not easy to estimate in the human subject the entire quantity of saliva secreted in the twenty-four hours; and great variations in this regard undoubtedly exist in different persons and even in the same individual at different times. An approximate estimate may be arrived at by noting as nearly as possible the average quantity secreted during the intervals of digestion and adding to it the quantity absorbed by the various articles of food. Estimates of this kind can be approximate only, and those made by Dalton are apparently the most satisfactory. The following represents, according to Dalton, the quantities of saliva secreted during mastication and during the intervals of meals:

Saliva required for mastication	17·32 oz.	(491 grammes).
Saliva secreted in intervals of meals	27·93 oz.	(792 grammes).
Total quantity per day	45·25 oz.	(1,283 grammes).

The total daily quantity of saliva, therefore, is a little more than two and three-fourths pounds.

Remembering that the quantity of saliva must necessarily be subject to great variations, this estimate may be taken as giving a sufficiently close approximation of the quantity of saliva ordinarily secreted. It must be borne in mind, however, with reference to this and the other digestive secretions, that this large quantity of fluid is at no one time removed from the blood but is reabsorbed nearly as fast as secreted, and that normally, none of it is discharged from the organism.

General Properties and Composition of the Saliva.—The mixed fluid taken from the mouth is colorless, somewhat opaline, frothy and slightly viscid. It generally has a faint and somewhat disagreeable odor very soon after it is discharged. If it be allowed to stand, it deposits a whitish sediment, composed mainly of desquamated epithelial scales with a few leucocytes, leaving the supernatant fluid tolerably clear. Its specific gravity is variable, ranging between 1004 or 1006 and 1008. Its reaction is almost constantly alkaline; although, under certain abnormal conditions of the system, it has occasionally been observed to be neutral, and sometimes, though rarely, acid. The saliva becomes slightly opalescent by boiling or on the addition of strong acids. The addition of absolute alcohol produces an abundant, whitish, flocculent precipitate. Almost invariably the mixed saliva presents a more or less intense blood-red tint on the addition of a per-salt of iron, which is due to the presence of a sulphocyanide either of potassium or of sodium.

A number of analyses of the human mixed saliva have been made by different chemists, presenting, however, few differences, except in the relative proportions of water and solid ingredients, which are probably quite variable. The following is an analysis by Bidder and Schmidt:

COMPOSITION OF HUMAN SALIVA.

Water	995·16
Epithelium	1·62
Soluble organic matter	1·34
Potassium sulphocyanide	0·06
Sodium, calcium and magnesium phosphates	0·98
Potassium chloride } Sodium chloride }	0·84
	1,000·00

The organic matter of the mixed saliva, called by Berzelius, ptyaline, on the addition of an excess of absolute alcohol, is coagulated in the form of whitish flakes which may be readily separated by filtration. This substance has been studied by Mialhe and is described by him under the name of animal diastase. This author regards it as the active principle of the saliva. It has no direct influence upon the nitrogenized alimentary matters, but when brought in contact with hydrated starch, readily transforms it, first into dextrine and afterward into glucose. According to Mialhe, the energy of this action is such that one part is sufficient to effect the transformation of more than two thousand parts of starch.

The presence of a certain quantity of potassium sulphocyanide in the mixed saliva can be demonstrated by the addition of a per-salt of iron. That this is a constant and normal ingredient of the human saliva, can not be doubted.

Very little need be said concerning the other inorganic constituents of saliva, except that they are of such a nature as almost invariably to render the fluid distinctly alkaline. They exist in small proportion and do not appear to be connected in any way with the action of the saliva as a digestive fluid.

Uses of the Saliva.

