teenth day, with all the appearances of inanition. Another fed on barley alone died in the same way during the fourth week. The third was fed alternately day by day with potato and barley, for three weeks, and afterward with potato and barley given together. This animal increased in size and was perfectly well nourished.

In 1769, long before any of the above-mentioned experiments were performed, Dr. Stark, a young English physiologist, fell a victim at an early age to experiments on his own person on the physiological effects of different kinds of food. He lived for forty-four days on bread and water, for twenty-nine days on bread, sugar and water, and for twenty-four days on bread, water and olive-oil; until finally his constitution became broken, and he died from the effects of his experiments.

CHAPTER VII.

DIGESTION—MASTICATION, INSALIVATION AND DEGLUTITION.

Prehension of food—Mastication—Physiological anatomy of the teeth—Anatomy of the maxillary bones—Temporo-maxillary articulation—Muscles of mastication—Action of the tongue, lips and cheeks in mastication—Parotid saliva—Submaxillary saliva—Sublingual saliva—Fluids from the smaller glands of the mouth, tongue and fauces—Mixed saliva—Quantity of saliva—General properties and composition of the saliva—Action of the saliva on starch—Uses of the saliva—Physiological anatomy of the parts concerned in deglutition—Mechanism of deglutition—First period of deglutition—Second period of deglutition—Protection of the posterior nares during the second period of deglutition—Protection of the opening of the larynx and uses of the epiglottis in deglutition—Third period of deglutition—Deglutition of air.

INORGANIC alimentary substances are, with few exceptions, introduced in the form in which they exist in the blood and require no preparation or change before they are absorbed; but organic nitrogenized substances are always united with more or less matter possessing no nutritive properties, from which they must be separated, and even when pure, they always undergo certain changes before they are taken up by the blood. The non-nitrogenized matters also undergo changes in constitution or in form preparatory to absorption.

Prehension of Food.—Prehension of food in the adult is a process so simple and well known that it demands little more than a passing mention. The mechanism of sucking in the infant and of drinking is a little more complicated. In sucking, the lips are closed around the nipple, the velum pendulum palati is applied to the back of the tongue so as to close the buccal cavity posteriorly, and the tongue, acting as a piston, produces a virtual vacuum in the mouth, by which the liquids are drawn in with considerable force. This may be done independently of the act of respiration, which is necessarily arrested only during deglutition; for the mere act of suction has never anything to do with the condition of the thoracic walls. The mechanism of drinking from a vessel is essentially the same. The vessel is inclined

so that the lips are kept covered with the liquid and are closed around the edge. By a gentle, sucking action the liquid is then introduced. This is the ordinary mechanism of drinking; but sometimes the head is thrown back and the liquid is poured into the mouth, as in "tossing off" the contents of a small vessel.

MASTICATION.

In order that digestion may take place in a perfectly natural manner, it is necessary that the food, as it is received into the stomach, should be so far comminuted and incorporated with the fluids of the mouth as to be readily acted upon by the gastric juice; otherwise, gastric digestion is prolonged and difficult. Non-observance of this physiological law is a frequent cause of what is generally called dyspepsia.

Physiological Anatomy of the Organs of Mastication.—In the adult, each jaw is provided with sixteen teeth, all of which are about equally developed. The canines, so largely developed in the carnivora but which are rudimentary in the herbivora, and the incisors and molars, so fully developed in the herbivora, are, in man, of nearly the same length. Each tooth presents for anatomical description a crown, a neck and a root, or fang. The crown is that portion which is entirely uncovered by the gums; the root is that portion embedded in the alveolar cavities of the maxillary bones; and the neck is the portion, sometimes slightly constricted, situated between the crown and the root and covered by the edge of the gum. Each tooth presents, on section, several distinct structures.

