ANATOMY AND HISTOLOGY
OF THE
MOUTH AND TEETH

BROOMELL AND FISCHELIS

1923.

Philadelphia 6th ed

Blakiston

Fig. 194.—Chief varieties of cells encountered in health and disease (Wright's stain). 1. Normal red cell. 2. Common form of polymorphonuclear leucocyte. 3. Lesser lymphocyte. 4. Eosin ophilic myelocyte. 5. Eosinophilic leucocyte. 6–6. Neutrophilic leucocytes: upper left, transitional form, on right neutrophilic myelocytes. 7–7. Large lymphocytes. 8. Normoblast (angioblasts). 8. Normoblast showing division of nucleus. 9. Normoblast nucleus. 10–11. Basophilic leucocytes. 12. Megaloblast. (*Greene's Medical Diagnosis.*)

TO

C. N. PEIRCE, D. D. S.

AS A SOUVENIR OF A LONG AND VALUED FRIENDSHIP AND A

TESTIMONY OF ESTEEM FOR HIS PROFESSIONAL

AND PRIVATE WORTH

THIS VOLUME IS RESPECTFULLY DEDICATED

BY THE AUTHORS

PREFACE TO THE SIXTH EDITION

A renewed and apparently greater demand for copies of this dental text book has influenced the authors to prepare a new edition. A careful reading of the previous editions brought to light certain more or less incoherent statements, a few typographical errors, some misplaced cuts, and other inexcusable minor defects, which have been overcome in the new edition.

A few changes in terminology have been introduced. The superficial and deeper muscles of the face and neck have been named in accordance with the accepted terminology of Morris and other authorities. The term "cutting edge" as applied to the surface anatomy of the teeth, has given way to the more appropriate expression "incisal edge." Many new cuts reproduced from hand drawings used in connection with the descriptive anatomy of the teeth, have supplanted a similar number of photographic reproductions, many of which were defective in minor detail.

The index has been revised, many additional subheadings being added.

Grateful acknowledgment is made to my son and co-worker Dr. Willard S. Broomell, instructor in dental anatomy and operative technic in the Temple University Dental School, Philadelphia, for preparing new cuts and other valuable assistance rendered in the work of revision. Credit is also given to Mr. A. Chas. Stein and Mr. F. J. Gleason, students in the above school for drawings made in their regular course of study, and used for illustrative purposes.

Thanks are due and extended to the publishers for their generous assistance and guidance in preparing the revisions.

1923.

PREFACE TO THE FIRST EDITION

In the preparation of this work it has been the aim of the author to systematically describe those parts of human anatomy which come directly under the care of the stomatologist. In the earlier chapters, which are devoted to a gross description of the mouth and those tissues which enter into its construction, there has been no attempt at originality other than in the arrangement, which includes a complete description of one part before another is taken up.

In the writing and classification of the succeeding chapters the writer has attempted what others, though wiser and better qualified, appeared unwilling to undertake, and it is from the works of such as these that the foundation for the present work has been derived.

Within the last few years the progress in nearly every branch of dental education has made a work of this character an imperative want. Dental therapeutics and dental chemistry have been well-nigh reconstructed, while the investigations of the microscopist and physiologist have brought forth many valuable revelations. Next in importance has been the advance in, or rather the introduction of, technic teaching. Considerable space has, therefore, been devoted to the surface anatomy of the individual teeth, with a hope that it may be of value in dental anatomy technic.

While in one or two instances the writer has departed from the field assigned as a text, the parts thus included are so closely associated with the mouth, both in a constructive and in a functional manner, that the work would be lacking in completeness if they were omitted.

The illustrations are, with but few exceptions, the original work of the author, being reproduced by photograph from the actual subject. In many instances dissections were required to reveal the parts, this being particularly true of those illustrations included in the chapter on the Development of the Teeth, about one hundred dissections being required to accomplish the purpose. In preparing the illustrations descriptive of the various surfaces of the individual teeth, the progress of the work was materially interfered with by the difficulty experienced in securing normal teeth out of the mouth; may their number ever grow less.

The author desires to thus publicly acknowledge obligations to the works of Tomes, Black, Morris, Stöhr, Klein, and Strickler. He is also indebted to Prof. A. P. Brubaker and Dr. C. P. Shoemaker for valuable assistance rendered, and to P. Blakiston's Son & Co. for their many courtesies during the preparation of the volume.

That there is a place for such a work as this purports to be the writer has but little doubt; that the following pages will fill that demand is his earnest desire, and it remains for the reader to ascertain how far these demands have been met in the direction of its aim and endeavor.

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ANATOMY AND HISTOLOGY

OF THE HUMAN

MOUTH AND TEETH

PART I—ANATOMY

CHAPTER I

General Description of the Mouth, Location, Boundaries—The Buccal Orifice—The Lateral Walls of the Mouth—The Hard Palate, Dome or Roof of the Mouth—The Soft Palate and Fauces—The Floor of the Mouth—The Tongue and Its Attached Muscles.

The mouth in man (Fig. 1) (*stoma*, pl. *stomata*) is the entrance or gateway to the alimentary canal and is situated between the superior and inferior maxillary bones and their attached tissues. It contains the *active* organs of mastication, *the teeth*, the organs of taste, of which the tongue is chief, together with some of the parts which enter into the function of articulate speech. Anatomists usually divide this cavity into two compartments, the teeth serving to separate one from the other, the inner space or that occupied by the tongue, being called *the mouth*, while that between the teeth and lips or cheeks is known as the *vestibule of the mouth*. In this description all that space bounded anteriorly by the lips, posteriorly by the soft palate and pillars of the fauces, and laterally by the cheeks, will be considered as a single cavity, and the organs and structures contained therein, together with all parts directly interested in its formation, will constitute a text for this work.

The *entrance to the* cavity of the *mouth* is formed by a freely movable transverse orifice or slit, the *buccal orifice*, while communication is made with the pharynx posteriorly through the space known as the *fauces*. Entering into the construction of the mouth and assisting in the performance of its various functions are bones, ligaments, muscles, blood-vessels, nerves, glands, ducts, etc., each of which will be described in turn.

THE BUCCAL ORIFICE

The buccal orifice or entrance to the mouth, is a transverse opening somewhat variable in extent, the extremities of which are known as the *corners* or *angles of the mouth*. It is bounded by two fleshy

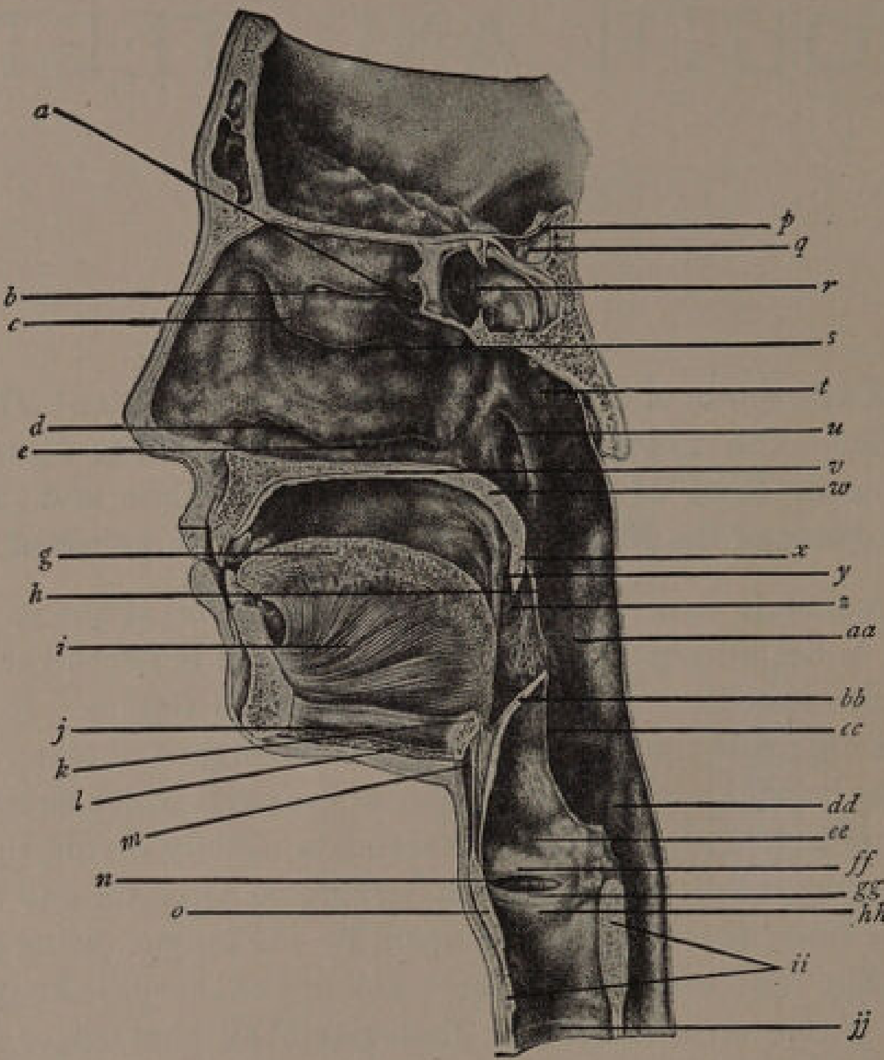


FIG. 1.—Outer wall of nasal fossa, with mouth, pharynx and larynx in vertical section (*Deaver.*)

a, Superior meatus; *b*, superior turbinate body; *c*, middle turbinate; *d*, inferior turbinate; *e*, inferior meatus; *g*, tongue; *h*, posterior pillar of fauces; *i*, geniohyoglossus muscle; *j*, geniohyoid muscle; *k*, hyoid bone; *l*, mylohyoid muscle; *m*, thyrohyoid membrane; *n*, ventricle of larynx; *o*, thyroid cartilage; *p*, diaphragma sellæ; *q*, cavum sellæ; *r*, sphenoidal sinus; *s*, middle meatus; *t*, rhinopharynx; *u*, Eustachian orifice; *v*, hard palate; *w*, soft palate; *x*, uvula, *y*, anterior pillar of fauces; *z*, tonsillar fossa; *aa*, oropharynx; *bb*, epiglottis; *cc*, aryepiglottic fold; *dd*, laryngopharynx; *ee*, suprarimal portion of larynx; *ff*, ventricular band; *gg*, vocal band; *hh*, infrarimal portion of larynx; *ii*, cricoid cartilage; *jj*, tracheal ring.

folds, the *upper* and *lower lips* (*labia*), the former usually being in the form of a double curve, coming together at the median line or center of the face and forming a small teat or tubercle, while the latter is made up of a single curve extending from angle to angle. While this general description applies to the labial forms most frequently met with, it must not be taken for a constant condition. In some instances the lips are thin, with straight parallel margins, more or less firmly set against the teeth, and seldom separated from one another when at rest. In another case they may be thick, full, and prominent, with their margins strongly curved, resting lightly against the teeth, and more or less separated from one another during rest. Accompanying these extremes as well as the intervening conditions are various other peculiarities, such as, the rigidity or flexibility of the muscular structure, etc. The upper lip generally overhangs the lower, but in some instances the lower lip is the most prominent. Externally the lips are covered by the common integument or skin, internally and over their contiguous surfaces by a specialized tissue, the mucous membrane. Between the external and internal coverings and forming the substance of these fleshy folds is a complexity of muscular fibers, in which are imbedded numerous blood-vessels, nerves, and glands (*labial glands*). By the various muscles which enter into their construction the lips are loosely attached to the surfaces of the maxillary bones.

The **integument,** or **external covering** of the lips, is similar to the skin covering other parts of the body. In the male it is subject to a peculiar change and modification of its outer layer, resulting in the production of a hairy growth.

The **mucous membrane,** or **internal covering** of the lips, the beginning of which is strongly manifest by its bright-pink color, is without moisture on the contiguous surfaces, is extremely sensitive, and contains a number of vascular papillæ, many of which are accompanied by nerve terminals. Mucous membranes are described as lining certain cavities or tracts, as the digestive tract, the respiratory tract, and the genitourinary tract, and it is upon the contiguous surfaces of the lips that the digestive mucous membrane begins. The line of junction between the integument and the mucous membrane is quite variable in form, but usually corresponds to the general curvature of the lips. Internally at the median line each lip is provided with a pronounced fold of mucous membrane, which is attached to the basal portion of the gum, the *frenum of the lip* (frænum labium superioris and inferioris), which, in a measure, as the name implies limits or controls the movements of the lips.

Muscles of the Lips.

The muscular fibers within the substance of the lips are principally those of a single muscle, the *orbicularis oris*, but associated with it are portions of the elevator and depressor muscles of the lips, the *quadratus labii superioris pars angularis, quadratus labii superioris, caput infravorbibale; quadratus labii inferioris,* and the *zygomaticus minor.*

Orbicularis Oris.—This is a sphincter muscle which surrounds and assists in controlling the buccal orifice. In form it is an oval sheet with the long axis placed transversely, the fibers being continued from one lip to the other by passing around the angles of the mouth. It is divided into an internal or labial portion and an external or facial portion. The labial portion has no bony attachment except through the medium of the adjacent muscles. The external or facial portion forms the deeper layer and blends with the surrounding muscles, works in conjunction with them, and is provided with the following small bony *attachments*: The nasolabial slips are attached to the septum of the nose, other fibers are attached to the incisive fossa of the maxilla over the position of the lateral incisor and to the incisive fossa of the mandible near the lateral incisor or cuspid.

Structure.—The muscle consists of three sets of fibers, one of which runs transversely, one in a vertical, and one in an anteroposterior direction. The transverse set is continuous with the fibers of the buccinator or cheek muscle, and forms the greater part of the muscle. The labial portion is also formed from the same fibers, while the vertical fibers form the superficial part of the facial portion and are continuous with the fibers of the levator and depressor muscles. Some of these latter fibers pass around the corners of the mouth, thus becoming transverse, those from above passing to the lower lip, while those from below pass to the upper lip. The anteroposterior fibers pass from before backward between the transverse fibers, and unite the mucous membrane to the skin. These are chiefly found in the labial portion of the muscle.

Relations.—The inner margin of the superficial surface is closely connected with the integument,while superimposed between this and the outer portion is a layer of fatty tissue. Upon the deep surface lies the mucous membrane of the mouth, separated from the muscular tissue by blood-vessels and mucous glands.

Action.—To bring the lips together, to draw the upper lip downward, and the lower lip upward; to draw together the corners of the mouth; to throw both lips outward; to draw them back against the teeth, and to oppose the action of all other muscles that blend into it and inclining to draw it in various directions.

Quadratus Labii Superioris Pars Angularis.—As its name implies, this muscle is an elevator of the upper lip and the wing of the nose. It is one of the superficial facial muscles, is thin and triangular, and is located by the side of the nose, extending from the infra-orbital ridge to the upper lip.

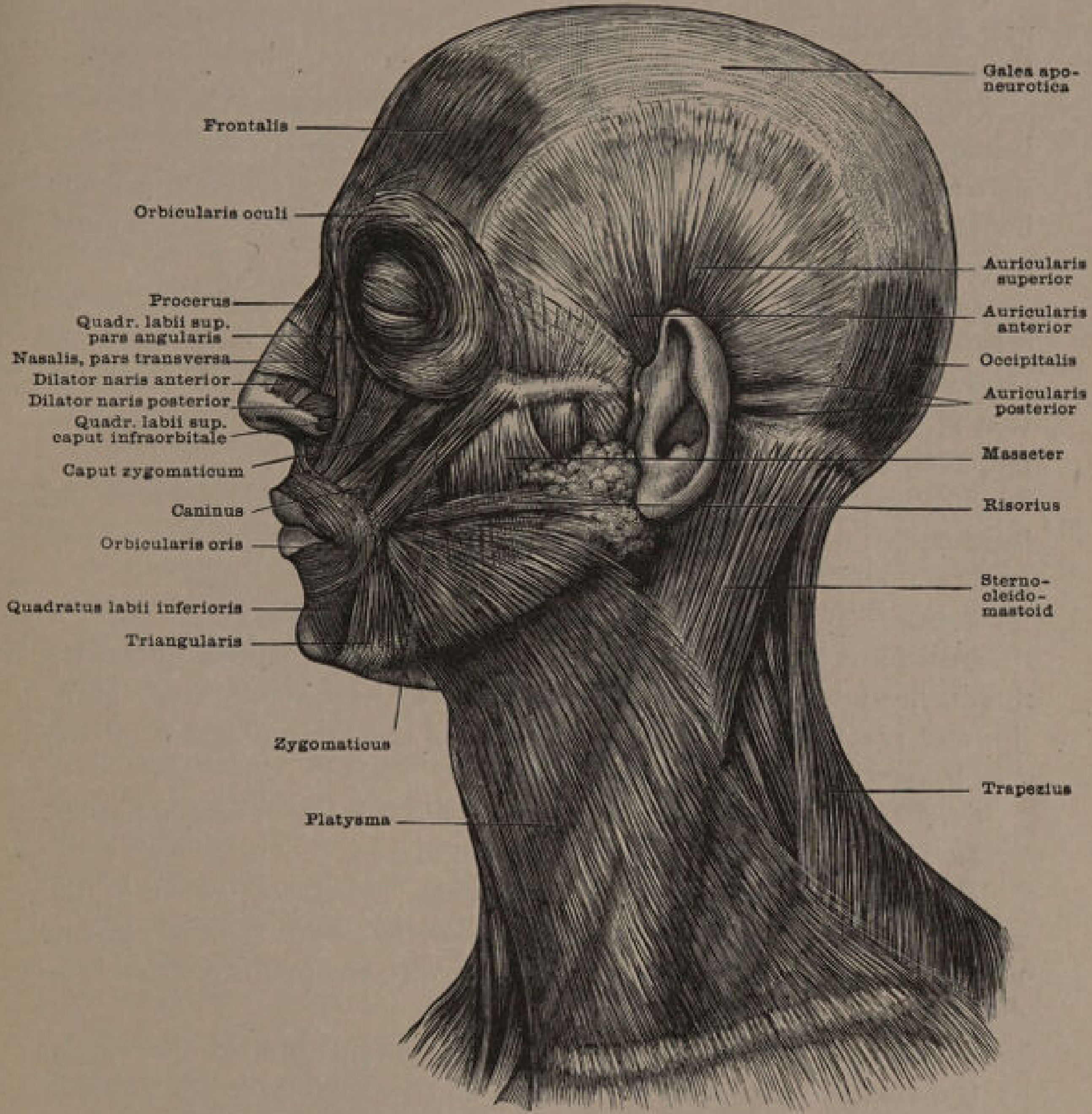


FIG. 2.—The superficial muscles of the head and neck. (*Morris.*)

Origin.—From the nasal process of the maxilla near its orbital margin.

Insertion.—From its origin it passes almost directly downward, dividing into two portions, the smaller of which is inserted into the nasal wing, while the larger portion is prolonged downward, blending into the orbicularis oris and quadratus labii superioris, caput infra-orbituale and forming a part of the substance of the upper lip.

Relations.—Superficially, by the integument; deeply, by the quadratus labii superious pars anguli oris and compressor narium.

Action.—By its smaller and shorter portion to raise the wing of the nose and to dilate the nostril; by its larger and longer portion to elevate the inner half of the upper lip.

Quadratus Labii Superioris Caput Infraorbitale.—This muscle belongs to the superficial layer, and derives its name from its action.

Origin.—From the facial surface of the superior maxilla, at a point between the orbital cavity and the infra-orbital foramen. Also by the attachment of a few fibers to the malar bone.

Insertion.—Passing downward and inward, it is inserted into the orbicularis oris and the integument of the upper lip. Near its lower third it joins the levator labii superioris alæque nasi, and acts in conjunction with it. Occasionally it is reinforced by fibers from the orbicularis palpebrarum, which it receives at its outer border.

Relations.—Superficially, by the orbicularis palpebrarum and the integument; deeply, by the levator anguli oris; the compressor nasi at its origin, and by the infra-orbital vessels and nerves.

Action.—To elevate the upper lip.

Quadratus Labii Superioris.—This muscle, also known as **levator menti,** lies immediately beneath the mucous membrane of the lower lip, and can best be dissected by everting the lip and lifting off the membrane.

Origin.—From the incisor fossa of the lower jaw at its upper border.

Insertion.—Into the integument of the skin.

Relations.—With the labial integument, the lower border of the orbicularis oris muscle, and its superficial surface with the oral mucous membrane. Deeply it is in close contact with the periosteum and the depressor labii inferioris.

Action.—To raise and cause to protrude the integument of the chin.

Quadratus Labii Inferioris.—This small muscle with its fellow of the opposite side is sometimes found within the mucous membrane forming the frenum of the upper lip.

Origin.—It arises from the incisive fossa along its lower margin and some of its fibers are attached to that part of the alveolar process closely associated with the fossa.

Insertion.—From the point of origin the fibers pass upward and are attached to the lower border of the nostrils and partition of the nose.

Some of the fibers of this muscle are also attached to the integument covering the wing of the nose. The balance pass downward and mingle with the fibers of the muscular structure of the upper lip.

Relations.—At its point of origin the fibers are closely associated with the mucous membrane forming the gums. Above this the muscular structure of the lip overlies these fibers. Deeply it rests upon the surface of the superior maxilla, and joins its fellow of the opposite side at the median line.

Action.—To depress the upper lip.

Quadratus Labii Inferioris, or Quadratus Menti.—The name of this muscle is derived from its form and action. It belongs to the second layer of facial muscles, is quadrilateral in shape, and consists of parallel fibers which meet above in the median line.

Origin.—At the outer aspect of the lower border of the inferior maxilla, from a point near the symphysis to the space beneath the first bicuspid tooth.

Insertion.—Its fibers pass upward and inward, and after uniting with its fellow of the opposite side, blend into the body of the orbicularis oris of the lower lip.

Relations.—By its superficial surface with the integument and a portion of the depressor anguli oris; deeply, with the mental nerve and vessels, a portion of the orbicularis oris, the mucous membrane lining the lower lip, and the labial glands.

Action.—To draw down and somewhat evert the lower lip.

Zygomaticus Minor.—An extremely slender muscle belonging to the superficial set of facial muscles. It is closely associated with a larger muscle, the zygomaticus major, belonging to the angular series, to be described, in connection with the muscles of the cheek.

Origin.—From the anterior inferior part of one of the facial bones—the malar—close to its junction with the superior maxilla.

Insertion.—It passes downward and forward, its fibers becoming lost in the special elevator muscle of the upper lip about midway between the median line and the angle of the mouth.

Relations.—Superficially, by the integument, by its deep surface with the levator anguli oris, facial portion of the orbicularis oris, and the mental branch of the facial nerve.

Action.—To elevate and somewhat evert the upper part of the lip.

The Blood-supply to the Lips.

The blood-supply to the lips is principally through the *superior* and *inferior coronary* arteries, both of which are branches of the *facial* artery. In addition to these the *inferior labial* artery and the submental, also branches of the *facial*, and the *mental branch* of the *inferior dental* artery supply a part of the lower lip.

The superior coronary artery courses along the inferior margin of the upper lip, between the mucous membrane and the fibers of the orbicularis oris. At the median line it anastomoses with its fellow of the opposite side.

Their inferior coronary artery, somewhat smaller than the superior, supplies the lower lip by coursing through its substance in a manner similar to the superior coronary and also anastomoses with its fellow of the opposite side at the median line.

Course of the Blood from the Heart to the Lips.—From the heart to the aorta, to the common carotid, to the external carotid, to the facial, to the superior and inferior coronary and the inferior labial arteries. After passing through the labial capillaries the blood is returned to the heart through the *superior* and *inferior coronary veins*, and the larger veins of which they are branches.

Nerves of the Lips.

The nerve-supply to the lips is principally by small branches of the *infra-orbital* nerve for the upper, and by branches of the *mental* nerve for the lower. The *buccal* and *superior maxillary* branches of the lower division of the facial nerve supply the orbicularis oris; the upper division of the facial nerve sends branches which supply the levator labii superioris alæque nasi, as well as the levator labii superioris and the zygomaticus minor, while the *superior maxillary* branch of the lower division of the facial supplies the depressor labii inferioris.

THE LATERAL WALLS OF THE MOUTH

The Cheeks (*buccæ*).—The lateral walls of the mouth are formed by the cheeks which are continuous with and similar in structure to the lips, being covered internally by mucous membrane and externally by the common integument. Immediately beneath the mucous membrane are numerous transverse muscular fibers, covered externally by a layer of subcutaneous fat, and lying between this and the integument other muscular tissue, the fibers of which radiate in various directions, according to the action of the muscle to which they belong. Besides muscular and fatty tissue, there are imbedded within the substance of the cheek blood-vessels, nerves, and glands. The fatty tissue spoken of as intervening between the muscular fibers give to the cheeks whatever fullness and rotundity they may possess.

The integument, or external covering of the cheek, is similar in structure to the skin covering other parts of the body, and, like the lips in the male, is productive of a hairy growth.

The mucous membrane, or internal covering of the cheek, is similar to that of the lips, containing numerous glands (*buccal glands*) which are almost identical to, but smaller than, the labial glands. In addition to the buccal glands which are distributed throughout the entire membrane, there are about five of larger size, which open into the mouth in the region of the molar teeth, and are called *molar glands* (see Glands of the Mouth).

The Muscles of the Cheeks (See Figs. 2 and 3).

The transverse muscular fibers referred to as being immediately beneath the mucous membrane are those of the *buccinator,* a muscle named from its action, that of being the chief muscle employed by the trumpeter. External to the buccinator is the *masseter,* one of the muscles of mastication, the elevator and depressor muscles of the angle of the mouth, the *caninis* and the *triangularis* and the dermal muscles, *zygomaticus major, zygomaticus minor,* and the *risorius.*

Buccinator.—This muscle forms the greater portion of the lateral wall of the mouth. It is deep-seated in the cheek, being one of the third stratum of facial muscles.

Origin.—The fibers are distinct in their origin from a part of the alveolar process of the superior maxillary bone, at a point immediately over the second and third molar teeth, from the anterior border of the pterygomaxillary ligament, a narrow band of tendinous fibers or raphe extending from the pterygoid plate of the sphenoid bone to the mylohyoid ridge of the inferior maxilla near the position of the third molar tooth. Some of its fibers also arise from the outer wall of the alveolar process of the inferior maxilla below the second and third molars.

Insertion.—The fibers pass forward and converge as they reach the lateral margins of the orbicularis oris; here the fibers of the upper portion pass downward and blend into the muscles of the lower lip, while the lower fibers pass upward and blend into those of the upper lip. Those fibers which arise from the inferior maxilla pass forward and also blend into the lower lip.

Relations.—Superficially, by the skin and subcutaneous fat, the duct of Stenson, the masseter muscle, a portion of the angular group, and the facial artery and vein. Passing over it are branches of the facial and buccal nerves, also a layer of deep fascia continuous with that which covers the upper part of the pharynx. By its deep surface it is in relation with the mucous membrane and buccal glands.

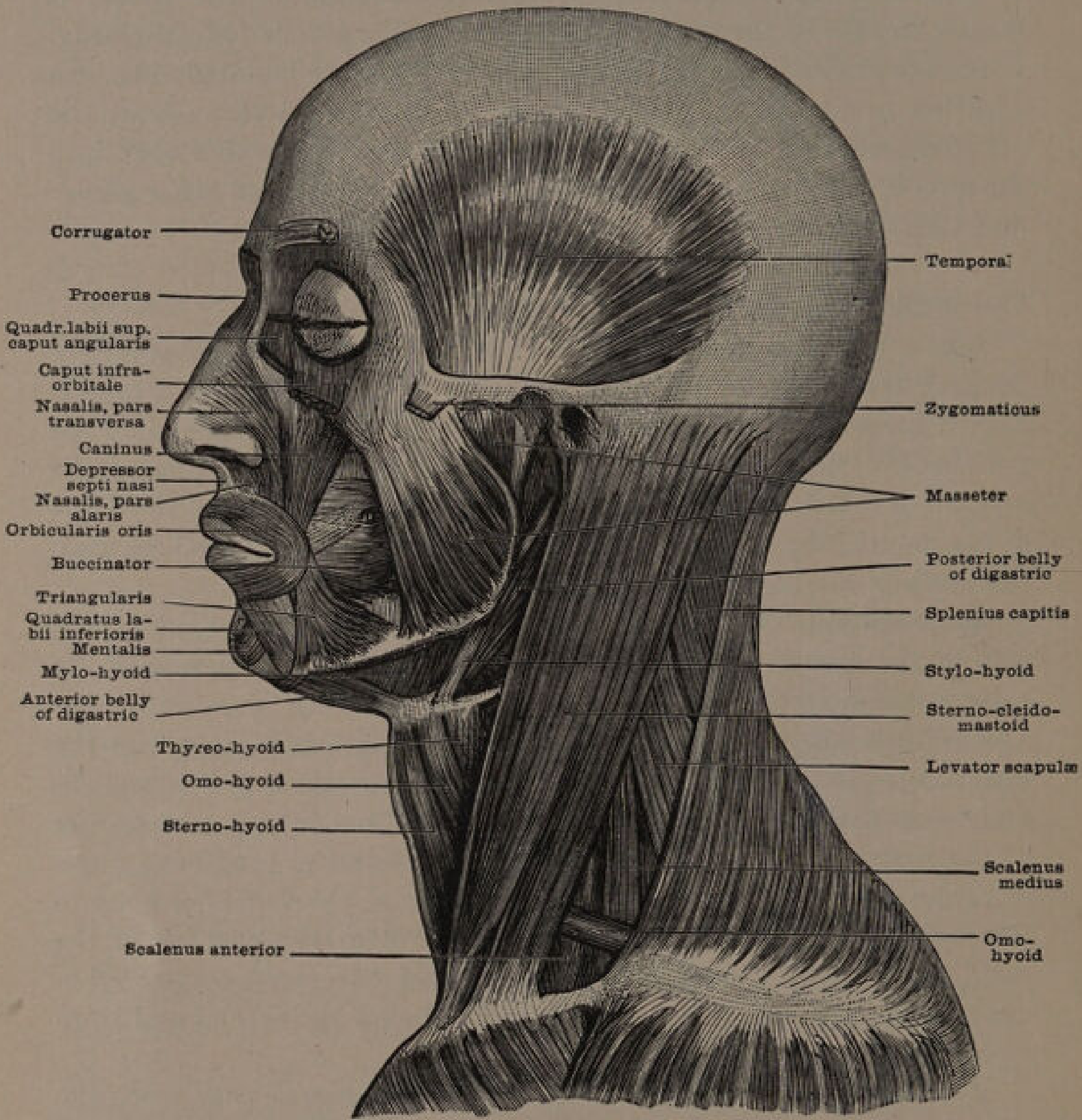


FIG. 3.—The deeper muscles of the face and neck. (*Morris.*)

Action.—To draw outward or backward the angles of the mouth, thus enlarging the buccal orifice and pressing the lips tightly against the teeth; to force the food between the occlusal surfaces of the molar and bicuspid teeth during mastication; to diminish the concavity of the cheek, compressing the air contained therein and forcing it forward. It becomes an auxiliary in deglutition by shortening the cavity of the pharynx from before backward, through its connection with the superior constrictor.

Masseter.—This muscle is placed immediately external to the buccinator, and is one of the principal muscles of mastication. It is short, thick, and somewhat quadrate in form, and is composed of two sets of fibers, superficial and deep. The fibers of the fromer are directed obliquely downward and backward; those of the latter, which are much shorter, pass almost vertically downward.

Origin.—The superficial layer, from the malar process of the superior maxilla, and from the anterior portion of the zygomatic arch of the malar bone. The deep layer from the posterior third of the zygomatic arch, as well as from the greater part of its inner surface.

Insertion.—The superficial fibers are inserted into the ramus and angle of the inferior maxilla, and the deep fibers into the upper half of the outer surface of the ramus.

Relations.—By its external surface with the zygomaticus major, risorius, and platysma myoides muscles, the parotid gland and its duct; by the transverse facial artery, the facial vein, and facial nerve, and by the integument. By its internal surface with the ramus of the inferior maxilla, a mass of fat which separates it from the buccinator, and with the temporal muscle. Its posterior margin is in relation with the parotid gland, and its anterior with the facial artery and vein.

Action.—The principal action of this muscle is to close the jaw and to draw it slightly forward. (For further description, see Muscles of Mastication, part I, chap. IV.)

The Angular Series.—The remaining muscles of the cheek are those of the angular series, or those muscles which are inserted into the angle of the mouth, two coming obliquely from above—the *levator anguli oris* and the *zygomaticus major*—one running almost horizontally forward—*the risorius*—and one ascending from below—the *depressor anguli oris.*

Caninis.—This muscle, which receives its name from its origin, belongs to the second layer of facial muscles. It is formed in the shape of a triangular sheet.

Origin.—From the canine fossa of the superior maxilla, immediately below the infra-orbital foramen.

Insertion.—Passing downward and outward it is inserted into the angle of the mouth, its fibers blending with those of the orbicularis oris and the other angular muscles.

Relations.—Superficially, with the levator labii superioris, the zygomaticus minor, and the infra-orbital vessels and nerves; deeply, with the facial portion of the orbicularis oris and buccinator muscles, and the mucous membrane of the mouth.

Action.—Especially to elevate the angle of the mouth, and to assist in drawing these angles inward, decreasing the size of the buccal orifice.

Zygomaticus Major.—This muscle, the companion of which has been described in connection with the muscles of the lips, belongs to the first facial layer. It is composed of a long, fleshy band of muscular fibers, which run direct from their point of origin to their point of insertion.

Origin.—From the malar bone, in close proximity to the zygomatic suture.

Insertion.—From its origin it passes obliquely downward to the angle of the mouth, and blends into the fibers of the orbicularis oris and depressor anguli oris.

Relations.—Superficially, with the skin and subcutaneous fat; deeply, with the malar bone, the masseter, and buccinator muscles, the facial and transverse facial arteries, the facial vein, and branches of the facial nerve.

Action.—To draw upward and outward the angles of the mouth, as in smiling or laughing. By contracting, it throws into prominence the cheek tissues in front of the malar bone, and forces the lower eyelid upward. When acting simultaneously with its fellow of the opposite side, the buccal aperture is widened, and the upper lip is elevated, exposing the superior teeth.

Risorius.—One of the superficial set of facial muscles, receiving its name from its supposed action in laughter (*ridere,* to laugh). It is flat and ribbon-shaped, and is frequently very small and poorly developed.

Origin.—From the deep fascia covering the masseter muscle and parotid gland, some of its fibers occasionally arising from the mastoid process of the temporal bone.

Insertion.—Passing transversely forward and inward to the angle of the mouth, its fibers blend with those of the orbicularis oris, and the depressor anguli oris.

Relations.—Superficially, with the integument and subcutaneous fat; deeply, with the masseter and buccinator muscles, the facial artery and vein, and branches of the facial nerve.

Action.—To draw the angles of the mouth directly outward, thereby increasing the width of the buccal orifice.

Triangularis.—Also one of the superficial layers of facial muscles, deriving its name in accordance with its action upon the angle of the mouth. It is a triangular-shaped muscle with its base below, becoming narrow as it ascends.

Origin.—From the lower border of the inferior maxilla, and from its external oblique line below the cuspid, bicuspid, and first molar teeth.

Insertion.—Passing upward and inward it is inserted into the integument at the angle of the mouth, its fibers blending into those of the muscles previously described as coming together at this point.

Relations.—Externally, with the integument; deeply or internally, with the depressor labii inferioris, the buccinator, and the inferior coronary artery.

Action.—To draw down the angle of the mouth and to slightly extend it.

Blood-supply to the Cheeks.

The blood-supply to the cheeks is principally through the *facial* artery and its direct branches, the superior and inferior *coronary*, the *transverse facial*, and branches from the internal maxillary.

The Facial Artery and Branches.—The facial artery, also called the *external maxillary*, enters the cheek after passing over the body of the mandible at the anterior edge of the masseter muscle. It courses obliquely forward and upward through the substance of the cheek, until it reaches the inner angle or canthus of the eye, where it joins the nasal branch of the ophthalmic artery, and is called the *angular artery*. Near the center of the cheek the *inferior labial artery* is given off, which passes forward and downward to the lower lip, but supplies a portion of the cheek in so doing. Midway between the center of the cheek and the angle of the mouth the *superior and inferior coronary arteries* are given off, supplying that part of the cheek immediately adjacent to the angle of the mouth, after which they pass on to supply the upper and lower lips. The *masseteric branch* is given off in the immediate center of the cheek, at a point immediately below the inferior labial, passes directly upward over the masseter muscle, and anastomoses with branches of the internal maxillary and transverse facial. There are also given off from the main trunk near the center of the cheek the *buccal* branches, which pass upward over the buccinator muscle, and also anastomose with branches of the internal maxillary and transverse facial arteries.

The Transverse Facial Artery.—This is the largest branch of the temporal artery. It is at first deeply seated in the substance of the parotid gland, after leaving which it courses transversely over and supplies the masseter muscle, sends off small branches which supply the integument of the cheek, and anastomoses with the buccal, infra-orbital, and the facial arteries. Besides the arteries already named, the deeper

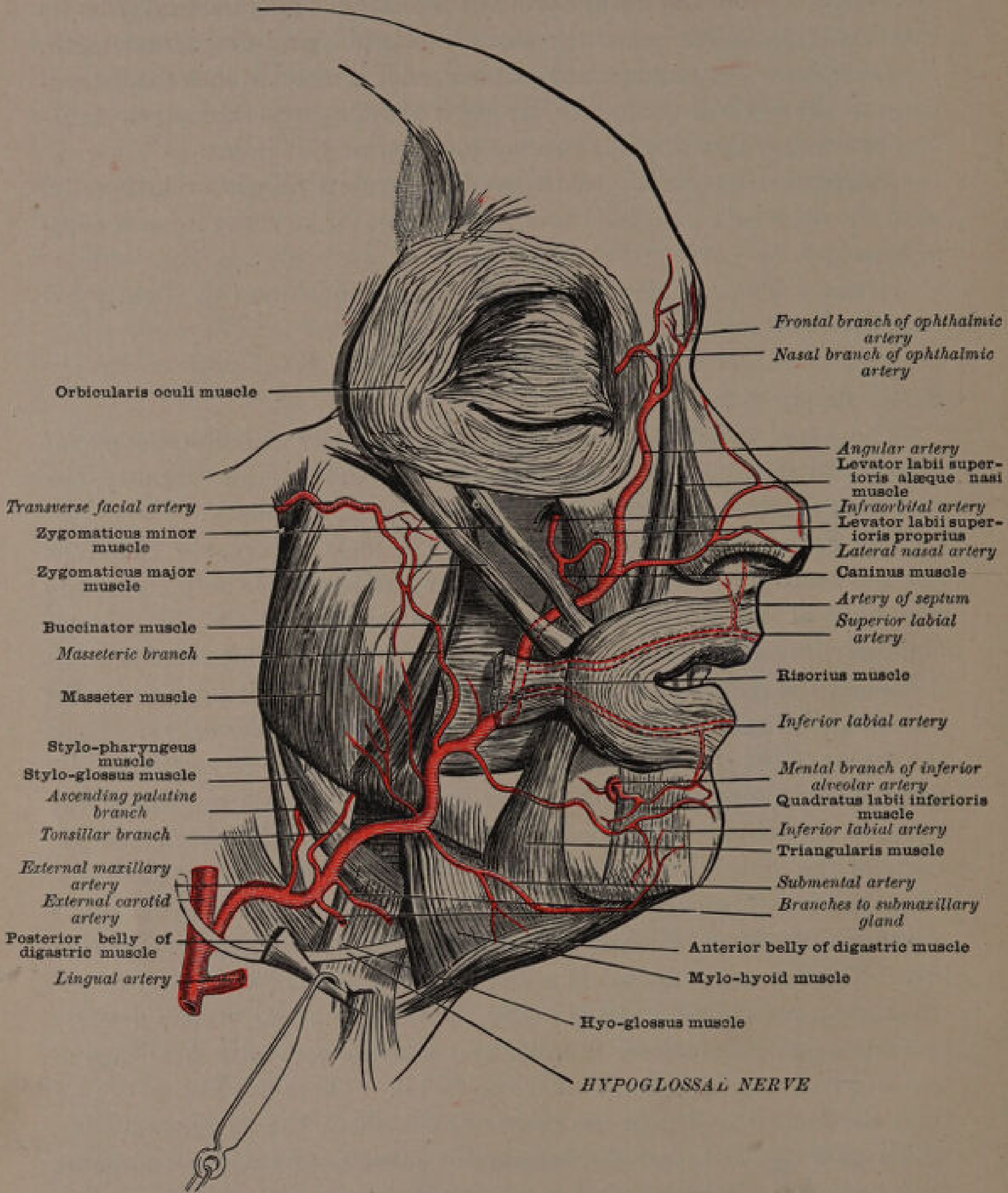


FIG. 4.—Scheme of the right external maxillary artery. (*Morris after Walsham.*)

portions of the cheek receive blood from two branches of the internal maxillary artery, the *masseteric branch* and the *buccal branch*. The former supplies the masseter muscle and anastomoses with the masseteric branch of the facial while the latter supplies the buccinator muscle and anastomoses with the buccal branches of the facial.

Course of the Blood from the Heart to the Cheeks.—From the heart to the aorta, to the common carotid, to the external carotid, to the facial and its direct branches, or from the external carotid to the temporal, to the transverse facial and branches.

From the cheeks the blood is returned to the heart principally through the *facial vein*, a division of the *anterior superficial vein*. It enters the cheek at a point midway between the lower eyelid and the wing of the nose, passes obliquely downward, being in close contact with the anterior edge of the masseter muscle over the body of the lower jaw, joining the internal jugular vein in the neck. The *transverse facial vein* which follows the course of the transverse facial artery, and the *superior* and *inferior coronary veins* also collect and convey a portion of the blood from the cheeks to the larger veins and thence to the heart.

Nerves of the Cheeks.

The nerve-supply to the cheeks is principally through the *seventh* or *facial nerve* and its branches, the *buccal* branch supplying a greater part of their substance. There are also a few fibers of the *infra-orbital* branch of the seventh nerve distributed to the labiobuccal region. The *buccal branch* of the lower division of the facial, also the *buccal branch* of the inferior maxillary division of the fifth nerve, supplies the buccinator muscle. The *infra-orbital branch* of the upper division of the facial nerve supplies the zygomaticus major and the levator anguli oris; the *buccal branch* supplies the risorius, and the *supramaxillary branch* of the lower division of the facial nerve supplies the depressor anguli oris.

THE INTERIOR OF THE MOUTH

For convenience of description the mouth may be divided into two parts—a *superior portion* and an *inferior portion*. In dissecting, this division may be accomplished by an incision beginning at the angles of the mouth and carried backward and slightly upward through the substance of the cheeks until the temporomandibular articulation is reached. After disarticulating this joint, another incision is made, beginning at the joint on either side, carried downward and foward, then obliquely across the throat, until the two come together at the median line. This latter incision must be deep enough to completely sever the tissues of the throat.

The superior portion of the mouth consists of the *hard palate*, or *roof of the mouth*, the *soft palate*, and the sixteen *upper teeth*, the latter firmly set in the bone and surrounded by a dense fibrous tissue—*the gums* or *gingiva*. The inferior portion consists of the tongue and its attached muscles, forming the *floor of the mouth*, the sixteen *lower teeth* and the gingival tissue surrounding them.

THE SUPERIOR PORTION OF THE MOUTH (Fig. 5)

The osseous framework, or base upon which this half of the mouth is constructed, is composed of a part of four bones—the two maxillary, or upper jaw bones, and the two palate bones (see Bones of the Mouth, p. 37).

The Hard Palate, or Roof of the Mouth (Figs. 5 and 6).

This is formed by the union of the palatal processes of the maxillary bones and the horizontal plates of the two palate bones at the center or median line. It is limited in front and laterally by the margins of the alveolar process, or that portion of the bone which gives support to the teeth, and ends posteriorly in an irregular border, to which is attached a muscular-like curtain—the soft palate. The hard palate is covered throughout by a thick and firm mucous membrane, seldom so highly colored as that lining the lips and cheeks. The mucous membrane is closely adherent to the bone through its common covering, the periosteum. In the center of the hard palate is a ridge or fold of mucous membrane, which follows the median line from before backward; this is called the *palatal* or *median raphe*, and indicates the line of union formed during the development of the parts. Anteriorly, the raphe ends in a small papilla, which marks the opening of a canal in the bone —*the anterior palatal canal*. Posteriorly, the raphe usually diminishes, in size, but occasionally is well marked through the whole extent of the hard palate. Near the center of the hard palate it frequently separates into two or more smaller ridges, which are proportionately diminished in size, and are continued backward side by side. On either side of this central ridge, anteriorly, the mucous membrane presents a number of fantastically arranged folds, the *palatal rugæ* (wrinkles). These folds are usually quite numerous and prominent, but are occasionally but slightly developed. The character of the rugæ may be indicative of the character or temperament of the individual. Accompanying these varying conditions in the rugæ will be found a corresponding variation in the raphe. The anterior and lateral margins of the mucous membrane covering the hard palate form the palatal portion of the *gingiva*.

In figure 6 the hard palate is shown with its mucoperiosteum removed. It will be observed that the bony plates are perforated by numerous small openings or foramina, broken by depressions for the accommodation of the various mucous glands, *palital glands*, and trans-

FIG. 5.—The superior portion or roof of the mouth.

versed by longitudinal grooves which give lodgment to blood-vessels and nerves.

The arch formed by the hard palate from side to side (palatal arch) varies greatly in form, imparting much knowledge in regard to the temperament of the individual, and in a measure controlling the quality of the voice. Thus, in the sanguine temperament the roof of the mouth presents almost a perfect oval. In the bilious type it is comparatively high and flat, as it passes from the base of one alveolar process to the other, from which point it descends abruptly to the necks of the teeth. In the nervous type the roof is high and semi-elliptical or parabolic in shape, and in the lymphatic it is low and flat.

In the same illustration the union or suture between the four bones may be seen at the median line. Near the anterior third of this central suture is the opening of the incisive or anterior palatal canal, the *anterior palatal foramen*, the location of which has been referred to in the description of the mucous membrane. Near the posterior border, and situated within the suture which unites the maxillary bones with the palate bones (the palatomaxillary suture), are two other foramina, the *posterior palatal;* and immediately posterior to these, and separated by a thin ridge of bone, are the *accessory palatal foramina*, these being in the tuberosity of the palate bones. (For further description of these foramina, see Bones of the Mouth, p. 37.) From the vessels and nerves which enter the hard palate through these various foramina, the mucous membrane and glands receive their blood- and nerve-supply.

Blood-supply to the Hard Palate.—This is principally derived from the *posterior* or *descending palatal* branch of the *internal maxillary* or *deep facial artery*, which passes downward in the posterior palatal canal and emerges through the posterior palatal foramen. Immediately on reaching the palate it divides into an anterior and a posterior branch, the former passing forward in a groove provided for it to the anterior palatal foramen, where it anastomoses with the nasopalatal artery. The groove in which the artery lies in its passage forward is usually at the base of the alveolar process, and in some instances is converted into a canal for a part of its length. The posterior branches pass backward and downward to supply the soft palate. In connection with supplying the hard palate proper, this artery carries blood to the palatal alveolar walls, to the mucous glands, the mucous membrane, and the gums.

Course of the Blood from the Heart to the Hard Palate.—From the heart to the aorta, to the common carotid, to the external carotid, to the internal maxillary, to the posterior or descending palatal branch of the latter. From the hard palate the blood is returned to the heart by the *superior palatal* and *inferior* or *descending palatal veins*, the former following the course of the superior palatal artery, while the latter originates at a point near the junction of the hard and soft palates, passes downward, and joins the facial vein below the body of the inferior maxilla.

Nerves of the Hard Palate.—The nerves of the hard palate are the *anterior* or *large palatal* and branches from the nasopalatal, both of which are branches of the sphenopalatal (Meckel's) ganglion. The anterior palatal nerve arises from the inferior angle of the ganglion, passes downward, accompanied by the descending palatal artery, through the posterior palatal canal, from which it emerges at the posterior palatal foramen. From this point it passes forward in a groove of the hard palate, and joins the nasopalatal nerve as it emerges from the anterior palatal foramen. Accompanying this nerve in its course

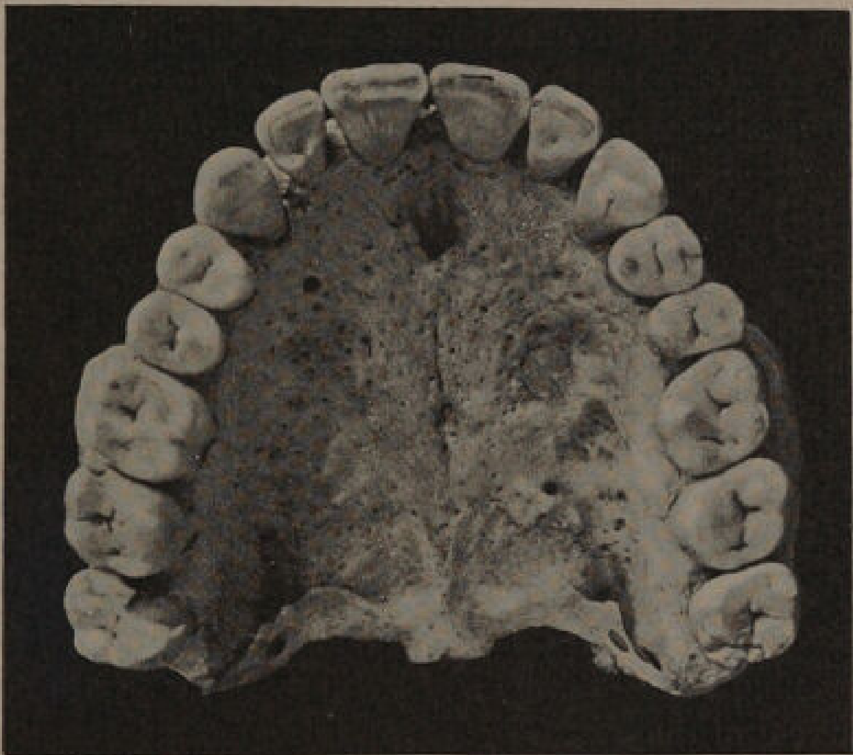


FIG. 6.—The hard palate, or roof of the mouth, with its membranous covering removed.

through the posterior palatal canal are other branches of the sphenopalatal ganglion, which pass to the soft palate, and will be described in that connection. The nerves of the hard palate are all sensory in function, and filaments are distributed to the mucous membrane and glands and to the palatal portion of the gums.