In 1831, Leuchs discovered that hydrated starch, mixed with fresh saliva and warmed, became liquid and was converted into sugar. This fact has since been repeatedly confirmed; and it is now a matter of common observation that hydrated starch or unleavened bread, taken into the mouth, almost instantly loses the property of striking a blue color with iodine and responds to the ordinary tests for sugar. Of the rapidity of this action any one can easily convince himself by the simple experiment of taking a little cooked starch into the mouth, mixing it well with the saliva, and testing in the ordinary way for sugar. This can hardly be done so rapidly that the reaction is not manifested, and the presence of sugar is also indicated by the taste. Although the human mixed saliva will finally exert the same action on uncooked starch, the transformation takes place much more slowly.

It has been shown that all the varieties of human saliva have the same effect on starch as the mixed fluids of the mouth. Dalton found no difference between the pure parotid saliva and the mixed saliva of the human subject, as regards the power of transforming starch into sugar. Bernard

obtained the pure secretions from the parotid and from the submaxillary glands in the human subject, by drawing the fluids out of the ducts as they open into the mouth, by means of a small syringe with the nozzle arranged so as to fit over the papillæ, and demonstrated their action on starch. Longet showed that a mixture of the secretions of the submaxillary and the sublingual glands has the same property.

Several carbohydrates are formed as intermediate products between the hydrated starch and glucose, which latter is the final result of the action of the salivary ferment. After passing through one or two conditions slightly different from that of pure dextrine, the starch is converted into dextrine, which is changed into maltose ($C_{12}H_{22}O_{11}$), and the maltose is finally converted into glucose ($C_6H_{12}O_6$). This action is due entirely to the presence of ptyaline, although its intensity is increased in moderately alkaline solutions or by the addition of certain salts, especially sodium chloride. Feeble acids diminish the activity of this change, and it is arrested by strong mineral acids; although direct experiments have shown that the action of the saliva is slowly and feebly continued in the stomach. The temperature at which the action of the salivary ferment is most vigorous is about 100° Fahr. (38° C.); and any considerable variation from this temperature arrests the process.

In early infancy the action of the saliva upon starch is not so vigorous as in the adult, and it is said that immediately after birth the parotid secretion is the only one of the salivary fluids which contains ptyaline. In a few months, however, ptyaline appears in the submaxillary and sublingual secretions.

It is evident that the saliva, in addition to its mechanical action, transforms a considerable portion of the cooked starch, which is the common form in which starch is taken by the human subject, into sugar; but it is by no means the only fluid engaged in its digestion, similar properties belonging to the pancreatic and the intestinal juices. The last-named fluids are probably more active, even, than the saliva. The saliva acts slowly and imperfectly on raw starch, which becomes hydrated in the stomach and is digested mainly by the fluids of the small intestine. In all probability the saliva does not digest all the hydrated starch taken as food, the greater part passing unchanged from the stomach into the intestine. Those who attribute merely a mechanical action to the saliva draw their conclusions entirely from experiments on the lower animals, particularly the carnivora; and such observations can not properly be applied to the human subject.

In treating of the various fluids which are combined to form the mixed saliva, their mechanical uses have necessarily been touched upon. To sum up this part of the subject, however, it may be stated that the fluids of the mouth and pharynx have quite as important an office in preparing the food for deglutition and for the action of the juices in the stomach as in the digestion of starch. It is a matter of common experience that the rapid deglutition of very dry articles is impossible. In the human subject, although mastication and insalivation are by no means so complete as in some of the lower animals, the quantity of saliva absorbed by the various articles of food

is very large. It seems impossible that the fluid thus incorporated with the food should not have an important influence on the changes which take place in the stomach, although it must be confessed that information on this point is very meagre, except as regards the digestion of starch.

It is undoubtedly the abundant secretion of the parotid glands which becomes most completely incorporated with the food during mastication and which serves to unite the dry particles into a coherent mass. The secretions from the submaxillary and sublingual glands and from the small glands and follicles of the mouth, being more viscid and less in quantity than the parotid secretion, penetrate the alimentary bolus less easily and form a glairy coating on its exterior, agglutinating the particles near the surface with peculiar tenacity.

When the processes of mastication and insalivation have been completed, and the food has passed into the pharynx, it meets with the secretion of the pharyngeal glands, which still farther coats the surface with the viscid fluid which covers the mucous membrane in this situation, thus facilitating the first processes of deglutition.