Enamel of the Teeth.—The crown is covered by the enamel, which is by far the hardest structure in the economy. This is white and glistening and is thickest on the lower portion of the tooth, especially over the surfaces which, from being opposed to each other on either jaw, are most exposed to wear. It here exists in several concentric layers. The incrustation of enamel becomes gradually thinner toward the neck, where it ceases. The enamel is made up of pentagonal or hexagonal rods, one end resting upon the subjacent structure, and the other, when there exists but a single layer of enamel, terminating just beneath the cuticle of the teeth.

The exposed surfaces of the teeth are still farther protected by a membrane, $\frac{1}{30000}$ to $\frac{1}{15000}$ of an inch (0·8 to 1·7 μ) in thickness, closely adherent to the enamel, called the cuticle of the enamel (Nasmyth's membrane). The cuticle presents a strong resistance to reagents and is useful in protecting the teeth from the action of acids which may find their way into the mouth.

Dentine.—The largest portion of the teeth is composed of dentine, or ivory. In many respects, particularly in its composition, this resembles bone; but it is much harder and does not possess the lacunæ and canaliculi which are characteristic of the true osseous structure. The dentine bounds and encloses the central cavity of the tooth, extending in the crown to the enamel, and in the root, to the cement. It is formed of a homogeneous, fundamental substance, which is penetrated by a large number of canals radiating from the pulp-cavity toward the exterior. These are called the dentinal tubules or canals. They are $\frac{1}{25000}$ to $\frac{1}{12000}$ of an inch (1 to 2 μ) in diameter, with walls of a thickness a little less than their caliber. Their course is slightly wavy or spiral. Beginning at the pulp-cavity, into which these canals open, they are found to branch and occasionally anastomose, their communications and branches becoming more frequent as they approach the external surface of the tooth. The canals of largest diameter are found next the pulp-cavity, and they become smaller as they branch. The structure which forms the walls of these tubules is somewhat denser than the intermediate portion, which is sometimes called the intertubular substance of the dentine; but in some portions of the tooth, the tubules are so abundant that their walls touch each other, and there is, therefore, no intertubular substance. Near the origin and near the peripheral terminations of the dentinal tubules, are sometimes found solid, globular masses of dentine, called dentine-globules, which irregularly bound triangular or stellate cavities of very variable size. Sometimes these cavities form regular zones near the peripheral termination of the tubules. The dentine is sometimes marked by concentric lines, indicating a lamellated arrangement. In the natural condition, the dentinal tubules are filled with a clear liquid, which penetrates from the vascular structures in the pulp-cavity.

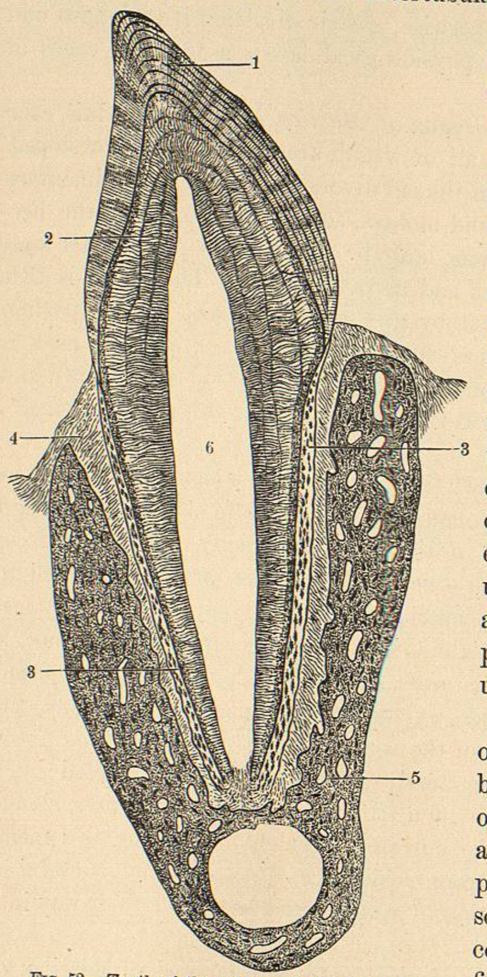

FIG. 52.—*Tooth of the cat, in situ* (Waldeyer). 1, enamel; 2, dentine; 3, cement; 4, periosteum of the alveolar cavity; 5, lower jaw; 6, pulp-cavity.