THE SOFT PALATE (Figs. 6 and 7)

The soft palate is attached to the posterior border of the hard palate, from which it is continued as a backward prolongation of its soft tissue. Hanging downward, with its free borders inclining backward, it may be considered as forming a part of the posterior boundary of the mouth. It partially separates the mouth from the nasal cavity and from the pharynx. It is attached laterally to the walls of the pharynx, while its lower border is free. The *substance* of the soft palate is composed of a number of thin, but dense, muscular fibers, blood-vessels, nerves, and mucous glands, the latter being similar to those of the hard palate. The anterior surface of this muscular curtain is concave, directed forward and downward, and is traversed by a median raphe. The posterior surface is convex, directed backward and upward, and is continuous with the nasal cavity. Suspended from the center of its free border is a small rounded or conic membranous appendix, the *uvula*, and passing outward from the base of this at either side are two curved muscular folds which extend outward and downward, and are known as the *pillars of the fauces*. From the position which these folds occupy they are divided into the *anterior* and the *posterior* pillars of the fauces. The anterior pillar is formed from muscular fibers which extend from the soft palate to the side and base of the tongue (palatoglossus muscle), and is somewhat prominent as it passes downward, outward, and forward. The posterior pillar approaches more closely to its fellow of the opposite side than does the anterior. It is formed of muscular fibers which extend from the soft palate above to the pharynx below (palatopharyngeus muscle). It is somewhat concave in its downward and backward course, and while closely united to the anterior pillar above, is separated from it below, leaving a triangular interval or niche in which is lodged a small, almond-shaped body, the *tonsil*, the space being known as the *tonsillar recess*. The intervening space—bounded by the margins of the soft palate above, the root of the tongue below, and the pillars laterally—is called the *isthmus of the fauces*, which establishes the communication between the mouth and the pharynx. The free margins of the soft palate, assisted by the pillars of the fauces, mark the *posterior boundary of the mouth*. The entire surface of the soft palate and its prolongations, the pillars of the fauces, is covered with mucous membrane, being continuous with that of the mouth on its anterior surface, and with that of the nasal cavity on its posterior surface.

Muscles of the Soft Palate.

On each side the muscles of the soft palate are the *palatoglossus*, *palatopharyngeus*, *levator palati*, and *tensor palati*, together with the *ayzgos uvulæ*.

Palatoglossus.—A small fasciculus of fibers, somewhat cylindric in form, expanding at either end into a thin sheet. It is named from its attachment to the soft palate and to the tongue. It is the prominence of this muscle, together with its covering of mucous membrane, that forms the anterior pillar of the fauces.

Origin.—By a thin muscular sheet from the under surface of the aponeurosis of the soft palate near the median line, its fibers uniting with those of the opposite side. It passes downward in front of the tonsil and against the pharyngeal wall.

Insertion.—Into the side and base of the tongue.

Relations.—Superficially, it is covered by the mucous membrane of the soft palate and tongue; deeply, in contact with the aponeurosis of the soft palate, the superior constrictor muscle of the pharynx, and one of the muscles of the tongue—the hyoglossus.

Action.—The lateral walls of the soft palate are drawn down, and the sides of the tongue are drawn upward and slightly backward. Acting in conjunction with the palatopharyngeus, the opening of the fauces is constricted.

Palatopharyngeus.—This muscle—also named from its attachments—is broad above, where it forms the greater part of the lower half of the soft palate. Near the median line a few of its fibers blend with those of its fellow of the opposite side.

Origin.—By two heads from a point near the raphe or median line of the soft palate, passing downward and slightly backward, forming, with its covering of mucous membrane, the posterior pillar of the fauces.

Insertion.—Into the posterior border of the thyroid cartilage, and to the inner surface of the lower part of the pharynx.

Relations.—In the soft palate, superficially, with the mucous membrane, both anteriorly and posteriorly; above, with the levator palati; and beneath by the mucous glands. In the posterior pillar it is surrounded with mucous membrane, and in the pharynx by the constrictor muscles of the pharynx and the mucous membrane.

Action.—To constrict the opening of the fauces, by bringing together the posterior pillars, thus depressing the soft palate and elevating the pharynx. It controls the position of the soft palate during respiration, and elevates the pharynx during deglutition.

Levator Palati.—This is a moderately thick muscle, and derives its name from its action upon the soft palate.

Origin.—By a short tendon from the under surface of the petrous portion of the temporal bone, and from the posterior and inferior aspect of the cartilage of the Eustachian tube.

Insertion.—After passing downward by the side of the posterior nares it is inserted into the median line of the soft palate, where its fibers unite with those of its fellow of the opposite side.

Relations.—Externally, with the tensor palati and superior constrictor muscles; internally and posteriorly, with the mucous membrane.

Action.—To raise the soft palate, bring it against the posterior wall of the pharynx.

Tensor Palati.—This is a slender and flattened muscular sheet, and receives its name from its action upon the soft palate.

Origin.—From the scaphoid fossa at the base of the internal pterygoid plate and the spinous process of the sphenoid bone; also from the outer side of the anterior aspect of the Eustachian tube.

Insertion.—After descending between the internal pterygoid muscle and the internal pterygoid plate, and winding around the hamular process of the latter, it is inserted into the transverse ridge on the horizontal portion of the palate bone, and at the median line of the soft palate where it is continuous with the aponeurosis of the opposite side.

Action.—To tighten or spread the soft palate laterally, forming a septum between the posterior nares and the pharynx. It also opens the Eustachian tube during deglutition.

The azygos uvulæ (so named because it was at one time supposed to be a single muscle) is composed of a pair of small muscles which *originate* from the aponeurosis of the soft palate and the nasal spine of the palate bone. They pass downward and form or are *inserted* into the uvula.

Relations.—Anteriorly, with the levator palati, palatoglossi, and a part of the palatopharyngei; posteriorly, to the mucous membrane.

Action.—To shorten or draw up the uvula.

Blood-supply to the Soft Palate.

The *posterior* or *descending palatal branch* of the *deep facial artery*, after emerging from the posterior palatal canal, sends its posterior division backward and downward to the soft palate, in the substance of which they anastomose with the ascending palatal artery. After passing over the superior border of the pharynx, the *ascending pharyngeal artery* sends off branches which are distributed to the soft palate. A few branches of the superior palatal branch of the *internal maxillary* and a few twigs from the *lingual artery* also convey blood to the parts.

Course of the Blood from Heart to the Soft Palate.—From the heart to the aorta, to the common carotid, to the external carotid, to the facial or lingual, to the various branches named above, to the soft palate. The return of the blood to the heart is principally through the *superior* and *inferior* or *descending palatal veins*, both of which closely follow the course of the arteries of the same name.

Nerves of the Soft Palate.—The *small*, or *posterior*, *palatal*, the *external palatal* (both of which are branches of Meckel's ganglion),

FIG. 7.—The inferior portion or floor of the mouth.

branches of the *glossopharyngeal* nerve, and the following nerves which supply the various muscles: filaments from the pharyngeal plexus to the palatoglossus and palatopharyngeus, branches of the Vidian to the levator palati and azygos uvullæ, and from the mandibular division of the fifth nerve to the tensor palati.*

THE INFERIOR PORTION OR FLOOR OF THE MOUTH (Fig. 7)

This half of the cavity of the mouth contains the *tongue* and its attached muscles, the sixteen *lower teeth* firmly implanted in the bone

* A description of the upper teeth will be found in another chapter.

and the gums covering the alveolar walls. The base or osseous framework about which this portion of the mouth is constructed is principally made up of a single bone, the mandible, or lower jaw bone (see Bones of the Mouth, p. 37). The *hyoid bone*, situated between the angles of the mandible in the upper part of the neck, and at the base of the tongue, giving attachment to many of the muscles about the floor of

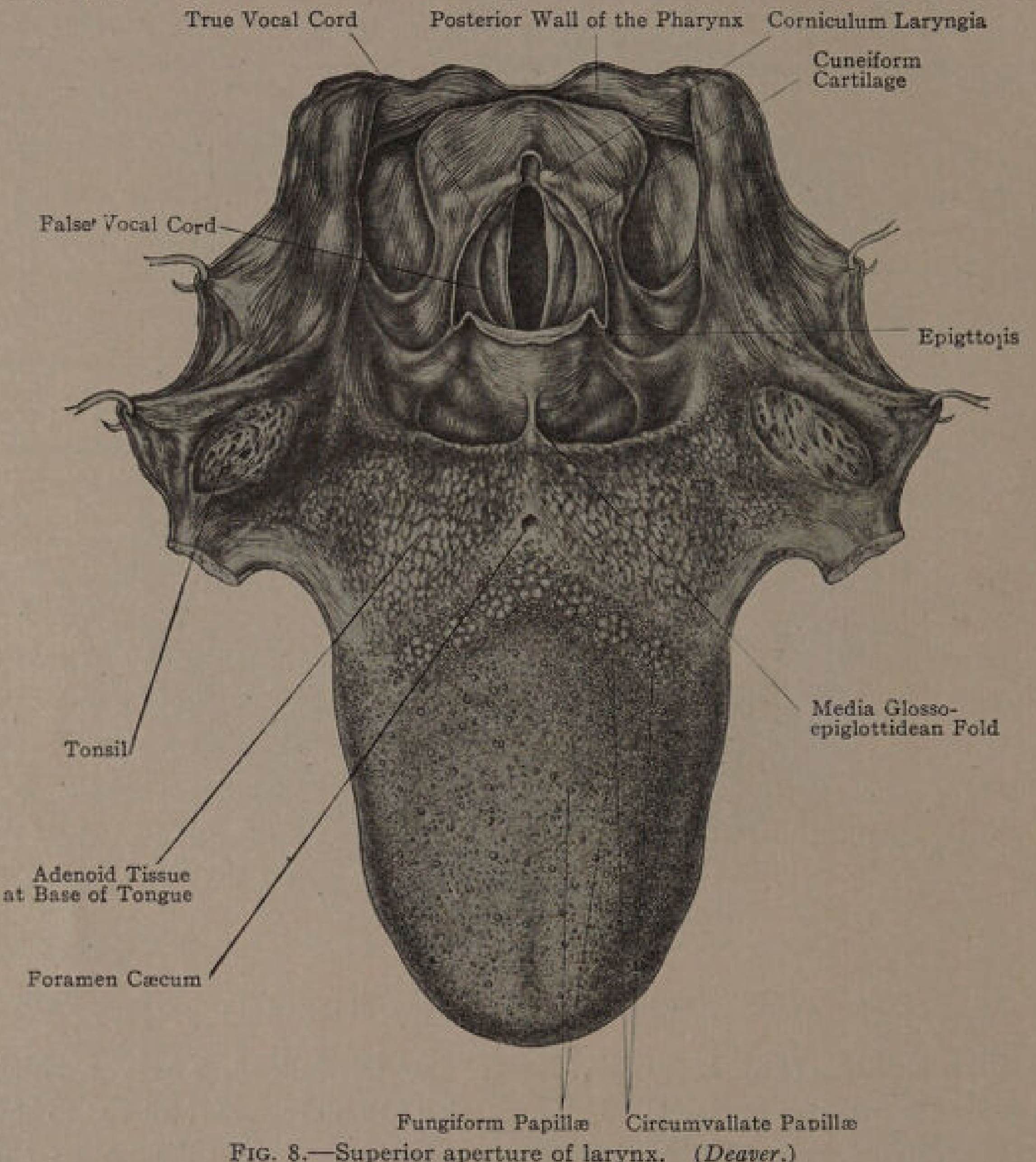


FIG. 8.—Superior aperture of larynx. (*Deaver.*)

the mouth, may also be considered in this connection. The floor of the mouth is bounded anteriorly by the lower lip, laterally by the cheeks, and below by the muscles attached to the external and internal oblique lines of the mandible and to the under surface of the tongue.

THE TONGUE (*Lingua*) (Fig. 8)

The tongue is a freely movable, highly sensitive, muscular organ. It assists in the function of articulate speech, participating, also, in the special sense of taste, and in mastication and deglutition. The organ is attached posteriorly to a U-shaped bone, the hyoid bone, which of itself is movable, and is located in the neck between the angles of the mandible and the thyroid cartilage.

The tongue is suspended and kept in its position in the mouth by numerous muscles, some of which are attached to the base of the skull, and others to the mandible and hyoid bone.

The size of the tongue bears little or no relation to the size of the individual, but is proportioned to the capacity of the alveolar arch, which space it completely fills when at rest. The shape of the tongue is influenced by the shape of the alveolar arch; thus, when the arch is contracted, narrow, and pointed, the margins of the tongue, when at rest, will assume that form (*a*, Fig. 9); but when the arch is broad and rounded anteriorly, the margins of the tongue will also be broad and rounded (*b*, Fig. 9).

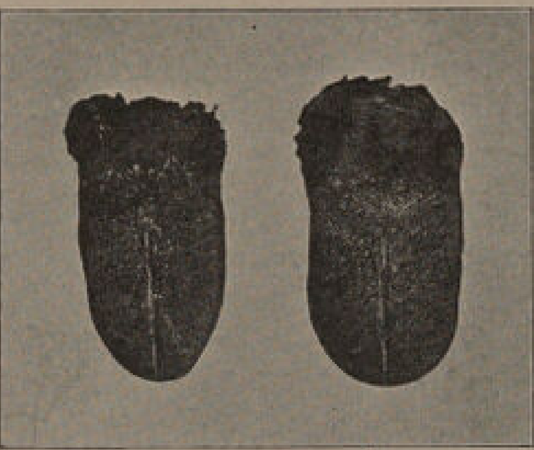


FIG. 9.

The substance of the tongue is composed of muscular fibers, which are arranged in a complicated manner, crossing one another at various angles, thus making the movements of the organ exceedingly varied and extensive. Fibrous, areolar, fatty and glandular tissue also enter into its structure, and it is freely supplied with blood-vessels and nerves. Its free surface is covered by a specialized mucous membrane, and over its entire surface are numerous mucous follicles and papillæ.

Before continuing the description of the tongue, it will be necessary to name its parts. The upper surface, or that facing the roof of the mouth, is the *dorsum* (*dorsum linguæ*); those portions directed toward the cheeks are known as the *margins* of the tongue; the thin narrow portion directed forward and against the inner surface of the lower front teeth, is the *apex* or tip (*apex linguæ*). That portion between the frenum and extending back to the pillars of the fauces is the *base*, while that part of the dorsum immediately posterior to the tip is the *post-tip*, that region which lies between the post-tip and the base being the *pre-base*. The dorsum, sides, and tip are free, while the base is attached by muscles to the surrounding bony tissue.

From the base to the epiglottis is a fold which serves to limit the movement of the latter organ, and to the sides of the base the pillars of the fauces are attached. Under the anterior free extremity at the median line is a fibrous muscular lamina or ligament, the *frenum* (frenum linguæ), which connects this part of the organ with the lower jaw and marks the anterior border of the base of the tongue. The tongue is divided through its anterior two-thirds by a slight longitudinal furrow, the *median raphe*, which ends posteriorly near a small foramen, not constant in the adult tongue, but plainly observed in early life the *foramen cæcum*. This foramen represents the upper termination of the thyreoglossus duct.

Papillæ of the Tongue.—Over the anterior two-thirds of the dorsum and the sides and tip of the tongue are a number of small, soft, conic eminences, which are known as the papillæ of the tongue. These are most numerous over the anterior part of the dorsum, while posteriorly they are covered and partly hidden by an epithelial coating. In general, the papillæ are quite similar to those of the integument, not being compound organs in their blood and nerve supply. In consequence of their variation in form and arrangement the papillæ are variously named. The largest papillæ, being arranged like the letter **V**, are called the *circumvallate* or *falciform;* those of medium size, the *fungiform*, are so named from their resemblance to a young mushroom; and the smallest and most numerous are known as the *conic* or *filiform* papillæ. Each papilla presents a broad, free end, and is attached by a constricted base, which rests in a small, cup-like concavity, about the margins of which is a well-formed circular rim. Beneath the thick epithelium of these parts are numerous secondary papillæ, and about the base of each papilla are the openings of one or more glands.

The *circumvallate* or *falciform* papillæ (Fig. 8) form a **V**-shaped line at the posterior boundary of the dorsum. They are few in number (varying from six to twelve), but are largest in size, not infrequently measuring ¼ of an inch in diameter. These papillæ are generally regarded as being gustatory, or directly interested in the sense of taste. Each papilla is capped with a small secondary papilla.

The *fungiform* papillæ (Fig. 8), of medium size, varying from 1/20 to 1/50 of an inch in diameter, are scattered over the dorsum, sides, and tip of the tongue at irregular intervals, and are much more highly colored than the smaller papillæ which surround them. They vary greatly in number, and being principally gustatory, account in a great measure for the diversity in the acuteness of the sense of taste in different individuals. These papillæ, like the circumvallate, are capped with smaller secondary papillæ.

The *conic* or *filiform* papillæ (Fig. 8) are the smallest and most numerous, and are thickly scattered over the entire surface of the dorsum in front of the circumvallate as well as over the sides and tip of the tongue. They are placed closely together, and with such regularity that they fairly ridge the tongue with delicate lines, which run parallel with the circumvallate in that region, but as the tip is approached they become transversely inclined. These papillæ are generally regarded as being tactile or directly interested in the sense of touch, and are concerned in directing the movements of the food during mastication. They also possess secondary papillæ upon their surfaces.

Immediately posterior to the circumvallate papillæ are two shallow grooves which follow the V-shaped line of the papillæ and unite at the foramen cæcum. These grooves serve to indicate the line of junction between the anterior and posterior portions of the tongue. The latter not being within the cavity of the mouth will not be described.

Muscles of the Tongue (Fig. 10).

The muscles of the tongue are both *extrinsic-outward* or external, and *intrinsic-inherent*, inward, or special.

The extrinsic muscles include those which have their origin from the base of the skull, the hyoid bone, or the mandible, and are the *hyoglossus*, *geniohyoglossus*, *styloglossus*, *palatoglossus*, and a few fibers of the superior constrictor of the pharynx. The intrinsic muscles which make up the bulk of the tongue are two in number, the *superior lingualis* and *inferior lingualis*.

Hyoglossus.—As its name implies, this muscle extends from the hyoid bone to the tongue. Its fibers are so arranged that they form a thin square sheet.

Origin.—It arises from the whole length of the upper border of the great cornu, from the body, and by a few fibers from the lesser cornu of the hyoid bone. At their point of origin the fibers are in the form of a thin sheet, and ascend toward the tongue almost parallel to one another, but before reaching the tongue the anterior fibers pass slightly forward, and at the upper margin of the side of the tongue bend inward and join the fibers of the superior lingualis. In their distribution to this part of the tongue they form a kind of submucous covering to the organ.

Insertion.—Into the posterior half of the side of the tongue, between the styloglossus and superior lingualis muscles.

Relations.—Externally, with the digastricus, styloglossus, stylohyoid, and mylohyoid muscles, the lingual and hypoglossal nerves, Wharton's duct, and the sublingual gland. Internally, with the lingu-

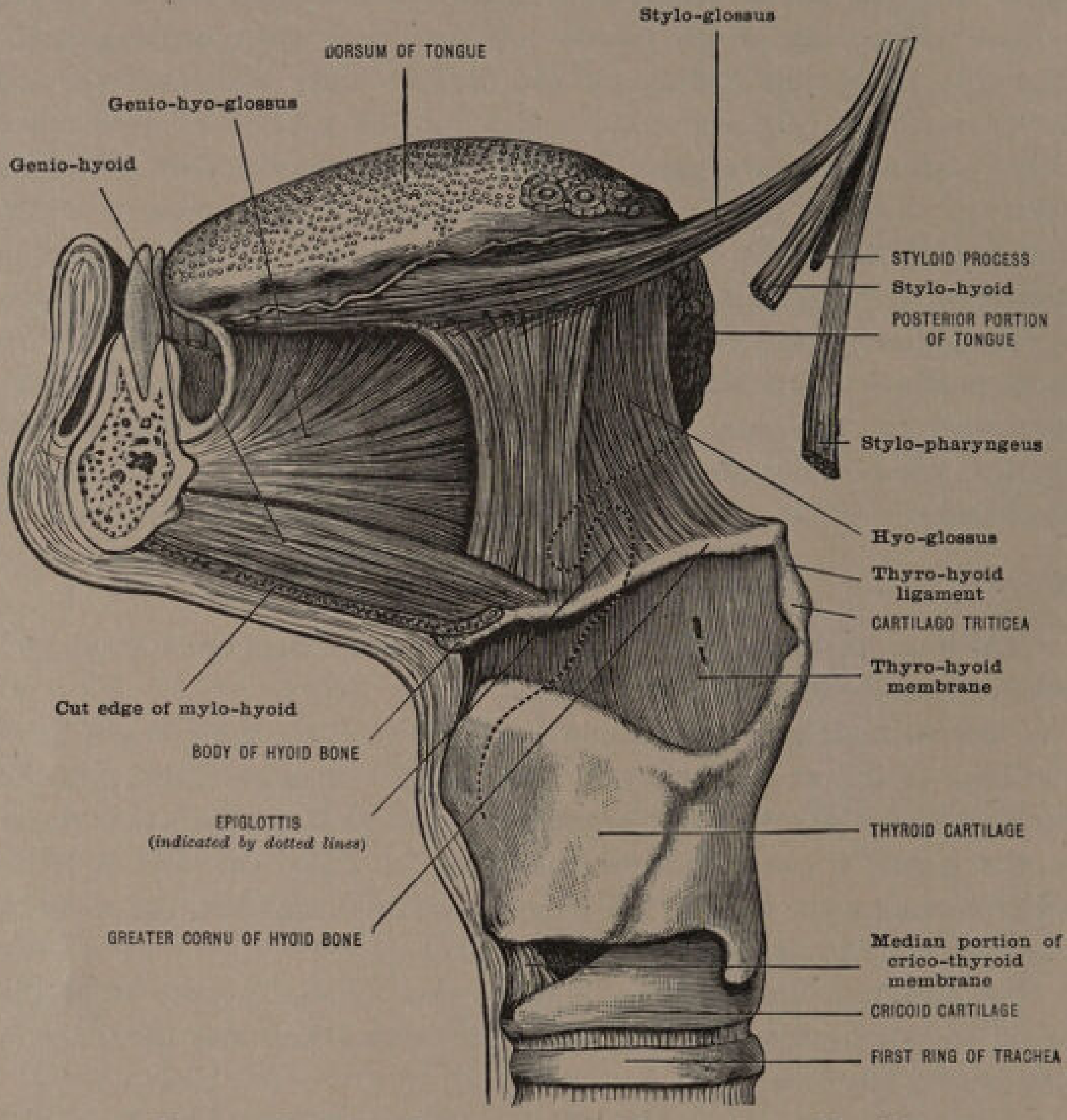


FIG. 10.—Side view of the tongue, with its muscles. (*Morris*.)

alis, geniohyoglossus, and middle constrictor of the pharynx muscles, the lingual artery, and the glossopharyngeal nerve.

Action.—To extend the tongue and to draw it backward, also to draw downward the sides of the tongue, making its dorsum more convex transversely.

Geniohyoglossus (Fig. 10).—This muscle also receives its name from its three points of attachment, the chin internally, the hyoid bone, and the tongue. It is a triangular-shaped muscle, narrow and pointed at its attachment to the mandible, and broad and fan-shaped on approaching the tongue. Being near the median line, it is separated from its fellow of the opposite side by a thin layer of connective tissue, the *septum* of the tongue.

Origin.—It arises by a short tendon from the upper genial tubercle

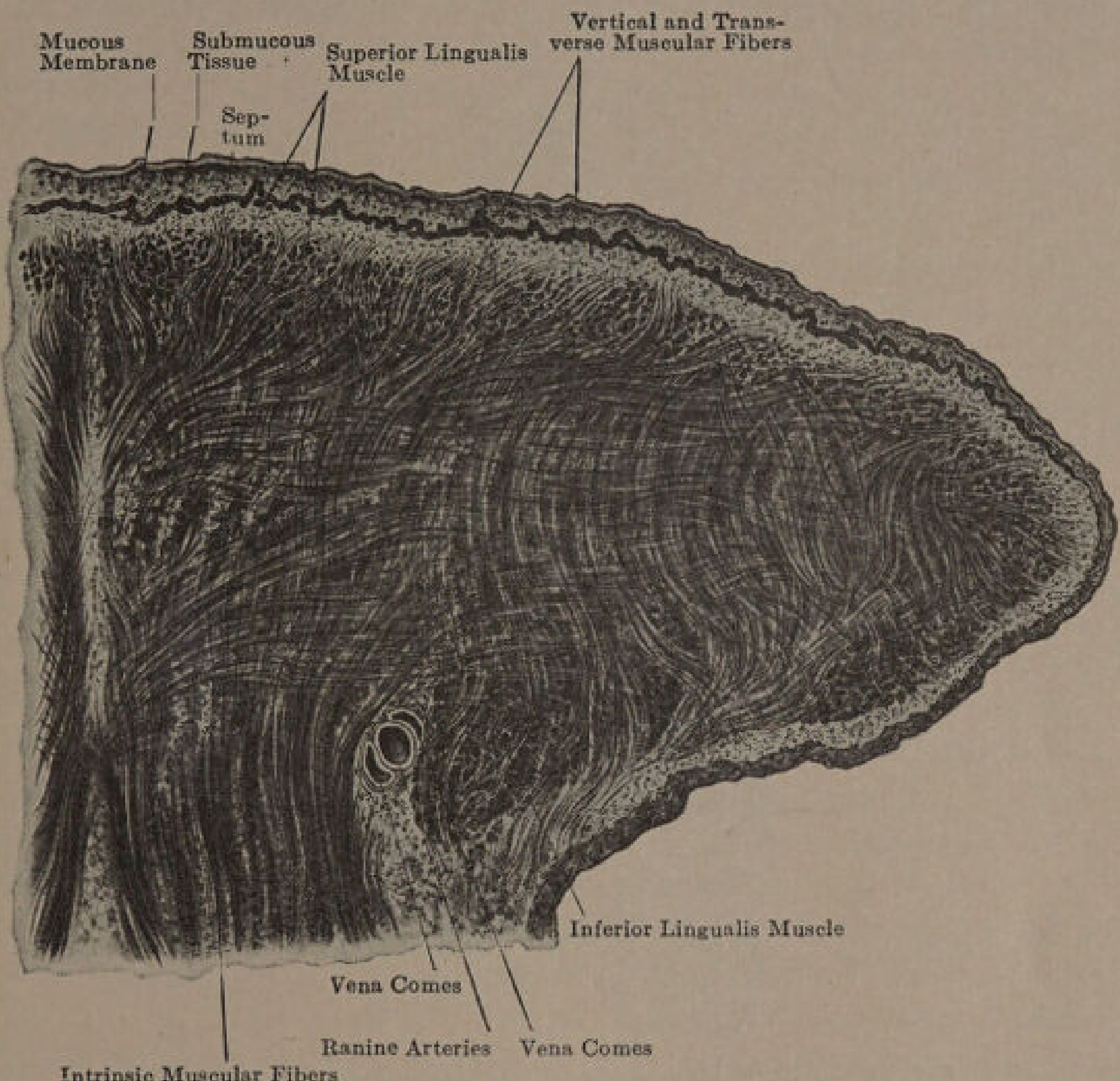


FIG. 11.—Transverse section of one-half of tongue. (*Deaver.*)

of the lower jaw, from which point its fleshy fibers diverge fan-like to its extensive insertion.

Insertion.—To the whole length of the tongue from base to apex immediately external to the median line, into the body of the hyoid bone, and by a few fibers into the side of the pharynx.

Relations.—By its inner surface, with the septum of the tongue and its fellow of the opposite side; by its outer surface, with the hyoglossus, mylohyoides, styloglossus, and lingualis muscles, sublingual gland, lingual artery, and hypoglossal nerve. Superiorly, with the mucous membrane of the floor of the mouth; inferiorly, with the geniohyoid muscle.

Action.—Its anterior fibers assist in drawing back the tip of the tongue, its posterior fibers throwing forward and protruding the tongue. This muscle also depresses the center of the dorsum longitudinally, making it concave transversely, and some of the lower fibers which are

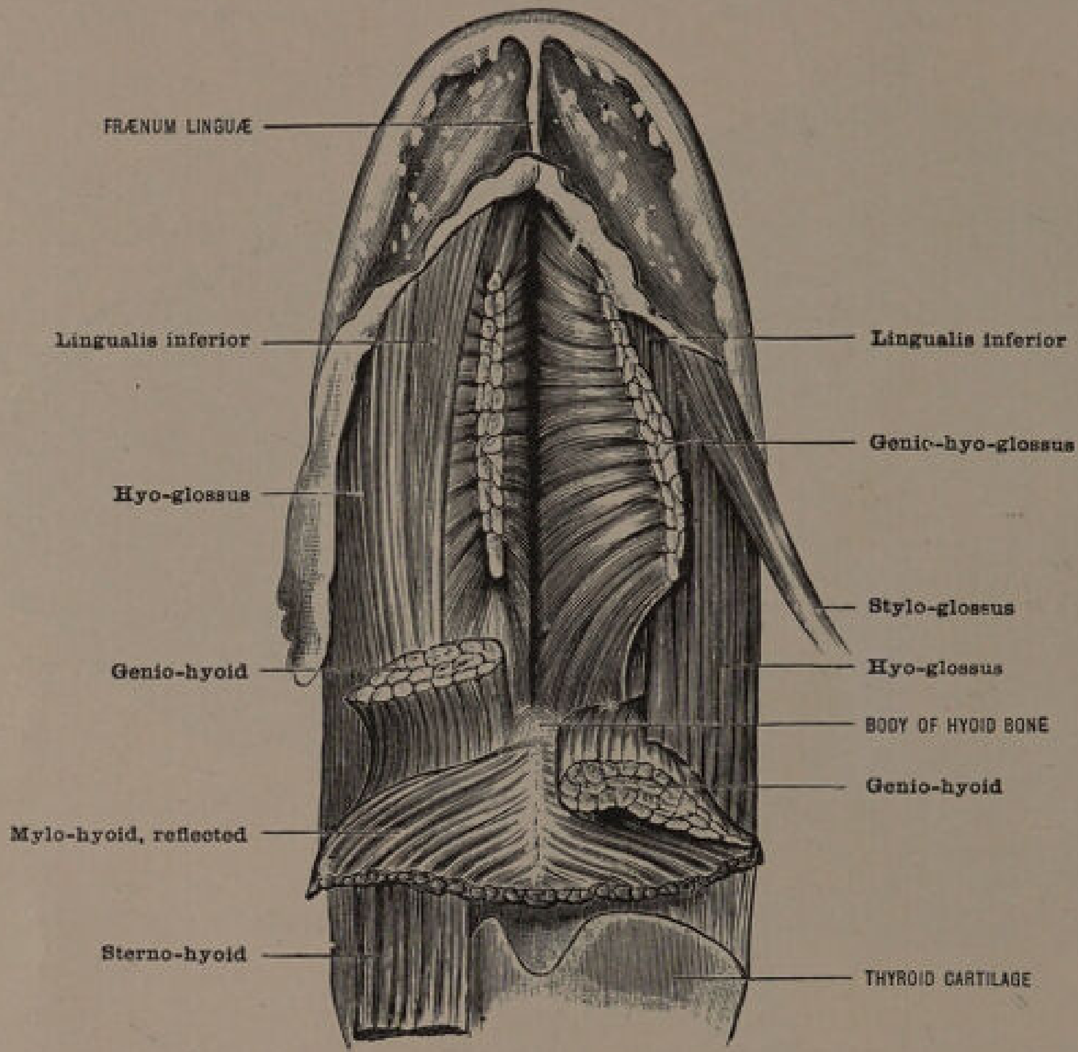


FIG. 12.—Under surface of the tongue with muscles. (*Morris.*)

attached to the hyoid bone elevate the bone and assist in raising the tongue.

Styloglossus.—Also named from its attachment, is a long fan-shaped muscle, somewhat compressed laterally.

Origin.—From its point of origin at the tip of the styloid process of the temporal bone, and from a portion of the stylomaxillary ligament, it passes with a long curve, forward, slightly downward, then upward and inward to its place of insertion at the side of the tongue.

Insertion.—Upon reaching the side of the tongue it divides into two portions, the fibers of one portion passing transversely inward, while the others pass longitudinally along the side of the tongue.

Relations.—Externally, with the internal pterygoid muscle, partoid and sublingual glands, lineal nerve, and the mucous membrane of the mouth; internally, with the superior constrictor and hyoglossus muscles, and with the tonsil.

Action.—To draw the tongue backward and to produce a transverse concavity to its upper surface by elevating its sides.

Superior Lingualis.—This is one of the intrinsic muscles, and is situated immediately beneath the mucous membrane, extending from the base to the tip of the organ.

Inferior Lingualis (Fig. 12).—This muscle is placed near the under surface of the tongue, and is composed of two bands which extend from base to apex, some of its fibers being attached posteriorly to the hyoid bone, and in passing forward are placed between the hyoglossus and genio-hyoglossus. Anteriorly, its fibers blend with those of the styloglossus.

Many of the fibers of this muscle run transversely and are placed between the two former intrinsic muscles. These, together with some fatty tissue compose the greater part of the substance of the tongue. The fibers are attached at the median line to the fibrocartilaginous septum of the tongue, and laterally to the mucous membrane. In connection with the transverse fibers there are a few placed vertically, which pass by long curves from the dorsum to the under surface of the tongue.

Blood-vessels of the Tongue (Fig. 13).

This organ receives its blood principally through the *lingual*, *facial*, and *ascending pharyngeal* arteries. The *lingual artery* arises from the front of the external carotid near the facial, and often as a common trunk with it. From its point of origin to the tongue it is divided into three portions, the first or oblique, the second or horizontal, and the third or ascending, and it is this latter portion which directly supplies the tongue. Ascending tortuously beneath the hyoglossus muscle, it reaches the under surface of the tongue, and, lying between the lingualis and hyoglossus muscles, it is continued to the under surface of the tip of the tongue, at which point it is called the *ranine artery*. At a point about corresponding with the posterior margin of the hyoglossus muscle a branch is given off (the *dorsalis linguæ*), which passes almost directly upward, and, after dividing into two or more small branches, supplies the back part of the dorsum of the tongue and the mucous membrane about the circumvallate papillæ. At the anterior border of the hyoglossus muscle another branch is given off (the *sublingual artery*) supplying the anterior muscular structure of the floor of the mouth. The facial artery by one of its muscular branches supplies the styloglossus muscle.

Course of the Blood from the Heart to the Tongue.—From the heart to the aorta, to the common carotid, to the external carotid, to the lingual artery and its smaller branches to the tongue. From the tongue

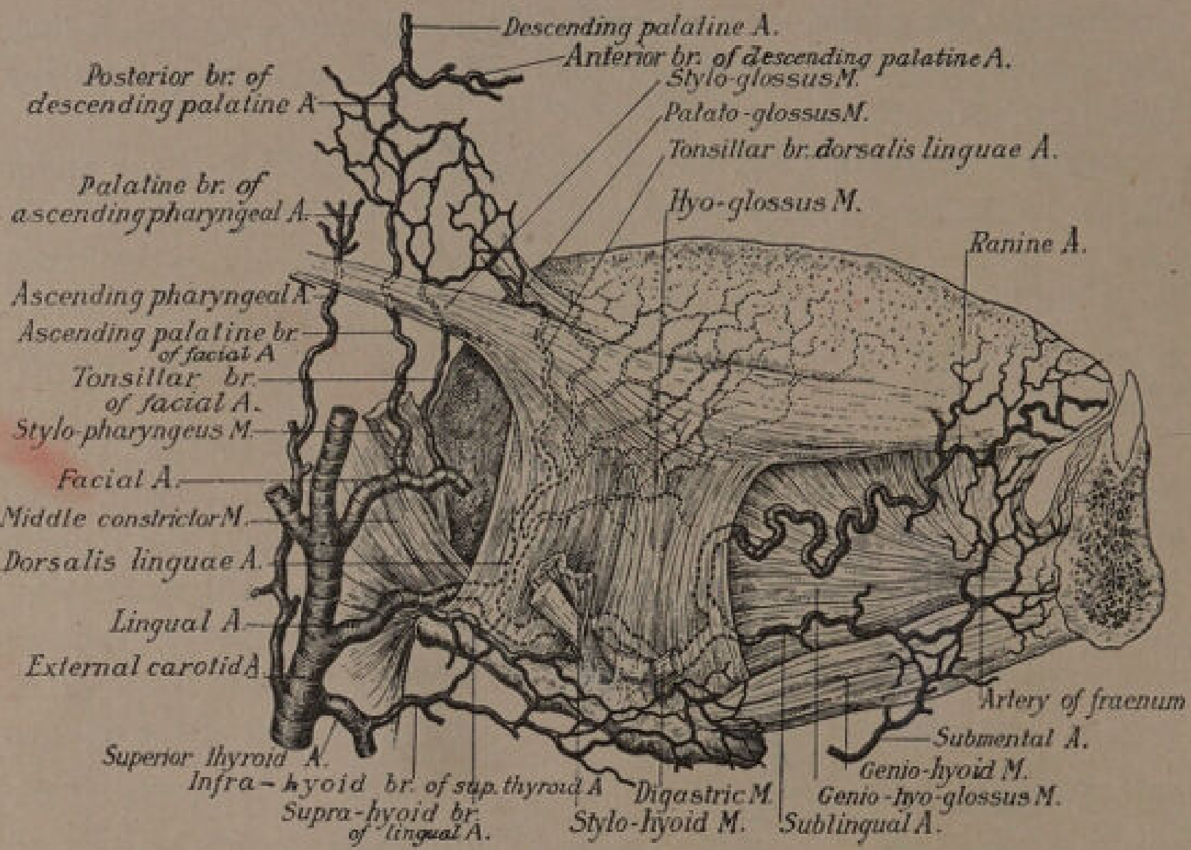


FIG. 13.—Arteries of tongue and tonsil. (*Deaver.*)

the blood is returned to the heart principally through the *lingual* vein, which begins at the ranine vein beneath the tip of the tongue, passes backward under cover of the mucous membrane, following the course of the lingual artery until the hyoglossus muscle is reached, beyond which point the fibers of the muscle separate the artery from the vein. After receiving the sublingual and dorsalis linguæ veins, the course of which corresponds to the arteries of the same name, the vein passes backward and downward and empties into the internal jugular.

Nerves of the Tongue.

The *mandibular division* of the *fifth* nerve by its lingual branch supplies the papillæ of the anterior portion and sides of the tongue, while the *lingual branch* of the *glassopharyngeal* supplies the circumvallate papillæ, the base, and posterior sides. A few branches of the superior laryngeal are distributed to the back part of the root of the organ. The motor nerve of the tongue is the *hypoglossal* or *twelfth*, supplying both the extrinsic and intrinsic muscles.*

* A description of the lower teeth will be found in another chapter.

CHAPTER II

Muscular Tissues of the Mouth; of the Lips; of the Cheeks; of the Soft Palate; of the Tongue

MUSCULAR TISSUES OF THE MOUTH

Muscular Tissues of the Lips.—The minute bundles forming the fasciculi of —the *orbicularis oris*—are distributed between the submucosa of the mucomembranous portion and the subcutaneous tissue of the cutaneous portion of the lips. The muscular fibers radiate in three principal directions upon either side of the median line: from the angle of the mouth toward the median line, and from the fleshy slips of the maxilla and mandible—the musculi incisivi. As the fibers from the angle of the mouth pass to the substance of the lip, they are arranged in a laminated manner. When the median line is reached, one set of fibers terminates somewhat abruptly in the subcutaneous tissue, another set is continued beyond the median line and attached to the cutis of the opposite side, while a third set, without crossing the median line, is attached to the incisive fossæ of the maxilla and mandible. The numerous muscular fibers of the internal labial or mucomembranous portion, and the external, facial, or cuticular portion, penetrate the parts and terminate in close proximity to the epithelium or to the base of the papillæ. Delicate, hair-like fibers which are continuous with the sarcolemma slightly penetrate the cutis and membrana propria. A few of the fibers, which may be classed with the terminals of the outrunning muscles from the lips, are arranged in a number of fasciculi in the subcutaneous portion, pass through the fasciculi of the orbicularis oris, reach the submucous tissue, where they cross and recross one another, and finally pass into the membrana propria, where they end in fan-like terminals. The fasciculi of the orbicularis differ somewhat in the upper and lower lips; in the former the bundles are strongly developed toward the angle of the mouth, while in the latter the median bundles are the strongest. The labial muscular tissues are of the transversely striated variety. The fibers are cylindric in form, having rounded or pointed extremities in the interior, and broad or flattened ends where they come in contact with the periosteum. When examined with a high power each fiber shows alternately broad and narrow striæ, the former being dim, while the latter is bright in appearance. With a stronger power both the broad and narrow striæ are seen to be transversely striated.

Muscular Tissues of the Cheeks.—The muscles entering into the construction of the lateral walls of the mouth have already been described on page 9, giving the relations existing between the individual muscles, together with the general disposition of the various fasciculi. Histologically considered, these muscles partake of all the characteristics of striated or voluntary muscular tissue. In the body of the buccinator and masseter the fibers are cylindric and have definitely pointed or rounded ends. Near their termini, particularly in the latter muscle, the inner extremities of the terminal fibers are pointed, while the outer ends, or those by which the attachment is formed, are broad and rather flat.

Muscular Tissue of the Soft Palate.—The disposition of the striated muscular tissue of the soft palate is extremely complicated. The *azygos uvulæ*, the only true longitudinal muscle in the soft palate, has its origin from aponeurosis of the soft palate and from the nasal spine of the palate-bone, the fibers passing backward upon either side of the median line. This is a double muscle, and near its point of origin the two portions are distinct and separated by a definite space, but upon reaching the base of the uvula they become closely associated. The fasciculi do not continue to the apex of the uvula, but immediately beyond the center of its length are thrown out fan-like toward the sides, terminating in a manner similar to the fibers of the lips. In passing from before backward a number of small fasciculi are given off, which reach out laterally and traverse the glandular lobes, completely surrounding them, after which they again return to the principal fibers at the median line. The *palatopharyngeus* is divisible into two parts, the upper extremities of which lie partly in front and partly behind the levator muscles. The greater number of the fibers of one set, situated in front of the levators, form a curved, flattened aponeurosis. The fibrous border of the hard palate serves as an attachment for the convex border of this portion, while the other border, which is concave, is directly toward the arch of the levator muscles. The fibers of the palatopharyngeus, situated behind the levators, form a number of loose fasciculi interspersed by fat-cells. In passing toward the free border of the soft palate the fibers become much more delicate, and, separating, some course in front and others behind this muscle. In this location the fibers become closely associated with the glands, and either end here or are continued to the submucosa, or even to the membrana propria of the mucous membrane. The fibers of the palato-pharyngeus unite with the fibers of the levators, and an arch-like fasciculus is formed by this union which, subdividing, passes in front of the azygos uvulæ to the opposite side. All of these fibers run outward and downward, and unite with the extremities of the other palatal muscles, the fibers of which are somewhat more regularly distributed. Like the muscles of the lips and cheeks, the several fasciculi of the palatal muscles form a delicate plexus, and a quantity of fatty tissue is found between the various fasciculi.

Muscular Tissues of the Tongue.—The tongue is divided into two equal lateral portions by a median septum or raphe, the *septum linguæ*. This central septum, composed of a vertical layer of compact, fibrous, connective tissue, extends the entire length and depth of the lingual median line. Beginning at the hyoid bone, it gradually increases in prominence until the middle of the organ is reached, beyond which point it becomes less pronounced and finally disappears near the tip. The muscular bundles are arranged longitudinally, transversely, and vertically. The former lie immediately beneath the mucous membrane, including the *superior lingualis* above and the *inferior lingualis* below, together with the greater part of the *styloglossus*. The superior lingualis extends from the base to the tip of the organ, and by short fasciculi its fibers are attached to the overlying tissues. The fibers of this muscle are placed between the hyo- and styloglossi muscles of the opposite side, both of which overlap the fibers of the lingualis near the base of the tongue. The inferior lingualis also gives off several small fasciculi and fibers to the mucous membrane beneath, and is composed of two bands which reach from the base to the apex, each being placed between the hyoglossus and genio-hyoglossus. The transverse fibers, which are placed between the superior and inferior lingualis, originate from the septum linguæ, and form the bulk of the tongue. From their point of origin these fibers course outward and upward to the sides of the tongue. Those fibers which are vertically disposed decussate with the transverse fibers, and pass from the dorsum toward the under surface of the tongue, the fibers curving gracefully with their concavity directed toward the under surface. In most instances the ascending vertical fibers, as well as the transverse fasciculi, pass between those longitudinally disposed and connect with the submucosa.

CHAPTER III

The Bones of the Mouth: The Maxillae, The Palate Bones, The Mandible

MAXILLARY BONES

The *maxillary bones*, two in number, one on each side of the median line or center of the face, are irregular in shape, and may be classed as the largest bones of the facial group, with the probable exception of the mandible. From the central position which they occupy they contribute largely to the bony framework of this portion of the skull. They are not only instrumental in forming the major portion of the roof of the mouth or hard palate, but assist in the formation of the floor of the orbit, and the sides and base of the nasal cavity. They furnish a solid and firm foundation for the sixteen upper teeth, and by their variety in form contribute much to the facial profile as well as to the character and quality of the voice. The outer or facial surface of these bones provides attachment for numerous muscles. Each maxillary bone presents for examination a *body*, *four surfaces*, and *four processes*. The body may be described as forming an irregular triangle, its general contour depending much upon the temperament of the subject. Within the body of the bone is an irregular cavity, the *maxillary sinus* or *antrum of Highmore*.

The four surfaces of the body of the bone are the superior or orbital, the lateral or facial, the proximal or nasal, and the posterior or zygomatic.

The superior or orbital surface, which assists in forming the greater portion of the floor of the orbit, is slightly concave over its anterior two-thirds, and somewhat convex over the remaining or posterior third. The three borders of this surface form almost an equilateral triangle, and are named, as indicated by their location, the anterior, the posterior, and the mesial or proximal. The *anterior border* is convex from before backward and slightly concave throughout its length. That portion which forms a part of the lower border of the completed orbit is smooth, while the remaining portion is roughened to form an articulation with the malar bone. The *posterior border* extends from the center of the malar process backward and inward to the orbital process of the palate bone, which articulates with the maxilla at this point. A portion of this border, together with the orbital process of the palate bone, is instrumental in forming the anterior boundary of the sphenomaxillary fissure.

The mesial or proximal border is marked by an irregular thin edge, which articulates with a portion of two bones, the lacrimal anteriorly, and the os planum of the ethmoid posteriorly. Only the posterior two-thirds of this border presents an articulating edge, the remaining or anterior third being smooth and forming the commencement of the lacrimal groove, which in the articulated skull becomes a canal, passing downward and backward to communicate with the inferior meatus of the nose. Beginning at the posterior border of this surface and running forward will be found a deep groove—the *infra-orbital groove.* When near the center of the surface, this groove dips down and is covered by a layer of bone, from which point it passes forward as a canal—the *infra-orbital canal*—making its exit at a point about ½ of an inch below the border of the orbit, near the center of the facial surface of the bone, the foramen thus formed being the *infra-orbital foramen.* Near the root of the nasal process, and immediately within the anterior border of this surface, is a small depression which marks the origin of the inferior oblique muscle of the eyeball.

The Lateral or Facial Surface (Fig. 14).—This surface is made up of the anterior part of the bone; it is irregularly concave, and presents a greater variety in form than any other part of the bone, with the single exception of the palatal process. It is bounded above by the infra-obital ridge, and the roughened surface of the malar process which articulates with the molar bone; below, by the border of the alveolar process; anteriorly, by the frail concave border of the opening into the nasal cavity, the anterior nasal spine, and the perpendicular margins of the bone beneath. Posteriorly, this srface is separated from the posterior or zygomatic surface by a strong projecting eminence, the malar process.

The canine fossa is a deep depression, situated almost in the center of this surface, the bone at this point being extremely thin and closely related to the floor of the antrum. The concave floor of this fossa is frequently traversed by one or two smaller convex ridges, corresponding to the roots of the bicuspid teeth.

The canine eminence is a prominent ridge running vertical to the body of the bone immediately anterior to the canine fossa, and corresponding in position to the root of the cuspid tooth, the size and type of the tooth having much to do with extent and prominence. This ridge gives origin to one of the depressor muscles of the upper lip, and also to one of the depressor muscles of the wing of the nose. The *incisive* or *myrtiform fossa* is a depression found between the canine eminence and the inner margin of the bone. The depth of this fossa is in a measure controlled by the position and size of the teeth, and by the amount of prominence in the canine eminence.