It has been observed that the saliva engages bubbles of air in the alimentary mass. In mastication, a considerable quantity of air is mixed with the food, and this facilitates the penetration of the gastric juice. It is well known that moist, heavy bread, and articles that can not become impregnated in this way with air, are not easily acted upon in the stomach.

Deglutition.

Deglutition is the act by which solid and liquid articles are passed from the mouth into the stomach. The process involves first, the passage, by an automatic movement, of the alimentary mass through the isthmus of the fauces into the pharynx; then a rapid contraction of the constrictors of the pharynx, by which it is forced into the œsophagus; and finally, a peristaltic action of the muscular walls of the œsophagus, extending from its opening at the pharynx to the stomach.

Physiological Anatomy of the Parts concerned in Deglutition.—The parts concerned in this process are the tongue, the muscular walls of the pharynx and the œsophagus. In the passage of food and drink through the pharynx, it is necessary to completely protect from the entrance of foreign matters a number of openings which are exclusively for the passage of air. These are the posterior nares and the Eustachian tubes above, and the opening of the larynx below.

The tongue—a muscular organ capable of a great variety of movements—is the chief agent in the first processes of deglutition. A study of the muscles which are brought into action in deglutition would involve an anatomical description so elaborate as to be out of place in this work. The movements of the tongue, however, will be described in connection with the mechanism of deglutition.

The pharynx, in which the most complex of the movements of deglutition take place, is an irregular, funnel-shaped cavity, its longest diameter being

transverse and opposite the cornua of the hyoid bone, with its smallest portion at the opening into the œsophagus. Its length is about four and a half inches (11·43 centimetres). It is connected superiorly and posteriorly with the basilar process of the occipital bone and with the upper cervical vertebræ. It is incompletely separated from the cavity of the mouth by the velum pendulum palati, a movable, musculo-membranous fold continuous with the roof of the mouth and marked by a line in the centre, which indicates its original development by two lateral halves. This, which is called the soft palate, when relaxed, presents a concave surface looking toward the mouth, a free, arched border, and a conical process hanging from the centre, called the uvula. On either side of the soft palate, are two curved pillars, or arches.

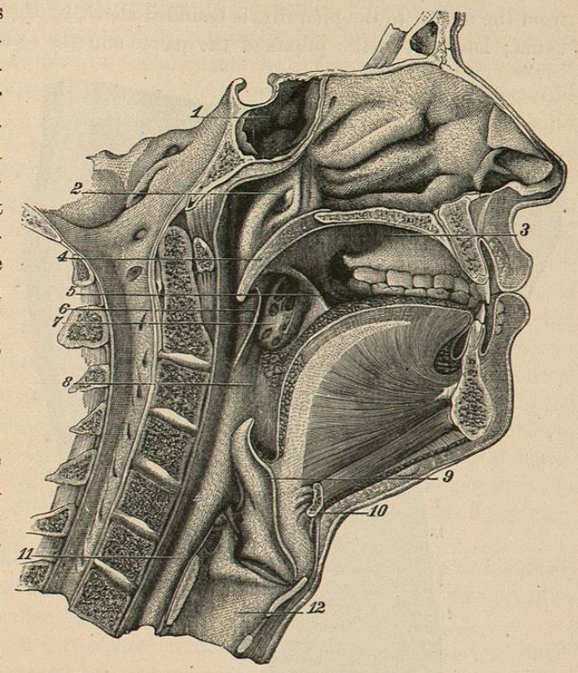

Fig. 55.—*Cavities of the mouth and pharynx, etc.* (Sappey).
Section, in the median line, of the face and the superior portion of the neck, designed to show the mouth in its relations to the nasal fossæ, the pharynx and the larynx: 1, sphenoidal sinuses; 2, internal orifice of the Eustachian tube; 3, palatine arch; 4, velum pendulum palati; 5, anterior pillar of the soft palate; 6, posterior pillar of the soft palate; 7, tonsil; 8, lingual portion of the cavity of the pharynx; 9, epiglottis; 10, section of the hyoid bone; 11, laryngeal portion of the cavity of the pharynx; 12, cavity of the larynx.