Cement.—Covering the dentine of the root, is a thin layer of true bony structure, called the cement, or crusta petrosa. This is thickest at the summit and at the deeper portions of the root, where it is sometimes lamellated, and it becomes thinner near the neck. It finally becomes continuous with the enamel of the crown, so that the dentine is everywhere completely covered. The cement is closely adherent to the dentine and to the periosteum lining the alveolar cavities.

Pulp-Cavity.—In the interior of each tooth, extending from the apex of the root or roots into the crown, is the pulp-cavity, which contains minute

blood-vessels and nervous filaments, held together by longitudinal fibres of connective tissue. This is the only portion of the tooth endowed with sensibility. The blood-vessels and nerves penetrate by a little orifice at the extremity of each root.

The dentine and enamel of the teeth must be regarded as perfected structures; for when the second, or permanent teeth are lost, they are never reproduced, and when these parts are invaded by wear or by decay, they are not restored.

The thirty-two permanent teeth are classified as follows:

1. Eight incisors, four in each jaw, called the central and lateral incisors.
2. Four canines, or cuspidati, two in each jaw, just back of the incisors. The upper canines are sometimes called the eye-teeth, and the lower canines, the stomach-teeth.
3. Eight bicuspid—the small, or false molars—just back of the canines; four in each jaw.
4. Twelve molars, or multicuspid, situated just back of the bicuspid; six in each jaw.

The incisors are wedge-shaped, flattened antero-posteriorly, and bevelled at the expense of the posterior face, giving them a sharp, cutting edge, which is sometimes perfectly straight but is generally more or less rounded. Each incisor has a single root. The special use of the incisor teeth is to divide the food as it is taken into the mouth. The permanent incisors make their appearance between the seventh and the eighth years.

The canines are more conical and pointed than the incisors, and have longer and larger roots, especially those in the upper jaw. Their roots are single. They are used, with the incisors, in dividing the food. The permanent canines make their appearance between the eleventh and the twelfth years.

The bicuspid teeth are shorter and thicker than the canines. Their opposed surfaces are rather broad and are marked by two eminences. The upper bicuspids are larger than the lower. The roots are single, but in the upper jaw they are slightly bifurcated at their extremities. They are used, with the true molars, in triturating the food. The permanent bicuspids make their appearance between the ninth and the tenth years.

The molar teeth, called respectively—counting from before backward—the first, second and third molars, are the largest of all and are, *par excellence*, the teeth used in mastication. Their form is that of a cube, rounded laterally and provided with four or five eminences on their opposed surfaces. The first molars are the largest. They have generally three roots in the upper jaw and two in the lower, although they sometimes have four or even five roots. The second molars are but little smaller than the first and resemble them in nearly every particular. The third molars, called frequently the wisdom-teeth, are much smaller than the others and are by no means so useful in mastication. The first molars are the first of the permanent teeth, making their appearance between the sixth and the seventh years. The second molars appear between the twelfth and the thirteenth years; and the third molars, between the seventeenth and the twenty-first years, and sometimes even much later. In some instances the third molars are never developed.

The upper jaw has ordinarily a somewhat longer and broader arch than the lower; so that when the mouth is closed the teeth are not brought into exact apposition, but the upper teeth overlap the lower teeth both in front and laterally. The lower teeth are all somewhat smaller than the corresponding teeth in the upper jaw and generally make their appearance a little earlier.

The physiological anatomy of the maxillary bones and of the temporo-maxillary articulation necessarily precedes the study of the muscles of mastication and the mechanism of their action.