The infra-orbital foramen, which transmits the infra-orbital nerves and blood-vessels, is immediately below the center of the infra-orbital

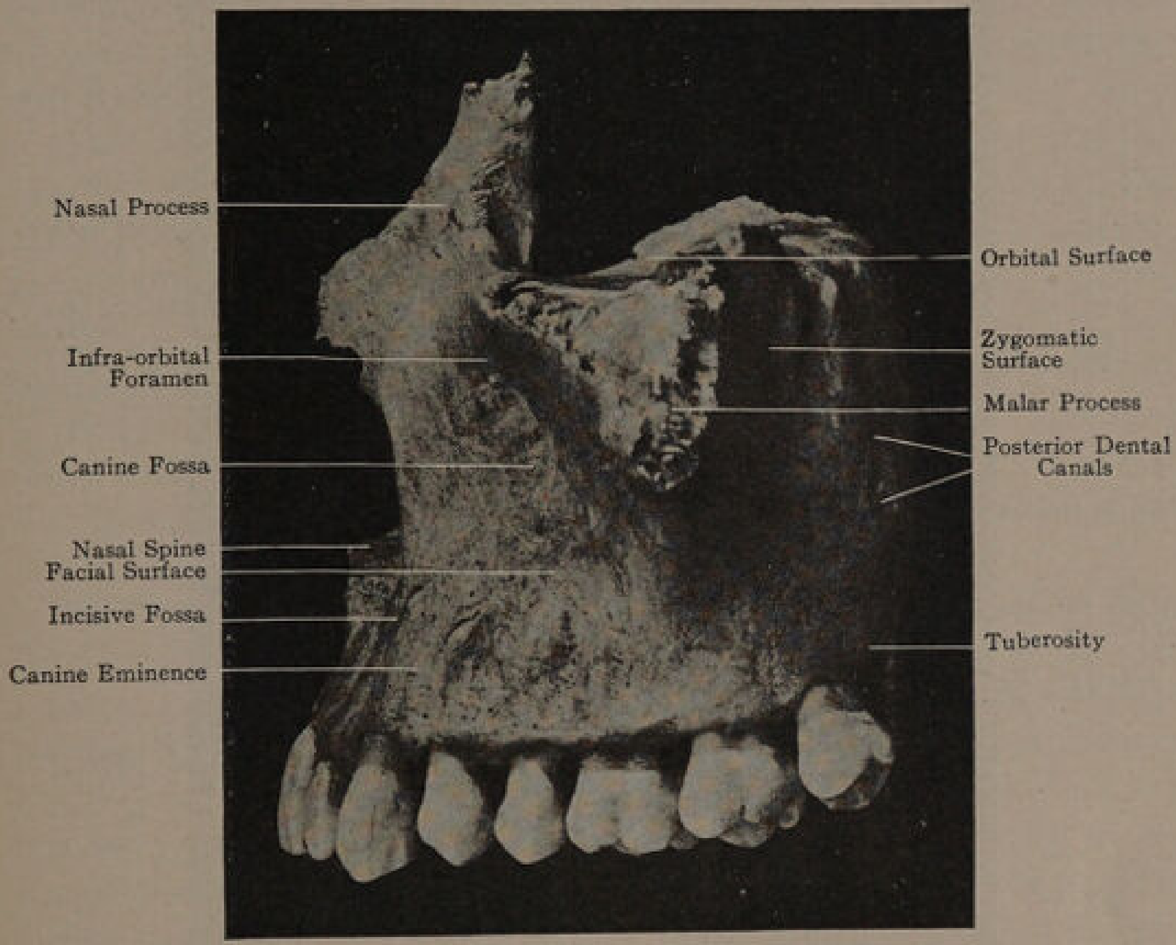


FIG. 14.—Left superior maxilla, outer or facial surface.

ridge, and near the upper margin of the canine fossa. It is oval in form, and faces almost directly toward the median line. Between this foramen and the infra-orbital ridge is the point of origin for the principal elevator muscle of the upper lip, the levator labii superioris proprius. The whole extent of the facial surface may present a number of vertical ridges, or the same space may be regular and smooth, the condition being controlled by the size and shape of the tooth-roots and the thickness of the bone overlying them. One of the elevator muscles of the angle of the mouth, the levator anguli oris, is attached to this surface near the upper border of the canine fossa.

The Proximal or Nasal Surface (Fig. 15).—Above, this surface presents a large, irregular opening into the maxillary sinus, this opening being almost completely closed in the articulated skull by neighboring bones. In front of the opening into the sinus, and standing perpendicular from the body of the bone, is the strong ascending plate of the nasal process, marked near its lower extremity by a rough, horizontal ridge, the *inferior turbinated crest,* which gives attachment

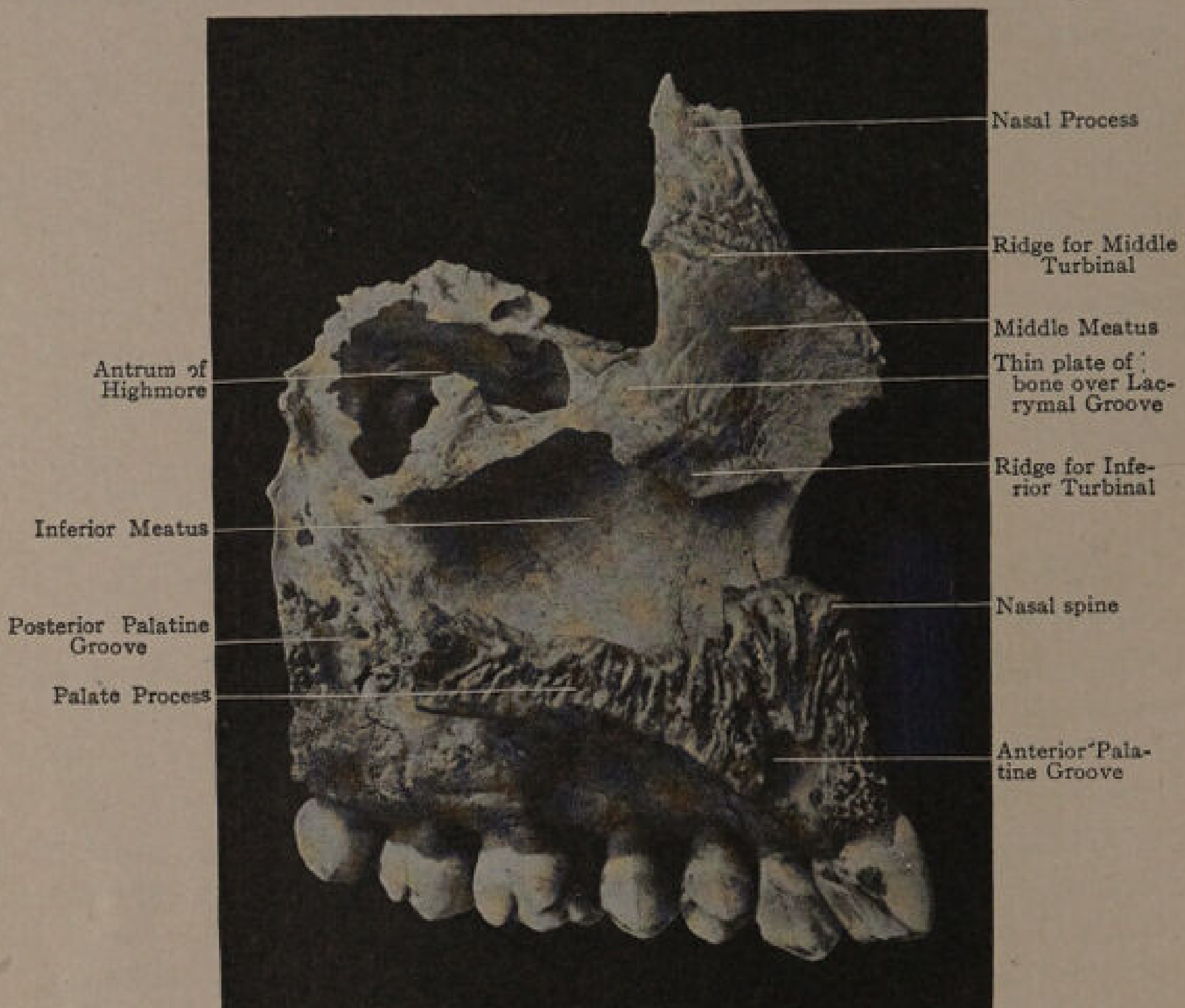


Fig. 15.—Left maxilla, internal, proximal, or nasal surface.

to the inferior turbinated bone. The smooth, concave surface immediately above this ridge corresponds to the middle meatus of the nose, and forms the external wall of that passage. Below the opening into the sinus and the nasal process, and occupying the anterior two-thirds of the middle of this surface, is a large semicircular space, forming the outer wall of the inferior meatus of the nose. Below this space, and projecting inward from the body of the bone, is *the palatal process,* which articulates with the corresponding process of the opposite bone. At the anterior superior angle of the nasal surface, and passing downward just behind the nasal process, is the lacrimal groove. In the articulated skull this groove becomes a canal, the *lacrimal canal*, the ethmoid and the inferior turbinated bones assisting in its formation. The canal passes downward and slightly backward, and opens into the inferior meatus of the nose. It is about ½ of an inch in length, and gives passage to the lacrimonasal duct.

The lacrimal tubercle is a small prominence of bone formed at the junction of the anterior border of this surface, with the external surface of the nasal spine. The extended portion of the lacrimal duct, the lacrimal sac, finds lodgment at this point.

The posterior palatine or palatomaxillary canal commences near the middle of the posterior border of this surface, appearing in the disarticulated bone as a groove, and, passing downward and forward, gives passage to the posterior palatine vessels and anterior palatine nerves. The canal is made complete by the articulation of the maxillar with the vertical plate of the palate bone. On the posterior portion of the nasal surface, extending from the irregular opening into the antrum downward to a point opposite the palatal process, is a roughened surface about ½ of an inch in width, which marks the extent of articulation with the palate bone.

The proximal or nasal surface presents four borders—superior, inferior, anterior, and posterior. The superior border is irregular, and articulates with the lacrimal and ethmoid bones. The inferior border projects inward, and forms a strong horizontal plate—the palatal process. This process defines the border from before backward to the posterior third, at which point it is marked by the lower border of the roughed surface which articulates with the palate bone. The anterior border is sharp, frail, and irregular in outline, and forms the free margin of the opening into the nasal cavity. The posterior border is marked by the inner margin of the zygomatic surface, being smooth upon its upper half, and roughened upon its lower half, at which point it articulates with the palate bone.

The Posterior or Zygomatic Surface (Fig. 15).—This surface is partly convex and partly concave, and is bounded above by a well-defined margin, which serves as the dividing-line between this and the superior or orbital surface. This border is also marked by a roughened margin on the posterior portion of the malar process, the orbital portion of the palate bone articulating at this point. The major portion of this border is smooth and rounded, forming the lower border of the sphenomaxillary fissure, and marked by a notch, the commencement of the infra-orbital groove. The outer border of the surface is formed by the malar process, and by a line drawn from this point directly downward to the alveolar process. The inner border is smooth and somewhat irregular above, while below it is roughened for articulation with the palate bone.

The tuberosity, which also forms a portion of the inferior border of this surface, is a roughened and rounded eminence, and is penetrated by a number of nutrient vessels, which enter the many small foramina at this point. Between the tuberosity and the body of the zygomatic surface are several large apertures leading into canals, which pass into, and give nourishment to, the substance of the bone. These canals transmit the posterior dental blood-vessels and nerves, one of which, after passing over the outer wall of the maxillary sinus, unites with the anterior dental canal. The tuberosity is posterior to, and above, the third molar, in some instances extending directly backward from this tooth for the distance of half an inch or more, but usually the tooth penetrates the base of the tuberosity, leaving but a thin layer of bone posterior to it.

The inferior border of the posterior or zygomatic surface is formed by that portion of the alveolar process which supports the second and third molars.

The bone presents four processes for examination—the nasal, the malar, the palatal, and the alveolar.

The nasal process is strong, and irregular, standing vertically above the body of the bone proper, and forming the lateral boundary of the nose. This process is greatly increased in strength by the infra-orbital ridge joining it at or near its base, and ascending its external anterior surface to some extent. That portion of the process posterior to its junction with the infra-orbital ridge assists in forming the inner wall of the orbit.

The external or anterior surface of the nasal process is marked by a number of shallow grooves, traces of the development of the bone. Scattered over this surface are a number of small foramina, the entrances to minute canals transmitting nutrient vessels to the body of the bone. This surface gives origin to one of the lip muscles, the levator labii superioris alæque nasi.

The internal surface of the nasal process is usually described as including all that portion between the superior border and the floor of the anterior nares. The surface is marked by two concave portions and two ridges. The two ridges divide the surface into three parts forming the superior meatus, the middle meatus, and the inferior meatus of the nose. The *superior meatus* is the smallest of the three, and occupies the slightly concave shape above the superior ridge. The *middle meatus*, partly concave, and partly convex, includes the space between the superior and the inferior ridges, and extends from the free margin of the bone in front to the lacrimal groove behind. The *inferior meatus*, which is much the largest, occupies all that concave surface between the inferior ridge above and the palatal process below, and extends from the anterior margin of the bone backward to the point of articulation with the palate bone. The two ridges previously referred to are known as the *superior turbinated crest*, which articulates with the middle turbinated bone, and the *inferior turbinated crest*, which articulates with the inferior turbinated bone.

The malar process is a large, irregular portion of bone situated at the angle of separation between the facial and zygomatic surfaces, and presents a triangular, roughened surface for articulation with the malar bone. The superior boundary of this process is formed by the orbital surface and the outer end of the infra-orbital ridge; the inferior boundary may be marked by an irregular imaginary line running from the upper margin of the canine fossa to a point between the first and second molars, while the posterior inferior boundary may be traced from the outer superior angle of the zygomatic surface downward and forward to the point above referred to. This process, as well as the nasal process, is subject to much variety in form and general outline. The malar process, assisting as it does in forming what is commonly called the cheek bone, is quite variable in size, and in certain types and races it is so prominent as to become a controlling feature in the facial contour. One of the muscles of mastication—the masseter—has a portion of its origin from the malar process.

The palatal process is more directly interested in the formation of the cavity of the mouth than any other portion of the maxillary bone. By articulating with its fellow of the opposite side, it forms about three-fourths of the hard palate, the remaining fourth being formed by a portion of the palate bones. It is thick and strong, and projects horizontally inward from the inner surface of the body of the bone. It presents two surfaces for examination—a superior or nasal surface, and an inferior or oral surface. The *superior* or *nasal surface* is smooth and more or less concave, and forms the floor of the nares. The *inferior* or *oral surface* is also concave, but is much roughened by numerous small projections, and depressions which lodge the mucous (palital) glands. Upon the anterior portion of this surface are a number of small foramina, which mark the entrance to numerous small canals giving passage to nutrient vessels to supply the body of the bone. Near the center of the posterior third are the antero-posterior grooves, which accommodate the posterior palatine nerves and blood-vessels. This process also presents for examination three borders, the anterior, posterior, and mesial. The *anterior* border is thick and somewhat irregular; the *posterior* border is thin and frail, and articulates with a portion of the palate bone. The *mesial* border presents a wide articulating surface in front, behind it is narrow, the whole extent of this border articulating with the corresponding process of the opposite bone.

The Nasal Spine.—At the anterior superior angle of the palatal process is a well-defined spine—the nasal spine—being formed by a prolongation of the process beyond the level of the facial surface of the bone. This process, when articulated with its fellow of the opposite side, forms the base of the nose.

The Nasal Crest.—Beginning at the base of the nasal spine, and extending backward along the median border of the bone, is a sharp, irregular ledge the nasal crest. This portion of the process articulates with the vomer.

The incisor crest is a continuation of the nasal crest anteriorly, projecting beyond the nasal spine in the form of a sharp, spear-like point.

The incisive foramen, or *foramen of Stenson*, is situated immediately back of the incisor crest, and leads downward and forward from the nasal chamber toward the mouth, entering that cavity just back of the central incisor. This passage in the single bone is a simple groove, but in the articulated skull it becomes the anterior palatine canal, which, after passing downward, opens on the nasal surface of the palatal process by four foramina—the incisive foramina, and the foramina of Scarpa, or the naso-palatine foramina. These foramina transmit the naso-palatine nerves.

The palatal process is subject to a greater variety in form than any other portion of the bone, this variation in the articulated skull being the cause of the many different curves assumed by the roof or dome of the mouth.

The Alveolar Process.—This process forms the lower margin of the bone, and extends from the base of the tuberosity behind to the median line in front, at which point it articulates with the same process of the opposite bone. It has an outer and an inner margin corresponding to the buccal and palatal surfaces of the roots of the teeth, which are firmly imbedded in it. Its general form from before backward is that of a gradual curve, somewhat variable in different bones, the extent of this variation depending on the type or race to which the bone belongs. The body of the process is made up of an outer and an inner plate, which are connected by numerous septa of cancellated bone. The *outer plate* is continuous with the facial and zygomatic surface of the body of the bone, and assists in forming these surfaces. It is quite thin and frail, and the position of the alveoli or tooth sockets beneath are well shown by the numerous vertical ridges upon it. The inferior margin of the outer plate is reinforced by an additional thickness of bone, forming the border of the alveolar sockets. The *inner plate* of the alveolar process is much heavier and stronger than the outer plate, and extends from the margins of the alveoli below to the palatal process above. The inferior margin of this plate is strongly reinforced in the region of the molars. The construction of the inner plate is, to a great degree, controlled by the shape and position of the palatal process. In the lymphatic temperament this process, when articulated with its fellow, forms a flat or shallow dome to the oral cavity, and in so doing gradually curves into the alveolar process, giving it additional thickness. The depth of the process in this type is not great, and the roots of the teeth are short and heavy in proportion. In the bilious temperament the inner alveolar plate is deep and abrupt, extending from the inferior margin upward in almost a perpendicular direction to the palatal process which joins it almost at right angles. The alveolar process gives origin to one of the cheek muscles—the buccinator—which is attached to the outer plate near its upper margin, and directly over the space occupied by the second bicuspid and first molar.

The Alveoli or Tooth Sockets.—These cavities are formed by the outer and inner plate of the alveolar process, and by numerous connecting septa of bone placed between the two plates. The shape and depth of each cavity is regulated by the form and length of the roots of the teeth which they support. The first socket, or that next to the median line, gives support to the central incisor. It forms almost a perfect cone, and has an average depth of half an inch. Its lower border is circular, and the anterior or labial portion describes a larger circle than the posterior or palatal half. The mesial and distal walls are somewhat flattened. The second cavity, proceeding backward from the median line, supports the lateral incisor. It is also conic, but somewhat smaller than the preceding. It is seldom over 3/8 to 5/16 of an inch in depth. It is much flattened on its mesial and distal walls, giving the appearance of an oblong, rather than a round, cavity in transverse section. This socket, as well as that for the central incisor, occupies an almost vertical position in the process. Very frequently the socket for the lateral incisor presents a slight distal curve at its upper extremity. The third socket, or that giving support to the cuspid, is much larger and deeper than either of those previously described. It extends upward, inward, and backward with an average depth of 5/8 to 3/4 of an inch. In transverse section, its labial wall presents a much larger circle than its palatal margin. The labial and distal walls are much flattened and somewhat convex. The general direction of this socket is slightly to the distal. The socket which supports the first bicuspid is usually divided from mesial to distal by a thin septum of bone, thus forming an outer or buccal socket, and an inner or palatal socket. This division seldom exists to the full depth of the cavity, but usually begins about midway of its length. The lower margin of this socket is oblong or egg-shaped, its outer or buccal portion forming a larger curve than its palatal. The lateral walls are slightly concave or flattened, until the point of separation is reached, when they become more circular, the alveoli above this point becoming cone-shaped. It is not uncommon for this socket to be a single cavity, and when thus formed it resembles a flattened cone, with the buccal and palatal margins rounded. The next socket gives support to the second bicuspid, in most instances being a single cavity, but in rare instances it is divided near its upper extremity. In general outline it resembles the socket for the first bicuspid.

The socket for the first molar is much larger than any of those previously described; its inferior margin presents a circular outline on its buccal and palatal portions, the former curve being larger than the latter. The mesial and distal walls are flattened and slightly concave. The upper three-fourths of this socket is divided into three separate compartments, to accommodate the roots common to this tooth, being so arranged that they are upon the buccal and one upon the palatal side. The septa separating the two buccal cavities from the palatal cavity are heavy and strong, while that placed between the two buccal sockets is thin and frail. The two buccal cavities are usually flattened upon their mesial and distal sides. The palatal socket is larger and somewhat deeper than the buccal, the average depth of all being about 1/2 of an inch. The socket for the second molar is similar in most respects to that for the first molar, except that it is somewhat smaller. The same description answers for the third molar socket, which in general is similar to the alveoli for the other molars. It is smaller than the second molar socket, and may be a single cavity, or it may be divided into compartments this resulting from a possible variation in the number of roots formed on this tooth.

Articulations.—Each maxillary bone articulates with its fellow of the opposite side, with the frontal, lacrimal, ethmoid, palate, vomer, malar, and inferior turbinated bones. Occasionally it articulates with the sphenoid bone.

Attachment of Muscles.—The muscles attached to this bone are eleven in number, and are as follows:

Compressor nares,
Orbicularis oris,
Levator labii superioris alæque nasi,
Levator anguli oris,
Depressor alæ nasi,
Internal pterygoid,
Orbicularis palpebrarum,
Levator labii superioris proprius,
Inferior oblique,
Buccinator,
Masseter.

Blood-supply.—Each maxilla receives its vascular supply from numerous large arteries. They are derived from the alveolar, infraorbital, nasopalatal, descending palatal, ethmoidal, nasal, frontal, and facial branches.

Development.—Each maxilla arises from four points of ossification, which are deposited in membrane. These four centers make their appearance as early as the eighth fetal week, this early beginning making it somewhat difficult to accurately follow its growth. The four centers are named, as located, premaxillary, maxillary, malar, and prepalatal. The premaxillary nucleus gives rise to the incisive portion of the bone, or that part supporting the incisor teeth. During early life this part of the bone is separated from the body of the bone, and is known as the premaxillary portion (Fig. 16.) Union between the premaxillary portion and the maxilla proper takes place about birth, and the suture thus formed is visible on the facial surface until the sixth or seventh year, and on the palatine surface until the adult period. The palatal suture extends as far back as the posterior border of the anterior palatal canal. This nucleus also sends a narrow process upward which forms part of the outer boundary of the anterior narial aperture. On the palatal aspect it furnishes a speculum which surrounds the anterior and mesial walls of Stenson's canal. The posterior limit of the premaxillary portion is indicated by the suture on the palatal surface. The maxillary nucleus forms the greater portion of the body of the true maxilla and the nasal process. The malar center gives origin to the malar process, and all that portion external to the infra-orbital groove. The prepalatine center gives rise to the nasal surface of the bone and that portion of the palatal process posterior to Stenson's canal.

Development of the Alveolar Process.—This process is represented at birth by the walls of a deep groove, in which are lodged the partly calcified, deciduous teeth and the germs of most of the permanent teeth (see Development of the Teeth).

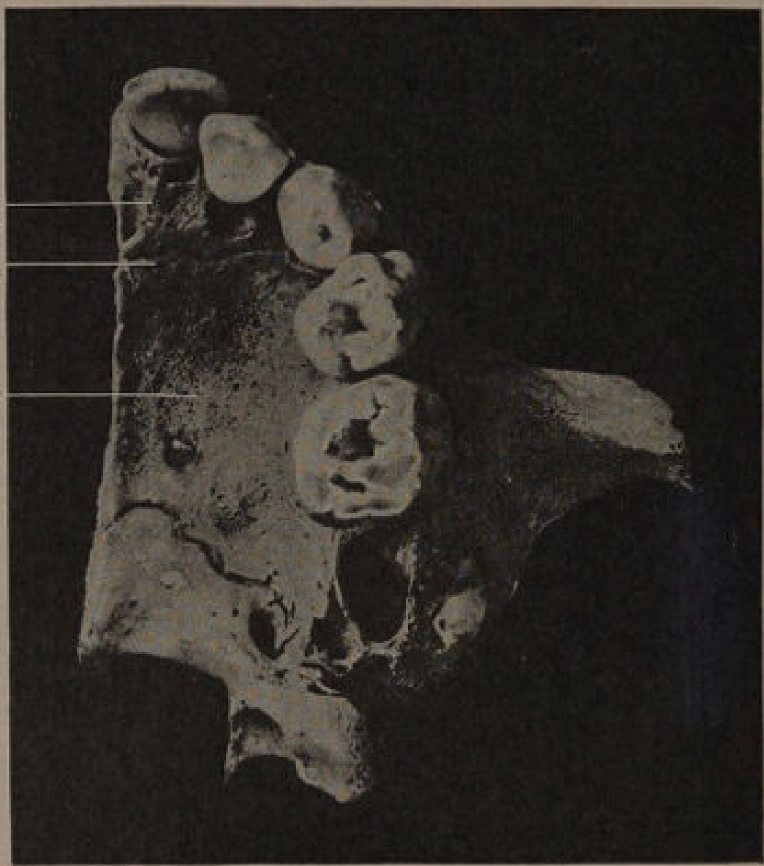


FIG. 16.—Left maxilla, about the third year, enlarged.

The growth of the process continues with the growth of the teeth until, finally, at about the seventh month after birth, the dental organs are completely encased within its walls. With the decalcification of the roots of the deciduous teeth comes the loss of the process surrounding them, and, as the permanent teeth advance to take their place in the arch, the process is again built up about their roots.

The Maxillary Sinus, or Antrum of Highmore* (Fig. 15).—This is a cavity situated within the body of the maxilla. Its general shape is that of a pyramid, with its base directed toward the median line,

* Described separately, in preference to including in general description of the bone.

or nasal surface, its apex pointing toward and extending into the malar process, and, in some instances, penetrating the malar bone. The size of the cavity varies in different subjects and in the opposite bone of the same subject. The average capacity is about three fluidrams, but this may be increased to six or eight fluidrams. The size of the bone and the prominence of the malar process control, in a measure, the size of the cavity; but not infrequently the largest bone will present the smallest sinus. Sex also appears to exert a controlling influence over the capacity of the cavity, it being greater in the male than in the female. In youth the cavity is quite small, the walls being much

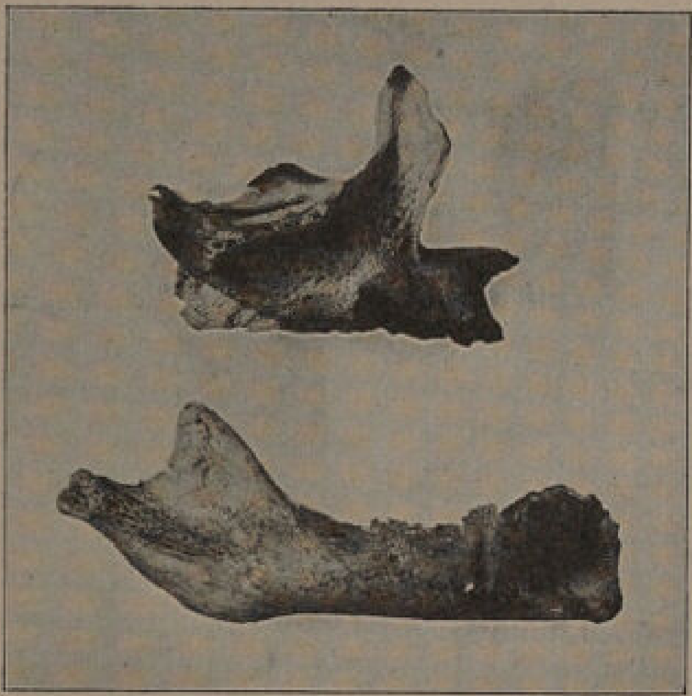


FIG. 17.—Developing maxillary bones about the fifth month after birth.

thicker proportionately than in the adult. The walls of the sinus in the matured subjects are quite thin and frail, and are four in number. The superior wall is formed by a thin plate of bone, the floor of the orbit. This surface is almost flat, and serves as a roof to the cavity. Near the anterior margin of this surface is a thick rib of bone which marks the course, and forms one of the walls of the infra-orbital canal.

The inner wall, or that looking toward the nasal surface, is formed by the thin bony layer separating this cavity from that of the nares. The outer or lateral surface, formed by the facial and zygomatic surfaces of the bone, is smooth, and convex from before backward. Near the center of this surface the cavity may penetrate the malar process, and in the disarticulated skull would present an opening at this point. The inferior wall is formed by the alveolar process, and is marked by a number of irregular eminences corresponding to the roots of the neighboring teeth. The teeth referred to are generally the first and second molars, and occasionally the second bicuspid. It is not unusual for the roots of one or more of these teeth to penetrate the floor of the sinus, in consequence of which the lining membrane of the cavity may become inflamed or infected from disease originating in these teeth.

The inferior wall is much the strongest of the four, and, besides the uneveness of the surface produced by the tooth-roots, it frequently supports a number of thin, bony partitions, which may completely or partly divide the floor of the cavity into numerous small compartments.

The posterior portion of the lateral wall is marked by the posterior dental canals, which give passage to the posterior nerves and blood-vessels. In like manner the anterior portion of the lateral wall is grooved for the reception of the anterior dental nerves and blood-vessels. Upon the inner wall, or that forming the base of the pyramid, is an opening which communicates with the middle meatus of the nose. In the articulated skull this opening is quite small, being from 1/8 to 1/4 of an inch in diameter. The correct idea of this opening cannot be obtained by study of the individual bone, as the numerous perforations then to be observed are closed or partly closed by articulation with adjacent bones. The mucous membrane lining the nasal cavity enters the sinus through the small aperture above referred to, and forms a continuous lining over its entire surface. M. H. Cryer by his investigations has thrown much light upon the relations of the maxillary sinus to the mouth and teeth, and demonstrated beyond a doubt that the relationship existing between the parts is susceptible to extensive variation. In some instances the cavity upon one side will be large, with its floor broken by the tooth-roots, while that upon the opposite side will be extremely small and far removed from the root apices. In fact, these researches have so revolutionized the subject under consideration that the foregoing description is only reliable in so far as it treats of the conditions most frequently met with.

THE PALATE BONE

The *palate bones* (Fig. 18, two in number, are situated immediately posterior to the two maxillæ, and with them complete the hard palate. They also assist in forming the boundaries of the orbital and nasal cavities, the sphenomaxillary, the sphenopalatine, and the pterygoid fossa, the sphenomaxillary fissure, the posterior ethmoidal cells, and the maxillary sinus. When in position in the skull, these bones are wedged between the maxillæ and the sphenoid bone. They are rectangular in outline, and each bone presents for examination a horizontal and a vertical plate, a tuberosity, and two processes, the orbital and the sphenoid.

The horizontal plate, smaller than the vertical, assists in forming the hard palate, and corresponds to the palatal process of the maxilla. In entering into the construction of the hard palate the form of this plate varies to the same degree as the palatal plate of the maxilla. In general, it is described as quadrilateral in shape, having two surfaces and four borders. The superior surface, which is concave from side to side, forms

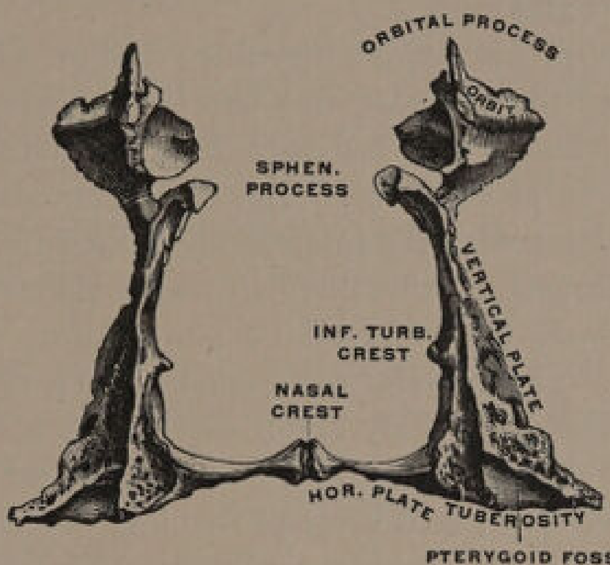


FIG. 18.—The two palate bones in their natural position, dorsal view. (*Testut.*)

the posterior floor of the nasal chamber. The inferior surface completes the hard palate posteriorly, and presents, near its posterior border, a transverse ridge for the attachment of one of the muscles of the soft palate (the tensor palati); the anterior border is serrated for articulation with the palatal process of the maxilla. The posterior border is free, curved, and sharp, and marks the posterior boundary of the hard palate. At the median line this border terminates in a sharp point, which, when articulated with the corresponding bone of the opposite side, forms the posterior nasal spine; to this point the azygos uvulæ muscle is attached. The external border is situated just below the junction of the horizontal and vertical plates. In this portion is a groove which assists in forming a portion of the posterior palatal canal. The internal border is broad and serrated for articulation with its fellow of the opposite side. When the palate bones are in position in the skull, these borders form a ridge, continuing the crest formed by the palatal process of the maxilla, this crest receiving the inferior border of the vomer.

The vertical plate is thin and frail and extends from the floor of the nasal chamber below to the upper extremity of the sphenopalatine notch above. It has two surfaces and four borders.

The external surface is roughened for articulation with the maxilla, excepting a small triangular surface near the upper extremity, which forms a portion of the sphenomaxillary fossa, and a small portion near the middle of the surface close to the anterior border, which forms a portion of the wall of the maxillary sinus. Near the posterior boundary of this surface is a vertical groove, which forms, when articulated with the maxilla, the posterior palatal canal, transmitting the descending palatal nerves and vessels.

The internal surface is divided into three shallow depressions by two transverse ridges—the superior and inferior turbinated crests. The lower depression thus formed assists in the construction of a portion of the interior meatus of the nose. The crest immediately above this depression articulates with the inferior turbinated bone. The central depression, the largest of the three, forms a portion of the middle meatus of the nose, the crest above articulating with the middle turbinated bone. The superior depression—much smaller but deeper than either of those previously described—forms a large part of the superior meatus. The anterior border of the vertical plate is thin and sharp, the inferior turbinated crest protruding near the center of the border, and forming the maxillary process. This process assists in closing the maxillary sinus by being received into the maxillary fissure of the maxilla. At the upper extremity of this border is the orbital process, which presents for examination five surfaces, three of which are articular. The anterior or maxillary surface is directed outward, upward, and downward. It is oblong in form and articulates with the posterior superior angle of the inner surface of the maxilla. The posterior or sphenoidal surface is directed backward, upward, and inward, and articulates with the vertical plate of the ethmoid bone. The superior or orbital surface is triangular in form, extending upward and outward, forming the posterior angle of the floor of the orbit. The external or zygomatic surface is smooth, oblong, and directed outward, backward, and downward, forming a portion of the sphenomaxillary fossa.

The posterior border of the vertical plate is irregular and serrated, and comes into relation with the internal pterygoid process, terminating below in a prominent tuberosity. This presents three grooves or flutes. The inner receives the internal pterygoid, the outer the external pterygoid process, while the middle groove completes the pterygoid fossa, and gives attachment to a portion of the internal pterygoid muscle. This process also gives rise to the superior constrictor of the pharynx. Passing through the tuberosity are a number of small canals, those on the nasal side being the accessory palatal canals. Near the junction of the tuberosity with the horizontal plate is the opening of the posterior palatal canal, and beyond this the small external palatal canals.

The sphenoidal process is at the superior end of the posterior border. It is variable in shape and curves upward, backward, and inward. It presents a superior, an external and an internal surface, and two borders—an anterior and a posterior.

The superior surface, the smallest of the three, is marked by a groove, which assists in forming the sphenopalatine canal. This surface articulates with the horizontal portion of the sphenoidal turbinated bone. The external surface assists in forming the sphenomaxillary fossa by its anterior portion, while the posterior portion is rough for articulation with the pterygoid plate of the ethmoid bone. The internal surface is instrumental in forming a portion of the outer wall of the posterior nares, and for this purpose is smooth and concave. The anterior border forms the posterior margin of the sphenopalatine notch. The posterior border is serrated, and articulates with the inner surface of the pterygoid process.

The superior border of the vertical plate is divided by a deep notch or foramen, which divides the orbital from the sphenoidal process. This opening is the sphenopalatine notch or foramen, and transmits the sphenopalatine vessels and nerves from the sphenopalatine fossa to the nasal chamber.

The inferior border of the vertical plate joints the external border of the horizontal plate. Extending downward and backward from the inferior and posterior borders is the pyramidal process, the borders of which are serrated for articulation with both pterygoid plates of the sphenoid bone.

Articulations.—The palate bone articulates with the sphenoid, superior maxilla, sphenoidal turbinated, inferior turbinated, ethmoid, and with its fellow of the opposite side.

Attachment of Muscles.—The following muscles are attached to the palate bone:

Tensor palati,	Internal pterygoid,
Azygos uuulæ,	Superior constrictor of pharynx.

Blood-supply.—The arteries which supply this bone are derived from branches of the descending palatine, the sphenopalatine, and pterygopalatine.

Development.—The palate bone is developed from a single center deposited in membrane. This center makes its appearance about the eight or ninth fetal week, near the line of junction between the horizontal and vertical plates. At birth these plates are about the same length, but soon after this period, when the nasal sinuses increase in height, the vertical plate begins to lengthen, and continues to do so until it becomes nearly double the length of the horizontal plate.

THE MANDIBLE

The Mandible, or Lower Jaw Bone (Fig. 19).—This bone, having no osseous union with the skull proper, may be considered as one of its appendicular elements. It is the heaviest and strongest bone of the head, gives support to the sixteen lower teeth, and serves as a framework for the lower half or floor of the mouth. It is situated at the lower extremity of the face, and immediately below the maxillary and malar bones, while its posterior extremities rest against the glenoid fossa of the temporal bone, forming a movable articulation with this cavity. In general, the bone is symmetric in outline, and presents for examination a horizontal portion, or *body*, and two vertical portions, or *rami*, which in the adult are almost perpendicular to, or at right angles with, the body of the bone.

The body, or horizontal portion, consists of two identical halves, which meet at the median line and form a slight vertical ridge, the *symphysis*. This line indicates the point of union between the two lateral halves, which at birth are usually separated, but soon after this period become firmly united. Each lateral half of the body presents two surfaces—an external and an internal; and two borders—a superior and an inferior.

The external or facial surface (Fig. 19) is smooth and convex, and furnishes a number of points for examination. Beginning at the median line, the symphysis ends below in a prominent triangular surface—the *mental protuberance.*

The Incisive Fossa.—Passing backward from the symphysis, and immediately above the triangular ridge which forms the mental process, is a decided but shallow depression—the incisive fossa. This fossa gives origin to one of the elevator muscles of the chin—the levator menti. Slightly posterior to and below this fossa, on a line corresponding to the position of the cuspid tooth, is an oblong depression for the origin of the depressor muscle of the lower lip—depressor labii inferioris.

The External Oblique Line.—Extending obliquely across the facial surface from the mental process to the base of the vertical portion of the bone, and continuous with its anterior margin, is a well-defined ridge—

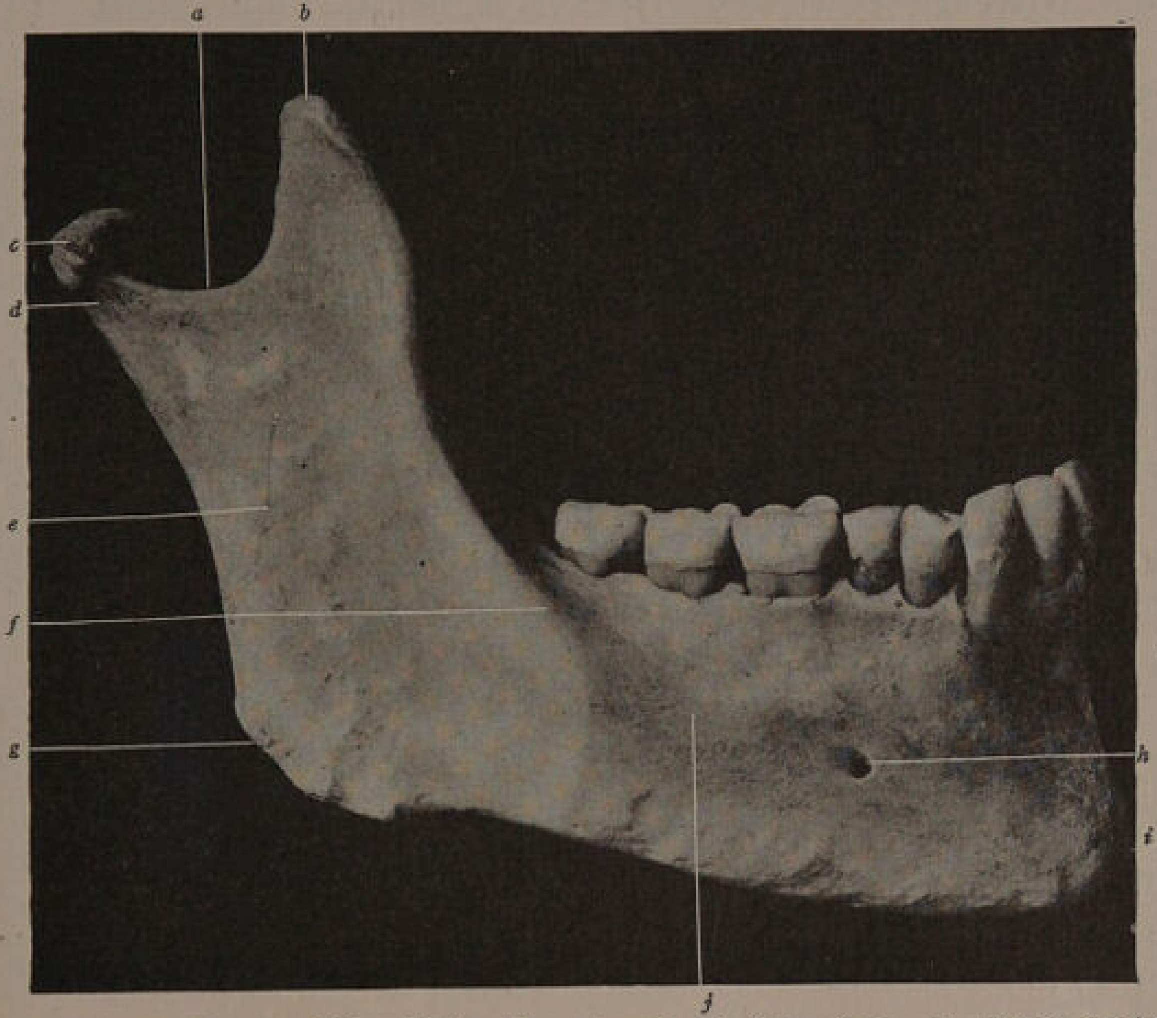


FIG. 19.—The mandible. Right side, external or facial surface. *a*, sigmoid notch; *b*, coronoid process; *c*, condyle; *d*, neck of condyle; *e*, ramus; *f*, external oblique line; *g*, angle *h*, mental foramen; *i*, mental protuberance; *j*, body.

the external oblique line. Near the center of this ridge, or below the position occupied by the bicuspid and first molar, is the point of attachment of the depressor muscle of the angle of the mouth—the depressor anguli oris. Somewhat anterior to and above this point is the origin of the depressor muscle of the lower lip—the depressor labii inferioris. Between the line of origin of the depressor anguli oris and the inferior border of the bone is a roughened surface for the attachment of the platysma myoides muscle. This roughened surface divides the body of the bone into an upper and a lower portion. That portion above is known as the alveolar or mucous portion, while that below is called the basilar or non-mucous portion. The attachment of the platysma myoides muscle at this point marks the lower boundary or floor of the mouth. The superior or alveolar portion of the bone is within the cavity of the mouth, and is covered with mucous membrane and mucoperiosteum; while the inferior or basilar portion is outside and below the cavity, and is covered with periosteum similar to other bones.

The Mental or Anterior Dental Foramen.—Midway between the superior and inferior border of the body, and usually below the second bicuspid tooth, is a large foramen—the mental or anterior dental foramen—giving passage to the mental branches of the inferior dental nerve and accompanying blood-vessels. The position of this foramen is not constant, but, as previously stated, it is usually below the second bicuspid, or between this and the first bicuspid. The buccinator muscle, which forms a large portion of the lateral wall of the mouth, has its origin from the facial surface of the mandible, being attached to the alveolar portion immediately below the molar teeth.

The Internal Surface of the Body of the Bone (Fig. 20).—The median line is marked by a slight vertical depression, representing the line of union, and corresponding to the symphysis externally.

The Mylohyoid, or Internal Oblique Ridge.—The internal surface is divided into two portions by a well-defined ridge—the mylohyoid, or internal oblique ridge. It occupies a position closely corresponding to the external oblique ridge on the facial surface. Beginning near the base of the bone at the median line, it passes backward and upward, increasing in prominence until the base of the vertical portion of the bone is reached, into which it gradually disappears. This ridge gives origin to the mylohyoid muscle, which forms the central portion of the floor of the mouth. Corresponding to the facial surface of the bone, the attachment of the mylohyoideus muscle forms the dividing line between the mucous membrane and mucoperiosteum covering the upper portion of the body of the bone, and the periosteum covering the inferior portion.

The Genial Tubercles.—Near the lower third, at the median line, is a roughened eminence—the genial tubercles. Taken collectively, these are in two pairs—a superior and an inferior. The superior pair (usually the largest) give origin to the geniohyoglossus muscle, and the lower pair to the geniohyoid muscle.

The Sublingual Fossa.—By the side of the genial tubercles, and above the mylohyoid ridge, is a shallow, smooth depression—the sublingual fossa. One of the salivary glands—the sublingual—is partially imbedded in this fossa.

The Digastric Fossa.—Below, the mylohyoid ridge, and near the median line, is a slight depression—the digastric fossa—which affords attachment for the digastric muscle.

The Submaxiliary Fossa.—In the center of the internal surface, extending from before backward, between the mylohyoid ridge and the

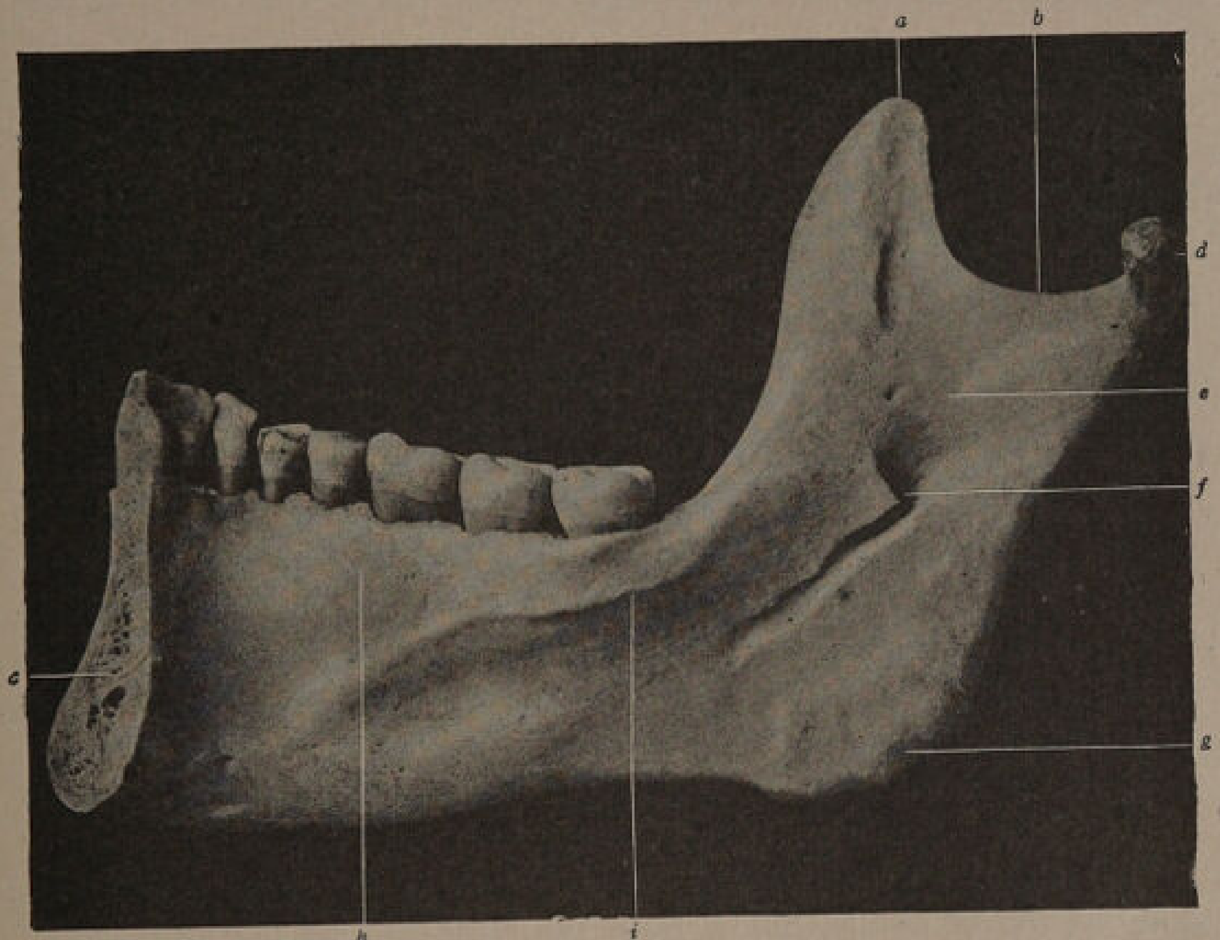


FIG. 20.—The mandible. Right side, internal surface. *a*, Coronoid process; *b*, sigmoid notch; *c*, cancellated tissue; *d*, condyle; *e*, ramus; *f*, inferior dental or mandibular foramen; *g*, angle; *h*, body; *i*, internal oblique line.

lower border of the bone, is an oblong depression—the submaxillary fossa. In this fossa rests another of the salivary glands—the maxillary.

The Superior or Alveolar Border.—This border extends from the junction of the body, with the vertical plate on one side, to the corresponding point on the other. The construction of this border is similar to the alveolar border of the maxillæ. At the anterior portion it is narrow, but gradually increases in width as it proceeds backward—in some instances following the line of the body of the bone; in others, nclining inward, or to the lingual. Each lateral half is marked by eight sockets, for the accommodation of the sixteen lower teeth. They are smaller in proportion than the alveolar sockets in the maxillæ. The socket nearest the median line receives the central incisor, and is the smallest of the number. It has an average depth of 7/16 of an inch, is conic from above downward, oblong in transverse section, with its lateral walls flattened. The second socket gives support to the lateral incisor; it is a trifle larger than the central incisor socket, but in other respects is quite similar. The socket for the cuspid is situated at the anterior angle of this border, and is much larger and deeper than the incisor sockets. It has an average depth of 9/16 of an inch; its lateral walls are compressed, and sometimes slightly concave. In transverse section the labial wall forms a larger curve than the internal or lingual wall. Passing backward, the next two sockets are for the support of the bicuspids; they are circular in outline, with an average depth of 1/2 of an inch. The cavity for the first bicuspid is usually a little larger than that for the second. In rare instances one or the other of these sockets will be divided for the accommodation of two roots. The sockets for the first and second molars present a circular outline upon their free margins, but below they divide into two flattened, cone-shaped cavities—one anterior and one posterior. The flattened sides of these cavities are concave in the center, and at their lower third curve backward. The average depth of these sockets is 1/2 of an inch. The socket for the third molar, like its superior fellow, is variable both in form and position, frequently being crowded inside or outside of the tooth-line. In some instances it is divided into two or more compartments. The average depth is not over 3/8 of an inch.

The alveolar process, which composes the superior border of the body of the mandible, differs from the same process in the maxillæ in one very important particular: instead of the outer plate being thin and frail, it is equally as heavy as the inner or lingual plate. When the tooth-line is inclined inward from the body of the bone, the posterior outer wall is much heavier than the inner or lingual wall.