The anterior pillars of the fauces are formed by the palato-glossus muscle on either side and run obliquely downward and forward, the mucous membrane which covers them becoming continuous with the membrane over the base of the tongue. The posterior pillars are more closely approximated to each other than the anterior. They run obliquely downward and backward, their mucous membrane becoming continuous with the membrane covering the sides of the pharynx. Between the lower portion of the anterior and posterior pillars, are the tonsils; and in the substance of and beneath the mucous membrane of the palate and pharynx, are small glands, which have already been described.

In Fig. 55, are shown the cavities of the mouth and pharynx with their relations to the nares and the larynx.

The isthmus of the fauces, or the strait through which the food passes from the mouth to the pharynx, is bounded above, by the soft palate and the uvula; laterally, by the pillars of the palate and the tonsils; and below, by the base of the tongue.

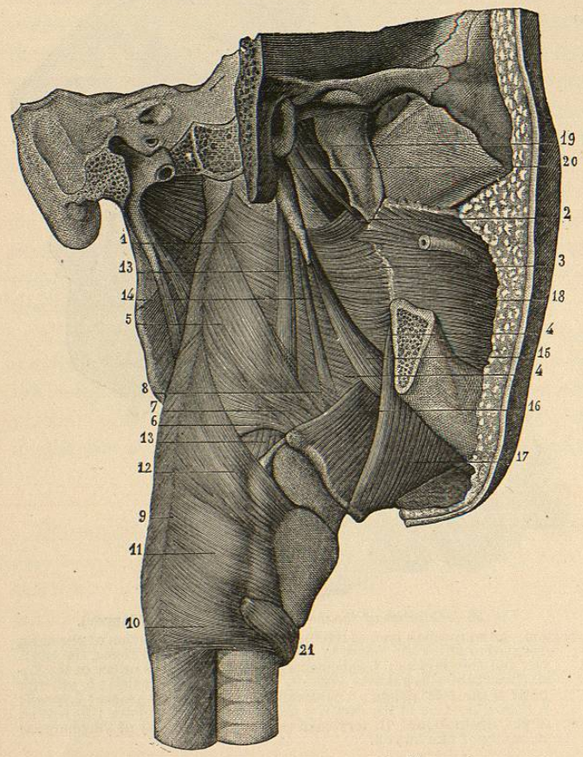

FIG. 56.—*Muscles of the pharynx, etc.* (Sappey).

1, 2, 3, 4, 4, superior constrictor; 5, 6, 7, 8, middle constrictor; 9, 10, 11, 12, inferior constrictor; 13, 13, stylo-pharyngeus; 14, stylo-hyoid muscle; 15, stylo-glossus; 16, hyo-glossus; 17, mylo-hyoid muscle; 18, buccinator muscle; 19, tensor palati; 20, levator palati.

The openings into the pharynx above are the posterior nares and the orifices of the Eustachian tubes. Below, are the openings of the œsophagus and of the larynx.

The muscles of the pharynx are the superior constrictor, the stylo-pharyngeus, the middle constrictor and the inferior constrictor; and it is easy to see, from the situation of these muscles, which is shown in Fig. 56, how, by their successive action from above downward, the food is passed into the œsophagus.

The muscles which form the fleshy portions of the soft palate are likewise important in deglutition. These are the levator palati, the tensor palati, the palato-glossus and the palato-pharyngeus. The azygos uvulæ, which forms the fleshy portion of the uvula, has no marked or important action in deglutition.