The superior maxillary bones are immovably articulated with the other bones of the head, and do not usually take any active part in mastication. Their inferior borders, with the upper teeth embedded in the alveolar cavities, present fixed surfaces against which the food is pressed by the action of the muscles which move the lower jaw.

The inferior maxilla is a single bone. Its body is horizontal, of a horse-shoe shape, and in the alveolar cavities in its superior border, are the lower teeth. Below the teeth, both externally and internally, are surfaces for the attachments of the muscles concerned in the various movements of the jaw and for one of the muscles of the tongue.

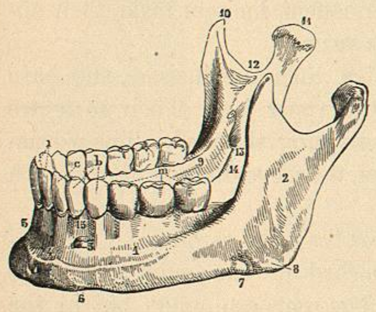

Fig. 53.—*Inferior maxilla* (Sappey).
1, body; 2, ramus; 3, symphysis; 4, incisive fossa; 5, mental foramen; 6, attachment of the digastric muscle; 7, depression at the site of the facial artery; 8, angle; 9, attachment of the superior constrictor of the pharynx; 10, coronoid process; 11, condyle; 12, sigmoid notch; 13, opening of the inferior dental canal; 14, groove for the mylo-hyoid muscle; 15, alveolar border; i, incisor teeth; c, canine teeth; b, bicuspid teeth; m, molars.

Temporo-Maxillary Articulation.—In man the articulation of the lower jaw with the temporal bone is such as to allow an antero-posterior sliding movement and a lateral movement, in addition to the movements of elevation and depression. The condyloid process is convex, with an ovoid surface, the general direction of its long diameter being transverse, and slightly oblique from without inward and from before backward. This process is received into a cavity of corresponding shape in the temporal bone, the glenoid fossa, which is bounded anteriorly by a rounded eminence, called the eminentia articularis.

Between the condyle of the lower jaw and the glenoid fossa, is an oblong, interarticular disk of fibro-cartilage. This disk is thicker at the edges than in the centre. It is pliable and is so situated that when the lower jaw is projected forward, making the lower teeth project beyond the upper, it is applied to the convex surface of the eminentia articularis and presents a concave surface for articulation with the condyle. One of the uses of this cartilage is to constantly present a proper articulating surface upon the articular eminence and thus permit the antero-posterior sliding movement of the lower jaw. It is also important in the lateral movements of the jaw, in which one of the condyles remains in the glenoid cavity and the other is projected, so that the bone undergoes a slight rotation.

Muscles of Mastication.—To the lower jaw are attached certain muscles by which it is depressed, and others by which it is elevated, projected forward, drawn backward and moved from side to side. The following are the principal muscles concerned in the production of these varied movements:

MUSCLES OF MASTICATION.

Muscles which depress the lower jaw.

MUSCLE.	ATTACHMENTS.
Digastric	Mastoid process of the temporal bone—Lower border of the inferior maxilla near the symphysis, with its central tendon held to the side of the body of the hyoid bone.
Mylo-hyoid	Body of the hyoid bone—Mylo-hyoid ridge on the internal surface of the inferior maxilla.
Genio-hyoid	Body of the hyoid bone—Inferior genial tubercle on the inner surface of the inferior maxilla, near the symphysis.
Platysma myoides	Clavicle, acromion and fascia—Anterior half of the body of the inferior maxilla, near the inferior border.

Muscles which elevate the lower jaw and move it laterally and antero-posteriorly.