The Inferior Border of the Body of the Bone.—This border extends from a slight depression, to be observed at the point of union between the body and ramus, to the corresponding point upon the opposite side. It is strong, rounded, and compact, and gives to the bone the greatest portion of its strength. Near its junction with the ramus is the facial notch, so named from the facial artery passing over this point.

The Ramus, or Vertical Portion of the Bone.—This vertical plate is quadrilateral in outline, and presents two surfaces—external and internal; four borders—superior, inferior, anterior, and posterior; and two processes—the condyloid and the coronoid.

The external surface is flat and smooth. Near the center it is slightly concave and roughened for the attachment of one of the muscles of mastication—the masseter.

The internal surface presents near the center an oblong opening—the *inferior dental* or *mandibular foramen*—leading into the inferior dental or mandibular canal. Surrounding this foramen, on its posterior internal margin, is the mandibular spine, to which is attached the sphenomandibular ligament. Running obliquely downward from the base of the foramen, and beneath the spine, is a decided groove—the mylohyoid groove—which accommodates the mylohyoid nerve, artery, and vein, which pass forward to supply the floor of the mouth. Below and behind this groove the surface is roughened for the attachment of another muscle of mastication—the internal pterygoid.

The Inferior Dental or Mandibular Canal.—Beginning at the foramen of the same name, this canal enters the body of the bone, passes downward and forward horizontally, until it finds an exit at the mental foramen. This canal lies immediately below the alveolar sockets, and from it are given off smaller canals which open into the tooth-sockets through minute foramina. Near the mental foramen the canal divides into a number of smaller ones, which pass forward through the substance of the bone to the sockets of the cuspid and incisor teeth.

The Superior Border of the Ramus.—This border is crescent-shaped, and is otherwise known as the *sigmoid notch*. Arising from its anterior portion is a flattened, cone-shaped process—the *coronoid process*. On its posterior portion is a rounded or oblong eminence—the *condyloid* process. The concave or crescent-shaped margin of this border is thin and smooth in front, becoming wider and heavier as it approaches the condyle.

The Coronoid Process.—The anterior margin of this process, being a continuation of the external oblique line, is heavier at the base than at the apex. The outer surface is smooth, and affords attachment to the masseter, and a few fibers of the temporal muscle. The internal surface is marked by a vertical ridge, which passes downward, increasing in size, and finally joining the internal oblique line at a point posterior to the third molar. The surface anterior to this ridge is grooved, and gives attachment to a part of the temporal muscle above, and the biccinator muscle below. The surface posterior to this ridge affords attachment for the greater part of the temporal muscle. The posterior border of this surface is thin, and forms the anterior margin of the sigmoid notch.

The Condyloid Process.—This may be described as the expanded extremity of the posterior border of the ramus, and is quite variable in form (see Occlusion of the Teeth). It is divided into a superior or articular portion, and an inferior portion, or neck.

The articular portion of the condyle is more or less oblong, and is convex above, fitting into the glenoid fossa of the temporal bone, and forming, with the interarticular cartilage which lies between the two surfaces, the temporomandibular articulation.

The neck is that constricted portion immediately below the articular surface. It is flattened in front and presents a pit—the pterygoid fossa—to which a portion of the pterygoid muscle is attached. Immediately below the point of junction between the neck and the articular surface externally is the condyloid tubercle, to which is attached the external lateral ligament.

The Inferior Border of the Ramus.—This border is thick, rounded, and continuous with the lower border of the body of the bone. At the point of junction between this and the posterior border is the angle of the jaw. The angle has a slight outward inclination, and is roughened for the attachment of a part of the superficial portion of the masseter muscle.

The anterior border has been described in connection with the coronoid process.

The posterior border is smooth and rounded on its upper half, the lower half being roughened for the attachment of the stylomaxillary ligament.

Attachment of Muscles.—The following muscles are attached to the mandible:

Buccinator,	Superior constrictor of pharynx,
Depressor labii inferioris,	Masseter,
Depressor anguli inferioris,	Orbicularis oris,
Levator menti,	Internal and external pterygoid,
Geniohyoglossus,	Geniohyoid,
Platysma myoides,	Mylohyoid,
Digastric,	Temporal.

Development.*—On account of its early functional activity, the mandible is among the first bones to ossify. Development takes place from six centers for each lateral half, the nuclei being deposited as early as the sixth or eighth fetal week, and after their establishment the developmental process takes place very rapidly. The six centers of ossifica-

* See "Development of the Teeth."

tion are principally named according to their position. The early preparation for the development of the bone is found in the appearance of what is known as the mandibular plates, which are thrown out from the sides of the cranial base, and finally unite at the median line. Not long after this period a cartilaginous band—Meckel's cartilage—is developed in the substance of the mandibular plates, and it is about

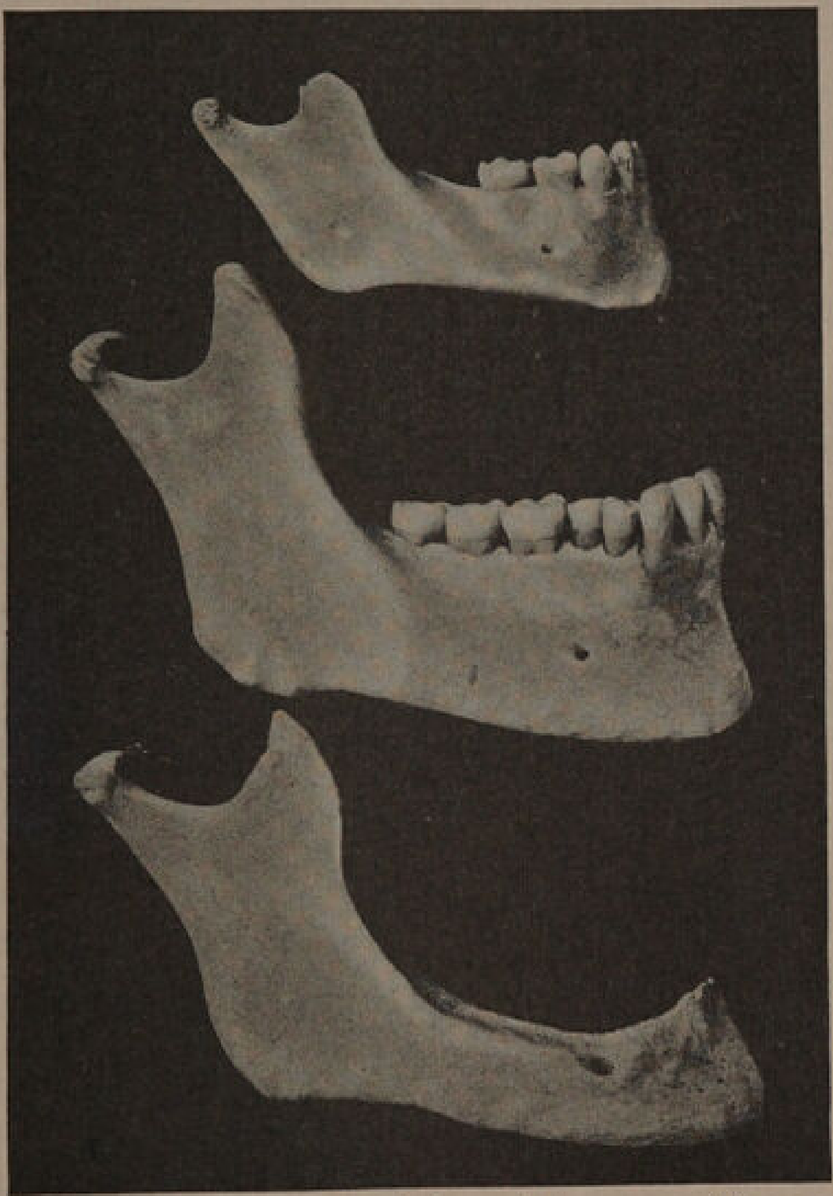


Fig. 21.—Chart showing the evolution and degeneracy of the mandible.

this cartilaginous framework that ossification first takes place. The various centers are distributed along the line of Meckel's cartilage, and are named as follows: Mental, dentinary, coronoid, condyloid, angular, and splenic. The *mental* center provides for the development of that portion of the bone between the median line and the mental foramen. The *dentinary* center forms the lower border and outer plate, and provides for the establishment of the crypts inclosing the developing tooth-follicles.

The *coronoid* and *condyloid* centers are both instrumental in constructing these processes, and the angular center provides for the angle of the bone. The *splenic* center is somewhat later in making its appearance, and from it the inner plate of the mandible is formed, the line of union between it and the dentinary center being indicated by the mylohyoid groove. While, as above stated, most of the centers of development are along or near the line of Meckel's cartilage, the condyloid and coronoid processes are developed from other cartilage. Soon after birth the two lateral halves of the mandible begin to coalesce at the median line, this union taking place from below upward; and by the eighth or tenth month union is complete and the individual bone is established. The mandible is subject to a continuous change in form, not only in regards to its general contour, but also accommodating itself to the movements and growth of the teeth, the former taking place at or about the angle, while the latter occurs in the alveolar portion of the bone.

Figure 21 represents the changes which take place in the angle of the mandible from youth to old age. It will be observed that the angle formed in the adult bone, with the teeth in position, is almost a right angle; and that in youth, with the deciduous teeth in position, the angle is much more obtuse, which condition is again approached in old age.

THE HYOID BONE

This is a U-shaped bone placed in the upper part of the neck at the median line near the base of the tongue. It has no bony connection with other bones; it is classed as a floating bone. It is made up of a body and four processes.

The *body*, or central portion, is quadrilateral in outline, somewhat oblong from side to side, with its anterior aspect convex, and presents a longitudinal ridge which divides it into a superior and an interior portion. It is also usually divided at the median line by a slight vertical ridge. At the point of junction between the longitudinal and vertical ridges a slight tubercle is formed. The anterior surface is given up to the attachment of muscles. The posterior surface of the body of the bone is concave and smooth, and is directed backward and downward. The superior border gives attachment to the thyrohyoid membrane, while the inferior border, which somewhat thicker, gives attachment to the sternohyoid and thyrohyoid muscles.

The processes known as the *greater* and *lesser cornua* are four in number, one of each kind on either side.

The *greater cornua* project backward and upward, and their lower borders and anterior surfaces are occupied with muscles. The thyrohyoid ligament is attached to the posterior terminal corner.

The *lesser cornua* are short conical pieces of bone, and project upward and backward from the extremities of the body of the bone. They give attachment to the stylohyoid ligaments.

Development.—Ossification takes place from five centers, one for the body of the bone and one for each cornua.

Attachment of Muscles.—

Geniohyoglossus,	Sternohyoid,
Geniohyoid,	Lingualis,
Thyrohyoid,	Omohyoid,
Mylohyoid,	Digastric,
Hyoglossus,	Middle constrictor.

The thyrohyoid ligament, as well as the stylohyoid, and the thyrohyoid membrane are also attached to this bone.

CHAPTER IV

The Temporomandibular Articulation—The Muscles of Mastication

TEMPOROMANDIBULAR ARTICULATION

Although external to the cavity of the mouth, this articulation is so closely associated with the function of the teeth that it seems important that a brief description of its construction and action should be given. It receives its name from the two bones which enter into its formation—the temporal and the mandible.

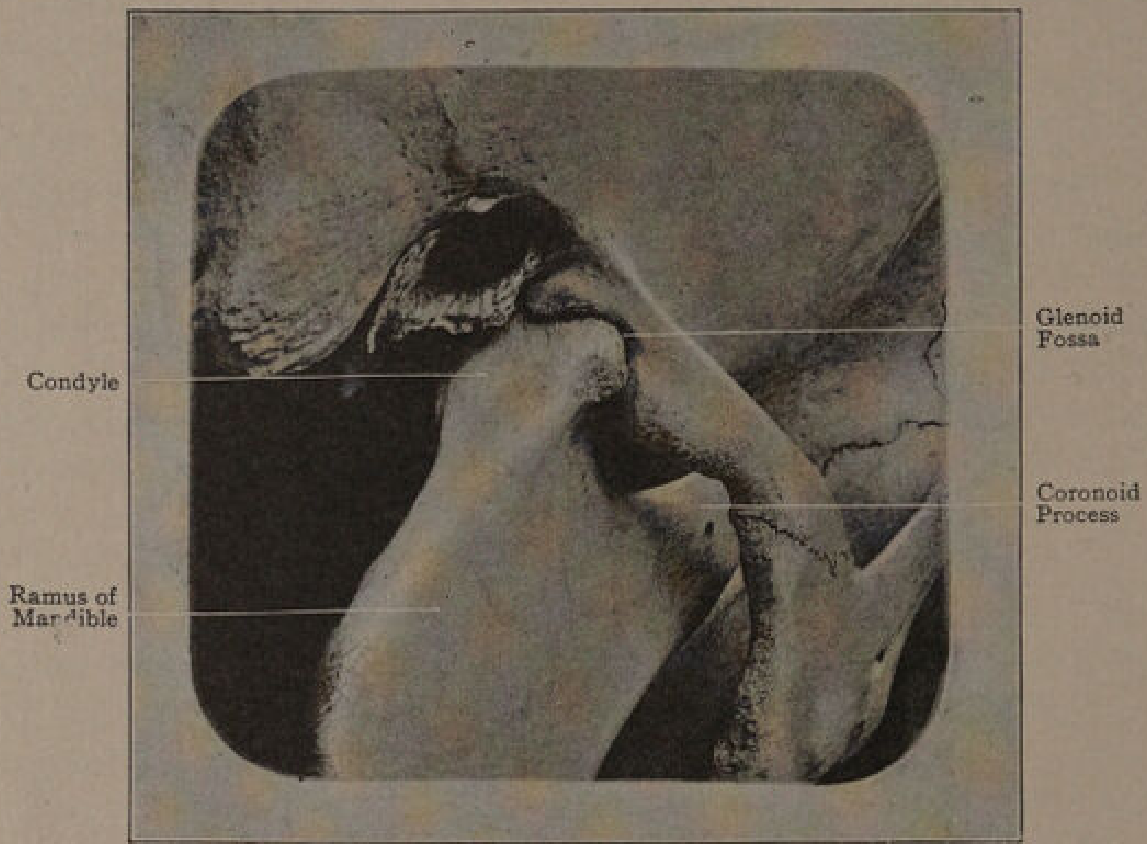


Fig. 22.—Temporomandibular articulation.

This joint is the seat of motion in the mandible, and entering into its construction are bones, ligaments, cartilage, and synovial membrane, these being the tissues essential to all diarthroidal or movable articulations. The various movable joints of the body are classified according to the nature of the movement, and correspond to the mechanical actions known as hinge joint, ball-and-socket joint, gliding joint, pulley joint, etc. The temporomandibular joint is of the diarthrodial class, and the movements which it possesses are a combination of the gliding movement (arthrodia) and of the hinge movement (ginglymus). The bony parts entering into the formation of the joint are the anterior portion of the glenoid fossa of the temporal bone and the condyloid process of the mandible (Fig. 22).

The glenoid fossa may be described as an oblong cavity, with its base directed upward, being bounded anteriorly by a heavy ridge of bone (the anterior root of the zygoma), posteriorly by an irregular, flattened portion of the bone (the tympanic plate of the petrous portion), internally by a union of the anterior and posterior boundaries, and externally by the middle root of the zygoma. The floor of the fossa is traversed by a well-marked fissure—the glenoid fissure (fissure of Glaserius)—which divides the fossa into two portions, an anterior and a posterior. The anterior half is deeper and more concave than the posterior, and is the articulating portion, being occupied by the condyle, while the posterior half gives lodgment to a part of one of the salivary glands, the parotid.

The condyloid process of the mandible having been described with that bone, reference will here be made to the variety of forms which it presents, and the influence which it exerts over the nature of tooth occlusion and articulation. This process, when narrow and oblong (Fig. 22), closely resembles the ginglymus, or hinge joint, and will be accompanied by teeth presenting deep, penetrating cusps, forming a positive and well-locked occlusion (Fig. 23, *B*), with little or no lateral motion. If the condyle presents the appearance shown in figure 24, which resembles the enarthrodia, or ball-and-socket joint (although it cannot be considered as such), the teeth associated with such a formation will be provided with short, rounding cusps, and the occlusion will be loose and wandering (Fig. 23, *A*). This difference in the form of the condyle will be accompanied by a corresponding variation in the concavity of the glenoid fossa. Not only does the osseous structure in the joint partake of individual characteristics, but likewise the muscles and ligaments; their functions being to operate the articulation, they are developed in accordance with the action required of them, which action is, in a measure, dependent upon the conditions existing in the mouth.

Both the condyle and the glenoid fossa are covered with articular cartilage. In the latter this membrane extends over its anterior border, to facilitate the play of the joint. The condyle is held in position in the fossa by three ligaments—the capsular, the sphenomaxillary, and stylomaxillary. The *capsular ligament* is divided into four portions—anterior and posterior, external and internal. The anterior portion consists of a few fibers connected with the anterior margin of the fibrocartilage, attached below to the anterior margin of the condyle and above to the

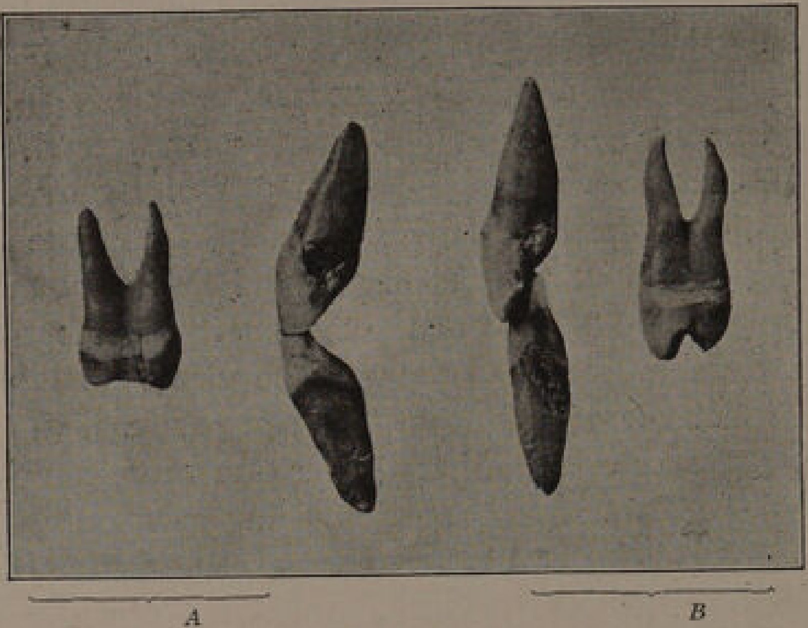


FIG. 23.

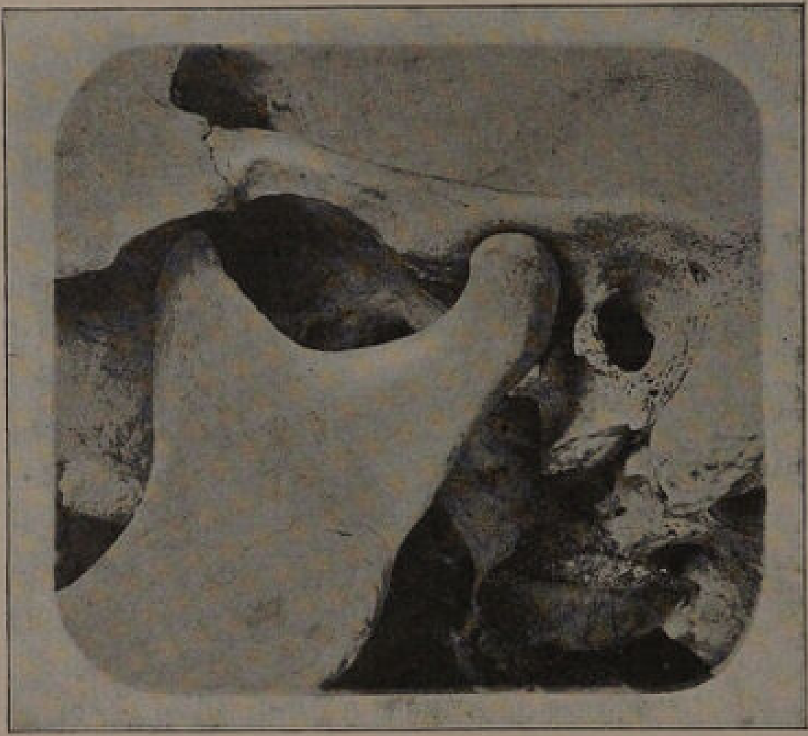


FIG. 24.

front of the glenoid ridge. The posterior portion is attached above just in front of the glenoid fissure, and is inserted into the posterior margin of the ramus of the maxilla just below the neck of the condyle. The external portion, otherwise known as the external lateral, is the strongest portion of the capsular ligament. It has a broad attachment above to the zygoma, from which point it passes downward and backward, and is inserted into the outer side of the neck of the condyle. The internal portion, or short internal lateral ligament, is composed of well-defined fibers, having a broad attachment above to the inner edge

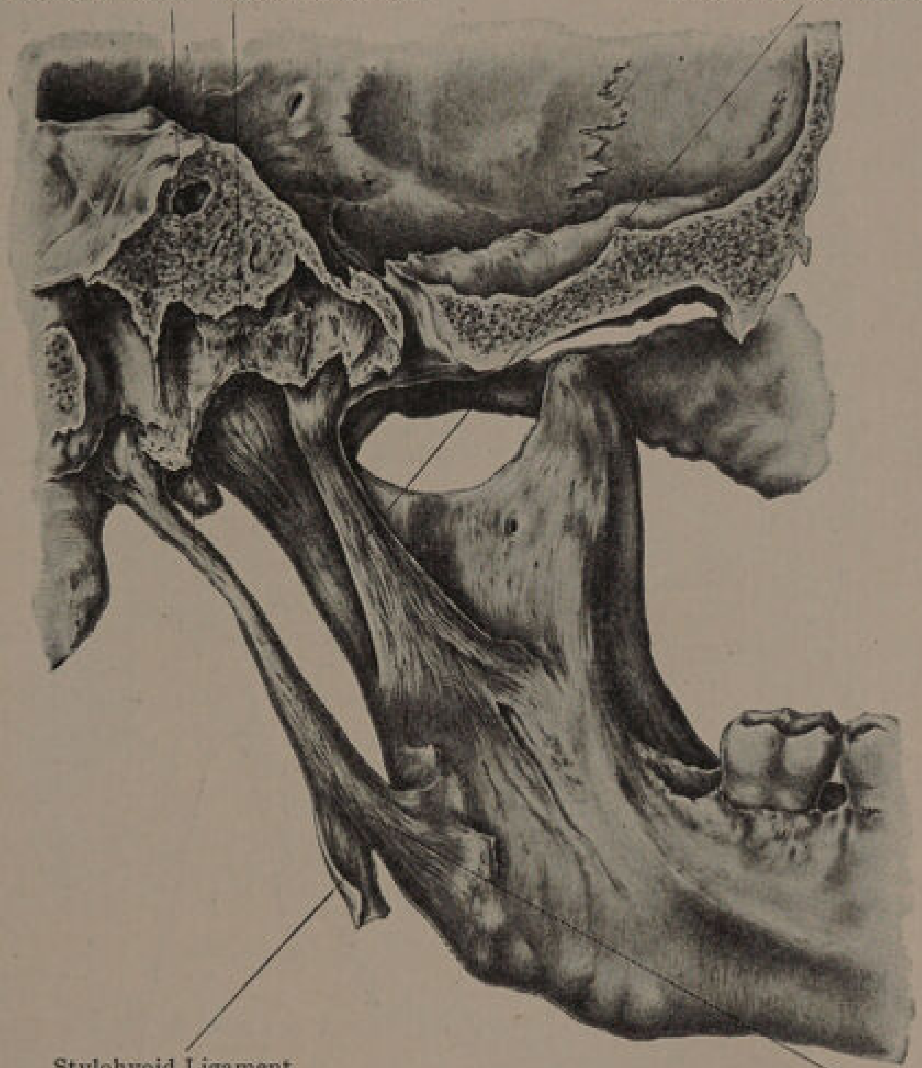


Fig. 25.—Temporomaxillary articulation—internal view. (*Deaver.*)

of the glenoid fossa and to the alar spine of the sphenoid bone; below it is inserted into the inner side of the neck of the condyle.

The *sphenomaxillary*, or long internal lateral *ligament*, is a thin, loose band, situated some distance from the joint proper, and, as its name implies, has its attachment above to the alar spine of the sphenoid bone, and also to that portion of the temporal bone contiguous to it. It passes downward and forward, and is inserted into the mandibular spine of the maxilla.

The *stylomaxillary ligament* extends, from the styloid process of the temporal bone, downward, and forward, to be inserted into the posterior border of the ramus of the inferior maxilla, at a point between the masseter and internal pterygoid muscles.

The *interarticular fibrocartilage* is an oval sheet placed between the two articulating surfaces. It is thinnest at the center and becomes

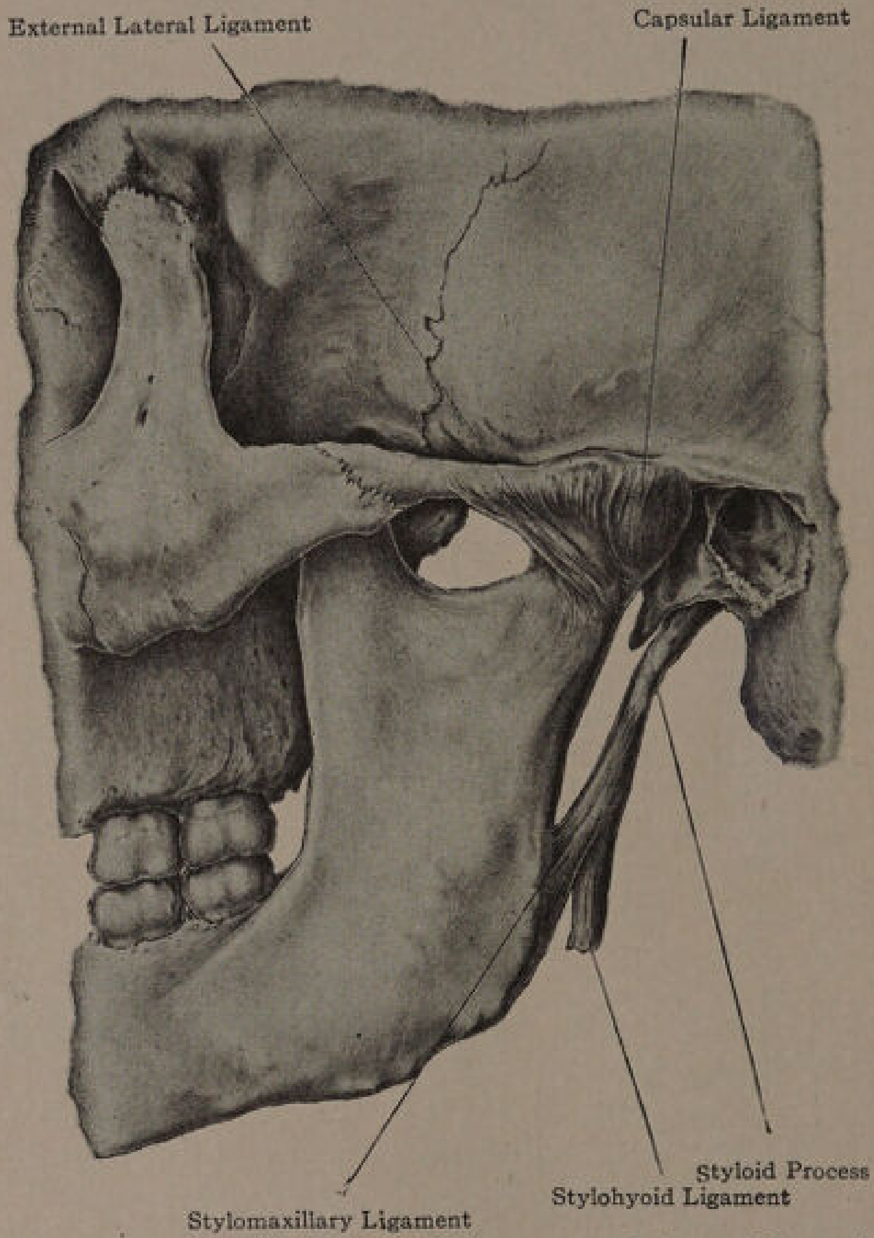


FIG. 26.—Temporomaxillary articulation—external view. (*Deaver.*)

thicker as the margins of the fossa are approached, at which point it is connected with the fibers of the capsular ligament. Being placed immediately between the two articular surfaces it divides the joint into two separate synovial cavities. Each of these synovial cavities is covered by a synovial membrane, that occupying the upper compartment being the largest, and passes from the margins of the glenoid fossa above to the upper surface of the interarticular cartilage below. The membrane which occupies the lower cavity is smaller, and passes from the under surface of the interarticular cartilage above to the margins of the condyle below. The *blood-supply* to this articulation is derived from the temporal, middle meningeal, and ascending pharyngeal arteries.

The *nerves* are derived from the masseteric and auriculotemporal.

The movements of this articulation present as great a range as any other joint in the human body. While the chief movement is of the ginglymoid or hinge character, brought into play in simple depression and elevation of the mandible, it also has the power of extension and

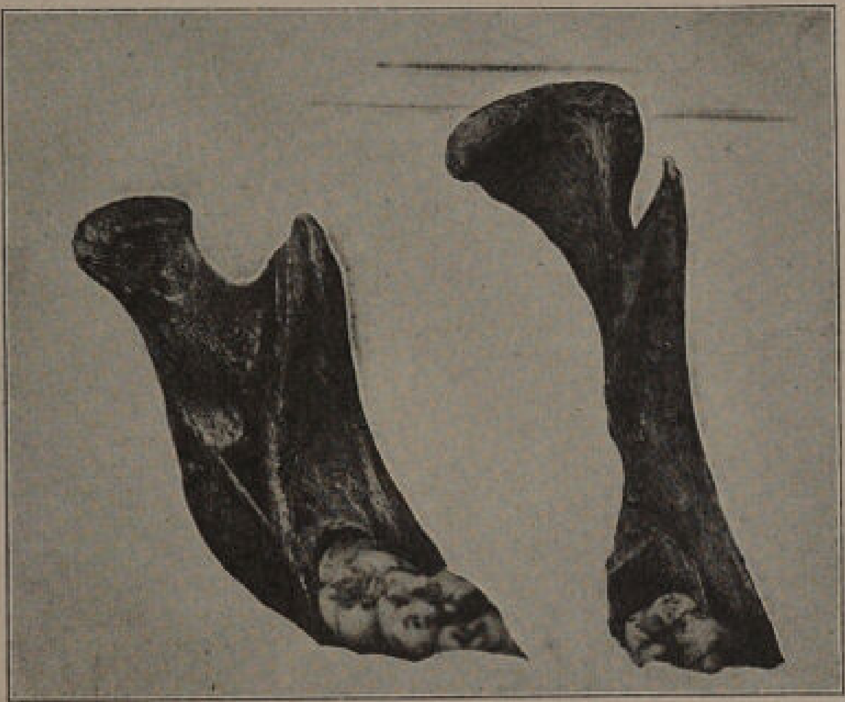


FIG. 27.—Showing variation in the shape of the condyles.

retraction, may be rotated from side to side, together with all the motions intermediate between these. When the mandible is depressed, the condyle moves on the fibrocartilage, and at the same time glides forward and slightly downward until it rests on the anterior border of the glenoid fossa;—this movement does not extend sufficiently to allow the condyle to rest upon the extreme summit of the border, except in cases of excessive movement, as in yawning, when the condyle may glide over the summit and the joint become disarticulated. When the mandible is elevated, the condyle slides backward and upward, and at the same time the fibrocartilage, which has extended with it, also retracts until the condyle is settled in the fossa. The movement of extension and retraction is by a horizontal gliding action, by which the mandible is thrust forward and drawn back again. In this movement, as well as in the one previously described, both condyles are similarly and simultaneously engaged. The lateral or triturating movement is made in an oblique direction. This consists in a rotation of the condyles within the fossæ, the cartilage gliding obliquely forward and outward on one side, and backward and inward on the other, this action taking place

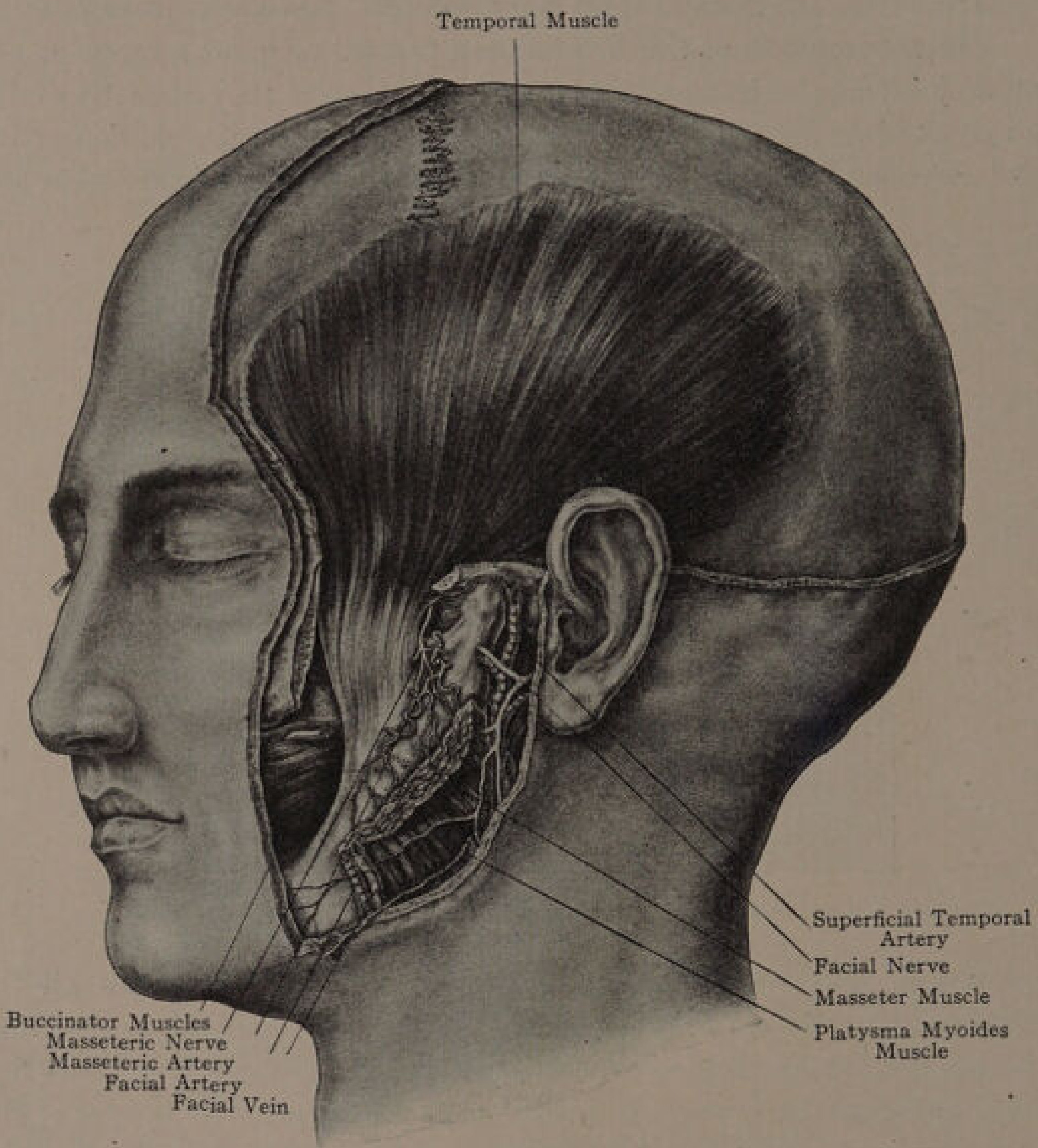


FIG. 28.—Temporal muscle. (*Deaver.*)

alternately. This movement is more or less developed in accordance with the nature of the tooth by occlusion, being favored by those teeth possessing but little cusp formation, with a consequent loose and wandering occlusion; while in that type of tooth associated with a long overbite and deep penetrating cusps, forming a firm and well-locked occlusion, this movement will be but little developed. If this movement be employed to throw the symphysis to one side and back again, and not from side to side, the condyle of that side rotates in the glenoid fossa, while the condyle of the opposite side is drawn forward and inward.

The Muscles of Mastication.

Occupying the back part of the side of the face, and forming an independent group, are four muscles, usually classed as the muscles of mastication. While this is true to a great degree, they are not the only muscles brought into action during this process. They are the *masseter*, *temporal*, *internal pterygoid*, and *external pterygoid*. The *masseter*, *temporal*, and *internal pterygoid* elevate or close the lower jaw, the principal function of the external pterygoid being to extend the lower jaw so that the lower teeth pass beyond the upper. The muscles which depress the mandivle such as happens when the head is thrown backward, are certain muscles of the neck.

The masseter muscle is made up of a strong quadrate sheet, consisting of two distinct layers extending from the zygomatic arch to the mandible. The layers of which the muscle is composed differ somewhat in size as well as in the directions which they take.

Origin.—The superficial layer, much the stronger and larger of the two, arises from the lower border of the malar bone, and from the anterior two-thirds of the zygomatic arch. The deep layer arises from the posterior third of the lower border and from nearly all the internal surface of the zygomatic arch.

Insertion.—After passing downward and backward it is inserted into the outer surface of the ramus of the mandible. The deep layer, passing downward and slightly forward, mingles with some of the fibers of the superficial portion, and is finally inserted into the upper half of the ramus of the mandible.

Action.—To draw slightly forward, and by its superficial layer to close the jaw. "In closing the jaw it acts with less mechanical disadvantage than is usual with muscles. When the pressure to be overcome is exerted upon the back teeth, the arm of the lever upon which the power acts is almost as long as that which intervenes between these teeth and the fulcrum. This fulcrum is not at the temporomaxillary joint, but at a point below the neck of the mandible, corresponding very nearly to the lower attachment of the internal lateral ligament. Moreover, the resultant force of the muscle acting, as it does, upward and forward, is perpendicular to the lever, which may roughly be described as a bar extending downward and forward from the neck of the mandible to the point of the chin." (Morris.)

Relations.—It is covered superficially by the skin and fascia of the platysma myoides, by the risorius and the masseter fascia, by the parotid gland and ducts, facial veins, and portions of the facial nerve. Deeply, the muscle lies in contact with the ramus of the jaw and the buccinator muscle, being separated from the latter by a layer of fat. A small portion of the temporal muscle also comes in relation to the deeper lying portion.

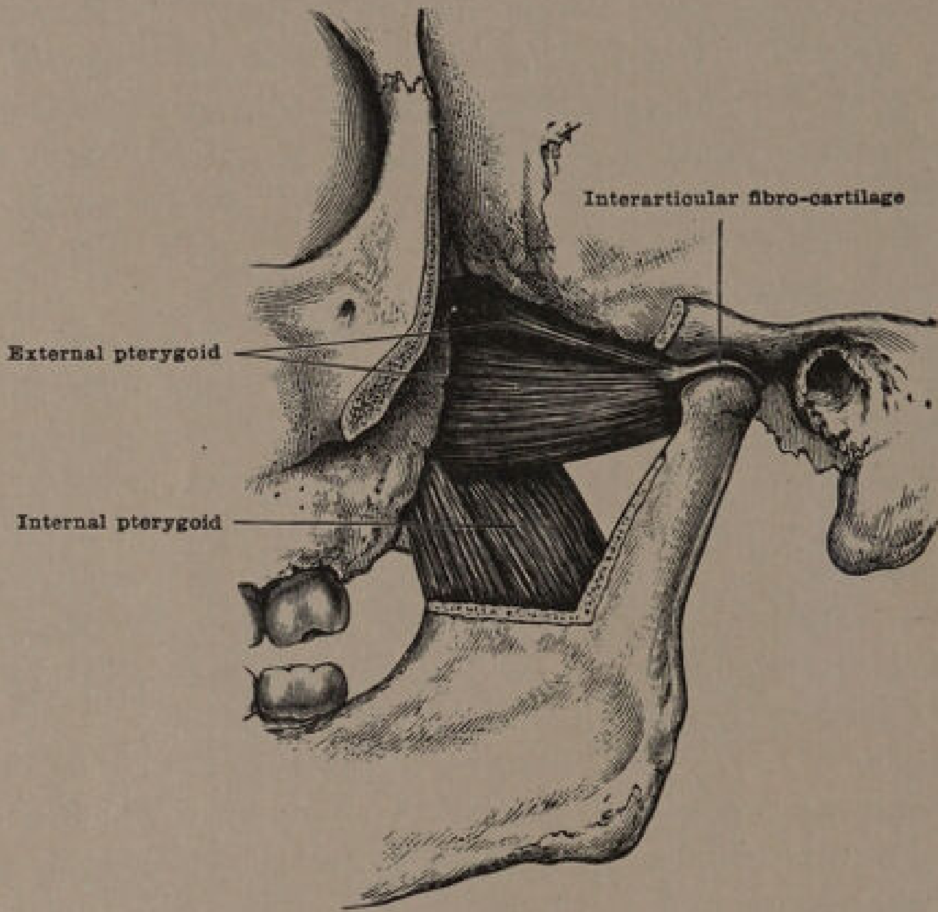


FIG. 29.—The pterygoid muscles. (*Morris.*)

The temporal muscle is covered by a strong membrane, the *temporal fascia,* which arises from the temporal ridge, and is inserted into both the inner and outer portions of the upper border of the zygomatic arch. Near this point it divides into two distinct layers, one passing to the inner, the other to the outer margins of the zygoma. Below the fascia is continuous with the masseteric fascia. Passing downward from this to the inferior borders of the ramus of the jaw, it envelops the masseter muscle. The muscle itself is radiating and fan-shaped in form, located in the temporal fossa, from which point it descends to the coronoid process of the mandible.

Origin.—From nearly the entire surface of the temporal fossa, from the temporal ridge, from the entire surface of the temporal fascia, down to its lower attachment to the zygomatic process.

Insertion.—Into the coronoid process of the mandible.

Action.—To close the lower jaw, some of its fibers drawing the jaw backward after the other muscles have protruded it.

Relations.—Its superficial portion is covered by the temporal fascia which separates it from some of the auricular muscles; branches of the facial nerve, the auriculotemporal nerve, and a portion of the epicranial aponeurosis. The temporal fossa and the external pterygoid muscles are in relation with it deeply.

The internal pterygoid muscle is a thick, quadrilateral, sheet-like muscle, and receives its name from its origin and relative position.

Origin.—From the inner surface of the external pterygoid plate; the tuberosity of the palate bone and a small portion of the maxilla.

Insertion.—Into the internal surface of the ramus of the mandible at its lower and posterior borders and extending as high as the mandibular foramen and mylohyoid.

Action.—To close the jaw and at the same time draw it backward and throw it toward the opposite side. "The same remarks which were made with respect to the very small loss of mechanical advantage in the masseter muscle apply to this muscle. When closed it will draw the jaw forward; and also it will help the external pterygoid in drawing the ramus of its own side toward the middle line." (Morris.)

Relations.—Superficially, the internal maxillary vessels, the external pterygoid muscle, the internal lateral ligament, the inferior dental and lingual nerves. Deeply, the submaxillary glands; the tensor palati and superior constrictor of the pharynx, as well as the stylohyoid and posterior border of the digastric muscles.

The external pterygoid muscle is composed of two triangular sheets, one passing in a horizontal and the other in a vertical direction. It receives its name from its attachment to the pterygoid process of the sphenoid bone as well as its relation to its companion muscle, the internal pterygoid.

Origin.—It is composed of two distinct heads, an upper and a lower. The upper head arises from the greater wing of the sphenoid bone, from the internal pterygoid ridge, and external to the foramen ovale and foramen spinosum. The lower head arises from the outer surface of the external pterygoid plate.

Insertion.—The upper head is inserted into the inter-articular fibro-cartilage, into the capsule of the joint as well as the neck of the condyle. The lower head is inserted into the neck of the condyle.

Action.—To draw the condyle and inter-articular fibrocartilage forward and inward. "The combination of these two movements produces the oblique movement of the lower molar teeth of one side, forward and inward with respect to the upper molars which are their opponents. It should be observed also that this inward movement of one side is the agent by which the ramus of the opposite side is moved outward. To assist in opening the mouth by depression of the lower jaw. As the transverse axis of this movement passes through the mandible at two points situated below the necks of the rami, it follows that a forward movement of the condyles and necks will assist in the backward movement of the angles and body which accompanies the depression of the mandible." (Morris.)

Relations.—Superficially, some of the fibers of the internal pterygoid, the temporal, and part of the masseter muscle. Deeply, the internal pterygoid muscle, the middle meningeal and inferior dental vessels, internal maxillary vessels, and masseteric and posterior deep temporal nerves passing behind or through the attachment to the upper head; the inferior dental and lingual gustatory nerves beneath the lower head.

CHAPTER V

A General Description of the Teeth—The Permanent Teeth: Classification, Surfaces, Etc.—The Dental Arch

A GENERAL DESCRIPTION OF THE TEETH

A Tooth (Fig. 30).—One of thirty-two specialized organs placed at the entrance to the alimentary canal (the mouth), the chief function being to seize, incise and masticate food. The typical form of a tooth is a modified cone or combination of cones, and is composed of two fundamental parts—the *crown* and the *root* or *roots*. The crown is that part which is exposed to the surface and visible in the mouth; while the root is that part which is implanted in the bone and covered by the mucous membrane. Intervening between these two parts, and usually occupying a portion of each, is a third division—the *neck*.

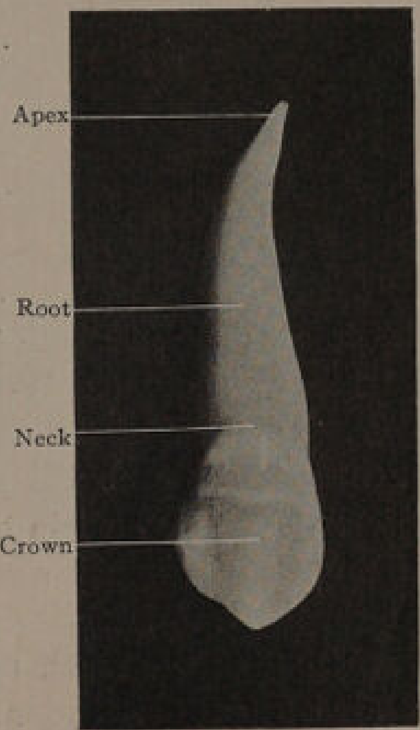


FIG. 30.

Completely covering the crown of a tooth is a hard, vitreous-like substance, *enamel;** the root is covered by a hard bone-like substance, *cementum;** while the interior or body of the organ is composed of a hard substance closely resembling bone, the *dentin.** The neck of a tooth, which serves to unite the crown to the root, and which is usually formed at the expense of each, is covered partly by enamel and partly by cementum. *Teeth* are classified according to their from, which is always in accordance with their function, into *simple* and *complex*. In the simple class the single modified cone is the predominating form, the free extremity of the crown serving as the base of the cone, while the apex is formed by the free end of the root. Included in this same classification are those teeth which are made up of

* See Tissues of the Teeth, Part II.

a double cone, or a simple cone and an inverted cone attached to each other at a common base the neck of the tooth (Fig. 30). The purposes for which such teeth are adapted are those of grasping, incising, and tearing, and they are so arranged that the free extremities of their crowns interlock or overhang the opposing teeth in the opposite jaw.

In the complex class (Fig. 31) the external form of the tooth is produced by a combination of cones, some of which are simple, others inverted, but all uniting at a common base—the neck of the tooth. In this class the simple cones form the roots of the tooth, while the crown is made up of a number of smaller cones, much modified. Such teeth are adapted to crushing and grinding, and are less inclined to interlock during active service.

Fig. 31.

The teeth are divided into two grand divisions—those of infancy and childhood, called *deciduous* or *temporary teeth*, and those of the adult period, known as *permanent teeth*. The latter class being most important, will first receive consideration.

The Permanent Teeth (Fig. 33).—The permanent teeth, thirty-two in number, are divided into those of the superior portion of the mouth, *upper*, and those of the inferior portion, *lower*. In number they are equally divided, each jaw giving support to sixteen. They are firmly more or less imbedded in the alveolar sockets of three of the bones of the mouth, the upper sixteen being attached to the two maxillary and the lower sixteen to the mandible. As above referred to, the attachment of the teeth to the bones is by implantation in sockets, the alveoli (see description, "Bones of the Mouth"). In this attachment there is a special development or bone, closely modeled to the roots of the teeth, and which is subservient to the ever-varying changes which take place during the development of the organs. The joint thus formed between the roots of the teeth and the alveoli is usually classed with the immovable or synarthrodial variety, and is styled *gomphosis*. Intervening between the roots of the teeth and the walls of the alveoli is a delicate membrane—the *alveolodental membrane*, which serves as a means of attachment between the tooth and the bone.

Before continuing the description of the teeth, a further classification, which refers alike to the upper and lower, must be presented.