The mucous membrane of the pharynx, aside from the various glands situated beneath it and in its substance, which have already been described, presents some peculiarities, which are interesting more from an anatomical than a physiological point of view. In the superior portion, which forms a cuboidal cavity just behind the posterior nares, the membrane is darker and much richer in blood-vessels than in other parts. Its surface is smooth and provided with ciliated, columnar epithelium, like that which covers the membrane of the posterior nares. Laterally, below the level of the opening of the Eustachian tubes, and posteriorly, at the point where it becomes vertical, the mucous membrane abruptly changes its character. The epithelial covering is here composed of flattened cells, similar to those which cover the mucous membrane of the œsophagus. The membrane is also paler and less vascular. It is provided with papillæ, some of which are simple, conical elevations, while others present two to six conical processes with a single base. These papillæ are rather thinly distributed over all of that portion of the mucous surface which is covered with flattened epithelium.

The contractions of the muscular walls of the pharynx force the alimentary bolus into the œsophagus, a tube possessed of thick, muscular walls, extending to the stomach. The œsophagus is about nine inches (23 centimetres) in length. It is cylindrical and is slightly constricted at its superior and inferior extremities. Its upper extremity is in the median line, behind the lower border of the cricoid cartilage and opposite the fifth cervical vertebra. At first, as it descends, it passes a little to the left of the cervical vertebræ. It then passes from left to right from the fourth or fifth to the ninth dorsal vertebra, to give place to the aorta. It finally passes a little to the left again, and from behind forward, to its opening into the stomach. In its passage through the diaphragm, it is surrounded by muscular fibres, so that when this muscle is contracted in inspiration, its action has a tendency to close the opening.

The coats of the œsophagus are two in number, unless there be included, as a third coat, the fibrous tissue which attaches the mucous membrane to the subjacent muscular tissue.

The external coat is composed of an external longitudinal, and an internal circular or transverse layer of muscular fibres. In the superior portion, the longitudinal fibres are arranged in three distinct fasciculi; one in front, which passes downward from the posterior surface of the cricoid cartilage, and one on either side, extending from the inferior constrictors of the pharynx. As the fibres descend, the fasciculi become less distinct and are finally blended into a uniform layer. The circular layer is somewhat thinner than the external layer. Its fibres are transverse near the superior and inferior extremities of the tube and are somewhat oblique in the intermediate portion. The muscular coat is $\frac{1}{50}$ to $\frac{1}{12}$ of an inch (0·5 to 2·1 mm.) in thickness.

In the upper third of the œsophagus, the muscular fibres are exclusively of the red or striated variety, with some anastomosing bundles; but lower down, there is a mixture of non-striated fibres, which appear first in the circular layer. These latter fibres become gradually more abundant, until, in the lower fourth, they largely predominate. A few striated fibres, however, are found as low down as the diaphragm.

The mucous membrane of the œsophagus is attached to the muscular tissue by a dense, fibrous layer. It is quite vascular and reddish above, but gradually becomes paler in the inferior portion. The mucous membrane is ordinarily thrown into longitudinal folds, which are obliterated when the

tube is distended. Its epithelium is thick, of the squamous variety, and is continuous with and similar to the covering of the lower portion of the pharynx. It is provided with papillæ of the same structure as those found in the pharynx, the conical variety predominating. Small, racemose glands are found throughout the tube, forming, by their aggregation at the lower extremity just before it opens into the stomach, a glandular ring.

Mechanism of Deglutition.—For convenience of description, physiologists have generally divided the process of deglutition into three periods. The first period is occupied by the passage of the alimentary bolus backward to the isthmus of the fauces. This may appropriately be considered as a distinct period, because the movements are effected by the action of muscles under the control of the will. The second period is occupied by the passage of the food from the isthmus of the fauces, through the pharynx, into the upper part of the œsophagus. The third period is occupied by the passage of the food through the œsophagus into the stomach.