Temporal	Temporal fossa—Coronoid process of the inferior maxilla.
Masseter	Malar process of the superior maxilla, lower border and internal surface of the zygomatic arch—Surface of the ramus of the inferior maxilla.
Internal pterygoid	Pterygoid fossa—Inner side of the ramus, and angle of the inferior maxilla.
External pterygoid	Pterygoid ridge of the sphenoid, the surface between it and the pterygoid process, external pterygoid plate, tuberosity of the palate and the superior maxillary bone—Inner surface of the neck of the condyle of the inferior maxilla and the interarticular fibro-cartilage.

Action of the Muscles which depress the Lower Jaw.—The most important of these muscles have for their fixed point of action, the hyoid bone, which is fixed by the muscles extending from it to the upper part of the chest. The central tendon of the digastric, as it perforates the stylo-hyoid, is connected with the hyoid bone by a loop of fibrous tissue; and acting from this bone as the fixed point, the anterior belly must of necessity tend to depress the jaw. The attachments of the mylo-hyoid and the genio-hyoid render their action in depressing the jaw sufficiently evident, which is also the case with the platysma myoides, acting from its attachments to the upper part of the thorax. In ordinary mastication the upper jaw undergoes a slight movement of elevation, and this becomes somewhat exaggerated when the mouth is opened to the fullest possible extent.

Action of the Muscles which elevate the Lower Jaw and move it laterally and antero-posteriorly.—The temporal, masseter and internal pterygoid muscles are chiefly concerned in the simple act of closing the jaws. Their anatomy alone gives a sufficiently clear idea of their mode of action; and their great power is explained by the number of their fibres, by the attachments of many of these fibres to the strong aponeuroses by which they are covered, and by the fact that the distance from their origin to their insertion is very short.

The attachments of the internal and external pterygoids are such that by their alternate action on either side, the jaw may be moved laterally, as their points of origin are situated in front of and internal to the temporo-maxillary articulation. The articulation of the lower jaw is of such a kind that in its lateral movements the condyles themselves can not be sufficiently displaced from side to side; but with the condyle on one side fixed or moved slightly backward, the other may be brought forward against the articular eminence, producing a movement of rotation.

The above explanation of the lateral movements of the jaw presupposes the possibility of movements in an antero-posterior direction. Movements in a forward direction, so as to make the lower teeth project beyond the upper, are effected by the pterygoids, the oblique fibres of the masseter and the anterior fibres of the temporal. By the combined action of the posterior fibres of the temporal, the digastric, mylo-hyoid and genio-hyoid, the jaw is brought back to its position. By the same action it may also be drawn back slightly from its normal position while at rest.

Action of the Tongue, Lips and Cheeks, in Mastication.—Experiments on living animals and phenomena observed in cases of lesions of the nervous system in the human subject have shown the importance of the tongue and cheeks in mastication. Section of the facial nerves is a common physiological experiment. Operations of this kind, and cases of facial palsy, which are not uncommon in the human subject, show that when the cheek is paralyzed the food accumulates between it and the teeth, producing great inconvenience.

The varied and complex movements of the tongue during mastication are not easily described. After solid food is taken into the mouth, the tongue prevents its escape from between the teeth, and by its constant movements, rolls the alimentary bolus over and over and passes it at times from one side to the other, so that the food may undergo thorough trituration. Aside from the uses of the tongue as an organ of taste, its surface is endowed with peculiar sensibility as regards the consistence, size and form of different articles; and this is undoubtedly important in determining when mastication is completed, although the thoroughness with which mastication is accomplished is much influenced by habit.

Tonic contraction of the orbicularis oris is necessary to keep the fluids within the mouth during repose; and this muscle is sometimes brought into action when the mouth is very full, to assist in keeping the food between the teeth. This latter office, however, is performed mainly by the buccina-

tor; the action of which is to press the food between the teeth and keep it in place during mastication, assisting, from time to time, in turning the alimentary bolus so as to subject new portions to trituration.

The process of mastication is regulated to a very great extent by the sensibility of the teeth to the impressions of hard and soft substances. It is only necessary to call attention to the ease and certainty with which the presence and the consistence of the smallest substance between the teeth are recognized, to show the importance of this tactile sense in mastication.