This classification is derived from the function and form of the teeth. Figure 33 shows thirty-two teeth placed side by side in two rows. In the center is a perpendicular line, which corresponds to the median line or center of the mouth, the teeth at either extremity being those which occupy the back part of the mouth. Without confining the description to either the upper or lower teeth, it will be observed that the first two teeth on each side of the median line are similarly formed, and receive their name from their function, all four being called *incisors* (*incidere*, to cut); the two larger incisors, being nearest the median line or center, are called *central incisors;* while the two smaller being placed

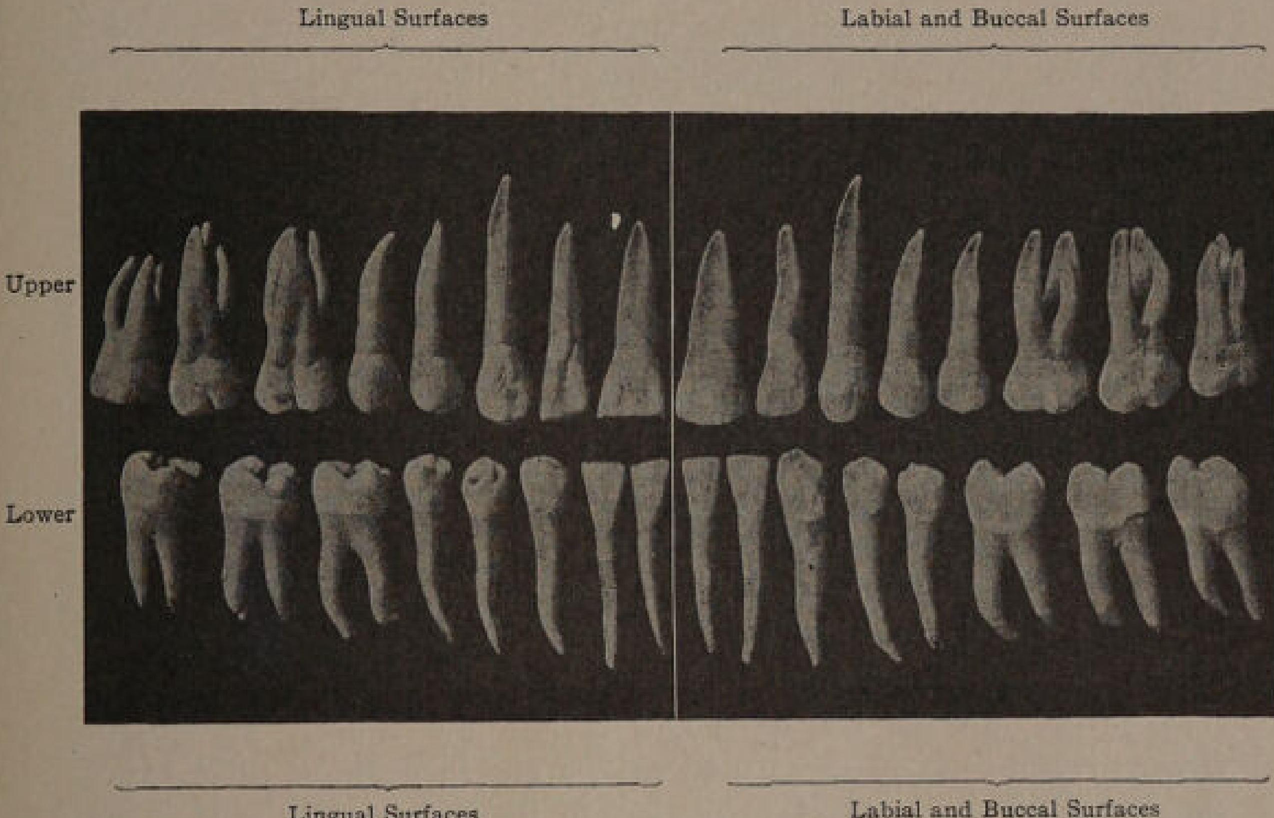


FIG. 32.—The permanent teeth.

at the side of the centrals, are known as *lateral incisors* (*lateralis*, the side). The third tooth from the median line upon either side is the *cuspid* (*cuspis*, a point), so named from possessing a single cusp or point. Passing to the right or left on the chart, or backward in the mouth, the fourth and fifth teeth from the median line are the *bicuspids* (*bi*, two; *cuspis*, a point), having two points or cusps. The bicuspid nearest the median line is the *first bicuspid;* that most distant from the median line is the *second bicuspid*. The sixth, seventh, and eighth teeth from the median line upon either side are those of another class, the *molars* (*mola*, a mill-stone), being named according to their function, that of crushing or grinding the food. Proceeding from before backward, the molars are denominated *first molar, second molar,* and *third molar.* To sum up, the names and number of the permanent teeth may be written by what is known as the **dental formula,** as follows:

$$\text{Incisors}\ldots\frac{2}{2}\quad\text{Cuspids}\ldots\frac{1}{1}\quad\text{Bicuspids}\ldots\frac{2}{2}\quad\text{Molars}\ldots\frac{3}{3}=\frac{8}{8}=16\times 2=32$$

The Surfaces of the Teeth.—The crown of each tooth presents five surfaces, which are variously named, in accordance with their function or suggestive of their location. The outer surface of the incisors and cuspids, or that contiguous to the lips (labia), is called the *labial surface;* the corresponding surface of the bicuspids and molars, or that contiguous to the cheeks (buccæ), is the *buccal surface.* That surface of both upper and lower teeth which faces the palate or tongue is characterized as the *lingual* surface.

The proximate surfaces of the teeth are named with regard to their relation to the median line, those surfaces nearest to this point being called *mesial,* those most distant, *distal.* In addition to these four surfaces, which represent what might be termed the sides of the teeth, a fifth surface is present, that which occludes with the teeth of the opposite jaw, and is called the *occlusal surface.*

In the incisors and cuspids this surface is formed by the converging of the labial and lingual surfaces, forming an edge to the free extremity of the crown, named, from its action in mastication, the *incisive* or *cutting-edge.* In the bicuspids and molars the various sides of the crowns remain nearly parallel to each other throughout their extent, thus providing an occlusal surface nearly equal to, or greater than, any of the others, and one well adapted to the purposes for which it is intended—that of grinding or crushing the food.

The Roots of the Teeth.—The upper incisors and cuspids are each provided with one root; the upper first bicuspid may have one or two roots, most frequently the latter; while in the second bicuspid a single root is usually present. The upper first and second molars are each supported in the jaw by three roots, and while the upper third molar most frequently has three roots, the number may vary, ranging from a single cone-shaped root to three, four, or even five smaller branches given off from a common base.

In the lower incisors, cuspids, and bicuspids, a single root is most frequently met with, although the latter, in rare instances, may be provided with two. The lower first and second molars are each provided with two roots, but in the third molar, like its upper fellow, the number may be diminished or increased. In the upper molars, two of the three roots are placed above the buccal half of the crown, and are called *buccal roots;* the remaining root is placed above the lingual half of the crown, and is designated as the *lingual root*. In the lower molars, one of the two roots is placed below the anterior or mesial half of the crown, and is named the *mesial root*, and the other below the posterior or distal half, and is known as the *distal root*. In those teeth with a complicated root formation, it would seem to be a question whether they are possessed of a single root, with two or more branches, or separate and distinct roots throughout. To determine this, some account must be taken of the point at which the bifurcation or trifurcation takes place. If this separation be in close proximity to the crown, the tooth should be considered as having more than one root (Fig. 33, A); but, on the other hand, if the point of separation be some distance from the crown, with a solid mass of root substance intervening, the tooth may be said to possess a single root, with two or more branches (Fig. 33, B). In the latter instance, that part of the tooth between the point of separation and the crown is called the root or root base; while the prolongations beyond the point of separation are known as the branches of the root.

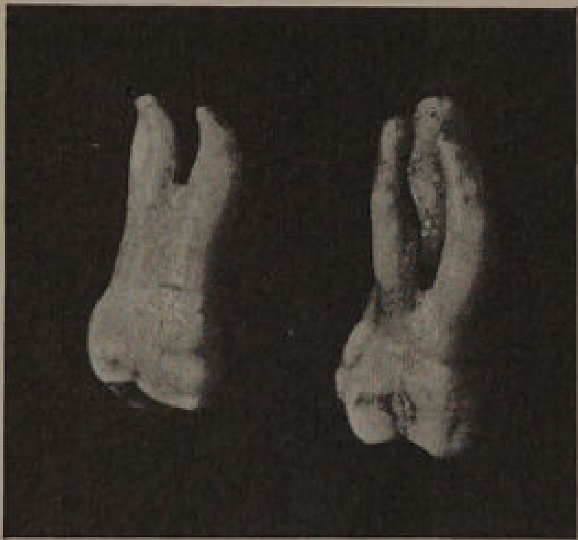

B A

FIG. 33.

The roots of the teeth are not only variable in number, but are also subject to much variety in form. In the *anterior teeth* (the incisors and cuspids) the roots are inclined to the form of the simple cone, which form, however, is frequently more or less broken by a slight curvature near their extremities, or by a slight compression of their lateral walls. In the *posterior teeth* (the bicuspids and molars) the roots are all inclined to the conical form, but do not approach so nearly the perfect cone as those of the anterior teeth. These roots are also more or less crooked and flattened laterally. The free extremity of the roots of the teeth, forming as they do the apex of these cone-like prolongations of the crowns, are known as the *apices* or *apical extremities*.

The extent to which the enamel covers the crowns of the teeth is marked by a well-defined line, which completely encircles the neck of the tooth, the *cervical line.*

The Dental Arch (Fig. 34).—The teeth are arranged in the jaws in the form of two parabolic curves, the superior arch describing the segment of a larger circle than the inferior, as a result of which the upper teeth slightly overhang the lower. Figure 34 represents the sixteen upper teeth in position in the bone, showing their occlusal and lingual surfaces. Viewed in this direction, the gradual change in the crowns of

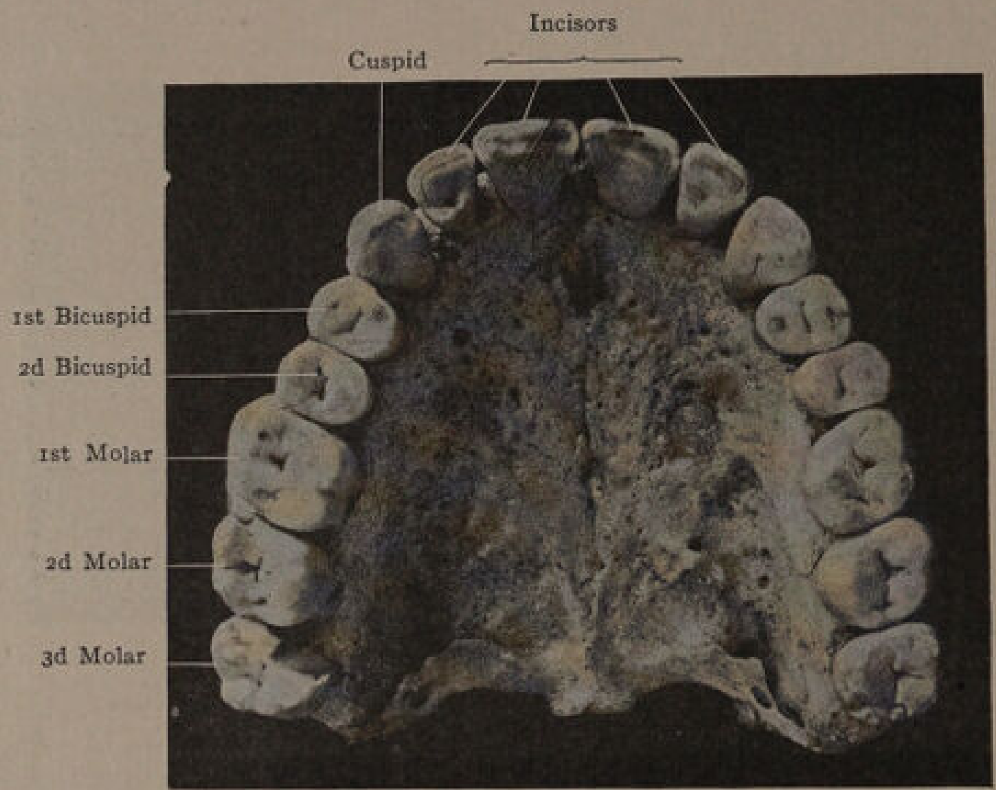


Fig. 34.—The dental arch.

the teeth from the simple incisors to the complex molars may be observed. An examination of the central incisors will show how perfectly they are adapted to the process of cutting or incising the food, the incisal-edge being sharp and the lingual surface comparatively smooth and unbroken. In the lateral incisors the cutting feature predominates, but the lingual surface is broken near the neck of the tooth by a slight depression, surmounted by a more or less pronounced fold of enamel, in many instances resembling a small cusp. The crown of the cuspid furnishes the intermediate form between the simple and the complex. This tooth, instead of being provided with a straight cutting-edge, is surmounted at the center of its occlusal surface with a well-defined point or cusp, descending from the summit of which are two incisal-edges, one passing to the mesial and one to the distal. The lingual surface of this tooth presents a marked contrast to the corresponding surface of the incisors, being broad and full, and frequently provided with a prominent ridge of enamel in the region of the neck, showing a rapid approach to the complex form. In the bicuspids the buccal half of the crown is quite similar to the crown of the cuspid, but in the lingual half a complete revolution has taken place. The enamel fold—but slightly apparent in the incisors, and somewhat increased in the cuspids—has now become a fully developed cusp, resulting in the production of an occlusal surface adapted to crushing or grinding, instead of incising or tearing. In the molars, the increase in the size of the tooth-crown is accompanied with an occlusal surface much more complex than any of the teeth previously described, and one well adapted to its function—that of crushing and grinding the food.

Arrangements of the Teeth in the Dental Arch (Fig. 34).—Beginning with the upper teeth, the central incisors are found occupying the center of the arch, and are, therefore, slightly in advance of the laterals. These teeth are so implanted in the alveoli that their crowns are not perpendicular, the incisal-edge being slightly more prominent than the neck of the tooth. The roots are also somewhat inclined from the median line, and as a result the crowns have slight mesial inclination, the mesial surfaces approximating each other at or near the incisal-edge, with a slight space intervening at the necks. In certain typal forms—the bilious, for example—when the front of the arch is flat, the labial surfaces of these teeth form nearly a direct line from side to side; while in those types in which the arch is well rounded anteriorly, notably in the sanguine temperament, the labial surfaces of these two teeth form a small segment of the arch, so that the mesial extremity of the incisal-edge of each tooth-crown is somewhat in advance of the distal. The lateral encisors are similarly implanted in the alveoli, causing their incisal-edges to project. The roots of the lateral incisors usually have a stronger distal inclination than those of the centrals, and the crowns show a more marked mesial inclination. The mesial surfaces approximate the distal surfaces of the central incisors at or near the incisal-edge. When the front of the arch is flattened, these teeth are but little less prominent than the central incisors, but when the arch is well rounded they continue the segment begun by the centrals, and are necessarily less prominent. While the occlusal surfaces of the teeth are usually considered as forming a perfect plane (see Occlusion of the Teeth), the lateral incisors are generally a trifle shorter than the centrals. The cuspids may be considered as occupying the corners or turning-points of the arch. They are more prominently placed than the adjoining teeth, this feature being increased by the bulging or general convexity of their labial surfaces. The extremity of the occlusal surface of the cuspids—*i.e.*, the point of the cusp—is a trifle below the cutting-edge of the laterals and about on a line with that of the centrals. While the apices of the roots of the cuspids are directed away from the median line, the crowns assume almost a perpendicular, this condition resulting from a bend in the tooth at the neck. Although the perpendicular position is most commonly assumed by the crown, it is not unusual to find either a mesial or distal inclination present. Reference has been made to the cuspid as occupying a position which might be termed the turning-points or corners of the arch, and in most instances it may be thus considered; but in certain typal forms—the sanguine, for example—the curve to the tooth-line is unbroken and passes over the cutting-edges of the incisors, the summit of the cusps of the cuspids, and is continued backward over the buccal cusps of the posterior teeth. The bicuspids are placed nearly perpendicular in the arch, but occasionally deviate from this by a slight mesial or buccal inclination. The length usually corresponds to that of the central incisors, and their buccal surfaces are slightly less prominent than the corresponding surfaces of the cuspids. The increase in the buccolingual diameter of the crowns of the bicuspids over that of the incisors and cuspids results in breaking the lingual line of the occlusal surfaces. In the bilious type, the tooth-line is carried directly backward from the cuspid to the first molar, making the buccal face of the bicuspids equally prominent, but when the arch is well rounded the second bicuspid is slightly more prominent than the first. The first and second molars usually assume a perpendicular position, but are occasionally inclined to the distal and buccal. The relative prominence of the buccal as well as the lingual surfaces of these teeth is also controlled by the form of the arch. The occlusal surfaces are about on a level with those of the bicuspids and central incisors, but generally the lack of development in the distal half of the crown of the second molar results in the production of a slight upward curve to the tooth-line level at this point (see Occlusion of the Teeth). On account of the limited accommodations afforded it, the position of the upper third molar is quite variable. It may be either to the buccal or to the lingual of the tooth-line, and is usually strongly inclined to the distal. In those cases in which there is a decided dip to the arch (see Occlusion of the Teeth), this tooth is relatively shorter than those anterior to it, but when the tooth-line level is a perfect plane, the length of this tooth corresponds to the other molars and bicuspids.

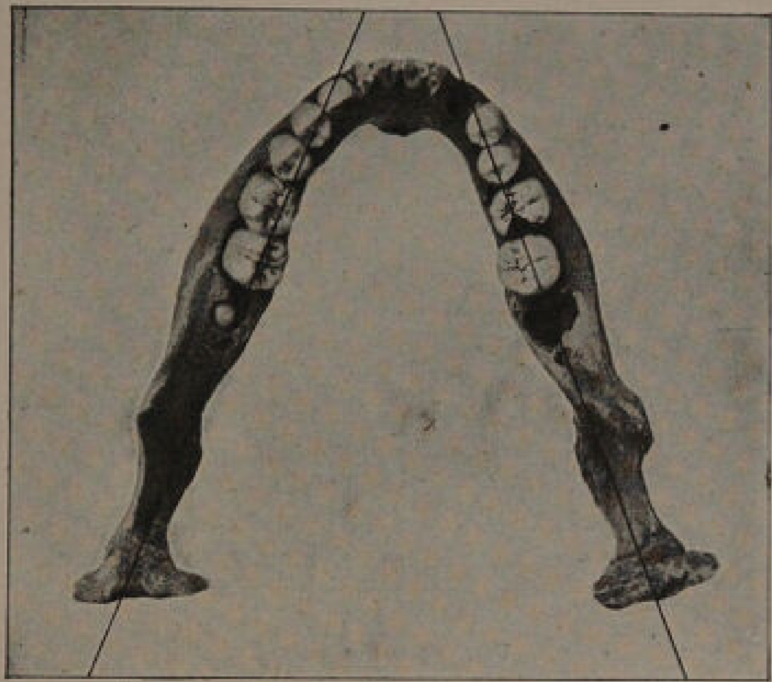


FIG. 35.—The tooth-line in the mandible.

The lower incisors are placed more nearly in a perpendicular position than the upper, and a reverse condition exists, in the lateral incisors

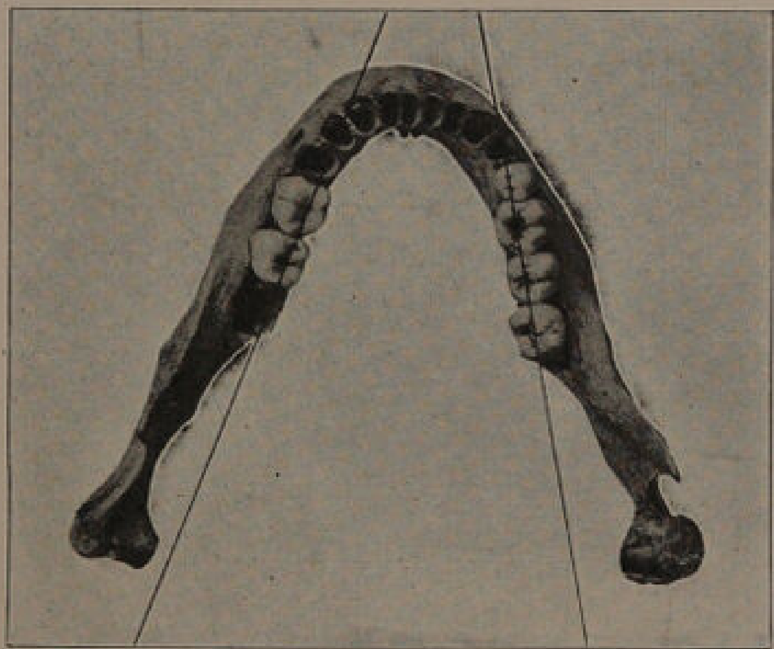


FIG. 36.—The tooth-line in the mandible.

being a trifle larger than the centrals. The lower cuspids are probably more constant in their position than any class of teeth in the mouth, in nearly all instances assuming a direct perpendicular. Like the upper cuspids, they may be said to establish the corners or turning-points of the lower arch, and are somewhat more prominent in the tooth-line

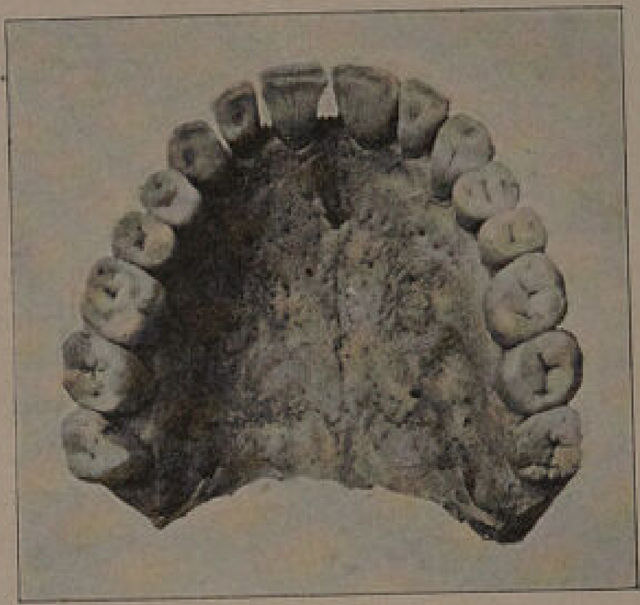


Fig. 37.—Sanguine.

than neighboring teeth. The crowns of all the six anterior lower teeth may be slightly inclined to the mesial. The lower bicuspids and molars, instead of having the buccal inclination possessed by the corresponding

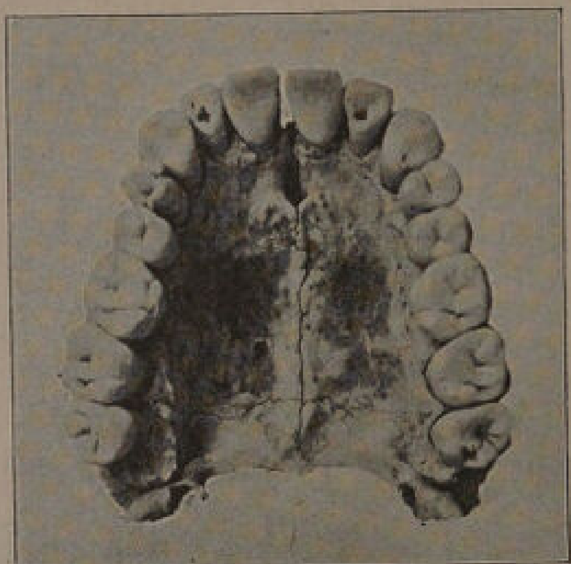


Fig. 38.—Bilious.

upper teeth, are inclined to the lingual. The first molar seldom deviates either to the mesial or the distal, the second molar is generally inclined to the mesial, while the third molar is strongly inclined to the mesial. In the lower arch the curve formed by the incisors and cuspids is the segment of a smaller circle than the corresponding curve in the upper arch. This curve may be continued over the buccal cusps of

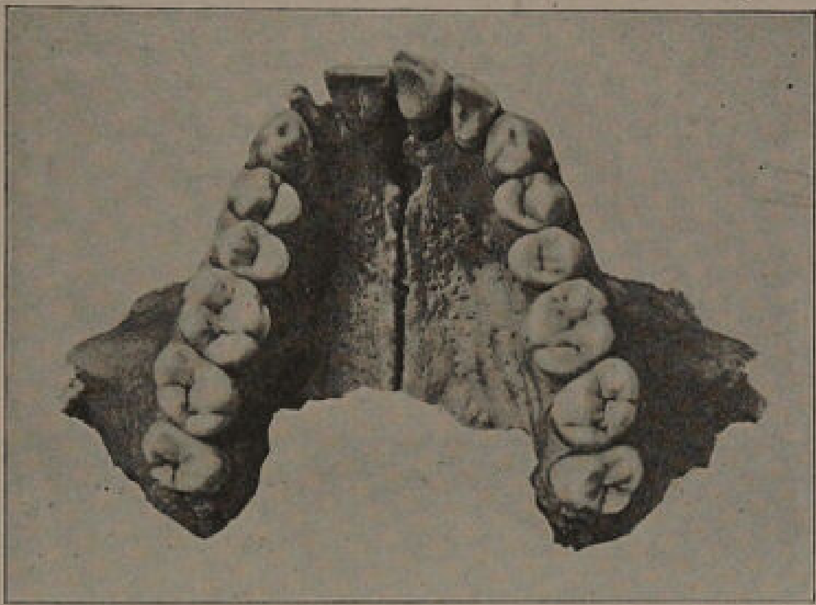


FIG. 39.—Nervous.

the bicuspids and molars, or it may be broken at the cuspid and continued backward in a direct line (Fig. 35). The teeth in the lower arch are placed directly over the body of the bone as far back as the

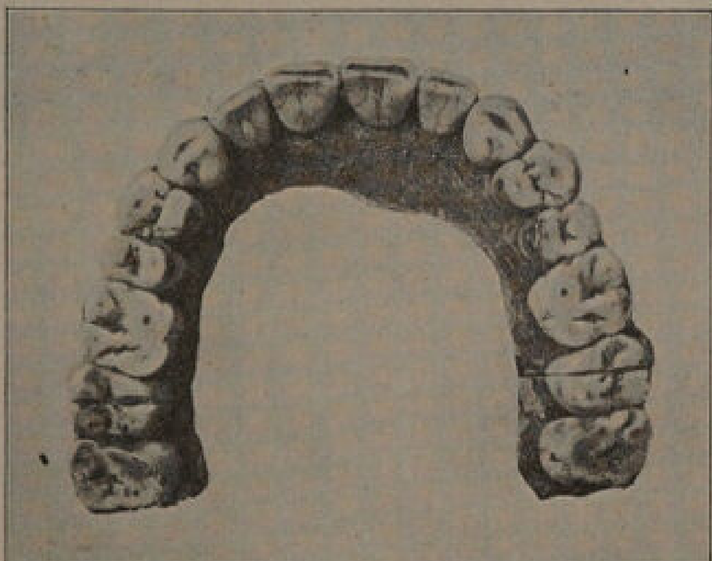


FIG. 40.—Lymphatic.

second bicuspids, while the molars frequently overhang the body of the bone by an extension of the alveoli inward (Fig. 36).

The curve described by the dental arch is quite variable, and this variation is generally referred to in connection with the temperament.

Thus, in the sanguine temperament (Fig. 37), the arch is well rounded anteriorly, the circle being continued backward to the region of the molars, where the line is broken by slightly inclining to the lingual. In this arch the distance in a straight line from the center of the second molar, on one side, to the center of the corresponding tooth on the other, is about equal to the distance from either of these points to the median line between the central incisors, forming an equilateral triangle. In the bilious temperament (Fig. 38) the arch presents a broad front from cuspid to cuspid, with but little curve; at these points it turns abruptly backward, being continued almost in a direct line to its extremity. In this arch the side of the triangle (represented by the line from molar to

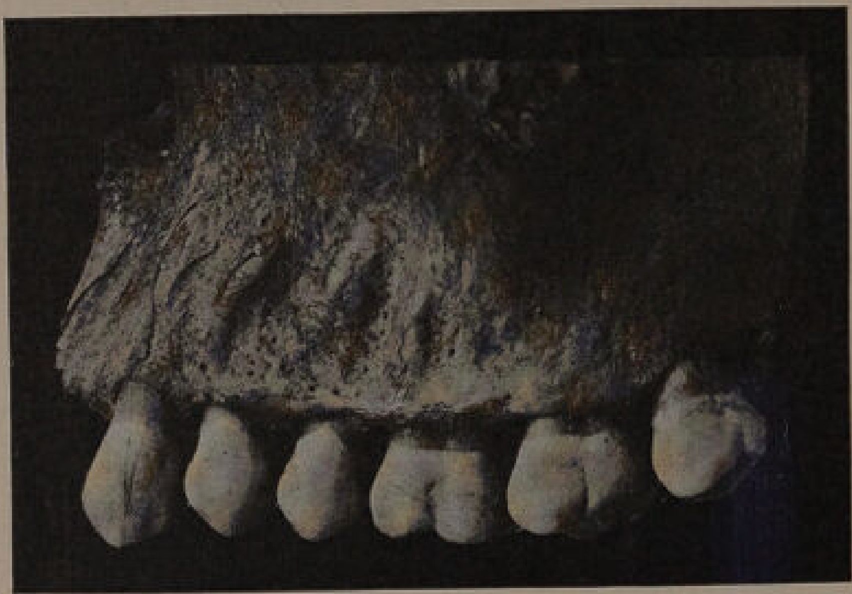


FIG. 41.—Section of maxilla showing interproximate spaces.

molar) is much reduced in length. In the nervous temperament (Fig. 39) the arch is Gothic in form, the segment formed by the anterior teeth being that of a much smaller circle than either of the types previously referred to. The distance from molar to molar is much less than the distance from molar to median line. In the lymphatic temperament (Fig. 40) the arch is well rounded and broad, the segment being that of a much larger circle than any of the above, the side of the triangle formed by the line from molar to molar being of the greatest length.

Interproximate Spaces.—In the mesiodistal direction the crowns of the teeth, as a class, are broader at their occlusal surfaces or cutting-edges than at their necks (Fig. 41). This bell-shaped form of the tooth-crowns cause their proximate surfaces to touch at a point, *contact point*, representing their greatest mediodistal diameter, which is usually nearest to the incisal-edge or occlusal surface. Between this point of contact and the cervical line there exists a **V**-shaped space, called the interproximate space. These spaces are largest in that class of teeth found in the nervous and bilious types, where the necks of the teeth are much constricted, and the bell-shaped crown strongly outlined. In teeth of this class the point of contact is slight, and the interproximate spaces are only partially occupied by the gum tissue, leaving a free passage between the point of contract and the gingival margins. In the sanguine and lymphatic temperament the proximate surfaces of the teeth are nearer parallel with one another, thus making the point of contact cover a greater extent of surface, thus reducing the capacity of the interproximate spaces.

CHAPTER VI

Occlusion and Articulation of the Teeth

As stated elsewhere, the teeth are arranged in the mouth in the form of two parabolic curves, one of which occupies the upper half and the other the lower half of the cavity. To properly perform their function it is necessary for the upper and lower teeth to come into contact, which

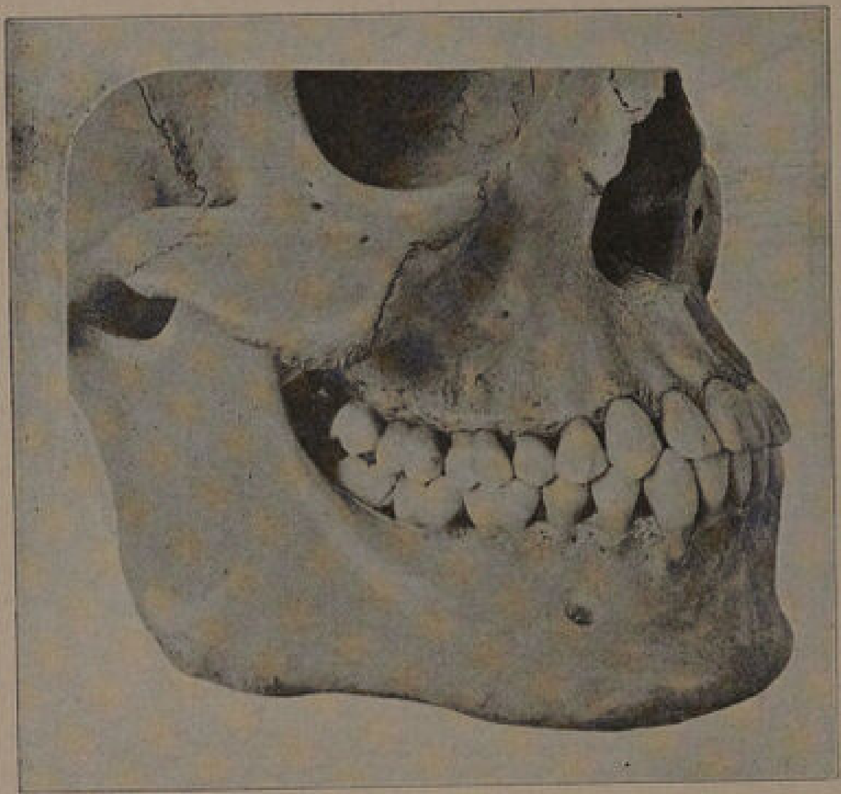


Fig. 42.—The teeth in occlusion.

they are enabled to do by the movement of the mandible, and it is the relation existing between the two when thus brought together that constitutes the *occlusion of the teeth*. During mastication the teeth do not only occlude, and remain stationary at a given point until the mandible is again depressed, but, through the combined movements of the mandible, the lower teeth are made to move from side to side, thus grinding or crushing any substance placed between their occlusal surfaces. This sliding antagonism of the teeth is properly termed the *articulation*, and it is important that a distinction be made between the terms "occlusion" and "articulation," the former referring to the relations existing between the upper and lower teeth when brought together normally and held firmly in that position, while the latter relates to the various gliding movements of the lower teeth after being brought into occlusion with the upper. In the majority of instances the segment described by the upper arch is somewhat larger than that formed by the lower, and the upper teeth project over and are partly outside of those in the lower arch. Figure 43 presents a labial and buccal view of the teeth in position in the alveoli, and also in occlusion. It will be observed that the upper teeth are not directly antagonistic to those of the same name in the lower arch. There are two reasons for this. First, the mesiodistal diameter of the upper central incisors is much greater than that of the corresponding lower teeth; second, the larger circle present in the upper arch. This arrangement provides that each tooth, instead of being antagonized by a single tooth of the opposite jaw, is met in occlusion by a portion of two teeth. The upper central incisor is met in occlusion by the entire incisal-edge of the lower central incisor and the mesial third of the incisal-edge of the lower lateral incisor. The upper lateral incisor is met in occlusion by the distal two-thirds of the incisal-edge of the lower lateral incisor and by the mesial incisal-edge of the lower cuspid. The upper cuspid is met in occlusion by the distal incisal-edge of the lower cuspid and by the mesial two-thirds of the buccal cusp of the lower first bicuspid. The upper first bicuspid is met in occlusion by the remaining or distal third of the lower first bicuspid and by the mesial two-thirds of the buccal cusp of the lower second bicuspid. The upper second bicuspid is met in occlusion by the remaining or distal third of the buccal cusp of the lower second bicuspid, and by the mesial incline of the mesiobuccal cusp of the lower first molar. The upper first molar is met in occlusion by the distal incline of the mesiobuccal cusp of the lower first molar, by the entire distal cusp of the same tooth, and by the mesial incline of the mesiobuccal cusp of the lower second molar. The upper second molar is met in occlusion by the distal incline of the mesiobuccal cusp of the lower second molar, by the entire distobuccal cusp of the same tooth, and by the mesial incline of the mesiobuccal cusp of the lower third molar. The upper third molar is met in occlusion by the distal incline of the mesiobuccal cusp of the lower third molar and by the entire distobuccal cusp of the same tooth, thus being the only tooth in the upper arch with but a single opponent. Likewise each lower tooth is met in occlusion by two in the superior arch, with the single exception of the central incisor, which occludes with the upper central alone. In certain types the segmental form of the upper arch is but little greater than that of the lower, and the incisal-edges of the upper incisors occlude almost directly upon the cutting-edges of the lower incisors. As a result, all of the upper teeth are forced to the distal, and the relationship between the upper and lower teeth is somewhat altered. In a normal occlusion the lingual cusps of the upper bicuspids and molars penetrate the fossæ of the lower teeth, and the buccal cusps of the lower bicuspids and molars rest in the fossæ of their upper opponents.

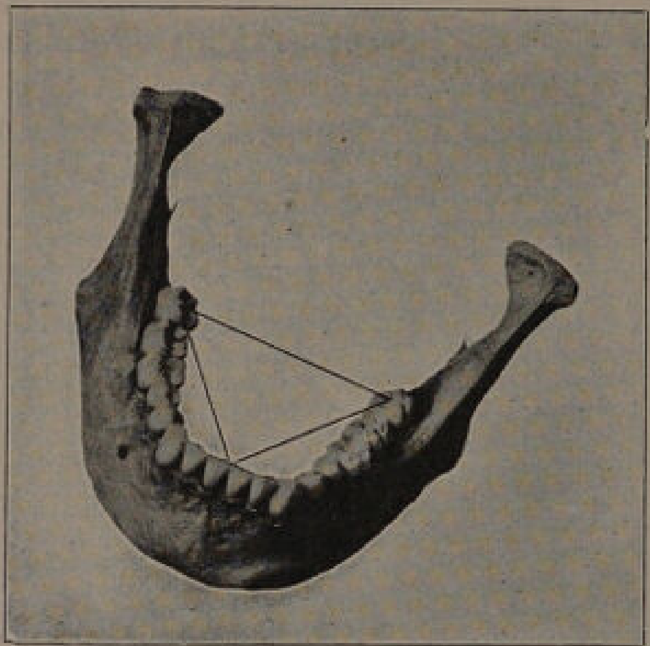


FIG. 43.—The mandible at the adult period, showing the equilateral triangle described by the dental arch.

To assist in the study of the occlusion of the teeth, some reference must be made to the tooth-line lever, or plane of occlusion. For this purpose the lines forming the facial angle are of value. These lines are as follows: A fixed line representing the base of the angle may be drawn from the center of the glenoid fossa, passing forward through the anterior nasal spine or base of the nose (A, Fig. 44), the angle being completed by a perpendicular line resting upon the labial surface of the upper incisors, passing upward and touching the most prominent part of the forehead (B, Fig. 44). The tooth-line level is approximately horizontal to this basal line, but instead of a perfect plane we usually find the upper arch dipping downward, while the lower arch will be provided with a corresponding depression. This dip to the arch which is known as the "compensating curve," or the "curve of Spee," is greatest in the region of the bicuspids, and the extent to which it may exist varies with the type of tooth and the consequent nature of the occlusion.

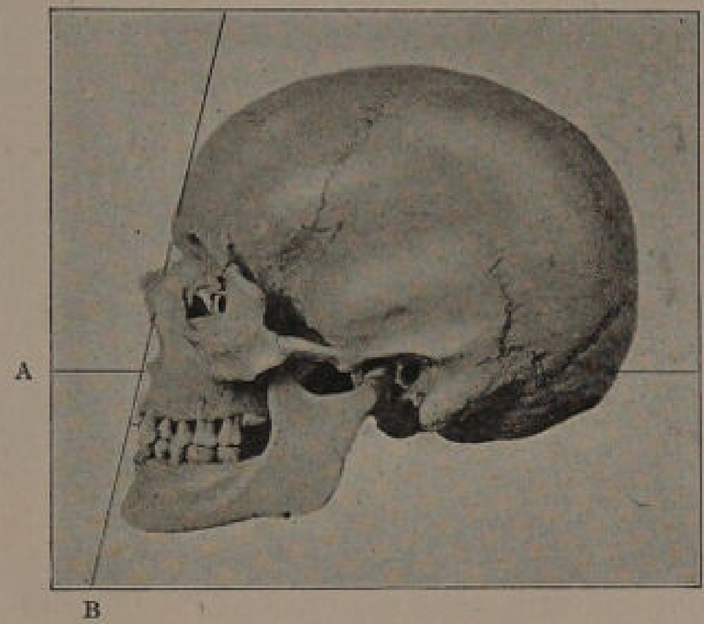


FIG. 44.—Lines showing facial angle, Caucasian or white race.

Thus far no reference has been made to what is commonly termed the *overbite*, and the *cusp forms* in the teeth. As these two factors exert

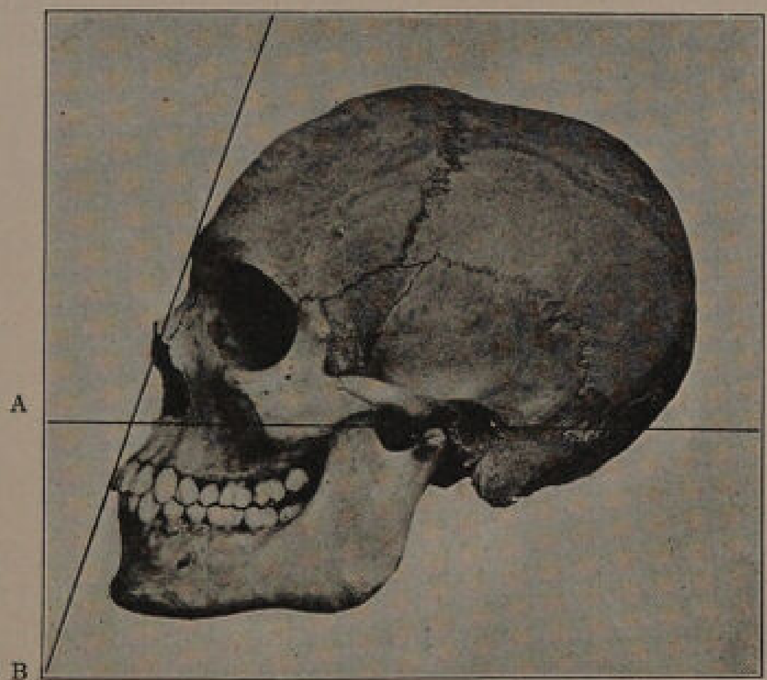


FIG. 45.—Lines showing facial angle, negro or mixed races.

a dominating influence over the character of the occlusion, the effects which they produce will be briefly described. The overbite is so named, from the fact that the upper teeth project beyond, or overhang and partly cover the labial and buccal surfaces of the lower teeth. This may be a pronounced feature in the occlusion, or it may exist to a very slight degree. Although the overbite is usually referred to as existing in the incisive region alone, it is not confined to these teeth, but is also present in the bicuspids and molars by the buccal cusps of the upper teeth overhanging those of the lower. The extent of the overbite is gradually

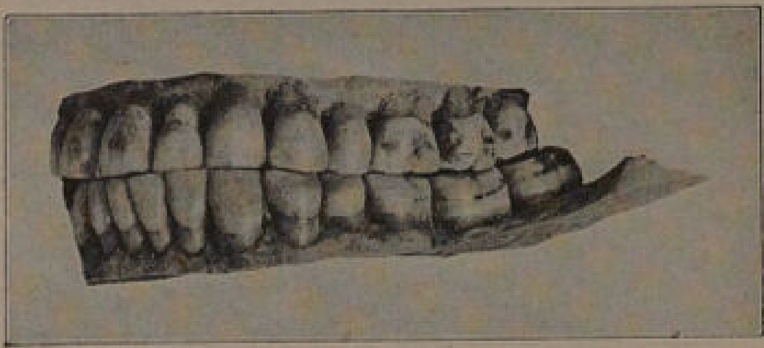


FIG. 46.—Lymphatic.

diminished from before backward, the central incisors presenting the greatest amount of overhanging surface, which condition is slightly decreased in the laterals, and a corresponding reduction is continued until the third molars are reached, at which point the overbite is scarcely observed. Where the overbite is extensive, as shown in figure 43, the upper incisors overhanging and hiding from view about one-third of the

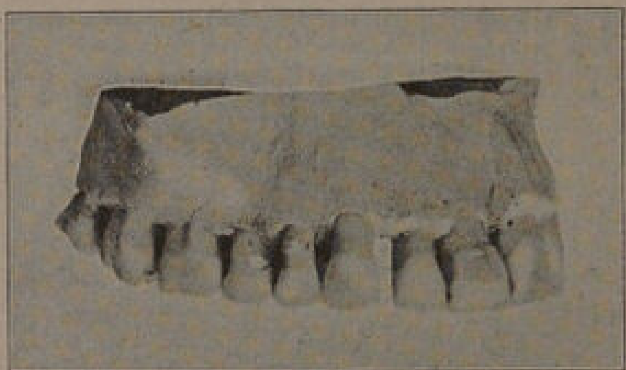


FIG. 47.—Sanguine.

labial surfaces of the lower incisors, the cusps of the bicuspids and molars will be correspondingly long and penetrating, the buccal cusps of the upper teeth extending well down over the buccal cusps of the corresponding lower teeth. In an occlusion of this class, which is usually found in the nervous and bilious types, the dip to the arch will become a prominent feature, the occlusion will be firm and well locked, and the lateral articular movements will be slight during mastication. In the lymphatic and sanguine temperaments the occlusion is loose and wandering, greater freedom of movement being permitted by the short overbite and the corresponding lack of cusp-formation. Figure 46 represents such an occlusion; the superior arch is but little greater in its

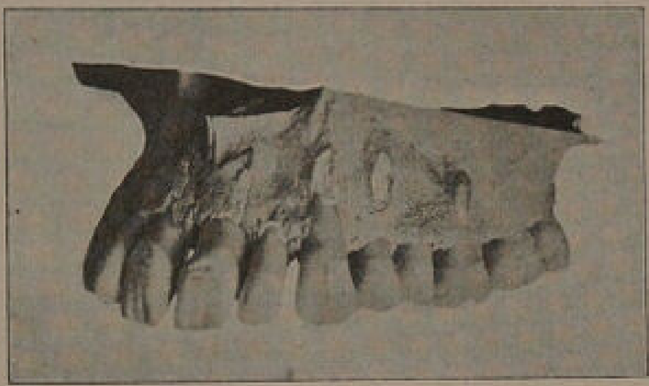


FIG. 48.—Bilious.

segmental outline than the inferior. The cutting-edges of the upper incisors are somewhat more prominent than those of the lower, but the former do not overlap the labial surfaces of the latter. In an occlusion of this character the dip to the arch is not so pronounced, and the articular movements are much more extensive.

CHAPTER VII

The Blood- and Nerve-supply to the Teeth

THE BLOOD-SUPPLY TO THE TEETH

Briefly stated, the course of the blood from the heart to the teeth is as follows: From the heart to the aorta, to the common carotid artery, to the external carotid artery, to the internal maxillary artery, from the various branches of which the teeth are supplied.

The Internal Maxillary Artery (Fig. 50).—This artery, otherwise known as the deep facial, is the larger of the two terminal branches of the external carotid. In addition to supplying the teeth, it is distributed to the roof and floor of the mouth, to the maxillary sinus, and to other parts of the face and head. It has its origin from the external carotid artery opposite the condyle of the mandible within the substance of the parotid gland, passes forward between the condyle of the jaw and the sphenomaxillary ligament, from which point it passes obliquely upward and forward between the external and internal pterygoid muscles until it reaches the sphenomaxillary fossa, where its terminal branches are given off. It is divided into three portions—the first or maxillary, the second or pterygoid, and the third or sphenomaxillary. The teeth are supplied from branches of the first and third divisions, the upper teeth receiving their blood-supply from the alveolar or superior maxillary and the infra-orbital branches of the third division, while the lower teeth are supplied by the inferior dental or mandibular branch of the first division.

The alveolar or maxillary branch arises, in common with the infra-orbital branch, from the internal maxillary as it passes into the spheno-maxillary fossa. It passes downward, in a tortuous manner, in a groove provided for it in the back of the maxilla. In its downward course it gives off the following *branches*: The *antral*, to suppy the antrum; the *dental* (known as the posterior dental arteries), which pass into the substance of the bone through the posterior dental canals to supply the molar and bicuspid teeth; the *alveolar* or gingival, to supply the gums; and the *buccal*, to the lateral walls of the mouth. The anterior upper teeth are supplied through the *infra-orbital branch* of the inter-

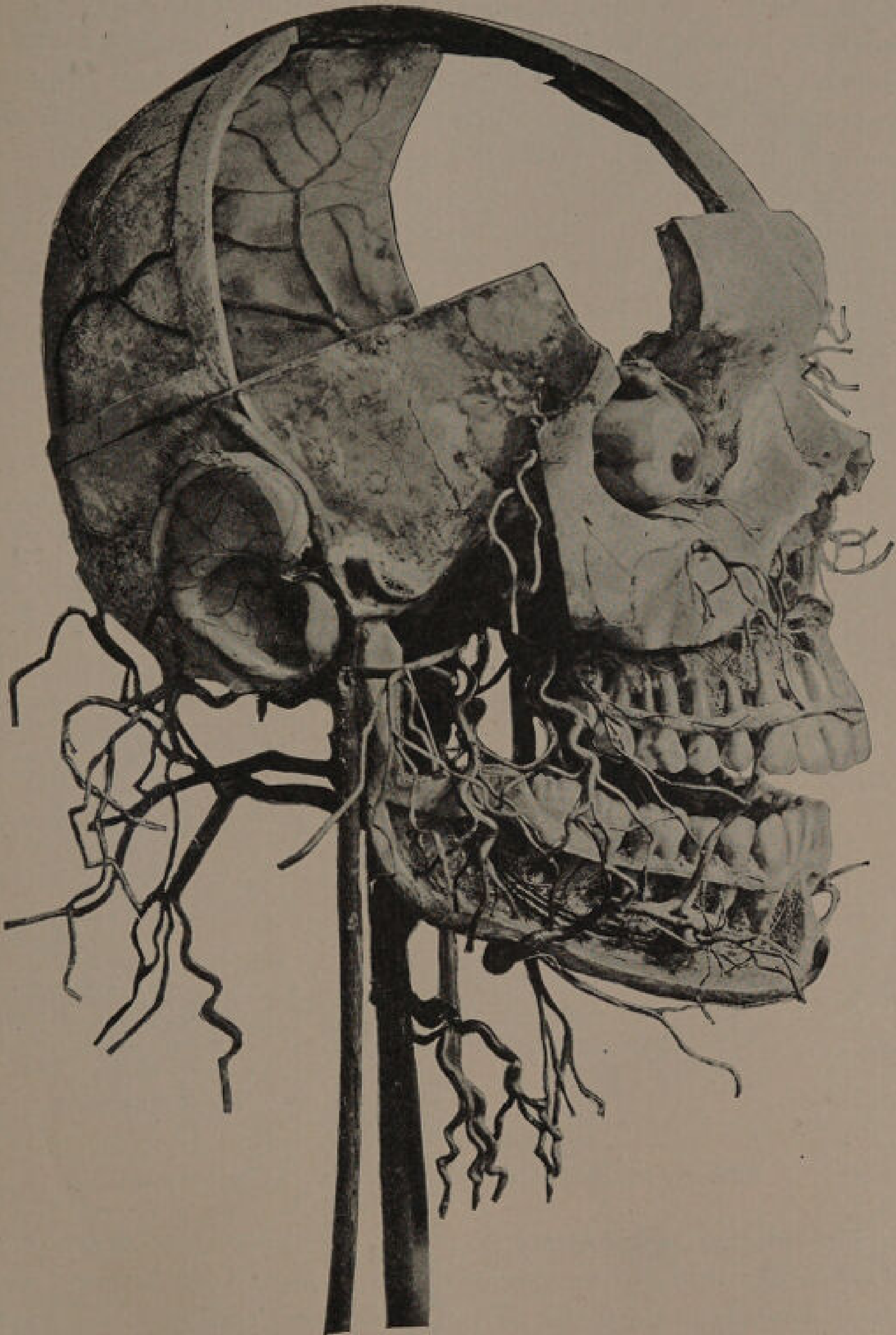


FIG. 49.—Dissection showing blood-supply to the teeth.

nal maxillary. This branch arises from the internal maxillary artery, generally, in common with the posterior dental. It passes forward in company with the maxillary division of the fifth nerve—first along the groove and then in the canal on the orbital plate of the maxilla, and finally makes its exit upon the face through the infra-orbital foramen. Besides giving off branches to the orbital and nasal cavities, it supplies the incisor and cuspid teeth through its anterior dental branch, which passes downward through a groove in the anterior wall of the maxilla.