In the first period the tongue is the important agent. At the beginning of this period, the mouth is closed and the tongue becomes slightly increased in width, and with the alimentary bolus behind it, is pressed from before backward against the roof of the mouth. The act of swallowing is always performed with difficulty when the mouth is not completely closed; for the tongue, from its attachments, must follow, to a certain extent, the movements of the lower jaw. The first part of the first period of deglutition, therefore, is simple; but when the food has passed beyond the hard palate, it comes in contact with the hanging velum, and the muscles are brought into action which render this membrane tense and oppose it in a certain degree to the backward movement of the base of the tongue. This is effected by the action of the tensor-palati and the palato-glossus. The moderate tension of the soft palate admits of its being applied to the smaller morsels, while the opening is dilated somewhat forcibly by masses of greater size.

It is easy to see, in analyzing the first period of deglutition, that liquids and the softer articles of food are assisted in their passage to the isthmus of the fauces by a slight suction force. This is effected by the action of the muscles of the tongue, elevating the sides and depressing the centre of the dorsum, while the soft palate is applied to the base.

The importance of the movements of the tongue during the first period of deglutition is shown by experiments on the inferior animals and by cases of loss of this organ in the human subject. In the case of a young girl, reported by De Jussieu (1718), in which there was congenital absence of the tongue, deglutition was impossible until the food had been pushed with the finger far back into the mouth. In cases of amputation of the tongue, a portion of its base generally remains, which is sufficient to press against the palate and thus act in the first period of deglutition.

The movements in the first period of deglutition are under the control of the will but are generally automatic. When the food has been thoroughly masticated, it requires an effort to prevent the act of swallowing. In this respect, the movements are like the acts of respiration, except that the imperative necessity of air in the system must, in a short time, overcome any voluntary effort by which respiration has been arrested.

The second period of deglutition involves more complex and important muscular action than the first. By a rapid succession of movements, the food is made to pass through the pharynx into the œsophagus. The movements are then entirely beyond the control of the will and belong to the kind called reflex. After the alimentary mass has passed beyond the isthmus of the fauces, it is easy to observe a sudden and peculiar movement of elevation of the larynx, by the action of muscles which usually depress the lower jaw, but which are now acting from this bone as the fixed point. The muscles which produce this movement act chiefly upon the hyoid bone. They are the digastric (particularly the anterior belly), the mylo-hyoid, the genio-hyoid, the stylo-hyoid and some of the fibres of the genio-glossus. It is probable, also, that the thyro-hyoid acts at this time to draw the larynx toward the hyoid bone. With this elevation of the larynx, there is necessarily an elevation of the anterior and inferior portions of the pharynx, which are, as it were, slipped under the alimentary bolus as it is held by the constrictors of the isthmus of the fauces.

Contraction of the constrictor muscles of the pharynx takes place almost simultaneously with the movement of elevation; and the superior constrictor is so situated as to grasp the morsel of food, and with it the soft palate. The muscles, the constrictors acting from the median raphe, draw up the anterior and inferior walls of the pharynx and pass the food rapidly into the upper part of the œsophagus. All these complex movements are accomplished with great rapidity, and the larynx and pharynx are then returned to their original position.

Protection of the Posterior Nares during the Second Period of Deglutition.—When the act of deglutition is performed with regularity, no portion of the liquids and solids swallowed ever finds its way into the air-passages. The entrance of foreign substances into the posterior nares is prevented in part by the action of the superior constrictors of the pharynx, which embrace, during their contraction, not only the alimentary mass, but the velum pendulum palati itself, and in part, also, by contraction of the muscles which form the posterior pillars of the soft palate.

During the first part of the second period of deglutition, the soft palate is slightly raised, being pressed upward by the morsel of food. This fact has been observed in cases in which the parts have been exposed by surgical operations, and its mechanism has also been observed in the human subject, by Bidder and by Kobelt.

While the food is passing through the pharynx, the palato-pharyngeal muscles, which form the posterior pillars of the soft palate, are in a condition of contraction by which the edges of the pillars are nearly approximated, forming, with the uvula between them, almost a complete diaphragm between the postero-superior and the antero-inferior parts of the pharynx. This, with the application of the posterior wall of the pharynx to the superior face of the soft palate, completes the protection of the posterior openings of the nasal fossæ.