Saliva.

The fluid which is mixed with the food in mastication, which moistens the mucous membrane of the mouth and which may be collected at any time in small quantity by the simple act of sputation, is composed of the secretions of a considerable number and variety of glands. The most important of these are the parotid, submaxillary and sublingual, which are usually called the salivary glands. The labial and buccal glands, the glands of the tongue and general mucous surface and certain glandular structures in the mucous membrane of the pharynx also contribute to the production of the saliva. The liquid which becomes more or less incorporated with the food before it descends to the stomach, and which must be regarded as the digestive fluid of the mouth, is known as the mixed saliva; but the study of the composition and properties of this fluid as a whole should be prefaced by a consideration of the different secretions of which it is composed. The salivary glands belong to the variety of glands called racemose. They resemble the other glands belonging to this class, and their structure will be more fully considered in connection with the physiology of secretion.

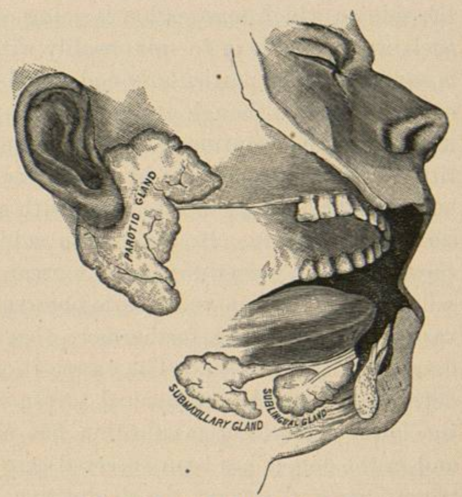

FIG. 54.—*Salivary glands* (Tracy).

Parotid Saliva.—The parotid is the largest of the three salivary glands. It is situated below and in front of the ear and opens by the duct of Steno into the mouth, at about the middle of the cheek. The papilla which marks the orifice of the duct is situated opposite the second large molar tooth of the upper jaw.

The organic matter of the parotid saliva is coagulable by heat (212° Fahr., or 100° C.), alcohol or the strong mineral acids. A compound of sulphocyanogen is now generally acknowledged to be a constant constituent of the parotid saliva. This can not be recognized by the ordinary tests in the fresh saliva taken from the duct of Steno, but in the clear, filtered fluid which passes after the precipitation of the organic matter, there is always a distinct, red color on the addition of ferric sulphate. As this reaction is more marked in the mixed saliva, the methods by which the presence of a sulphocyanide is to be recognized will be considered in connection with that fluid. In the human subject, the parotid secretion is more abundant than that of any other of the salivary glands; but the entire quantity in the twenty-four hours has not been directly estimated.

In the horse, ass and ox, it has been found that when mastication is performed on one side of the mouth, the flow from the gland on that side is greatly increased, exceeding by several times the quantity produced upon the opposite side (Colin). This fact has been confirmed by Dalton in the human subject.

The flow of saliva from the parotid takes place with greatly increased activity during the process of mastication. The orifice of the parotid duct is so situated that the fluid is poured directly upon the mass of food as it is undergoing trituration by the teeth; and as the secretion is more abundant on the side on which mastication is going on, and the consistence of the fluid is such as to enable it to mix readily with the food, the office of this gland is supposed to be particularly connected with mastication. This is undoubtedly the fact; although its flow is not absolutely confined to the period of mastication, but continues in small quantity during the intervals. Its quantity is regulated somewhat by the character of the food, being much greater when the articles taken into the mouth are dry than when they contain considerable moisture. In the human subject, the stimulus produced by sapid substances will sometimes cause a great increase in the flow of the parotid saliva. Mitscherlich and Eberle observed this in persons suffering from salivary fistula and noted, farthermore, that the mere sight or odor of food produced the same effect. The supposition that the flow from the parotid is dependent upon the mechanical pressure of the muscles or of the condyle of the lower jaw during mastication has no foundation in fact. In the horse and in the dog, it has been observed that the secretion of the parotids is completely arrested during the deglutition of liquids, while the flow from the other salivary glands is not affected (Bernard).