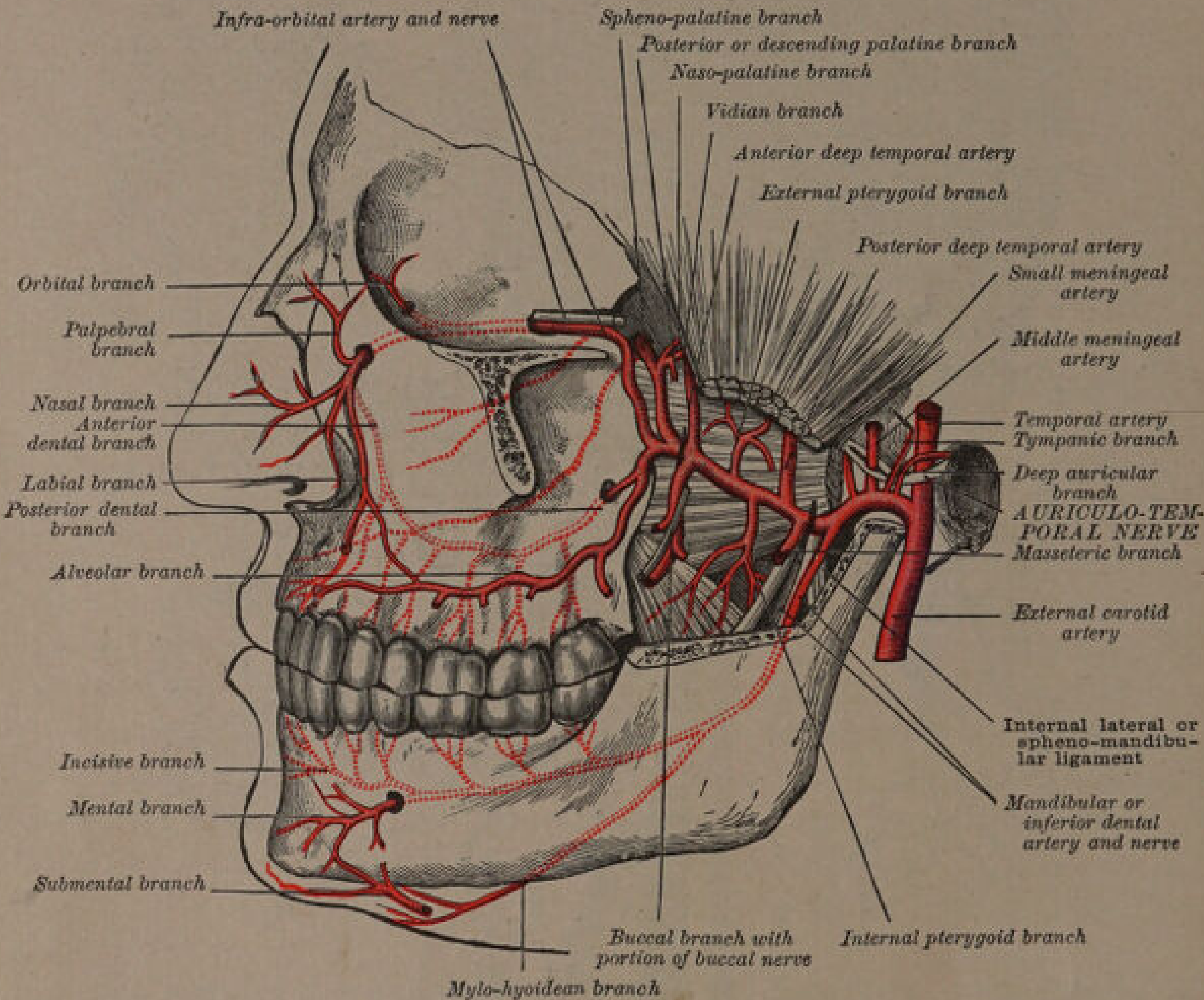


Fig. 50.—Scheme of internal maxillary artery. (*Morris*.)

The Inferior Dental Artery (Fig. 50).—The lower teeth receive their blood-supply through the inferior dental or mandibular artery. This artery arises from the under part of the internal maxillary as it passes downward and forward between the sphenomaxillary ligament and the neck of the jaw and enters the inferior dental canal through the inferior dental foramen. It passes forward in the canal accompanied by the inferior dental nerve, and in so doing sends off twigs to supply the molar

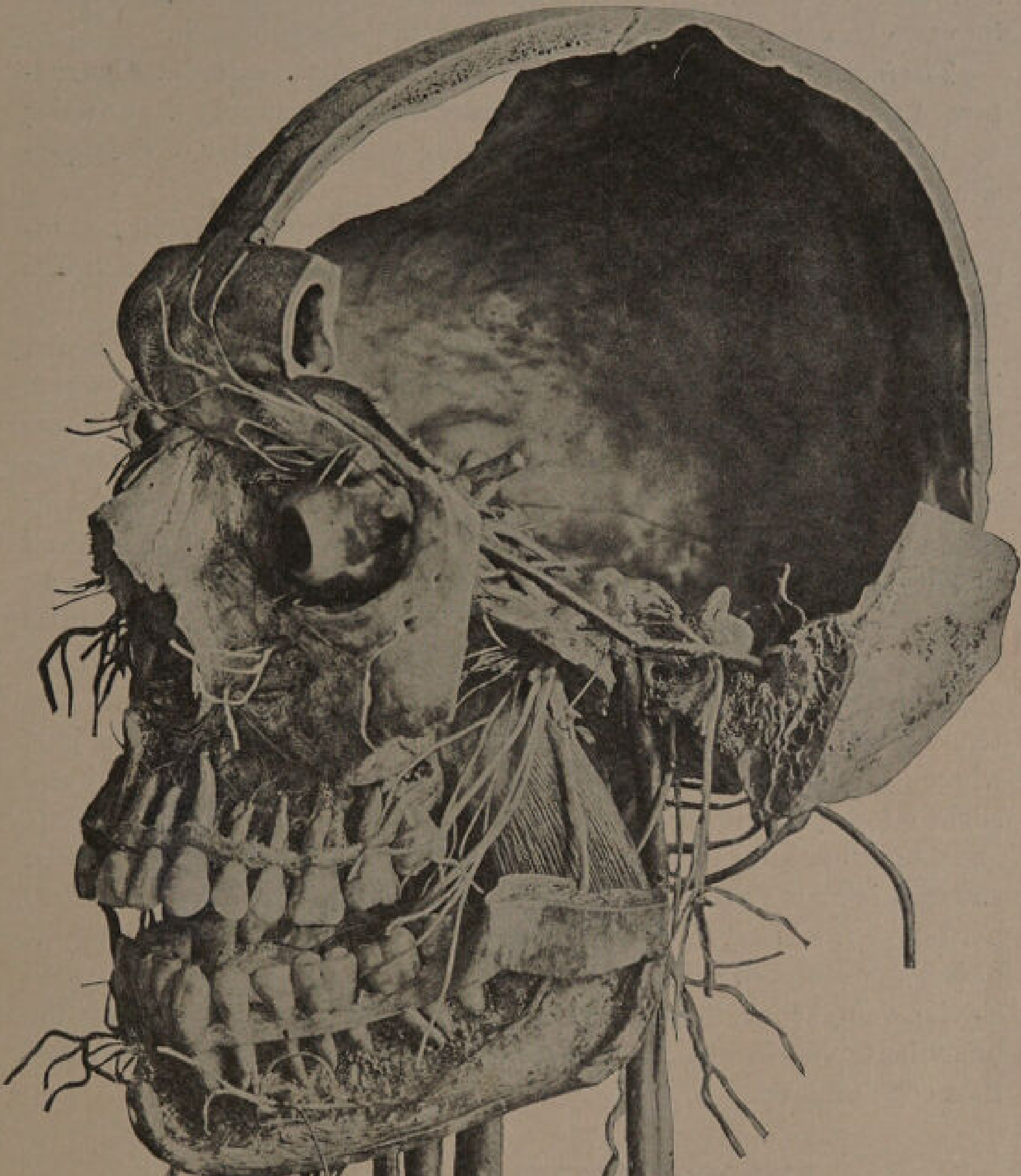


FIG. 51.—Dissection showing nerve-supply to the teeth.

and bicuspid teeth. When the mental foramen is reached, it divides into two *branches*, the *incisive* branch and the *mental* branch.

The incisive branch continues its course within the cancellated structure of the bone, sending off minute branches which supply the anterior teeth, the terminal branches anastomosing with the artery of the opposite side.

The mental branch passes out through the mental foramen accompanied by the mental branches of the inferior dental nerve, and supplies the tissues of the chin and lower lip.

The Veins.—The blood, in returning from the teeth to the heart, is first taken up by the posterior dental and inferior dental veins, which in their course follow closely that of their corresponding arteries. These veins, in conjunction with others which accompany branches of the internal maxillary artery, form the pterygoid plexus. At the posterior confluence of this plexus the returning blood empties into the internal maxillary vein. Accompanied by the internal maxillary artery it passes backward and outward, enters the parotid gland, and finally empties into the temporomaxillary vein midway between the zygoma and the angle of the jaw. After leaving the substance of the parotid gland, the temporomaxillary vein passes downward until near the angle of the jaw, where it divides into two branches, one of which passes downward and slightly forward, uniting with the facial to form the common facial vein, and the other, after passing downward and backward, empties into the external jugular vein. The external jugular vein returns the principal portion of the blood from the teeth, and from its point of beginning it passes almost perpendicularly downward and empties into the subclavian vein, which, by joining with the internal jugular vein, forms the innominate vein, which, in turn, empties into the superior vena cava, thus communicating with the heart.

THE NERVE-SUPPLY TO THE TEETH

The nerves supplying the teeth are derived from branches of the fifth cranial nerve, otherwise known as the trifacial or trigeminal nerve. The fifth nerve is the largest of the cranial nerves, and consists of two parts, a large root, (sensory) and a small root (motor). The larger portion passes into a ganglion (the Gasserian ganglion), frequently compared to the ganglion on the posterior root of the spinal nerve. It arises, or makes its appearance, at the surface of the brain, on the anterior part of the side of the pons Varolii. The sensory root, which, through its branches, supplies the teeth, is composed of from 80 to 100 filaments, each inclosed in a neurilemma, the entire bundle being bound together in a single nerve.

The fifth nerve is divided into three divisions: First, or *ophthalmic;* second, or *superior maxillary;* and third, or *inferior maxillary* (mandibular). The branches which supply the teeth are included in the second and third divisions, the upper teeth being supplied by branches from the superior maxillary nerve, and the lower teeth by branches from the inferior maxillary nerve.

The Second Division, or Maxillary Nerve (Fig. 52).—This nerve, composed entirely of sensory fibers, is intermediate in size between

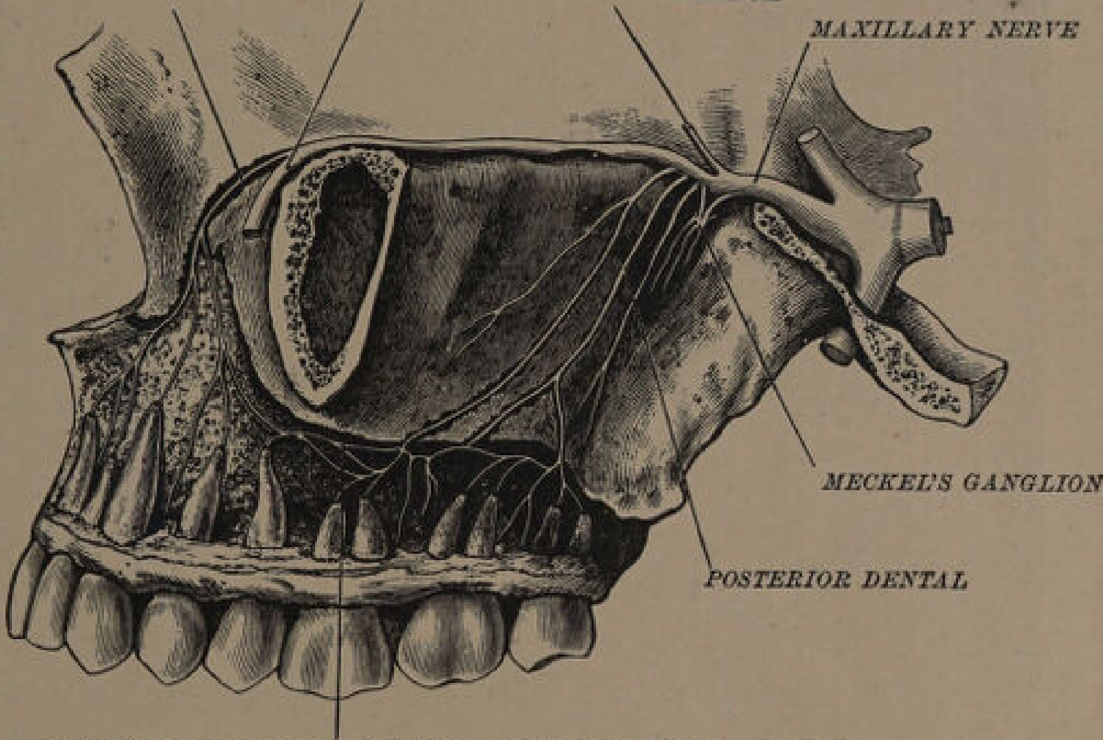


FIG. 52.—The maxillary nerve, seen from without. (*Morris, after Beaunis.*)

the inferior maxillary and the ophthalmic divisions. It passes forward from the Gasserian ganglion and leaves the cranium through the foramen rotundum. It traverses the upper part of the sphenomaxillary fossa, and passes into the orbit through the sphenomaxillary fissure; then passes forward along the infra-orbital groove, and enters the infra-orbital canal, where it receives the name of infra-orbital nerve. Passing through this canal, it emerges upon the face through the infra-orbital foramen. The maxillary nerve, beside supplying the teeth, sends off branches to the dura mater, to the orbit, and terminal branches in three groups—labial, nasal, and palpebral. The branches given off to the teeth are the *posterior superior dental*, the *middle superior dental*, and the *anterior superior dental*.

The posterior superior dental arises from the second division of the fifth nerve, by one or two roots, just before it passes into the infra-orbital canal. It is divided into a superior and an inferior set; the former passes forward and terminates in the canine fossa, while the latter, usually the larger, enters the posterior dental canals, and,

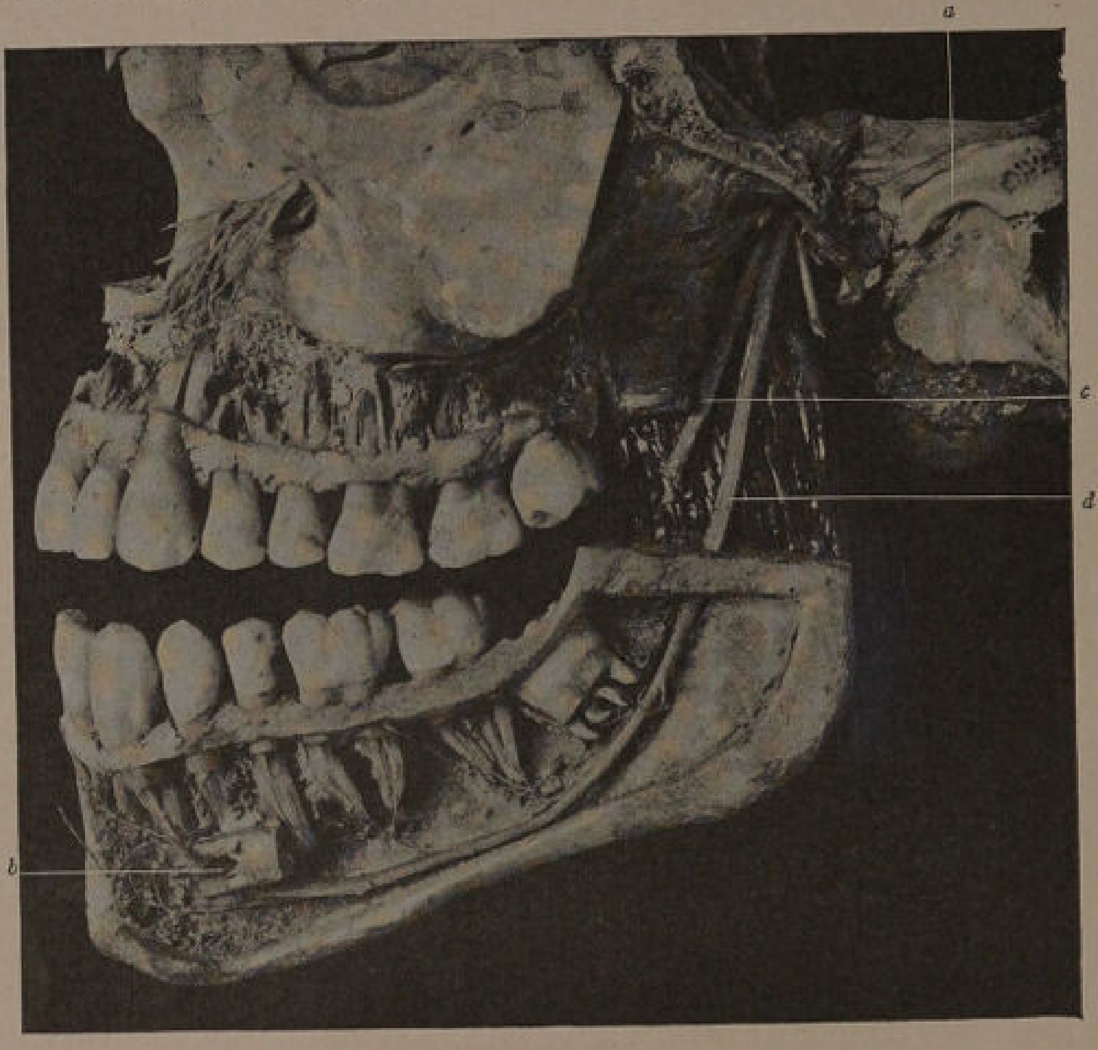


FIG. 53.—Dissection showing mandibular (third) division of fifth nerve. *a*, Temporal bone; *b*, mental branches emerging through mental foramen; *c*, lingual nerve; *d*, mandibular or inferior dental nerve.

following the line of the alveolar process through minute canals in the bone, sends off twigs to the molar teeth, ending in a plexiform manner by communicating with the middle superior dental nerve. This nerve is also distributed to the gums and adjacent buccal mucous membrane.

Middle Superior Dental Nerve.—The infra-orbital nerve, soon after entering its canal, gives off this branch, which passes outward, downward, and forward over the outer wall of the maxillary sinus, and, after forming plexuses with the posterior dental branches, gives off filaments to supply the bicuspid teeth.

The anterior superior dental nerve, which is the largest of the dental set, is given off from the infra-orbital nerve, enters a canal close to the infra-orbital foramen, passes over the anterior wall of the maxillary sinus, and, after communicating with the middle and posterior dental nerves, divides into ascending and descending branches, the latter being distributed to the incisor and cuspid teeth.

The Third Division, or Mandibular Nerve (Fig. 54).—This is the largest of the three divisions of the fifth nerve, and is both motor and sensory in its function. Besides being distributed to the lower teeth, it sends filaments to the lower portion of the face, the muscles of mastication, the tongue, and mandible. It arises from the Gasserian ganglion, passes downward, and emerges from the skull through the foramen ovale, after which it divides into a small anterior (motor) branch and a large posterior (sensory) branch.

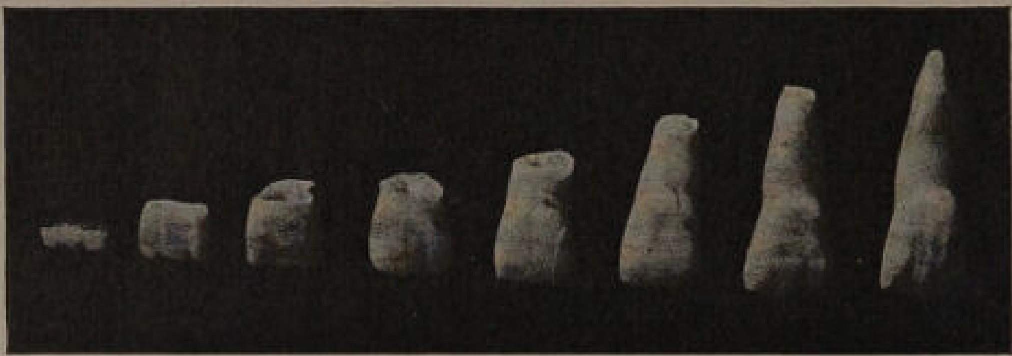
The Inferior Dental Nerve.—This is the largest branch of the inferior maxillary nerve. From its point of origin it passes downward internally to the external pterygoid muscle, and, upon reaching a point between the ramus of the mandible and the sphenomandibular ligament, it enters the inferior dental canal through the posterior or inferior dental foramen. Before entering the foramen, two branches are given off, a lingual and a mylohyoid branch. The nerve is accompanied through the inferior dental canal by the inferior dental artery, and, when the mental foramen is reached, it terminates by dividing into an *incisive* and a *mental* branch. Between the posterior dental foramen and the mental foramen the nerve gives off a series of twigs to the bicuspid and molar teeth, and these, by communicating with one another within the substance of the bone, form a fine plexus.

The incisive branch follows the incisive arteries through the substance of that part of the bone between the mental foramen and the symphysis, and supplies the incisor and bicuspid teeth, while the mental branch passes forward to supply the chin and lower lip.

CHAPTER VIII

A Description of the Upper Teeth in Detail—Calcification, Eruption, and Average Measurements—Their Surfaces, Ridges, Fossæ, Grooves, Sulci, Etc.

UPPER CENTRAL INCISOR



1st year	3d year	6th year	7th year	8th year	9th year	10th year	11th year

Fig. 54.

Calcification Begins, from Three Centers, during the First Year.
Calcification Completed, Tenth to Eleventh Year.
Erupted, Seventh to Eighth Year.
Average Length of Crown, .39.
Average Length of Root, .49.
Average Length over All, .88.

This tooth begins to calcify during the first year, the process taking place along the future incisal-edge of the tooth in three distinct lobes or plates, *centers of calcification*, which afterward unite and form three eminences or tubercles, the lines of this union being indicated upon the completed crown by two more or less defined grooves—*developmental grooves*. By the end of the third year the deposit of lime-salts has carried the process of calcification to a point about midway between the incisal-edge and the cervical line. By a continuation of this formative action the calcification of the crown is completed between the fifth and sixth year. At the beginning of the seventh year calcification has progressed to such an extent that the neck of the tooth and base of the root are fully outlined. Between the seventh and eighth year the incisal-edge of the tooth begins to make its appearance through the gum at a point either to the right or left of the median line, and, by a gradual absorption of the gingival tissue, the *eruption* of the tooth takes place. During the following year about one-eighth of an inch has been added to the length of the root. At the end of the eighth year the root has become calcified to about one-half of its completed length. During the ninth year, owing to a reduction in the diameter of the root, the extent of growth has almost doubled that of the previous year, the root beginning to assume it conical outline. At the eleventh year calcification is completed in the outer root walls (Fig. 54).

The Crown of the Upper Central Incisor presents for examination four surfaces—labial, lingual, mesial, and distal; two angles—a mesial and a distal; and an incisal-edge. The general form of the crown is that of a double inclined plane, or wedge-shape, the incisal-edge representing the junction of the two sides of the incline, one of which looks anteriorly (labial) and the other posteriorly (lingual). The labial side of the incline is convex, while the lingual is concave from the cutting-edge toward the root; but, upon reaching its upper or cervical third, it presents a slight general convexity. The base of the wedge is directed upward and partakes of the contour of the neck of the tooth.

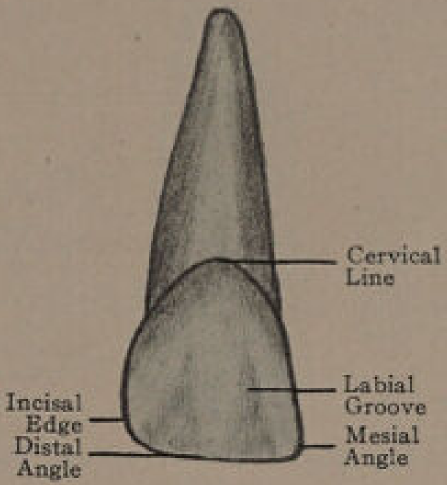


FIG. 55.—Upper central incisor, labial surface.

The Labial Surface of the Crown (Fig. 55).—In general outline this surface resembles an imperfect quadrilateral. The *margins* of the surface are the *mesial*, the *distal*, the *cervical*, and the *incisive*. The mesial margin begins at the lower border or incisal-edge and passes upward, usually with a slight distal inclination, gradually uniting with the cervical margin. The distal margin begins at the incisal-edge and passes upward with a slight mesial inclination, also joining the cervical margin. Both of these margins possess more or less general convexity, and, at their junction with the incisal-edge, form the mesial and distal angles of the crown. The cervical margin is rounded and gradually passes into the two lateral margins just described. The incisive margin is marked by the incisal-edge, and extends from the mesial angle on one side to the distal angle on the other. These four margins, which assist in giving to the tooth its typal form, are quite variable. This difference is particularly marked on the mesial and distal margins, where, in some instances, there is a decided convergence in the direction of the root, forming what is commonly termed the bell-shaped crown, while in others the same margins will be nearly parallel with each other, making the width of the crown almost as great at the cervical margin as at the incisal-edge. The mesial angle is usually pointed and square, while the distal is somewhat rounded. This surface of the crown is slightly convex from above downward, as well as from side to side, and in the majority of instances is of greater vertical than transverse extent. Beginning at the incisive margin are two slight longitudinal depressions or grooves—the *labial grooves*—which result from the developmental lobes previously composing the primitive incisal-edge, and, for this reason, are known as developmental grooves. In many instances one or more transverse ridges are found upon the cervical portion, but these are supplemental in character.

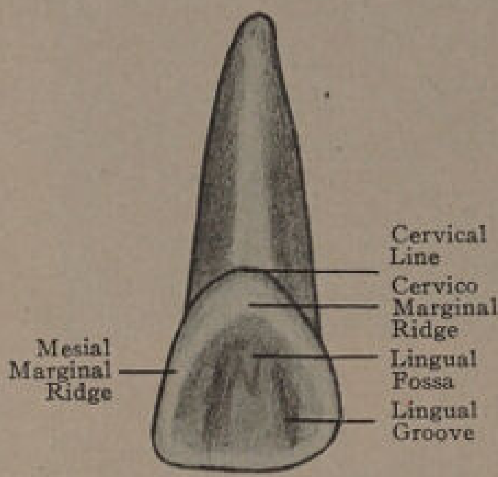


FIG. 56—Upper central incisor, lingual surface.

The Lingual Surface of the Crown (Fig. 56).—This surface has its borders formed by three marginal ridges and the incisal-edge. The marginal ridges are pronounced elevations of enamel, and surround the surface upon three sides, the intervening space in many instances being a decided concavity or fossa—the *lingual fossa.* The *mesial marginal ridge* begins at the mesial angle of the crown, passes upward, inward and backward, following the curvature of the mesial border. The *distal marginal ridge* begins at the distal angle of the crown in a somewhat less pronounced form, passes upward, backward, and inward, following the curvature of the distal surface. Upon reaching the cervical portion of the crown these two margins unite and form the *cervicomarginal ridge.* This ridge may be bold and prominent, or it may be but slightly developed. Near its center this surface is frequently broken by a depression or pit—the *lingual pit.* In some instances this pit is deeply penetrating; in others it assumes the form of a fissure, and may completely sever the marginal ridge at the cervex. The cervical border is sometimes elevated into a slightly developed tubercle or cusp—*cuspule.* When this is present it has the appearance of being produced by a fold of enamel, and encircling it is a well-marked fissure. The lingual fossa, is usually traversed by two longitudinal grooves, which correspond to the development grooves of the labial surface. When a cuspule is present, the fissure which surrounds it frequently passes into the fossa, or the fossa may be partly covered by the cuspule overhanging its cervical portion. When the cervicolingual fissure exists, it is not unusual for it to bifurcate and throw a branch along the inner border of each marginal ridge, or it may penetrate the fossa proper and divide it into two parts. The lingual surface is somewhat less in extent than the labial surface, this reduction being principally in a mediodistal direction, the length of the two surfaces from the incisal-edge to the cervical margin being about equal.

The Mesial Surface of the Crown (Fig. 57).—The outline of this surface resembles an inverted cone or triangle, the lines of which are more or less broken, the apex of the cone terminating at the incisal-edge and the base directed toward the root of the tooth. The base of the cone is made concave by the enamel margin or cervical line. The *margins* of the mesial surface are the *labial*, the *lingual*, and the *cervical*. The labial margin is convex and rounded throughout its entire extent, from the incisal-edge to the cervical line. The contour of this margin varies with the typal form of the crown, in some presenting a decided and well-marked convexity, in others being but slightly curved. The lingual margin is concave and rounded, but the line is somewhat broken. Beginning at the incisal-edge, it is decided and square, this feature usually including the lower third. As it passes upward and the center is approached, the line is more concave and rounded in a mesio-lingual direction, this latter feature increasing as the cervical line is approached. The cervical margin is that formed by the cervical line. It is usually defined, being concave or V-shaped, with the point of the V more or less rounded, and with its free ends pointing one in a labial and one in a lingual direction, the former being a trifle longer than the latter. The surface between the borders presents a slight general convexity, but with an inclination to flatness near the cervical portion, which is occasionally developed into a slight concavity. Whatever deviations may be present in the borders of this surface, from those assumed in the description just given, their union at the cutting-edge will always be in a direct line with the long axis of the tooth.

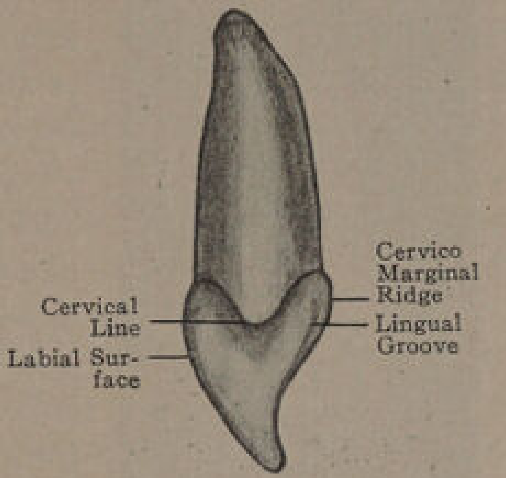


FIG. 57.—Upper central incisor, mesial surface.

The Distal Surface of the Crown.—In a general way, this surface resembles the mesial surface just described. There are, however, one or two minor points of distinction: the borders are all more rounded, the labial border presenting a greater convexity, and the lingual a more perfectly formed concavity. The surface is quite full in the center, from which it slopes away in all directions, thus producing a decided general convexity. The cervical margin of the surface is almost identical with the cervical margin of the mesial surface. The distance in a direct line from the cervical border to the cutting-edge is a trifle less than the corresponding measurement on the mesial surface. The distal angle is equally constant in its position, and, being connected with the mesial angle in a direct line by the incisal-edge, finds this latter margin always in the labiolingual center of the crown.

Fig. 58—A young upper central incisor, labial surface, showing developmental grooves—a.

The Incisal-edge of the Central Incisor.—The cutting or incisive edge receives its name from its function, that of cutting or incising the food. It is formed by the junction of the labial and lingual surfaces of the crown, and extends almost in a direct line from the mesial to the distal surface; at its union with the mesial surface it assists in forming the mesial angle of the crown, and serves the same purpose by its union with the distal surface. In the majority of instances it is an unbroken line. In passing from themesial to the distal angle it converges slightly in the direction of the root, thus making the crown a trifle larger on the mesial than on the distal side. In the recently erupted tooth (Fig. 58) the line is broken by the developmental grooves; these usually disappear by wear, but occasionally traces of their existence remain, and thus permanently break the positive line that would otherwise be present. As the incisal-edge approaches the distal angle of the crown it is inclined to slope away, producing a less positive angle than the corresponding mesial angle. In some instances the incisal-edge is quite thin and inclined to sharpness, in others it is blunt and dull, the former condition being present when there is a decided overbite, the latter occurring when this feature is less pronounced. The incisal-edge is frequently referred to as the *occlusal surface*, this term being employed to make the description more uniform with the bicuspids and molars, and for this reason is permissible; but it is only in rare instances that the surfaces occlude directly with the opposing teeth, the condition being most frequent in teeth of the lymphatic type, and in cases of malocclusion.

The Cervical Margin.—This margin, which is distinctly outlined by the free extremity of the enamel covering of the crown, also marks the extent of the root. The margins formed by this line are those of a double concavity and a double convexity. On the labial and lingual portions it is concave rootward, while on the mesial and distal sides it is convex in this direction. If a line be drawn around the tooth at the extreme upper point of the enamel, it will be found to touch only the labial and lingual prolongations, while a space will exist between the line thus drawn and the cervical margins of the proximate surfaces. The character of the cervical curvature varies with the type of the tooth, being more or less pronounced as the case may be. In a typical central incisor the cervical line of the labial surface will usually form the segment of a larger circle than that of the lingual, and, while the mesial convexity may be gracefully curved, the distal may incline to angularity.

The Neck of the Tooth.—The neck of this tooth partakes partly of the outline of the crown and partly of the root. It is principally formed by a sudden sloping of the enamel margin to meet the root. It is broader on the labial than on the lingual surface, and is somewhat flattened laterally, with an occasional depression or concavity on its mesial portion. The neck of this tooth is seldom a decided anatomic feature, being less pronounced than upon any other tooth. In the bicuspids and molars both the crowns and the roots assist in forming the neck by a constriction of their adjacent parts, while in this tooth the neck is formed chiefly at the expense of the crown.

The Root of the Upper Central Incisor.—The root of this tooth is conic in form, its base directed downward, its apex upward. Viewed in transverse sections its outline is that of a rounded triangle, one side of which faces in a labial, one in a mesiolingual, and one in a distolingual direction. The labial side is the most flattened, while the two remaining sides are of equal length and oval in form. This triangular outline usually continues throughout the entire length of the root, but in some instances, near the apical end, may have a decided or slight distal curve, included in which will be a more circular form. The taper of the root from the base to the apex is very gradual upon the labial and lingual surfaces, until the apical third is reached, when the two sides converge more rapidly. The mesial and distal surfaces are somewhat flattened and taper very gradually from the base to the apex. In a majority of instances the root is much longer than the crown, but in rare cases its length is barely equal to, or less than, that of the crown.

Bilious Type.—The crown of the upper central incisor in this type is of greater longitudinal than transverse extent; large in size, abounding in angles rather than curves. It possesses neither brilliancy nor transparency of surface, but is slightly inclined to translucency. The labial surface is flat, with more or less decided transverse ridges in the cervical portion. The labial grooves are generally present in the form of well-defined depressions. On account of the angular nature of the tooth, this surface approaches closely to the quadrilateral form. The mesial and distal surfaces are flat, with their margins bold and well defined. The lingual surface also shows the angular nature of the crown in having its marginal ridges squarely set and its developmental grooves definitely outlined. The incisal-edge is rather thin, square, and sharp, the line frequently being imperfectly formed. The mesial and distal angles are both well produced, and the cervical margin, in keeping with the rest of the tooth, is inclined to angularity.

Nervous Type.—The central incisor common to this temperament is delicate and graceful in outline. The crown is of medium size, with the length predominating over breadth. The enamel is inclined to transparency, and is of a bluish-white or bluish-gray color, presenting much brilliancy. The labial surface is fairly well rounded, and the labial grooves are present as slightly rounded depressions, which frequently extend well toward the cervical margin, where they gradually disappear. In general outline this surface partakes of the triangular form, the crown of the tooth being broad at the incisal-edge and much constricted at the neck. The mesial and distal surfaces show a convexity in every direction, and the nature of the occlusion is manifest from the decided wedge-shape appearance of the crown providing for a long overbite. Upon the lingual surface but little in the way of detail is to be observed, the entire surface from the incisal-edge to the cervical ridge being smooth and concave. The cuspule previously referred to is occasionally present in this type, breaking the general smoothness of the surface to some extent. The marginal ridges are poorly defined; the incisal-edge is a sharp, unbroken line; the mesial and distal angles are present in the form of long, graceful curves, rather than definite angles, this being particularly true of the distal angle. The cervical line is decidedly curved, the labial and lingual portions being deeply concave rootward, while the mesial and distal are decidedly convex.

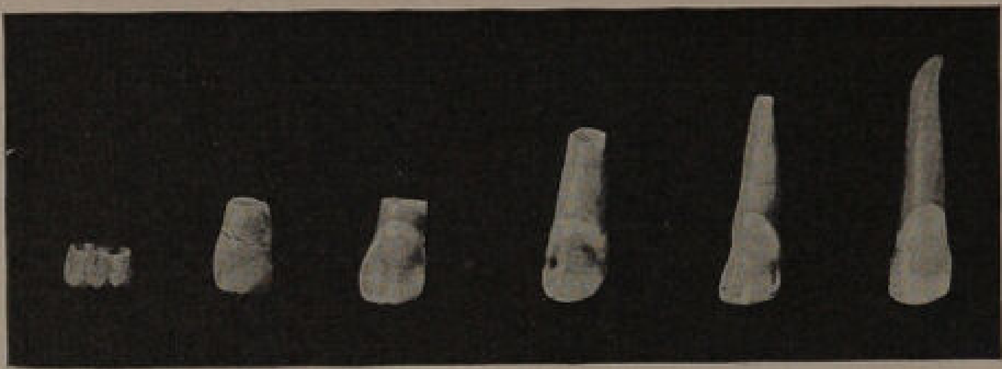
Sanguineous Type.—The crown of the central incisor is usually above the average in size, but is well proportioned, abounding in curves and rounded outlines. The enamel is inclined to translucency, particularly near the incisal-edge with a brownish or cream yellow the predominating color. The labial surface is smooth and rounded; the depressions formed by the labial grooves are slight, and extend but a short distance from the incisal-edge. The surface is somewhat greater in longitudinal than in transverse extent, and approaches much nearer to a circular form than the corresponding tooth of other types. The mesial and distal surfaces are well rounded, making the point of contact with approximating teeth near the center of the surface. The lingual surface abounds in heavy rounded lines; the marginal and cervical ridges are particularly prominent, reducing the extent of the lingual fossa. A cuspule is frequently present in the form of a well-rounded prominence. The incisal-edge is of moderate thickness and slopes away from the center in either direction to assist in forming the rounded mesial and distal angles. The cervical curvature on the labial and lingual surfaces is an unbroken semicircle, while that of the mesial and distal surfaces is less uniform.

Lymphatic Type.—In the central incisor of this typal form the crown is large, but not shapely, and the breadth is equal to, or exceeds, the length. The enamel coloring is muddy or brownish-yellow, and the surface is lacking in brilliancy. The labial surface is flat and smooth, with a faint sign of the labial grooves. The general outline of this surface is that of a circular cone, with the incisal-edge for the base, and the apex formed on the cervical margin. The mesial and distal aspects present a striking contrast to the types previously described, by having a labiolingual diameter greater than that represented between the cervical line and the incisal-edge. These two surfaces are convex in a labiolingual direction only, making the point of contact with approximating teeth an extended surface rather than a single point.

The lingual surface is heavy and bulky, frequently to such a degree as to produce a general convexity rather than a concavity, as found in most typal forms. This surface is frequently broken by one or more longitudinal grooves, but is seldom crossed by transverse lines of any kind. The incisal-edge is barely deserving of the name. Although formed by the free borders of the labial and lingual surfaces, these two planes are so far separated at their incisive margins that the space between them, instead of being an edge, becomes a more or less broadened surface, and one against which the lower incisors frequently occlude.

The line thus formed is straight and direct from the mesial to the distal angle of the crown, both of which are well produced. The cervical curvature is represented by the segment of a much larger circle than that found upon teeth of other types, and the neck of the tooth is heavy and bulky, showing but little constriction at this point.

UPPER LATERAL INCISOR



4th year 5th year 7th year 9th year 10th year 11th year

FIG. 59.

CALCIFICATION BEGINS, FROM THREE CENTERS, DURING THE FIRST YEAR.
CALCIFICATION COMPLETED, TENTH TO ELEVENTH YEAR.
ERUPTED, SEVENTH TO EIGHTH YEAR.
AVERAGE LENGTH OF CROWN, .34.
AVERAGE LENGTH OF ROOT, .51.
AVERAGE LENGTH OVER ALL, .85.

Like the central incisor, calcification in this tooth begins during the first year, the process taking place in the same manner, from three centers, along the future incisal-edge, and gradually extending in the direction of the root. By the expiration of the third year the incisal-edge and the angles of the crown are fully formed; the fourth year finds the crown calcified to nearly one-half its length; by the fifth year the cervical ridge is reached while the sixth year usually completes the process of calcification in the crown. At the close of the seventh year the base of the root is fully outlined, during the following year about one-eighth of an inch is added to its length, and still greater progress is made during the ninth year, by which time fully three-fourths of the root length has become calcified. During the tenth year the apical end of the root begins to form by a sudden doubling-over of the free calcifying margins, and by the eleventh year the surface of the root is complete (Fig. 59). By the above description it will be observed that at the time of eruption the root of this tooth is only calcified to about one-half of its completed length, and the same may be said of the central incisor; but so much time elapses between the beginning of the eruptive stage and the period at which this phenomenon is completed that the calcification of the root is usually finished by the time the tooth assumes its permanent position in the jaw.

The crown of the upper lateral incisor, like that of the upper central incisor, presents for examination four surfaces—labial, lingual, mesial, and distal—a cervical margin, an incisal-edge, and a mesial and distal angle. The general contour of the crown closely resembles that of the upper central incisor, except that it measures about one-third less from mesial to distal, and is a trifle shorter form the incisal-edge to the cervical line. As in the central incisor, the labial and distal surfaces form a double incline plane, and unite below to form the incisal-edge. The labial side of the incline is convex, while the lingual is concave, but seldom so marked as that of the central incisor. The base of the wedge, or double incline, formed by the cervical margin, is correspondingly smaller than that of the crown of the central incisor.

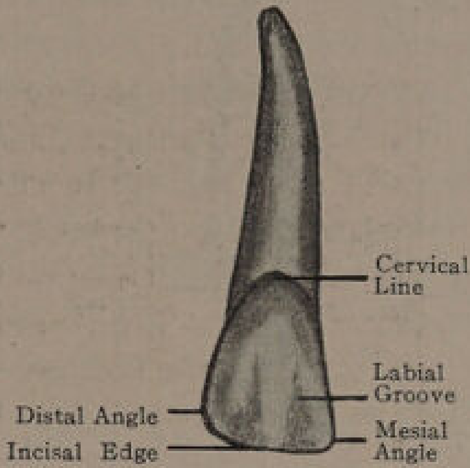


FIG. 60.—Upper lateral incisor, labial surface.

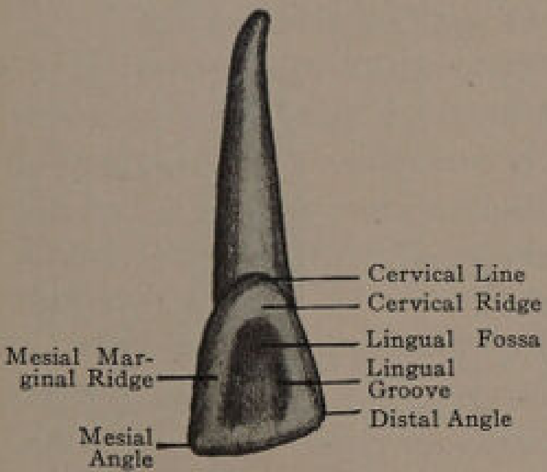


FIG. 61.—Upper lateral incisor, lingual surface.

The Labial Surface of the Crown (Fig. 60).—This surface of the crown of the upper lateral incisor is more irregular in outline than the corresponding surface of the central incisor. The *margins* of the surface are the *mesial, distal, cervical, and incisive.* The mesial margin begins at the mesial angle and passes upward with a decided distal inclination to meet the cervical margin. The distal margin is shorter and decidedly more convex than the mesial margin, this variation in outline being still more marked when compared with the corresponding margin of the central incisor. At the incisal-edge these two margins assist in forming the mesial and distal angles of the crown, and by their continuation and union above form the cervical margin. The incisive margin is formed by the incisal-edge. Like the central incisor, the four margins of this surface vary greatly in the different types; this is particularly true of the two lateral margins, which at times are found to be in the form of a direct line, or even slightly concave, while in others they are both decidedly convex. This surface of the crown shows a greater general convexity than the labial surface of the central incisor, the cervical portion presenting a curve much more decided than that near the incisal-edge. The *labial grooves* are in all respects similar to those described in connection with the central incisor, and extend from the incisal-edge toward the center of the surface, where they gradually disappear. Transverse ridges are occasionally found near the cervical portion of the surface.

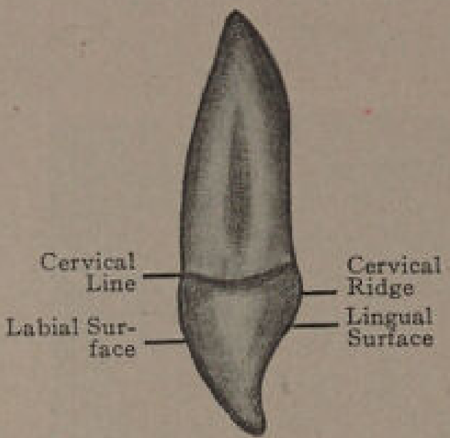


FIG. 62.—Upper lateral incisor, mesial surface.

The Lingual Surface of the Crown (Fig. 61).—This surface of the upper lateral incisor is subject to much variation in form, but presents the same points for examination as the corresponding surface of the central incisor. These consist of the marginal ridges, which are usually more pronounced than those of the central, making the concavity or fossa between them small and deep. In some instances the surface will be smooth and flat, with an entire absence of ridges or fossæ. The *distal marginal ridge* is shorter and more bowed than the mesial, and the *cervical ridge* is well marked and proportionately broader and stronger than in the central incisor. In some instances the marginal ridges are but slightly developed, with their cervical ends broadened and separated by a deep fissure, giving the appearance of a terminal fold in the enamel. The cervical ridge is frequently broken by a cuspule, which is usually more pronounced than when found upon the central incisor. The *lingual fossa* may be present as a smooth, unbroken concavity, or it may be subdivided by a longitudinal ridge, which often exists to such an extent as to force the remaining portions of the fossa well against the

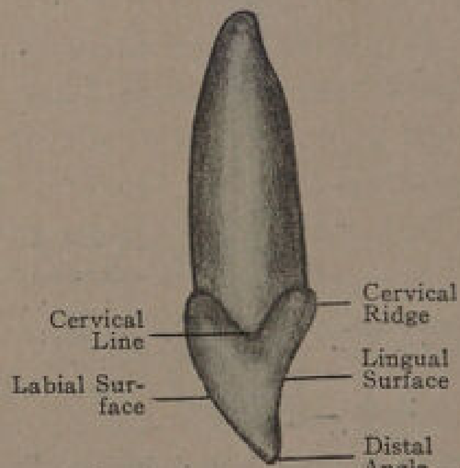


FIG. 63.—Upper lateral incisor, distal surface.

marginal ridges, where they will be observed as slight depressions rather than marked concavities.

The Mesial Surface of the Crown (Fig. 62).—Viewing the crown from this aspect, the outline is that of an inverted cone or triangle. The *lingual margin* of the surface is well defined, and the angle formed by the union of this surface with the lingual surface is moderately acute. The *labial margin* is well rounded, and passes into the labial surface without a decided line of demarcation. The surface on its upper or cervical third is usually flattened and occasionally concave. At the center, and continuing toward the incisal-edge, it is decidedly convex in every direction, thus producing a prominent point of contact with the distal surface of the central incisor.

The Distal Surface of the Crown (Fig. 63).—This surface also shows the characteristic wedge-shape of the crown, and is principally different from the mesial surface in being convex throughout. Near the center it is well rounded and full, providing a point of contact for the mesial surface of the cuspid. The *lingual margin*, while being more decided in outline than the labial, is much more rounded than the lingual margin of the mesial surface. From the most prominent point near its center the surface slopes away in every direction, the convexity being most marked near the incisal-edge.

The Incisal-edge of the Lateral Incisor.—In the young tooth the incisal-edge presents the three mamilla tubercles common to all incisors, the grooves which divide them passing up over the labial and lingual surfaces and forming the labial and lingual grooves. These tubercles soon disappear by wear, leaving the incisal-edge in the form of a direct line and connecting the two angles of the crown. Like the central incisor, this margin of the crown may be thin and sharp, or it may be thick and dull.

The Cervical Margin.—The line of demarcation between the crown and the root of the tooth resembles so closely that described in connection with the central incisor that it will only be necessary to mention one or two characteristic differences. The lingual side of the line presents a much smaller curve proportionately, and usually extends a little higher in the direction of the root than that represented upon the labial portion. The mesial and distal portions of the line dip well down, decreasing the length of the crown on these surfaces; the margin on the former surface is usually angular and V-shaped, while on the latter it is circular in form.

The Angles of the Crown.—The angles of the crown are the mesial and the distal, and are formed in the same manner as the same angles of the central incisor. The mesial angle is generally well produced, inmost instances being slightly acute; but when the incisal-edge is thin and frail, the angle is frequently much obliterated by wear. That portion of the crown of the upper lateral incisor which is usually referred to as the distal angle is scarcely worthy of the name. It is usually present as a long curve, which begins near the center of the incisal-edge and extends well up on the distal surface. This characteristic outline is sometimes so pronounced as to completely destroy the incisal-edge, the distal surface being carried forward by a long curve ending in the mesial angle.

The Neck of the Tooth.—In this tooth the neck is usually marked by a constriction much more pronounced than that found in the central incisor. On the labial and lingual surfaces it is principally formed by a sudden sloping of the enamel surface rootward, but on the two lateral surfaces it is formed by a flattening or slight concavity of both the crown and the root.

The Root of the Upper Lateral Incisor.—The root of this tooth is conic in form, and is much more flattened from mesial to distal than the root of the central incisor. At its junction with the crown it is circular in form, the labial portion forming the segment of a larger circle than the lingual, this feature being observed throughout its entire length. The flattening of the mesial and distal sides begins immediately above the neck, and gradually increases as the center of the root-length is approached, where it often develops into a slight longitudinal depression. As the apex of the root is approached, this longitudinal depression gradually disappears, and the root again becomes circular in form. The thickness of the root is about one-third greater from labial to lingual than from mesial to distal, and, while it is generally classed as a straight root, it is frequently provided with a pronounced distal curve near its apex. In some instances it is found with a double mesiodistal curve.

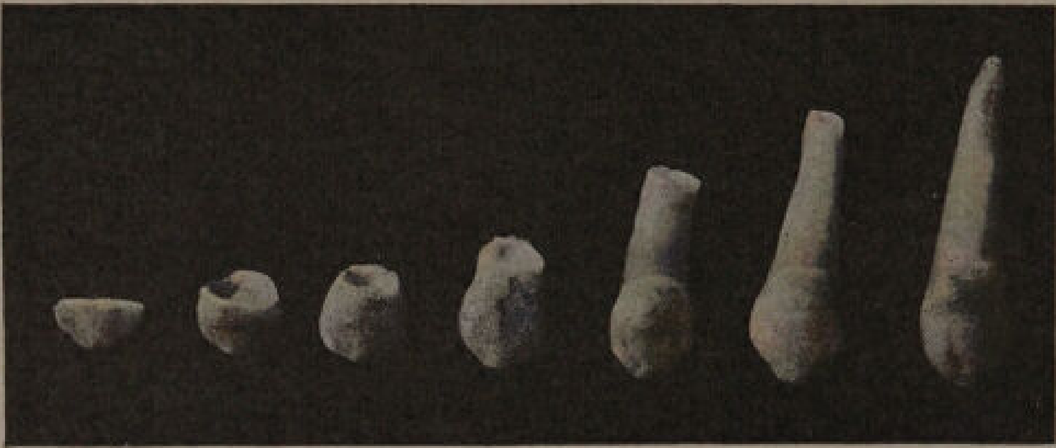
Bilious Type.—In this type the lateral incisor is frequently poorly developed, the incisal-edge and distal angle are wanting, the crown being in the form of a single conic cusp, the distal surface meeting the mesial at a point near the mesial angle. This form of crown might be classed as one of malformation, but the fact that it most frequently occurs in this temperament would appear to indicate a normal condition. When the crown takes the form common to incisors, it is of greater longitudinal than transverse extent, the angles are well produced, and the mesial and distal surfaces are flat and almost parallel with each other. The labial surface is flat and is frequently broken by transverse ridges near the cervical portion. The lingual surface presents well-marked outlines and margins, a cuspule is seldom present, and the lingual fossa is well marked, but not deep. The incisal-edge is thin and sharp, to provide for the overbite, which is rather long. The cervical border is square and angular.

Nervous Type.—In this typal form the neck of the tooth is a pronounced feature. The crown is long and narrow, the constriction forming the neck beginning well down on the crown and extending over the cervical line to the surface of the root. The labial surface is convex in every direction and the labial grooves fairly well defined. The mesial surface is convex near the center and incisal-edge, but often shows a slight concavity on its cervical portion. The distal surface is rounded and smooth. The lingual surface presents a general concavity, a cuspule being more frequently present than in other types. The lingual fossa is deep, and often extends beneath the cervicomarginal ridge in the form of a circular fissure. The incisal-edge is thin and sharp, providing for a long overbite; the mesial angle is pointed and well formed, while the distal is usually much rounded. The cervical line is well arched, forming the segment of a much smaller circle than that seen on the same tooth of other temperaments.

Sanguineous Type.—The crown is well proportioned, with the length slightly predominating over breadth, all the surfaces being more or less rounded and smooth, showing the crown to be made up of curves rather than angles. The labial surface presents a graceful convexity throughout; the mesial and distal surfaces are both convex, with their margins poorly defined. The lingual surface shows the rounded nature of the crown in having its fossa and marginal ridges oval and blending one into the other. The incisal-edge is moderately heavy and dull, in keeping with the overbite, which is short. The cervical line is made up of curves rather than angles.

Lymphatic Type.—In this type the crown is generally of greater transverse than longitudinal extent. The neck is poorly produced, the crown and root uniting without marked constriction of the parts. The labial surface is much flattened from mesial to distal, and but slightly convex in the direction of the long axis of the tooth. The mesial and distal surfaces are but little rounded and are nearly parallel with each other, so that the contact with adjoining teeth becomes an extent of surface rather than a single point. The lingual surface is convex above, but as the incisal-edge is approached it becomes flat, but seldom concave. The marginal ridges are not well shown and the lingual fossa is but a slight depression. The angles of the crown are well produced and the incisal-edge thick and blunt, this marginal surface frequently occluding directly upon the opposing lower teeth. The curvature of the cervical line is that of a long circle.

UPPER CUSPID



5th year 6th year 7th year 8th year 9th year 10th year 13th year

Fig. 64.

Calcification Begins, from Three Centers, During the Third Year.
Calcification Completed, Twelfth to Thirteenth Year.
Erupted, Twelfth to Thirteenth Year.
Average Length of Crown, .37.
Average Length of Root, .68.
Average Length over All, 1.05.

During the third year calcification begins in the central lobe, which is gradually extended laterally, until, at the fourth year it is met by the two lateral lobes, which are somewhat later in beginning, and by the fifth year the three are united, the former eventually establishing the single cusp of the tooth and the latter two the mesial and distal angles. About the sixth year two-thirds of the crown is formed, and by the seventh year the constriction which marks the beginning of the neck of the tooth commences to make its appearance. Between the seventh and eighth year calcification in the crown is completed and the cervical line established; during the following year nearly one-quarter of an inch is added to the length of the root, and by the beginning of the tenth year the root is formed for fully two-thirds of its entire length. Between the twelfth and thirteenth years or at the time of eruption, calcification is completed in the root so far as its surface is concerned (Fig. 64). In this latter particular the cuspid differs from other teeth, with the exception of the third molars, in being completely calcified previous to, or about the time of, its eruption. To reach its final position in the arch the tooth moves bodily downward, the bone filling in behind; while in the incisors, bicuspids, and molars the free calcifying root-extremities remain nearly stationary, the crowns being forced downward as the lime salts are deposited.

The crown of the upper cuspid presents for examination four surfaces—labial, lingual, mesial, and distal—two margins—the cervical margin and the incisal-edge—and a mesial and a distal angle. In general outline it is simple in form, resembling the primitive cone-shaped teeth of many fishes. When viewed by looking directly upon the mesial or distal surface, the wedge-shape common to the incisors is observed. The base of the double incline is, however, much broader proportionately than the corresponding measurement of the incisors. Looking at the crown from a labial or lingual direction, its function, as a penetrating and incising organ, may be observed in the single cusp from which it derives its name. The cusp, which is formed at the expense of the incisal-edge, divides this latter margin into two distinct portions—the *mesial incisal-edge* and the *incisal cutting-edge*.

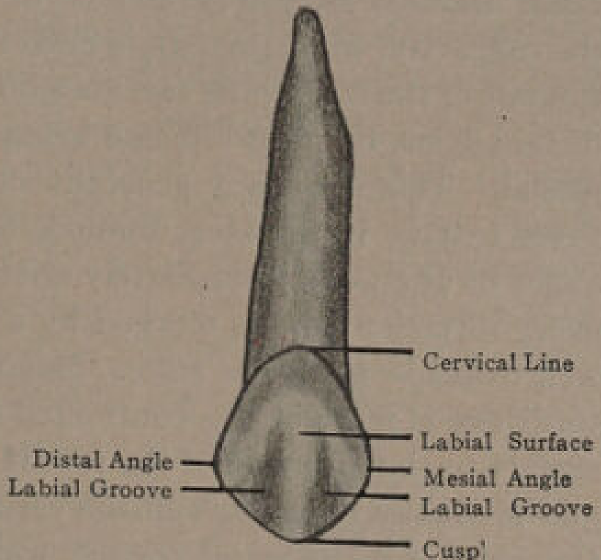


Fig. 65.—Upper cuspid, labial surface.

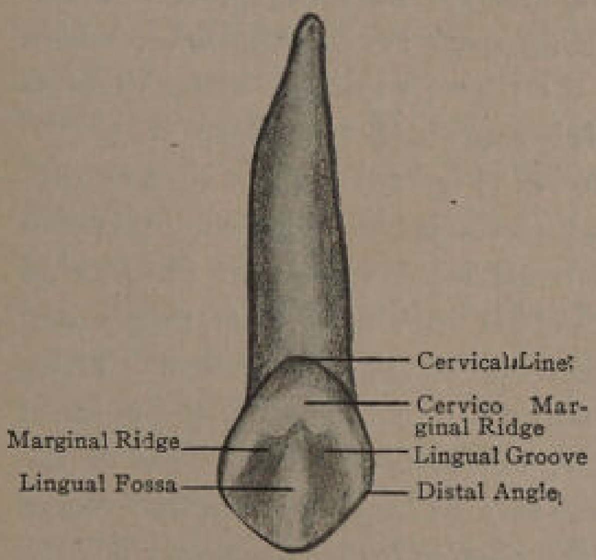


Fig. 66.—Upper cuspid, lingual surface.

The Labial Surface of the Crown (Fig. 65).—The contour of this surface is that of a broken circle more or less imperfectly drawn. It is bounded by five margins—mesial, distal, cervical, mesial-incisive, and distal-incisive. The *mesial margin* is rounded from labial to mesial, and slightly convex from the incisal-edge to the cervical line. The *distal margin* is also rounded from labial to distal, presents a greater convexity, and is somewhat shorter from the incisal-edge to the cervical line than the mesial margin. By a continuation and final union of these two lateral margins the *cervical margin* of the surface is formed, while by their union with the incisal-edges the mesial and distal angles of the crown are established. The *mesial-incisive margin* is usually slightly concave near its center, although in some instances it is convex. The *distal incisive margin* responds to the same description, although the concavity, when present, is nearest the point of the cusp. From the summit of the cusp these two margins slope away to join the mesial and distal angles, the distal incline being about one-fourth longer than the mesial. This surface is generally of greater longitudinal than transverse extent, its greatest mesiodistal diameter being from angle to angle, or at a point immediately above them. The surface is convex in every direction, and is marked by a central longitudinal ridge, usually well defined—*the labial ridge.* Beginning at the summit of the cusp, this ridge is more or less contracted laterally, but as it passes over the surface in the direction of the root it becomes broadened and flattened, and gradually disappears in the cervical portion. Upon either side of this ridge are the *labial grooves*, well defined at their beginning, but which gradually blend into the surface of the crown as they pass rootward. In some instances these grooves are so strongly defined as to form a decided ridge upon the mesial and distal margins of the surface—these are the *labial marginal ridges.*

The labial ridge and the two labial grooves mark the developmental lines of the crown, the former resulting from the middle lobe, which in this tooth is much the largest of the three, while the latter denotes the line of junction between the middle and the lateral lobes.

The Lingual Surface of the Crown (Fig. 66).—This surface presents nearly the same general outlines as the labial, with the exception of the cervical portion, which is more constricted, tending to produce an oblong or egg-shape. It usually abounds in well-defined ridges and depressions, giving to the tooth a rugged and strong appearance. There is but little general concavity to the surface in passing from the point of the cusp to the root. It may be flat, concave, or convex. As in the incisors, the margins of this surface are formed by three marginal ridges and by the incisal-edge. The *mesiomarginal ridge* is commonly a well-defined fold of enamel, beginning at the mesial angle and passing upward in the direction of the root, where it unites with the cervicomarginal ridge. It is sometimes quite narrow and rather sharply outlined; at others, it extends well toward the center of the surface in the form of a well-rounded fold. The *distomarginal ridge,* which is somewhat shorter than the mesial, begins at the distal angle and passes rootward to meet the cervical ridge. It is well rounded in every direction, but seldom so well produced as the mesial. The *cervicomarginal ridge*, which is formed by a continuation or union of the two former, nearly always partakes of their nature, except when broken by the presence of a cuspule, which is frequently found upon this tooth (Fig. 68). This small cusp of enamel may be bounded on one or both sides by a fissure, which often extends well under the cervicomarginal ridge, and sometimes completely separates it from the two lateral ridges. Passing through the center of the surface from the summit of the cusp to the base of the cervicomarginal ridge is the *lingual ridge*, which corresponds to the labial ridge of the labial surface. This ridge is usually well produced at or near the point of the cusp, and may continue so throughout, but most frequently becomes reduced in size near the center of the surface. Between this ridge and the mesio- and disto-marginal ridges are two longitudinal depressions—the *lingual grooves*.

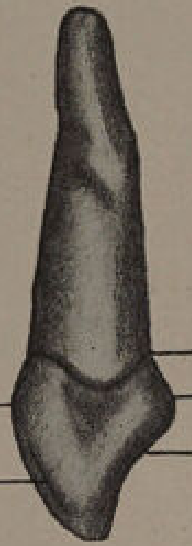


Fig. 67.—Left upper cuspid, distal surface.

Mesial Surface of the Crown.—In general outline this surface resembles that of the central incisor, excepting that the wedge-shape which it describes is more heavily set and blunt, with the surface extending beyond the base of the cone, in the direction of the root, to the extent of about one-third of its entire length. In some cases the base of the cone will be on a line with the cervical margin. The lower two-thirds of the surface, or that nearest the mesial angle, is convex in every direction; this convexity gradually disappears as the center is approached, beyond which point it is much flattened, usually ending in a slight concavity at the cervical margin. When looking directly upon this surface, its margins will be found within the profile lines, these being represented by the labial ridge anteriorly, and by the lingual and cervical ridges posteriorly. The *margins*, three in number, are the *labial*, which is well rounded and poorly defined; the *lingual*, more or less distinctly outlined and somewhat irregular; and the *cervical*, which is represented by the extent of the enamel covering of the crown; this latter margin being concave in the direction of the root. The most prominent point of this surface serves as a point of contact for the distal surface of the lateral incisor, the extent of contact being much influenced by the type of tooth, but in the cuspid this is usually a single point rather than an extent of surface.

The Distal Surface of the Crown (Fig. 67).—This surface in many respects is similar to the mesial, particularly in its general outline. The extent of surface is somewhat less and the convexity much more marked than that of the mesial surface. The position of the distal angle, which is the lower boundary of the surface, being much nearer the cervical line, makes this surface about one-third shorter than the mesial surface. The lateral margins of the surface, which are also within the profile lines, differ from those of the mesial in being more clearly defined. The *cervical margin* differs from that of the mesial surface by having a concavity with much less depth. As stated above, the surface is decidedly more convex than the mesial, the point of contact for the mesial surface of the first bicuspid being almost in the center. Near the cervical margin the surface is inclined to flatness, and frequently concave.

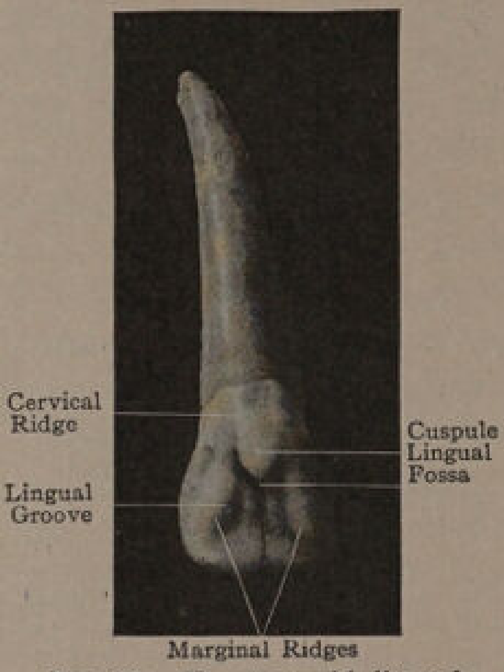


FIG. 68.—Upper cuspid, lingual surface, strongly developed.

The Incisal-edge, or Cusp.—As inferred in the beginning of this description, the cuspid is both an incising and a penetrating organ, the latter function being provided for by the presence of the single cusp, which divides the incisal-edge into an anterior or mesial portion and a posterior or distal portion. The *mesial incisal-edge* begins at the summit of the cusp and slopes away to meet the mesial angle, which it assists in forming. The outline of this edge is usually gracefully curved and unbroken unless permanently crossed by the labial groove. The *distal incisal-edge* is generally somewhat longer than the mesial. Immediately after leaving the summit of the cusp it may be slightly concave; but beyond this point it is well rounded, until it reaches the distal angle, into which it gradually disappears. This edge is also frequently broken by the labial groove. In its entirety the incisal-edge is subject to the same variations as those of the incisors—*i.e.*, it may be thin and sharp, or it may be thick and blunt.

The Cusp.—The single cusp from which this tooth derives its name is formed by the union of the labial ridge, the lingual ridge, and the mesial and distal incisal-edges. The summit of the cusp is constant in its position, always being in a direct line with the long axis of the tooth, whether it be viewed from a mesial or a lingual direction.

The Cervical Line.—To describe this fully would be to repeat what has already been said in connection with the incisors. This enamel margin differs in one particular only from that of the incisors, and that variation is not a constant one—the lingual portion is frequently extended in the direction of the root, producing a short, positive curve at that point.

The Angles of the Crown.—Owing to the rounded nature of the majority of cuspid crowns, the term angle, as applied to its free extremities, is almost a misnomer, and can only be considered as assisting in description. The mesial angle, which is formed by the union of the marginal ridges of the labial and lingual surfaces with the mesial incisal-edge, is seldom a well-produced angle, usually being rounded in every direction. The distal angle, which is formed in a manner similar to the mesial, is somewhat more deserving of the name, both the labio- and linguo-marginal ridges frequently presenting angularity. The position of the distal angle is usually well toward the center of the crown, and occasionally above this point, and, although it may descend, it is seldom found on a line with the mesial angle.

The Neck of the Upper Cuspid.—This may or may not be a distinctive feature, although when viewed from a labial aspect, the lateral flare or bulging of the crown gives the appearance of a decided constriction between the crown and the root; but, when examined from the mesial surface, this constricted appearance is not so marked, the contour of the crown passing into that of the root, with the cervical line alone marking the extent of each. The tooth at this point is well rounded anteriorly, flattened laterally, and again rounded posteriorly, the latter forming the segment of a smaller circle than that of the labial surface.

The Root.—This tooth possesses the largest and longest root of any of the teeth, in the latter respect usually exceeding the central incisor by about one-third, and the lateral incisor by one-fourth or more. Like the base of the crown, it is rounded on the labial and lingual surfaces, and is flattened laterally, this form usually being continued throughout its entire length. It gradually diminishes in size from the neck to the apex, and in its entirety forms a perfect cone. On the mesial and distal sides it is not only much flattened, but is frequently provided with a longitudinal depression, which is most marked near the center of its length. In some instances this root is possessed of a slight distal curve, which may be gradual from the base to the apex, or it may exist in a more positive way by a sudden distal curve near its apical extremity.

Bilious Type.—The rounded outlines common to the cuspid are less pronounced in this type than in any other, and instead of curves, angles are present. The crown is above the average size, length predominating over breadth, the cusp well formed, and the angles strong. The labial surface is often crossed by a number of transverse ridges near the cervical portion, the labial ridge is bold, as are also the labiomarginal ridges. The mesial and distal surfaces possess no distinguishing features, but the lingual, like the labial, shows the angular nature of the crown in having its margins and ridges squarely set.

A cuspule is more frequently found in this type than any other, and sometimes reaches down to a point corresponding to the transverse center of the crown. The neck is moderately well produced, and the cervical line decidedly **V**-shaped on its lateral portions, while on the labial and lingual it takes the form of a broken circle. The incisal-edges are rather heavy and square, and are nearly of equal length. In this temperament the cuspid often partakes of the form described in connection with the lateral incisor of the same type—*i.e.*, the absence of the incisal-edge and one or both angles, making the crown a perfect cone.

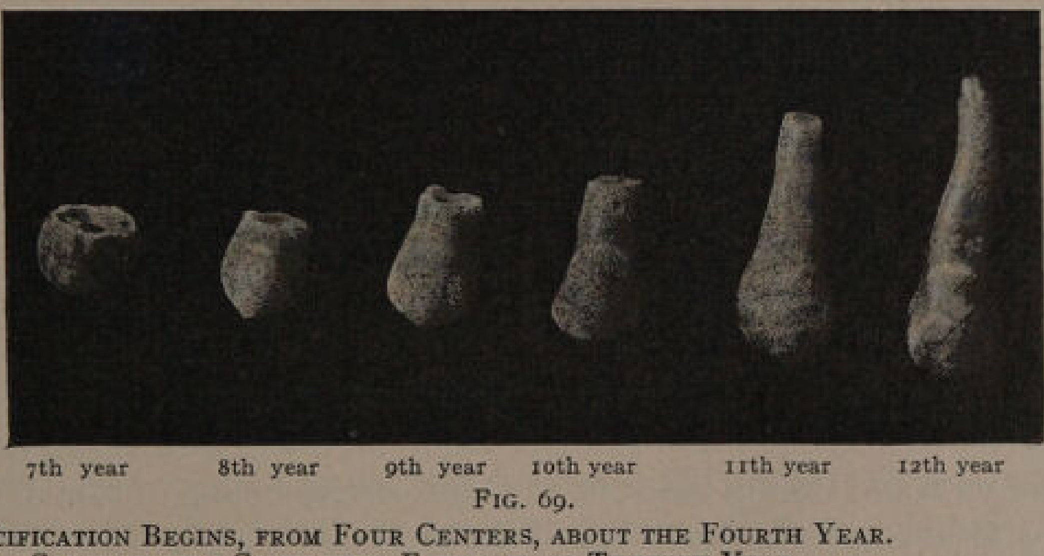
Nervous Type.—The crown is of much greater longitudinal than transverse extent, the outlines oval and gracefully formed, and the neck is much constricted from mesial to distal, being made so by the lateral flare of the body of the crown, which is a distinctive feature of this type. The labial ridge is well formed near the summit of the cusp, but usually disappears near the center of the surface. The labiomarginal ridges are seldom present, and the surface in general is convex and smooth. The mesial and distal surfaces show a pronounced convexity near the angles, and often a slight concavity between this point and the cervical line. The lingual surface, while generally showing all the descriptive lines, may be considered smooth; it is convex from mesial to distal, and slightly concave in the direction of the long axis of the tooth. The cusp is long and penetrating, the distal incisal-edge is much longer than the mesial, and both are inclined to sharpness. The cervical line on the labial and lingual surfaces is deeply arched, frequently giving to the gingival margin a receded appearance.

Sanguineous Type.—The crown in this type abounds in long curves, the longitudinal and transverse extents are nearly equal, the angles, owing to their circular form, are barely deserving the name.

while the cusp and incisal-edges are outlined by one long, oval sweep. The labial surface is prominent and convex, and the developmental grooves are fairly well shown. The mesial and distal surfaces show a moderate general convexity, while the lingual abounds in well-rounded ridges and borders. The constriction forming the neck of the tooth is moderate. The cervical line is in the form of perfectly arched curves, forming on the labial surface the segment of a circle corresponding to the circumference of the crown of the tooth.

Lymphatic Type.—In this type the crown is usually greater in its transverse than in its longitudinal measurement; it is lacking in graceful outline, and may best be described as being short, thick, and heavy set. None of the surfaces abound in descriptive lines, although transverse ridges are sometimes present on the labial surface near the cervix. Both the labial and lingual surfaces are convex in every direction, while the mesial and distal are inclined to flatness. The cusp is heavy and blunt, and the incisal-edges, which are nearly of equal length, are thick and dull. The mesial and distal angles are well produced. The cervical line is almost a direct line encircling the neck of the tooth, the segmental form on the labial surface being that of a much larger circle than any of those previously described. The neck is thick and heavy, and the root generally short.

UPPER FIRST BICUSPID



7th year 8th year 9th year 10th year 11th year 12th year

Fig. 69.

Calcification Begins, from Four Centers, about the Fourth Year.
Calcification Completed, Eleventh to Twelfth Year.
Erupted, Tenth to Eleventh Year.
Average Length of Crown, .32.
Average Length of Root, .48.
Average Length over All, .80.

This tooth, although presenting a crown of vastly different contour, is developed by a process almost identical with that of the incisors and cuspids. As the name implies, it is made up of two cusps, one forming the buccal and the other the lingual half of the crown. Calcification in the buccal cusp is from three centers and begins about the fourth year, the central lobe first receiving the lime salts. During the following year the two lateral lobes begin to calcify, soon followed by a union of the three, thus completing the margins and summit of the cusp. Unlike the incisors, but corresponding to the cuspid, the middle lobe is much the largest of the three, frequently forcing the developmental (buccal) grooves well toward the angles of the crown. The development of the lingual cusp corresponds to the development of the cervical ridge on the incisors and cuspids, except that it has a separate center of calcification, and a cusp almost as large as the buccal results. Between the fifth and sixth year union between the two cusps takes place, the line of confluence being permanently recorded by a well-defined groove, which traverses the crown from mesial to distal. This groove, although forced to occupy a different position, corresponds to the lingual groove of the incisors and cuspids. After the union of the cusps the process of calcification is continued into the body of the crown, and by the seventh year it is more than half completed. The eighth year usually finds the crown fully formed and the base of the root or roots outlined. As this tooth is generally provided with two roots, the first indication of bifurcation will be observed between the eighth and ninth years by a filling-in near the center of the mesial and distal walls, which finally become united by a thin septum of dentine and cementum. After this period the roots calcify separately, and by the middle of the ninth year about one-third of their length is established. During the following year, or at about the time of eruption, the development of the roots has extended to about three-fourths of their complete length, and between the eleventh and twelfth years, or at a time corresponding to that of the crown assuming its final position in the arch, calcification is completed (Fig. 69).

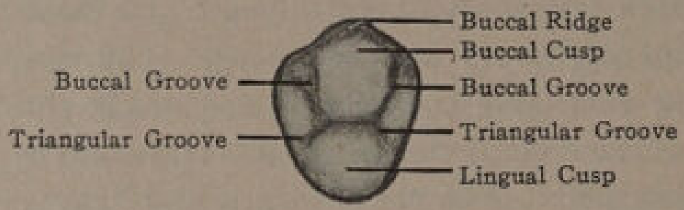


FIG. 70.—Upper first bicuspid, occlusal surface.

The Crown of the Upper First Bicuspid presents for examination five surfaces—buccal, lingual, mesial, distal, and occlusal. In general, the contour of the crown is irregularly quadrilateral, being about one-third greater in its buccolingual measurement than from mesial to distal. It is somewhat flattened from mesial to distal, but rounded on its buccal and lingual surfaces.

The Occlusal Surface of the Crown (Fig. 70).—The contour of the crown is best observed by a view of this surface, which may be described as trapezoidal or irregularly quadrilateral in form. The four margins of the surface are those which represent the four lateral surfaces—the buccal, lingual, mesial, and distal—the latter two being in the form of well-defined ridges—the *mesio-* and *disto-marginal ridges*. The buccal margin is formed by the mesial and distal inclines of the buccal cusp; it has a slight buccal convexity, and at its union with the proximate surfaces assists in forming the mesial and distal angles of the crown. The distal half of this margin is usually somewhat longer than the mesial, and the distal angle is less pronounced than the mesial. The lingual margin presents a much greater convexity than the buccal, but the curve formed is the segment of a much smaller circle. As in the buccal margin, the distal half of this margin is the longest, but unlike the former, its free extremities pass into the mesial and distal margins without producing angles. The mesio- and disto-marginal ridges are strong folds of enamel which arise from the mesial and distal angles and converge slightly as they pass to the lingual, where they are gradually lost in the lingual margin.

The Cusps (Fig. 70).—These are two in number, and are named, in accordance with their location, buccal and lingual. The *buccal cusp* is the larger and longer of the two. From the summit of this cusp four ridges descend—one in a mesial direction, forming the mesiobuccal marginal ridge; one in a distal directon, forming the distobuccal marginal ridge; one to the buccal surface, the *buccal ridge;* and a fourth, the *buccal triangular ridge*, descends the central incline. The mesial and distal ridges enter into the formation of the mesial and distal angles at their extremities; the latter is slightly longer than the former, and both are frequently broken near the center by the grooves of development—the *buccal grooves*. The buccal ridge may be well developed and extend almost to the cervical line, or it may be slight and disappear near the center of the surface. The buccal triangular ridge usually ends somewhat abruptly in the central groove, but in some instances it is continued and joins a similar ridge from the lingual cusp, this union forming the *transverse ridge*. The triangular ridge often bifurcates near the center of its incline, and is continued in two distinct but smaller ridges. The *lingual cusp* is much less angular than the buccal; the apex is usually rounded, while the descending ridges are generally three in number instead of four. The mesial and distal ridges are nearly of the same length, and pass without interruption into the mesio- and disto-marginal ridges. The triangular ridges is less clearly defined than its fellow of the buccal cusp, and it is not unusual for it to be entirely wanting. The lingual aspect of the cusp is smooth and rounded, presenting nothing in the form of a ridge in correspondence with the buccal ridge of the buccal cusp. The grooves and ridges on this cusp are supplemental rather than developmental in character. Like the incisors and cuspids, the summits of these cusps are usually in a direct line with the long axis of the tooth.

The *developmental grooves*, all of which are observed upon the occlusal surface, are the central, mesial, distal, two triangular, and two buccal. The central groove is the most marked, is deeply sulcate, and extends through the center of the surface from mesial to distal, ending just within the two marginal ridges in two irregularly formed depressions or pits—the *mesial* and *distal pits*. This groove marks the line of union between the buccal and lingual lobes. The mesial and distal grooves are not always well defined, but may usually be observed as fine lines passing over the central portion of the mesio- and disto-marginal ridges. The mesio- and disto-triangular grooves begin in the mesial and distal pits, and pass in the direction of the mesial and distal angles, where they are either lost, or may be traced as slight depressions passing over the buccal ridges near the angles, and they may further continue over the buccal surface in the direction of the root. These two grooves, together with the mesial and distal above referred to, form the outlines of the mesiobuccal and distobuccal developmental lobes. The buccal grooves will be described in connection with the buccal surface. Supplemental grooves are seldom found in connection with the buccal half of the occlusal surface, but are occasionally present on the central incline of the lingual cusp.

The Buccal Surface of the Crown (Fig. 71).—In many respects this surface resembles the corresponding or labial surface of the cuspid. It is bounded by four margins—occlusal, mesial, distal, and cervical. The occlusal half of the surface is formed of the buccal cusp, and is cone-shaped, while the cervical half is irregularly quadrilateral in form. The extent of surface from the cervical line to the point of the cusp is usually about one-third greater than the greatest mesiodistal diameter, which is represented by a line drawn from the mesial to the distal angle. The form shown is that of a general convexity, the summit of which is surmounted by a longitudinal ridge—the *buccal ridge*. This ridge, which is formed from the central developmental lobe, is most pronounced near the occlusal margin, and gradually disappears near the center of the surface. Upon either side of the buccal ridge are two grooves—the *buccal grooves*—which denote the line of union between the central and the two lateral lobes, and beyond these are the angles of the crown. The buccal ridge springs from the buccal cusp, the summit of which is generally in a direct line with the long axis of the tooth; when there is a deviation from this the summit is usually thrown a little to the mesial, resulting in a reduction of the length of the mesiobuccal marginal ridge.

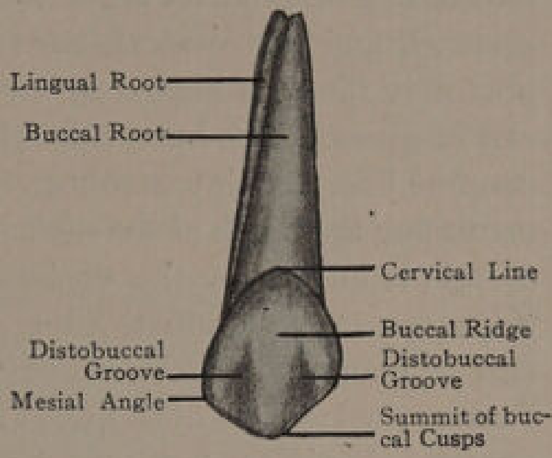


FIG. 71.—Upper first bicuspid, buccal surface.

As previously stated, the greatest mesiodistal diameter of the surface is on a line with the angles of the crown; this measurement is much reduced at the cervical line, so that the point of contact with adjoining teeth is thrown near to the occlusal margins of the crown. This variation in the transverse measurement also results in what is commonly referred to as the "bell shape" of the crown. The cervical margin of the surface is fairly well arched, but seldom to such a degree as the corresponding margin upon the incisors and cuspids.

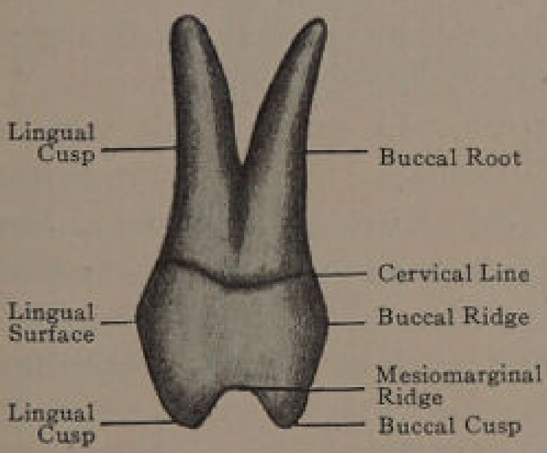


FIG. 72.—Upper first bicuspid, mesial surface.

The Lingual Surface of the Crown.—This surface is smooth and decidedly convex, the absence of strongly developed grooves and ridges contributing to the former fact. Like the buccal surface, its greatest transverse measurement is at the base of the cusp in which it terminates. The extent of the surface is about one-third less than that of the buccal, and its occluding and cervical margins are alone well defined, the mesiodistal convexity passing so gradually into these respective surfaces that a positive line of distinction can scarcely be recognized. In passing from the cervical line to the occlusal margin, the surface is rapidly carried toward the center of the crown. The cervical margin of this surface is usually in the form of a direct line encircling the neck, but occasionally presents a slight concavity in the direction of the root.

The Mesial Surface of the Crown (Fig. 72).—This surface of the crown has three of its borders well defined; these are the buccal, the occlusal, and the cervical, the remaining or lingual margin passing so gradually into the lingual surface that no positive line of demarcation can be given. The buccal margin extends from the mesial angle to the cervical line, and invariably presents a slight buccal inclination, thus increasing the width of the surface on its cervical portion. The occlusal margin is formed by the mesiomarginal ridge, and by a portion of the ridge descending from the lingual cusp. It is irregularly V-shaped, and in many instances is broken in the center of the mesial groove. The cervical margin differs from those of the incisors and cuspids, nearly always being in the form of a straight line from buccal to lingual. The surface in general is flattened, but shows a slight general convexity near the occlusal margin, and frequently a slight concavity immediately below the cervical line, this form placing the point of contact with the distal surface of the cuspid near the occlusal margin. The surface is occasionally divided into a buccal and a lingual portion by the mesial groove, which may extend to the cervical line, but which generally disappears near the center of the surface. The buccal half of the surface which is formed from the mesial developmental lobe is inclined to angularity, while the lingual half is decidedly rounded, particularly in the direction of the occlusal margin.

The Distal Surface of the Crown.—In general, this surface resembles the mesial, being flattened and bounded by three more or less distinct margins. The slight buccolingual convexity is not confined to the occlusal portion of the surface, but is inclined to extend to the cervical margin, in this particular being at variance with the mesial surface. This surface passes into the lingual by a much longer curve than that shown on the mesial surface.

The Angles of the Crown.—These are two in number and, as in the teeth previously described, are named, according to their location. *mesial* and *distal*. The mesial angle is formed by the union of the mesiomarginal ridge and the buccal marginal ridge. It is primarily the product of the mesial developmental lobe, and is usually well produced. The distal angle, which is formed in a like manner, is inclined to be more rounded.

The Neck of the Tooth.—In most typal forms the neck of the upper first bicuspid is well defined, particularly upon the mesial and distal surfaces. Viewing the tooth from a buccal aspect, the neck is a distinctive feature, but when studied from the mesial or distal sides, the constriction is scarcely observed, this being particularly the case if the tooth has but a single root. In general, the neck partakes of the contour of the crown, being convex on the buccal and lingual, and flattened and frequently slightly concave on the mesial and distal.

The Roots of the Upper First Bicuspid.—This tooth is usually developed with two roots, sometimes with only one, and in rare instances it may have three. When two roots are present, one is above the buccal and the other above the lingual half of the crown, and are

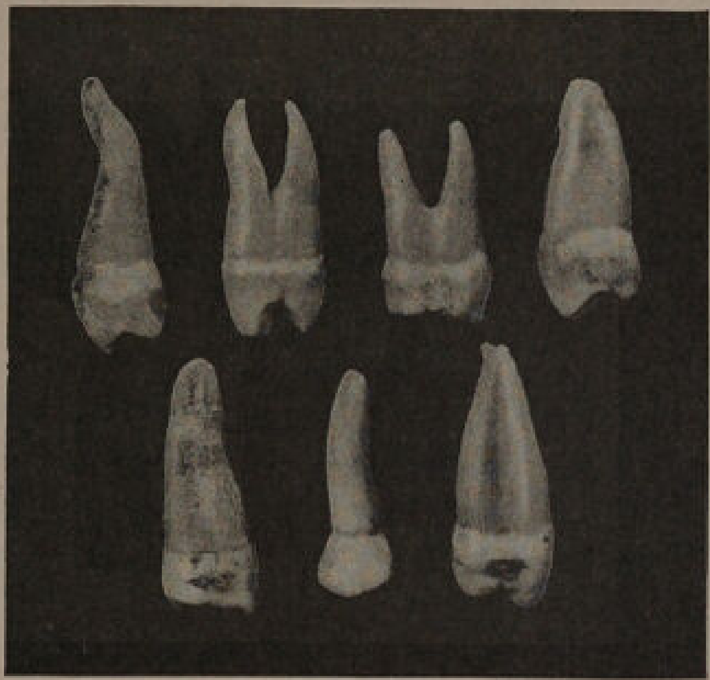


FIG. 73.—Types of bicuspids.

named, according to their location, *buccal* or *lingual*. In general form the two roots are quite similar, but the buccal is usually a trifle longer than the lingual. They taper off to a slender apex, and are inclined to curve in various directions near their extremities. The point of bifurcation is frequently some distance above the neck, so that the tooth may be said to possess a single root with two branches. Below the bifurcation the root assumes the form of the neck or cervical portion of the crown, but as the bifurcation is approached, the mesial and distal sides present a longitudinal groove, which gradually increases in depth until the single root becomes separated. The curves of the root-branches above referred to are, in the buccal branch, first to the buccal and then to the lingual; while the lingual branch first shows a slight lingual inclination immediately above the point of separation, followed by a gentle buccal curve as the apical end is reached. In some cases the bifurcation begins immediately above the neck of the tooth; in others it may occur in the apical third; while a third class is represented by the two roots being united throughout their entire length by a thin septum of dentin and cementum, or, as occasionally happens, by a layer of cementum alone. In this latter instance each root is provided with a distinct canal. When the tooth has but a single root, it is much flattened from mesial to distal, the flatness being slightly broken by an inclination to convexity. The four surfaces usually converge toward the apical end, which is oblong from buccal to lingual, and generally provided with a slight distal curve. The presence of three roots is so rare that the condition might be classed as a malformation; but when they do exist, two are usually attached to the buccal and one to the lingual half of the crown, with the point of separation near the neck of the tooth.

Bilious Type.—The upper first bicuspid of this temperamental type is marked by a crown of moderate length, the neck well pronounced, and the cusps and angles marked by angular outlines. The buccal ridge is strongly defined, and the buccal grooves, which extend well up on the buccal surface, cross the mesial and distal marginal ridges, separating them into two distinct parts. The cusps are long and penetrating, and are nearly of equal length, assisting to form the firm and well-locked occlusion common to this type. The mesial and distal surfaces are nearly parallel with each other; they are seldom convex, so that the approximating teeth are in contact over an extent of surface rather than a single point. The cervical line is but little curved.

Nervous Type.—In this temperament the bell-shaped crown is strongly observed, the crown being long and much constricted at its neck. The extreme length of the buccal cusp, and the marked cervical constriction, produce an appearance in the buccal surface resembling the labial surface of the cuspid. The developmental grooves are finely outlined, and the cusps long and penetrating, usually being more pronounced than in any other class. The marginal ridges are sharp and inclined to angularity; the mesial and distal surfaces are convex near their occlusal margins, but near the cervical line a pronounced concavity is observed, which is continued upon the corresponding root-surfaces. This formation forces the point of contact with adjoining teeth well toward the occlusal surface, and results in an extensive V-shaped interproximate space. The cervical line is sharply and gracefully formed, the curvature being well arched.

Sanguineous Type.—The typical upper first bicuspid of this class is provided with a crown well proportioned, its length being somewhat greater than its breadth, but about equal to its buccolingual measurement. The buccal surface is seldom broken by the buccal grooves, and is strongly convex in every direction. The lingual surface is much more rounded than the same surface of other types. The mesial and distal surfaces are usually smoothly convex, with an occasional slight concavity immediately below the cervical line. Upon the occlusal surface the grooves are rounded and obscure, rather than sharp and well defined, and the cusps, much less pronounced than in either of the types previously described, are rounded and smooth; this latter fact is particularly true of the lingual cusp, which is usually much smaller than the buccal. The marginal ridges of the buccal cusp are scarcely deserving of the name, being broad and rounded throughout. The form of the mesial and distal surfaces above described provides for a point of contact near the center of each surface, leaving a slight interproximate space both above and below this point.

Lymphatic Type.—An examination of the upper first bicuspid of the lymphatic type results in finding a tooth vastly different from any of those previously described. The length of the crown from the cervical line to the point of the cusp is less than either the mesiodistal or buccolingual measurements. In general appearance it is lacking in symmetry or poorly proportioned. The buccal surface presents a gradual convexity from mesial to distal, and seldom has the buccal ridge well developed. The lingual surface is smoothly convex and passes off into the lingual root without the interposition of a decided neck. The mesial and distal surfaces are flattened and sparingly convex, and are nearly parallel with each other, so that the contact with adjoining teeth is inclined to be distributed over the entire surface, leaving little or no interproximate space. The cusps are short, flat, and rounded, and the occlusal surface much flattened in general, corresponding with the nature of the occlusion which is loose and wandering. The developmental grooves and ridges are fairly well shown, while the marginal ridges and angles of the crown are smooth and rounded. The neck is less pronounced in this type than in any other, the curvature of the cervical line is very slight, the root is short and heavy set, frequently passing well up toward the apex before bifurcating.

UPPER SECOND BICUSPID

7th year 8th year 9th year 10th year 11th year 12th year

FIG. 74.

CALCIFICATION BEGINS, FROM FOUR CENTERS, ABOUT THE FIFTH YEAR.
CALCIFICATION COMPLETED, ELEVENTH TO TWELFTH YEAR.
ERUPTED, ELEVENTH TO TWELFTH YEAR.
AVERAGE LENGTH OF CROWN, .29.
AVERAGE LENGTH OF ROOT, .55.
AVERAGE LENGTH OVER ALL, .84.

The process of development in this tooth is identical with that of the first bicuspid, calcification in the buccal half of the crown taking place in one central and two lateral lobes, while the lingual half is developed from a single center. The calcifying process is about one year later than that in the first bicuspid, the summit of the buccal cusp receiving its lime salts about the beginning of the fifth year. During the following six months calcification begins in the lateral lobes, and also in the lingual lobe. By the sixth year the occlusal surface and a portion of the crown are completed by a union of the various lobes, and at seven years the crown is calcified for more than two thirds of its completed length. Between the eighth and ninth year the contour of the crown is established, and the neck of the tooth and outline of the root-base formed. At the tenth year about one-third of the root length is formed, and during the following year about 1/8 of an inch is added to it. By the eleventh or twelfth year calcification is completed (Fig. 74).

This tooth so closely resembles the first bicuspid that a description in detail will be unnecessary; there are, however, a few minor points which are at variance and must be described in order to distinguish one from the other. In general, the tooth is a trifle smaller than the first bicuspid, the cusps are somewhat shorter, and the various ridges less distinct. A distinguishing feature of the occlusal surface is found in the diminished length of the central groove (Fig. 75). This groove, as observed in the first bicuspid, extends from mesial to distal for fully three-fourths of the entire width of the surface; but in the second bicuspid it is diminished by one-third, being thus reduced by the broadened marginal ridges, which force the mesial and distal pits well toward the center. It is not uncommon to find the triangular grooves joining the central groove directly in the center of the surface, forming a central pit from which may radiate numerous small supplemental grooves and ridges. The summits of both the buccal and lingual cusps are nearer to the mesial than to the distal surface, thus increasing the length of the ridges which descend from them in a distal direction, and decreasing those which pass to the mesial. The buccal surface presents a greater convexity than that of the first bicuspid; the buccal grooves are usually shallow depressions and are frequently entirely wanting, thus giving the buccal ridge the appearance of extending its margins to the angles of the crown. Unlike the first bicuspid, the mesiodistal diameter of the mesial surface is but little more than the same measurements on the lingual surface. The neck of the tooth is not quite so pronounced as that of the first bicuspid, thus giving less of the bell shape to the crown. One very important difference between this tooth and the first bicuspid is in the root-formation. We have seen that the first bicuspid is generally provided with two roots, while in the second bicuspid a single root is usually present. Like the first bicuspid, there are exceptions to this, the tooth sometimes being provided with two, and in rare instances with three, roots. When the single root is present, it partakes of the form of the crown at its base, being well rounded on the buccal and lingual portions and much flattened on the mesial and distal. The mesiodistal diameter of the root at its base is only about one-third that of the buccolingual measurement, this proportionate size continuing throughout its entire length. In passing from the base to the apex the root

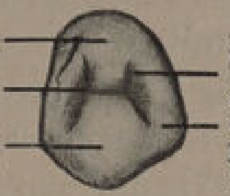


FIG. 75.—Second upper biscuspid occlusal surface.

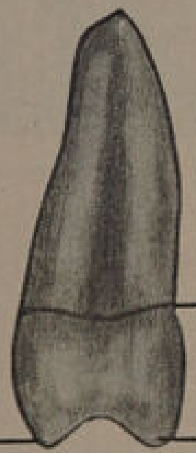


FIG. 76.—Upper second bicuspid, mesial surface. Most common form.

is gradually diminished in size, finally ending somewhat abruptly in an oblong extremity. In some instances the apical end is round and pointed, resembling the apex of the incisors and cuspids, but when thus formed the root is usually curved near its apical third and somewhat extended in length. The mesial and distal surfaces are provided with a well-defined longitudinal concavity, extending from the cervical margin to the apex and dividing the root into a buccal and a lingual portion. This depression is often so decided that the contour of the single root is almost lost, and in its place the appearance is that of two roots similar to those described in the first bicuspid. The length of the root is usually a little greater than that of the first bicuspid, but the crown being a trifle shorter, results in producing a tooth the entire length of which is about equal to that of the first bicuspid.

UPPER FIRST MOLAR

2d year 3d year 5th year 6th year 7th year 10th year 11th year

FIG. 77.

CALCIFICATION BEGINS, FROM FOUR CENTERS, ABOUT ONE MONTH BEFORE BIRTH.
CALCIFICATION COMPLETED, NINTH TO TENTH YEAR
ERUPTED, SIXTH TO SEVENTH YEAR.
AVERAGE LENGTH OF CROWN, .30.
AVERAGE LENGTH OF ROOT, .51.
AVERAGE LENGTH OVER ALL, .81.

This tooth being the first of the permanent set to erupt, precedes all others in the process of calcification, beginning to receive its lime salts as early as the eighth fetal month. The form of the crown being so entirely different from those previously described, embodies a developmental process which is also different, four distinct lobes being present, one for each cusp, these making their appearance during the first year after birth, closely followed by a completion of the occlusal surface by the union of the free calcifying margins, these lines of union being finally represented by the developmental grooves of the occlusal surface. After the completion of this surface, calcification proceeds in the direction of the base of the crown, and at the beginning of the third year about two-thirds of the crown is formed. During the fifth year the contour of the crown is completed, and at the beginning of the eruptive period, or about the sixth year, the developmental process has extended to the base of the roots, and an effort at trifurcation begun. At seven years the three roots with which the tooth is provided are branching out, each into its own socket, subsequent development in each being continued as a separate and distinct process. The tenth year more than half completes the calcifying process in the roots, and at the beginning of the eleventh year the root apices are formed. Like the first bicuspid, the crown of this tooth presents for examination five surfaces—occlusal, buccal, lingual, mesial and distal. In general contour it is irregularly quadrilateral, with the angles of the crown more or less rounded, two of its sides convex and two flattened or slightly concave. The length

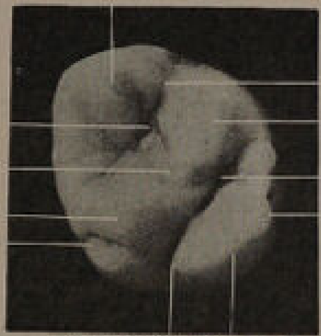


FIG. 78.—Upper first molar, occlusal surface.

of the crown from the cervical line to the summits of the cusps is about equal to, or slightly less than, its mesiodistal diameter, while the buccolingual measurement is usually a trifle greater than the mesiodistal.