The parotid saliva—aside from any chemical action which it may have upon the food, which will be fully considered in connection with the mixed saliva—evidently has an important mechanical office. It is discharged in large quantity during the act of mastication and is poured into the mouth in such a manner as to become of necessity thoroughly incorporated with the food. Its use is chiefly, although not exclusively, connected with mastication and indirectly, with deglutition; for it is only by becoming incorporated with this saliva, that dry, pulverulent substances can be swallowed.

Submaxillary Saliva.—In the human subject, the submaxillary is the second of the salivary glands in point of size. Its minute structure is nearly the same as that of the parotid. As its name implies, it is situated below the inferior maxillary bone. It is in the anterior part of what is known as the submaxillary triangle of the neck. Its excretory duct, the duct of Wharton, is about two inches (5 centimetres) in length and passes from the gland, beneath the tongue, to open by a small papilla by the side of the frenum.

The pure submaxillary saliva presents many important points of difference from the secretion of the parotid. It may be obtained by exposing the duct and introducing a fine silver tube, when, on the introduction of any sapid substance into the mouth, the secretion will flow in large, pearly drops. This variety of saliva is much more viscid than the parotid secretion. It is perfectly clear, and on cooling, it frequently becomes of a gelatinous consistence. Its organic matter is not coagulable by heat. It contains a sulphocyanide, but in very small quantity.

The submaxillary gland pours out its secretion in greatest abundance when sapid substances are introduced into the mouth; but unlike the parotid saliva, the secretion does not alternate on the two sides with alternation in mastication. Although sapid articles excite an abundant secretion from the submaxillary glands, they also increase the secretions from the parotids and sublinguals; and on the other hand, movements of mastication increase somewhat the flow from the submaxillaries, and these glands secrete a certain quantity of fluid during the intervals of digestion. The viscid consistence of the submaxillary saliva renders it less capable than the parotid secretion of penetrating the alimentary mass during mastication.

Sublingual Saliva.—The sublinguals, the smallest of the salivary glands, are situated beneath the tongue, on either side of the frenum. In minute structure they resemble the parotid and the submaxillary glands. Each gland has a number of excretory ducts, eight to twenty, which open into the mouth by the side of the frenum; and one of the ducts, larger than the others, joins the duct of the submaxillary gland near its opening in the mouth.

The secretion of the sublingual glands is more viscid, even, than the submaxillary saliva, but it differs in the fact that it does not gelantinize on cooling. It is so glutinous that it adheres strongly to any vessel and flows with difficulty from a tube introduced into the duct. Like the secretion from the other salivary glands, its reaction is distinctly alkaline. Its organic matter is not coagulable by heat, acids or the metallic salts.

It has been shown that the sublingual glands may be excited to secretion by impressions made by sapid substances upon the nerves of taste, although the flow is always less than from the submaxillary glands. The great viscidity of the sublingual saliva renders it less easily mixed with the alimentary bolus than the secretions from the parotid or the submaxillary glands.

Fluids from the Smaller Glands of the Mouth, Tongue and Pharynx.—Beneath the mucous membrane of the inner surface of the lips, are small, rounded, glandular bodies, opening into the buccal cavity, called the labial glands; and in the submucous tissue of the cheeks, are similar bodies, called the buccal glands. The latter are somewhat smaller than the labial glands. Two or three of the buccal glands are of considerable size and have ducts opening opposite the last molar tooth. These are sometimes distinguished as the molar glands. There are also a few small glands in the mucous membrane of the posterior half of the hard palate; but the glands on the under