The Occlusal Surface of the Crown (Fig. 78).—The coronal outline of this tooth is best studied when looking directly upon this surface, which shows the two convex sides above referred to, represented by the buccal and lingual margins, with the mesial and distal margins more or less flattened. The surface is bounded by these four margins, which are nearly of equal length, the angles formed by their union being more or less rounded, two of which, the mesiobuccal and the distolingual, are acute angles, while the mesiolingual and distobuccal are obtuse angles. The surface is divided into four developmental portions—the mesiobuccal, distobuccal, mesiolingual, and distolingual. Each one of these parts is surmounted by a well-defined point or cusp, which likewise is named in accordance with its location. These various parts are separated from one another by four developmental grooves—the mesial, the buccal, the distal, and the distolingual. In the center of the triangle formed by the central incline of the mesiobuccal, distobuccal, and mesiolingual cusps is a deep depression—the *central fossa*—while near the distal margin is a somewhat similar depression—the *distal fossa*. Traversing the surface in various directions are a number of ridges and grooves, each of which will be described in turn.

The Marginal Ridges of the Occlusal Surface.—These are four in number—the mesial, distal, buccal, and lingual. The *mesiomarginal ridge* is a well-pronounced elevation of enamel which passes from the mesiobuccal angle to the mesiolingual angle. It is slightly concave in the direction of the root, and is broken near the center of its concavity by the mesial groove, upon either side of which are frequently found one or two small points or tubercles, which are formed either by a division of the mesial developmental groove, or by one or more supplemental grooves. These grooves pass over the ridge and are continued for a short distance on the mesial surface. Descending from the mesiobuccal cusp, the ridge passes in a lingual direction to meet the mesiolingual cusp, and in so doing has a slight distal inclination until the mesial groove is reached, after passing which it makes a sweeping distal curve and is lost in the lingual margin. This ridge marks the line of junction between the occlusal surface and the mesial surface. The *distomarginal ridge* in some respects resembles the mesial just described, being concave and ascending in a buccal and lingual direction, with a somewhat rounded outline, to the summits of the distobuccal and distolingual cusps. The depth of the concavity is usually greater than that of the mesial margin, and is frequently crossed near the center by the distolingual groove, frequently so marked as to produce a **V**-shape to the center of the margin. There are oçcasionally found upon either side of this central groove one or more small tubercles, corresponding to those of the mesial ridge, but they are less frequent and less pronounced. This ridge forms the line of demarcation between the occlusal surface and the distal surface. The *buccomarginal ridge* begins at the mesiobuccal angle, and gradually ascends to the summit of the mesiobuccal cusp, from which it afterward descends in a distal direction to the buccal groove; continuing, it again ascends the distobuccal cusp, after descending from which it ends in the distobuccal angle. The nature of this ridge is a series of cutting-edges, giving to the cusps their angular nature. Besides the buccal groove, which make a decided break in the center of its course, the ridge is frequently crossed by numerous small supplemental grooves occurring in various locations and forming a series of minute tubercles; this latter condition is most frequently present in young teeth, and is soon obliterated by wear. The course of this ridge is not that of a direct line from mesial to distal, but in its ascent of the mesiobuccal cusp it is inclined to the buccal; in its descent it presents a corresponding return to the lingual, and the same variations are observed in passing over the distal cusp. The *linguomarginal ridge* begins at the mesiolingual angle of the crown and passes distally to the distolingual angle, differing from the three previously described by being heavy and rounded in its nature, more irregular in outline, and divided nearest to its distal extremity instead of in the center of its length. From the point of beginning it makes a curved ascent to the summit of the mesiolingual cusp; descending from this in a distobuccal direction, it divides, one portion passing to join the triangular ridge of the distobuccal cusp,

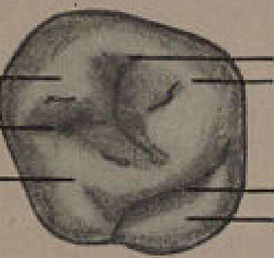


FIG. 79.

the two uniting to form the *oblique ridge*, the other portion continuing in the direction of the distolingual cusp, before reaching the base of which it is broken by the distolingual groove. From this groove the ridge makes a sudden and direct ascent to the summit of the distolingual cusp, after passing which it gradually descends in a long curve to join the distomarginal ridge. Like the buccal ridge, it is frequently crossed by numerous supplemental grooves. The ridge forms the lingual margin of the occlusal surface and gives to the cusps their angularity.

The Cusps (Fig. 79).—These are four in number—the mesiobuccal, distobuccal, mesiolingual, and distolingual.

The Mesiobuccal Cusp (Fig. 79).—In extent of surface this is usually the largest cusp, although it is sometimes exceeded by the mesiolingual. From the summit of the cusp three ridges descend—the *buccal ridge* to the buccal surface, the *buccomarginal ridge* making a double descent, and the *mesiobuccal triangular ridge*, the latter descending the central incline and ending in the central fossa. The mesial base of the cusp is frequently crossed by one or more supplemental grooves, which begin at the mesial margin and pass in the direction of the central fossa. The central slope of the cusp contributes to the formation of the central fossa, its extent in this direction being controlled by the mesial and buccal grooves, which together form the mesiobuccal triangular groove.

The Distobuccal Cusp (Fig. 79).—This cusp is frequently the smallest in extent of surface, but is usually longer and more pointed than the others. Like the mesiobuccal cusp, three ridges descend from it—the *buccal ridge* to the buccal surface two which spring from the buccomarginal ridge, and the *distobuccal triangular ridge*, which descends obliquely toward the distal center of the surface and joins a similar ridge (previously described) from the mesiolingual cusp, the two forming the oblique ridge. The mesial portion of the base of this cusp assists in forming the central fossa, while a portion of the distal contributes to the formation of the distal fossa. The inner boundary of the cusp is formed by the buccal groove, the distal groove, and by a portion of the distolingual groove.

The Mesiolingual Cusp (Fig. 79).—As above stated, this cusp is frequently the largest in extent of surface, and is somewhat rounded, with its summit poorly defined. The ridges which descend from it correspond in name and number to those of the buccal cusps, the linguomarginal ridge making a double descent, the mesiolingual ridge descending to the lingual surface, while the central incline is marked by the *mesiolingual triangular ridge*, which ends in the central fossa. Toward the mesial portion of the cusp one or more small ridges are frequently present, extending from the marginal ridge to the mesial groove. The distal descent of the marginal ridge is bifurcated, one portion making a sweeping curve and joining the transverse ridge from the buccal cusp, forming the oblique ridge previously referred to, the other portion passing in a distal direction and ending at the distolingual groove. The central incline of this cusp forms the lingual side of the central fossa, and its boundaries are outlined by the mesial, distal, and distolingual grooves.

The Distolingual Cusp (Fig. 79).—This cusp is usually the smallest of the four; it is triangular in outline, with the summit nearest the mesiolingual portion. The ridges which descend from this cusp are only two in number, one passing in a mesial direction and forming a portion of the linguomarginal ridge, the other passing to the distal, with a gradual buccal curve, to join the distomarginal ridge. Of the two remaining inclines, one looks in a distolingual direction, presenting a surface which is smooth and rounded; the other, sloping by a broad expanse in a mesiobuccal direction, ending in the distolingual groove, and also assisting to form the distal fossa. This latter incline is often crossed by small supplemental grooves, which take a winding course from the base to the summit of the incline. The inner margin or outline of the cusp is formed by the distolingual groove.

"*The Fifth Cusp*" (Fig. 78).—Although usually referred to as possessing but four cusps, this tooth is frequently developed with five, the additional lobe being situated on the lingual side of the mesiolingual cusp, about midway between its summit and the neck of the tooth. When present, it is distinctly separate from the main cusp by a well-developed groove—the *mesiolingual groove.* Both the cusp and the groove may be more or less developed, the former in some instances assuming dimensions corresponding to that of the distolingual cusp, and the latter sometimes being as well marked as the distolingual groove. When thus pronounced, the groove begins near the center of the mesial surface, and passes obliquely toward the summit of the mesiolingual cusp, before reaching which it makes an abrupt turn rootward, and joins the lingual terminal of the distolingual groove, this union frequently resulting in a well-defined pit—the *lingual pit.* This cusp, as usually found, is small and apparently without function. When occurring on the tooth of one side, it is usually present on the corresponding tooth of the opposite side. It is seldom present on any but the upper first molar.

The Fossæ and Grooves of the Occlusal Surface (Figs. 78, 79).—The fossæ are two in number—central and distal. The *central fossa* occupies a position near the center of the surface, and is formed by the central incline of the mesiobuccal, distobuccal, and mesiolingual cusp, which usually give it a three-sided form. Connecting the three sides of the fossa, and in a measure assisting in its construction, is the mesiomarginal ridge and the oblique ridge. The depth of this fossa, as well as that of the distal, is of course regulated by the length of the cusps, which in turn is much influenced by the temperamental type of the tooth. The floor of the fossa is deeply marked by two of the grooves of development—the *mesial groove* and the *buccal groove.* The former begins on the mesial surface, passes over the mesiomarginal ridge, and continues in an irregular line to the floor of the fossa; the latter, beginning near the center of the buccal surface, enters the fossa by crossing the buccomarginal ridge near the center of its length, and also ends in the *central pit* of the central fossa. As previously referred to, the union of these two grooves forms the *mesiobuccal triangular groove.* From the central pit of this fossa another groove is given off—the *distal groove.* It is usually well defined at its beginning, but as it passes over the oblique ridge it is generally partly obliterated, although occasionally being so marked as to divide this ridge. The *distal fossa* is much smaller than the central, and is of an entirely different form. Its walls are principally formed by the distolingual incline of the oblique ridge, and the mesiobuccal incline of the distolingual cusp; a portion of the disto-marginal ridge and the distal incline of the distobuccal cusp also assist in its formation. Like the central fossa, its sides are more or less irregular, from the presence of various grooves and ridges in its vicinity. The greatest length of the fossa is in a distolingual direction, and it is traversed by a deep developmental groove—the *distolingual groove*. When the distal groove crosses the oblique ridge, it usually extends to the floor of this fossa.

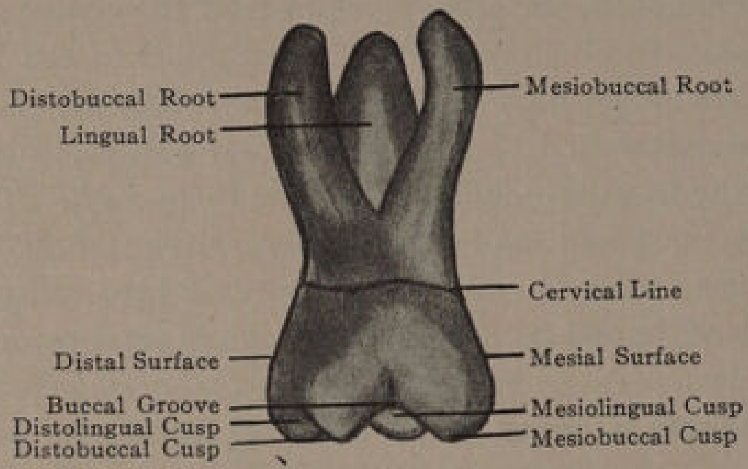


FIG. 80.—Upper first molar, buccal surface.

The Buccal Surface of the Crown (Fig. 80).—This surface, which is the result of a union between the mesial and distal developmental lobes, may be divided into a mesial and a distal half. These two portions are quite similar in outline, and are separated from each other by the buccal groove, which usually ends near the center or about halfway to the cervical line in a decided pit—the *buccal pit*. In some instances this groove is continued to the cervical line, or even somewhat beyond this. Both the mesial and distal half are provided with a longitudinal ridge (the *buccal ridges*)—one the *mesiobuccal ridge* and the other the *distobuccal ridge*. These are similarly formed and descend from the summits of the respective cusps, at which point they are usually well defined, but gradually disappear as they pass toward the cervical line. The location of the buccal groove being a little to the distal of the center of the surface, gives to the mesial portion a somewhat greater extent than the distal. The margins of the surface, which form an irregular quadrilateral, are the mesial, distal, occlusal, and cervical. The mesial and distal margins are rounded, and gradually converge as they pass rootward, making the average diameter of the surface about one-fourth less at the cervical line than at the base of the cusps. In some instances these margins are slightly concave over their cervical portion, and convex on approaching the occlusal margins; or the mesial may be concave and the distal convex throughout their entire length; in some types they appear as straight lines and are parallel with each other. The occlusal margin is formed by the marginal ridges as they pass over the two buccal cusps, being in the form of the letter **W**. The cervical margin is usually a direct line drawn around the circumference of the tooth, but in some instances deviating slightly from this. Immediately below the cervical line, and conforming to its general direction, is a rounded fold of enamel—the *cervical ridge*.

Lingual Surface of the Crown* (Fig. 81).—Like the buccal surface, this surface is developed from two lobes—the mesio- and distolingual lobes—the line of union between the two being recorded by a well-defined groove—the *lingual groove*. This groove, which is a continuation of the distolingual groove of the occlusal surface, usually ends near the center of the lingual surface in a well-defined pit—the *lingual pit*—or it may continue rootward and gradually disappear. It is located a little to the distal of the center of the surface, thus making the mesial a trifle larger than the distal portion. The mesial half of the surface is smooth and convex; the lingual incline of the mesiolingual cusp is seldom provided with a well-defined ridge, although usually referred to as the *mesiolingual ridge*. The distal half of the surface is also smooth and rounded, with the mesiodistal convexity much more marked than that of the mesial lobe. The cervical ridge is seldom so pronounced as that of the buccal surface, but the enamel frequently makes a sudden dip at this point to meet the cementum of the root.

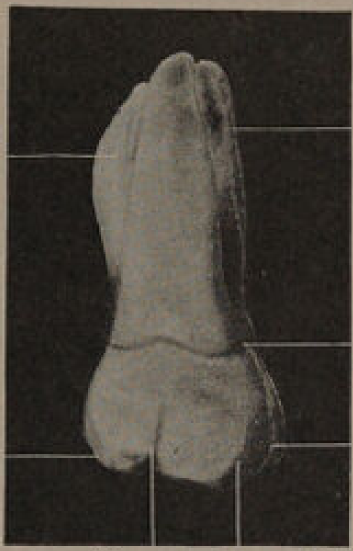


FIG. 81.—Upper first molar, lingual surface.

* When the fifth cusp is present, the anatomy of the mesial half of this surface is somewhat more complex.

That portion of the surface immediately below the cervical ridge is smooth and unbroken, slightly convex in the direction of the long axis of the tooth, and flattened or slightly convex from mesial to distal. The margins of the surface are the mesial, distal, occlusal, and cervical. The surface passes so gradually into the mesial and distal that it is somewhat difficult to define these margins. In general, the margins converge slightly in the direction of the root. Both the occlusal and cervical margins are similar to the corresponding margins of the buccal surface.

The Mesial Surface of the Crown (Fig. 82).—This surface is almost an unbroken plane, being smooth and flat. In some instances it is

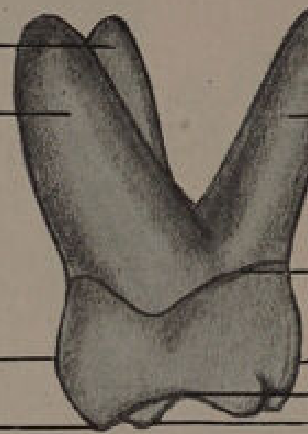


FIG. 82.—Upper first molar, mesial surface.

crossed near the center of its occlusal margin by a continuation of the mesial groove, but this is seldom so pronounced as to divide the surface. The occlusal third of the surface is inclined to a slight general convexity, providing a point of contact for the distal surface of the second bicuspid, but between this and the cervical line there is often a slight concavity. The margins of the surface are the occlusal, buccal, lingual, and cervical. The first named is formed by the mesiomarginal ridge of the occlusal surface, and is concave in the direction of the root. The buccal and ingual margins are rounded, and, unlike the lateral margins of the buccal and lingual surfaces, diverge in the direction of the roots. The cervical margin is slightly concave in the direction of the occlusal surface, and its length is much greater than that of any other margin of the crown. This surface is more extensive than either the buccal, lingual, or distal, and is about equal to that of the occlusal. When the fifth cusp is present it alters the form of the lingual margin of this surface by crossing it near the center, and extending for some little distance on the face of the surface.

The Distal Surface of the Crown.—Taken in its entirety, this surface usually presents a general convexity. The lingual half of the surface is usually somewhat more prominent than the buccal, the latter being flattened and frequently slightly concave, particularly near the cervical portion. In some instances the surface is traversed by a continuation of the distolingual groove, which, after passing over the distomarginal ridge, is continued in a longitudinal direction, dividing the surface into two equal parts. Not infrequently this groove, instead of existing as such, is represented as a shallow depression, often extending to the bifurcation of the roots. The margins of the surfaces are four in number: the occlusal, which closely resembles the corresponding margin of the mesial surface; the buccal, which is not well defined; the lingual, somewhat angular; and the cervical, formed by the cervical line.

The Neck of the Tooth.—When looking upon the buccal surface, the constricted portion forming the neck is greatest at a point immediately above the cervical line. Viewed in this direction the crown is usually bell-shaped, and both the crown and the base of the roots assist in producing the neck. Viewed from a lingual direction, the neck is a distinctve feature, but is seldom so marked as when examined from the opposite side. When studied from either a mesial or a distal aspect, the neck appears above the cervical line, the prominent fold of enamel immediately adjacent to this line forcing the neck rootward.

The Roots of the Upper First Molar.—The roots are three in number, two of which are on the buccal side, and are, therefore, called mesiobuccal and distobuccal roots, and one on the lingual side, known as the lingual root. These three roots are given off from a common base, which is sometimes referred to as the root, while those parts above the point of trifurcation are considered as root-branches. The number, location, and form of the roots of this tooth are, perhaps, more constant than those found in connection with any other cuspidate tooth. The common base from which the roots are given off is similar in contour to the crown of the tooth, excepting in those cases in which the form of the root is carried over this base to meet the neck of the tooth.

The mesiobuccal (Fig. 80) is flattened from mesial to distal, broad at its base from buccal to lingual, from which point it gradually tapers to the apex. At the base the mesiodistal measurement is less than one-third that of the buccolingual. In its course it is first inclined to the mesial, but after reaching the center of its length it makes a decided distal curve, which looks almost directly to the distal. The mesial side of this root is decidedly flattened at its base, but as the center of the surface is reached a shallow longitudinal groove is present, which is continued to the region of the apex. The distal side is also possessed of a similar groove, which extends throughout its entire length. Both the buccal and lingual sides of the root are smoothly convex, the latter being only about half the width of the former.

The distobuccal root (Fig. 80) is much the smallest of the three, and, while inclined to flatness on its mesial and distal sides, it is much more rounded than the mesial root. The mesial side is provided with a slight longitudinal groove, and in rare instances a similar groove exists on the distal side. The buccal and lingual sides are similar to those of the mesial root. The root is generally straight, and tapers gradually from base to apex, ending in a rounded point.

The lingual root (Fig. 81) is usually the largest and longest of the three, and is more rounded in form than either of the buccal roots. The lingual surface is inclined to flatness near its base, and is provided with a well-defined longitudinal groove, which is sometimes independently formed, while at others it is present as a continuation of the lingual groove. This root being the only one given off from the lingual side of the tooth, is constructed with a mesiodistal measurement about equal to that of the base of the crown at this point. From its place of beginning it passes first in a lingual and then in a buccal direction, forming a long curve and ending in a sharp-pointed apex.

Bilious Type.—The upper first molar of this temperament is manifest by a crown with angles well produced, the marginal ridges and cutting-edges of the cusps bold and well marked. The cusps are of medium length, with summits angular and pointed. The developmental grooves are deep and often sulcate, and numerous supplemental grooves are found upon the occlusal surface. The longitudinal and transverse measurements of the crown are about equal, and when viewed upon the occlusal surface, the angular nature of its anatomy is noted as a distinctive feature. The neck is fairly well developed, giving a slight bell-shape to the crown. The cervical line is made up of angles rather than curves, and the roots are long and straight.

Nervous Type.—Like the teeth previously described under this class, the crown of this tooth is of greater longitudinal than transverse extent; the neck is especially well formed, producing a decided bell-shape to the crown. The cusps are long and penetrating, the marginal ridges sharply defined, as are also those ridges upon the central incline of the cusps. The grooves of development are decided and frequently sulcate. The buccal surface is rounded and smooth, with the buccal groove extending well toward the cervical line. The lingual surface also presents a general convexity, and is usually divided by the lingual groove. The mesial surface is convex over its cervical third, and the occlusal margin is a decided convex ridge, serving as a point of contact for the adjoining tooth, and thus forming the characteristic V-shape common to this temperament. It is in this type that the fifth cusp is most frequently present. The cervical line is much curved, and the roots are slim and frail.

Sanguineous Type.—The crown of the upper first molar of this type usually presents a slightly greater longitudinal than transverse extent. The angles of the crown are poorly formed, being rounded and smooth. The cusps are of moderate length, and are rounded in their nature; the marginal ridges, as well as those ridges of the central incline of the cusps, are less distinct than either of the forms previously described. The buccal and lingual surfaces are convex and seldom broken by grooves; the mesial and distal surfaces are convex in every direction, throwing the point of contact with adjoining teeth near the center of the surface. The roots are inclined to be large and oval in form, while the cervical line is a series of long curves.

Lymphatic Type.—In this temperament the crown is much less in its longitudinal than transverse measurement. The neck of the tooth is poorly defined, the crown passing into the root-base without a marked constriction. The mesial and distal surfaces are flattened and nearly parallel with each other, providing a broad contact surface. The buccal and lingual surfaces each present a marked general convexity, the latter being frequently broken by the distolingual groove. The tooth is provided with cusps which are short and heavy-set; the marginal ridges, as well as all the ridges common to the occlusal surfaces, are poorly defined. The developmental grooves are shallow and terminate abruptly. There is but little curvature to the cervical line, and the roots are short, heavy-set, and inclined to cluster together.

UPPER SECOND MOLAR

7th year 8th year 9th year 10th year 11th year 12th year 16th year

Fig. 83.

Calcification Begins, from Four Centers, about the Fifth Year.
Calcification Completed, Sixteenth to Eighteenth Year.
Erupted, Twelfth to Fourteenth Year.
Average Length of Crown, .28.
Average Length of Root, .51.
Average Length over All, .79.

Calcification in this tooth takes place in precisely the same manner as that of the first molar, but the formative process is much later in beginning, the lime-salts commencing to accumulate in the four separate lobes about the fifth year. At the beginning of the sixth year the formation of the cusps is completed, soon after which they coalesce and the occlusal surface of the crown is established. At the beginning of the eighth year fully two-thirds of the crown is calcified, and the following year the crown and neck are completed and the root-base outlined. By the tenth year the beginning of separate root-development is observed; at the twelfth year, or at the time of eruption, the roots are formed to about one-half of their completed length, the process continuing until the sixteenth or seventeenth year, when calcification is completed and the root apices formed (Fig. 83). In many respects this tooth closely resembles the first molar previously described, the crown presenting the same number of surfaces similarly named, and also being provided with the same number of roots. Notwithstanding this fact, there are a number of ways in which they are at variance. The crown of the second molar is smaller than that of the first, and the quadrilateral outline common to the first molar is much compressed and broken in the second. The distal cusps are much smaller proportionately than the mesial cusps, this being particularly true of the distolingual cusp. This reduction in size of the distal cusps gives to that portion of the occlusal surface a slight distal incline.

Occlusal Surface of the Crown (Fig. 83).—The general contour of the crown is best studied by viewing it directly upon the occlusal surface; this aspect also shows to best advantage the difference in form between this and the first molar, as shown in figure 90. The mesial and lingual outlines closely resemble the corresponding outlines on the first molar, but the buccal and distal are much at variance, the former passing into the latter without a distinct line of demarcation, this gradual blending of one into the other being at the expense of the disto-

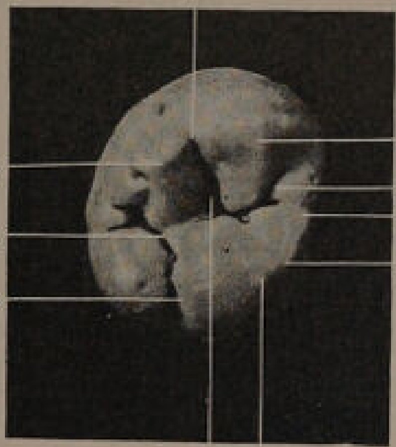


FIG. 84.—Upper second molar, occlusal surface.

buccal angle of the crown, which is poorly developed. The crown is much compressed in a distobuccal-mesiolingual direction, making this measurement of the occlusal surface about one-third less than the mesiobuccal-distolingual measurement. The cusps are much inclined to cluster toward the center of the surface, this being especially true of those on the lingual half.

Marginal Ridges of the Occlusal Surface (Fig. 84).—Like the occlusal surface of the upper first molar, this surface of the second molar is bounded by four marginal ridges—the mesial, distal, buccal, and lingual. They are usually less marked than those found on the first molar, and are much more variable in their individual anatomy. The *mesiomarginal ridge* extends from the summit of the mesiobuccal cusp to the summit of the mesiolingual cusp. It is concave in the direction of the body of the crown, and is broken near its central portion by the mesial groove. In some instances one or more small supplemental grooves are found to cross it. Compared with the mesiomarginal ridge of the first molar, its length is much less and the convexity not so pronounced. The *distomarginal ridge*, owing to the variation in form and size of the distal cusps, is difficult to describe definitely; suffice it to say that it extends from the summit of the distobuccal to the summit of the distolingual cusp. The concavity is V-shaped, and is usually crossed near the center by the distolingual groove. In some instances the distolingual cusp is almost wanting, in others the distobuccal is but little developed; when either of these conditions is present, the marginal ridge is extended either to the buccal or to the lingual, in a measure taking the place of the missing cusp. The mesial half of the *buccomarginal ridge* closely resembles the corresponding margin of the first molar; beginning at the mesiobuccal angle it ascends to the summit of the mesiobuccal cusp, after which it descends by a longer incline to the buccal groove. The distal half of the ridge, unlike that of the first molar, presents much variety, its form being controlled by the character and position of the distobuccal cusp, usually small. As most frequently observed, it ascends to the summit of the cusp, and in so doing it presents a decided lingual inclination. In passing down the distal incline the lingual inclination is increased and gradually passes into the distomarginal ridge. Branching off from the mesiomarginal ridge, the *linguomarginal ridge* ascends to the summit of the mesiolingual cusp and descends by a much shorter incline to the distolingual groove. This portion of the margin is thrown well toward the center of the surface, the location of the cusp carrying it to that point. Like the distal half of the buccal margin, the outline of the distal half of this margin is controlled by the position and form of the distolingual cusp. In the majority of cases, when the cusp is moderately strong, the ascent from the distobuccal groove to the summit of the cusp is short and abrupt, the descent being somewhat more gradual and with a decided buccal inclination it passes into the distomarginal ridge, or ends abruptly at the distal end of the distolingual groove.

The Cusps and Ridges (Fig. 84).—This tooth is provided with four lobes or cusps, two of which are located on the buccal, and two on the lingual side. They are usually smaller and less angular than the cusps of the first molar. This is particularly true of both the distal cusps, and especially of the distolingual cusp, which is often quite diminutive and occasionally entirely wanting. When this latter condition exists, the lingual half of the surface is for the most part occupied by what would otherwise be the mesiolingual cusp, the absence of the distal cusp permitting the distolingual groove to occupy a position near the extreme distolingual angle, that portion of the surface which is distal to the groove being a portion of the distomarginal ridge.

The Mesiobuccal Cusp (Fig. 84).—Like the corresponding cusp of the first molar, this cusp is usually the longest of the four, and in many instances covers a greater extent of surface than any of the others. Its base is outlined by the buccal and mesial grooves, the two together forming the mesiobuccal triangular groove. Descending from its summit to the buccal surface is the mesiobuccal ridge; the marginal ridge makes a double descent, one in a mesial and one in a distal direction, while sloping toward the central fossa is the mesiobuccal triangular ridge. The cusp is seldom traversed by supplemental grooves such as are found on the corresponding cusp of the first molar.

The Distobuccal Cusp (Fig. 84).—As previously stated, this cusp is not constant in its form; in some instances it is bold and well produced, corresponding closely to the mesiobuccal cusp just described. When thus pronounced it is possessed of ridges, and bounded by grooves which are similar to those described in connection with the first molar. More frequently the cusp is much rounded, its summit being carried well toward the center of the surface. When this formation exists, the buccal ridge is absent, the marginal ridges short and rounded; the distobuccal triangular ridge which descends from it toward the center of the crown is short and heavy set.

The Mesiolingual Cusp (Fig. 84).—In the majority of instances this is the largest cusp, particularly when there is a degenerate tendency in the distolingual cusp. Descending from its summit are a number of ridges, the marginal ridges being given off as already described, the mesiolingual triangular ridge descending the central incline to the central fossa, and when the cusp has an additional mesiodistal extent by the presence of a diminutive distal cusp, other ridges descend in the same direction. The lingual descent of the cusp is smooth and more rounded than the corresponding surface of the first molar, and is seldom elevated in the form of a definite ridge. The central outline of this cusp is marked by the mesial, the distal and the distolingual grooves.

The Distolingual Cusp (Fig. 84).—In no other cusp do we find such a diversity of form as in the distolingual cusp of the upper second molar. In some instances it is fully as prominent as its neighbor just described, in others appearing as a mere fold of enamel, and it is not uncommon to find it entirely wanting, the distomarginal ridge extending to occupy a portion of the space which it should claim. Deductions might be drawn from an average between these two extremes, wherein the existing cusp would be much smaller than any of the others, the summit rounded rather than sharp, but with a decided inclination to occupy the extreme distolingual angle of the surface, in this latter respect differing from the distobuccal cusp. The mesial and buccal outlines of the cusp are formed by the distolingual groove, and its mesiolingual incline contributes to the formation of the distal fossa.

The Fossæ and Grooves of the Occlusal Surface (Fig. 84).—These in name, number, and general form are similar to those of the first molar. The central fossa is never, strictly speaking, in the center of the surface, and is formed by the central incline of the mesiobuccal, distobuccal, and mesiolingual cusps. It is seldom so deep as the central fossa of the first molar. The distal fossa is more or less pronounced, its size and position being controlled by the extent of development in the distolingual cusp. The distolingual groove, which usually crosses the lingual surface of the first molar near its center, is not constant in its location on this tooth, in some cases being near the center, in others near the distolingual angle of the crown. The buccal groove is never constant in its location, usually crossing the bucco-marginal ridge and passing over the buccal surface near its mesiodistal center, but it is not uncommon to find it forced to the distal by a diminution in the size of the distal cusp.

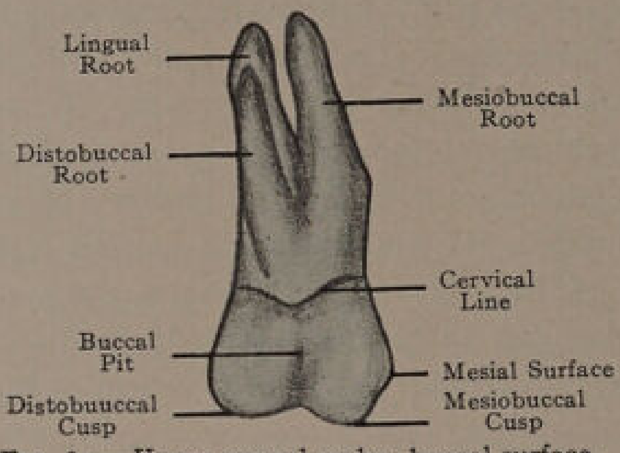


FIG. 85.—Upper second molar, buçcal surface.

Buccal Surface of the Crown (Fig. 85).—The most constant difference between this and the corresponding surface of the upper first molar is the wandering location of the buccal groove. While in the majority of instances it may be found near the mesiodistal center of the surface, it is not uncommon to find it passing over the distal third, or even as far posterior as the distobuccal angle. In general, the surface is somewhat more convex and necessarily less extensive than the buccal surface of the first molar. The buccal ridges which descend from the summit of the two buccal cusps are seldom so marked as those on the first molar, and in many instances the distal ridge is wanting. The distal half of the surface frequently passes into the distal surface, by a long gradual sweep, there being no line of demarcation between the two.

The Lingual Surface of the Crown (Fig. 86).—In keeping with the other surfaces just described, the lingual surface differs from the corresponding surface of the first molar in that it presents a greater general convexity. This is particularly true in passing from the cervical line to the occlusal surface. The lingual groove is also less constant in its location. In most instances it is to be found a little to the distal of the center, in others being as far posterior as the extreme distal third of the surface, and in rare instances it is entirely wanting. The general character of this surface, which is smooth and convex, is seldom broken by the presence of well-defined ridges, such as are usually found descending from the lingual cusps of the first molar. The mesial, distal, and buccal surfaces, as well as the surfaces under consideration, are proportionately smaller than those of the first molar, and, while this refers to both the transverse and longitudinal measurements, it is particularly applicable to the latter.

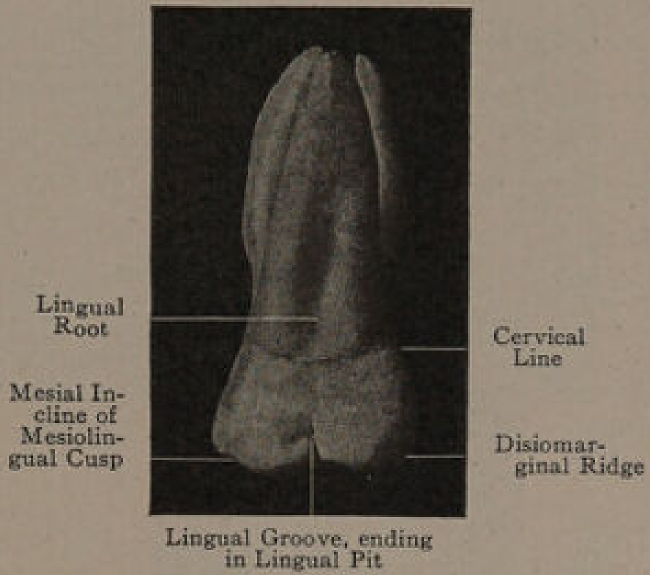


FIG. 86.—Upper second molar, lingual surface.

The Mesial Surface of the Crown (Fig. 87).—Aside from this surface being of less extent than the corresponding surface of the first molar, there are no other differences of importance. In many instances, however, there is a decided tendency for the surface to be concave from buccal to lingual, the convex distal surface of the first molar closely fitting into this concavity. Another variation which is frequently observed is that of the longer and more gradual sweep which it takes in passing into the lingual surface.

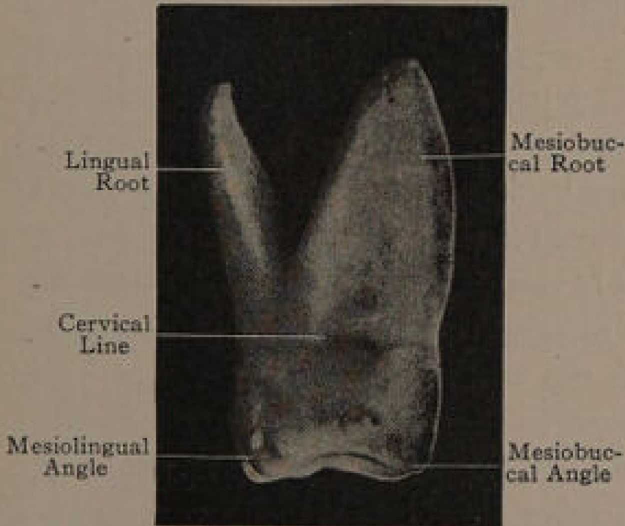


FIG. 87.—Upper second molar, mesial surface.

The Distal Surface of the Crown (Fig. 88).—This differs from the distal surface of the first molar principally in its more pronounced convexity. Its general form is also much influenced by the nature of the two distal cusps. If one or the other of these is sparingly developed, either the buccal or lingual half of the surface, as the case may be, is quickly rounded off to pass into the deficient lobe.

The Angles of the Crown.—The increased inclination for the crown of this tooth to general convexity dispels, in a measure, the presence of angles, as such, in correspondence to the four corners of the first molar. In some instances the crown is represented as a fairly well-formed quadrilateral, in which case the angles are well defined, but usually this outline is so much broken by a mesiodistal compression that the angular form of the crown is entirely abolished. But, whatever the form of the crown may be, it is well to adhere to the commonly accepted term, and speak of that point at which the sides of the crown unite as the angles, each being named in accordance with its location.

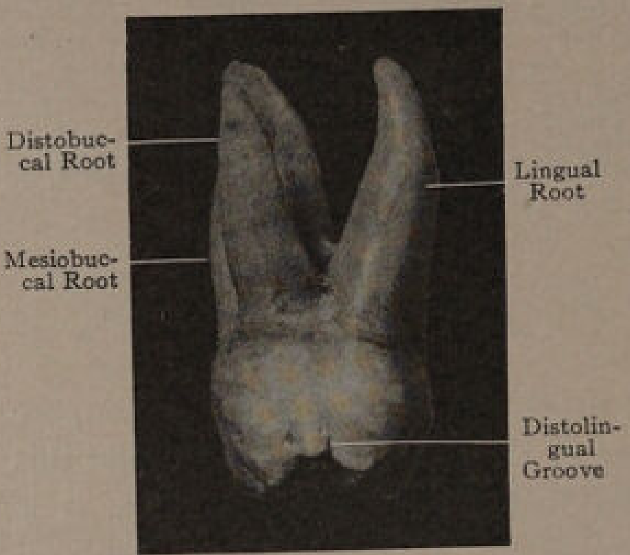


Fig. 88.—Upper second molar, distal surface.

The Neck of the Tooth.—The principal variation between the neck of this tooth and that of the first molar, is that produced by the greater general convexity of the crown, which contributes to the production of a neck much more constricted. There is also a greater variety in the contour of the neck, incident to the variation in the general outline of the crown.

The Roots of the Upper Second Molar.—These are the same in name and number as those of the first molar—two buccal and one lingual. In many respects they differ from the roots of the first molar. They are much smaller, frequently inclined to cluster together, and are often fused, in some instances, all three being united, in others the union existing between the two. When isolated, each root usually presents a decided distal curve near its apical third. When the crown is flattened from mesial to distal, as before described, the distobuccal root is forced to occupy a position much more to the lingual than that assumed by the mesiobuccal root. The lingual groove seldom passes over the lingual root, as observed on the first molar.

UPPER THIRD MOLAR

10th year 11th year 12th year 14th year 18th year

FIG. 89.

CALCIFICATION BEGINS, NINTH YEAR.
CALCIFICATION COMPLETED, EIGHTEENTH TO TWENTIETH YEAR.
ERUPTED, SEVENTEENTH TO TWENTIETH YEAR.
AVERAGE LENGTH OF CROWN, .24.
AVERAGE LENGTH OF ROOT, .44.
AVERAGE LENGTH OVER ALL, .68.

The calcification of this tooth takes place in precisely the same manner as that in the first and second molar, with the exception of the number of lobes, which are sometimes three and sometimes four. The limesalts begin to accumulate between the eighth and ninth year, and continue with somewhat more activity than that of the first and second molars. Between the ninth and tenth year the three or four cusps, of which the future tooth is to be composed, have coalesced, and by the eleventh year calcification in the crown of the tooth is completed; at the end of the following year the roots, which are variable in number, have made considerable progress; at the fourteenth year they are calcified to about half their length, while at a period between the eighteenth and nineteenth year the formative process is completed (Fig. 89). This tooth, like the cuspid, is usually fully formed before eruption takes place.

This tooth is subject to a greater variety of form than any other; in rare instances it is similar in general outline and cusp formation to the first molar, but in a vast majority of cases it is dissimilar, the most constant deviation being its size, which on the average is about one-third less. In the accompanying illustration (Fig. 90) the forms most frequently met with are shown. It will be observed that the contour of the tooth in general is much more rounded than either the first or second molar. The buccal angles of the crown are alone well marked, the mesial and distal surfaces passing into the lingual surface by a long, gradual sweep, and thus obliterating the lingual angles. In many instances the tooth is tritubercular, and is usually made so by the absence

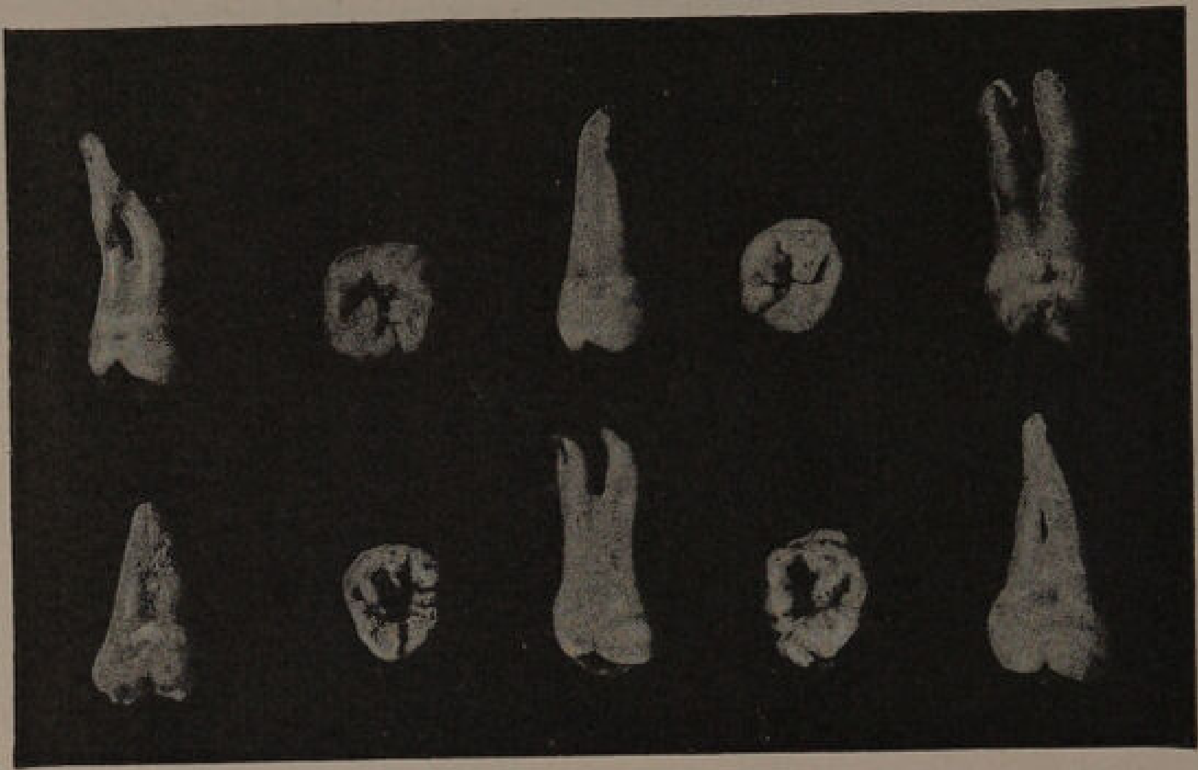


FIG. 90.—Various types of upper third molar.

or diminutive size of the distolingual cusp. Just as this cusp was inclined to degenerate in the second molar, so we find this retrograde tendency increased in the third molar. With this change in the construction of the occlusal surface, there is a corresponding variation in the grooves, ridges, and fossæ.

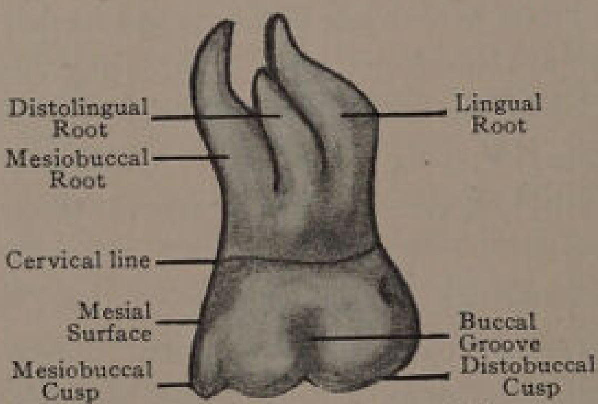


FIG. 91.—Upper third molar, mesial surface.

Mesial Surface of the Crown (Fig. 91).—In many particulars this surface corresponds in form and outline to the mesial surface of the first molar; it is, however, usually much more convex, seldom presenting a concavity or even a positive flatness. The surface is not only rounded from buccal to lingual, but also from the cervical line to its occlusal margin. Thus formed, a point of contact is provided near the center of the surface. The occlusal margin, the buccal margin, and the cervical margin are almost identical to those of the first molar, but in most instances the lingual margin is wanting, the surface gradually passing into the lingual without a decided line of demarcation.

Distal Surface of the Crown.—This surface is much less extensive in comparison to the size of the crown than the corresponding surface of either the first or second molar. It is decidedly rounded in every direction and is frequently crossed by the distal developmental groove, and sometimes by one or more supplemental grooves. The general form of the surface is much influenced by the presence or absence of the distolingual cusp; with the former, the surface is more extensive, presenting less convexity and resembling more closely the distal surface of the first and second molars; with the latter, the extent of the surface is decreased and the convexity increased.

Buccal Surface of the Crown.—The mesial portion of this surface is in no way at variance with the mesial portion of the buccal surface of the first or second molar, but much variety of form exists in the distal portion. The buccal groove which serves to separate these two portions is located well toward the distal third of the surface, thus reducing the size of the distal portion to about one-third that of the mesial portion. In general, the surface is but little more convex than the corresponding surface of the first and second molar. Its mesial border is definitely outlined, as are also the cervical and occlusal margins, but the distal margin cannot be definitely located, the surface tending to pass gradually into the distal surface. Like the distal, the extent of this surface is much regulated by the size and shape of the distobuccal cusp, which, like the distolingual cusp, is inclined to degenerate.

Lingual Surface of the Crown.—Like the distal surface previously described, the form of this surface is much influenced by the presence or absence of the distolingual cusp. When this cusp is wanting or but little developed, the surface presented is decidedly convex and smooth; in many instances the mesiodistal curvature described is almost a perfect semicircle, and in passing from the cervical line to the occlusal margin the surface is carried well toward the center of the crown by a long gradual sweep toward the lingual. The lingual groove is usually absent. The change in form produced by the presence of the distolingual cusp is principally noticeable in a less pronounced convexity and the presence of the lingual groove, which may be noticed as a slight depression or as a well-defined groove. This groove, when present is always located near what would represent the distolingual angle of the crown; the distolingual cusp seldom if every being of sufficient size to force its location near the center of the surface as in the first molar. In some instances this groove is shown upon the lingual surface when the cusp is not present; in this case the distomarginal ridge represents in a manner the cusp by its bold, heavy development.

Occlusal Surface of the Crown. (Fig. 92).—When looking directly upon this surface, an opportunity is presented to study the general contour of the crown; the most noticeable difference in this respect between this tooth and the first molar being observed in its smaller size, and the absence of well-marked angles. It will be noted that the mesial and buccal outlines in a measure resemble the corresponding outlines of the first and second molars, but there is scarcely any similarity existing when comparing the distal and lingual outlines. In some instances the crown is triangular (Fig. 103); in others the mesiobuccal and bucco-marginal outlines form an obtuse angle, the free ends of which are joined together by a long semicircle, the latter constituting the distal and lingual outlines. Again, almost the reverse of this last-mentioned form is seen, the buccal and distal outlines constructing the angle, while the semicircular connection between the two is made up of the mesial and lingual outlines.

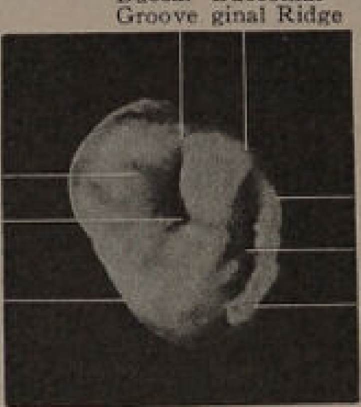


FIG. 92.—Upper third molar, occlusal surface.

The Marginal Ridges. (Fig 92).—The *mesiomarginal ridge* is usually well defined, and in most instances is crossed near its center by the mesial groove, and frequently by two or more supplemental grooves. This marginal ridge is probably the most constant in form, the numerous variations to which the surface is liable seldom making any material alteration in it. Unlike the ridge above described, the *distomarginal ridge* is most variable in its construction, nearly all of the forms characteristic of the occlusal surface exerting a controlling influence over it. In rare instances, the ridge resembles that of the first and second molars, but this form is most frequently interfered with by the absence or diminutive size of the distolingual cusp, the ridge itself frequently supplying the place of the cusp. In many cases the ridge is elevated near its central part by being reinforced by a portion of the oblique ridge. When the distolingual cusp is wanting, this ridge not infrequently descends from the summit of the distobuccal cusp to the summit of the lingual cusp. The *buccomarginal ridge* may be described as similar in most respects to the corresponding margin on the first and second molars, the principal variation being in the distal half, which is much shorter and less pronounced. In the *linguomarginal ridge*, again, much variety in outline is noticeable. In nearly all instances the ridge is thrown much nearer the center of the body of the crown, and, when the tooth is bicuspid in form, it simply makes a mesial ascent of the lingual cusp, followed by a gradual incline, and passes into the distal ridge, as above noted. When the distolingual cusp is present, the ridge is similar to that upon the first and second molars, with the exception of the distal portion, which is less clearly marked.

The Cusps (Fig. 92).—As previously stated, the form most frequently met with is tritubercular, two of the cusps being upon the buccal and one upon the lingual half of the surface.

The Mesiobuccal Cusp (Fig. 92).—This cusp corresponds in nearly every particular to the mesiobuccal cusp of the first and second molars; it is the most constant in size and form of the three. Its summit is usually angular, and the numerous ridges which descend from it are well defined and similar in name and number to those of the first molar.

Distobuccal Cusp (Fig. 92).—The constant inclination to degeneracy in the distal portion of the crown of the tooth is noticeable in this cusp, which is much smaller than the mesiobuccal and scarcely half as large as the corresponding cusp of the first and second molars. In some instances, however, it is inferior only in size, retaining its angularity, being possessed of small but well-defined ridges.

The Lingual Cusp (Fig. 92).—When the three cusps alone are present, this one is much the largest, the extent of the surface covered being all of the lingual half of the crown. The summit of the cusp, which is thrown well toward the center of the body of the crown, is prominent, but seldom angular. Only in rare instances will there be found a lingual ridge descending therefrom, but the central incline is usually marked by a number of wrinkles or folds of enamel resembling minute ridges. The central boundary of this cusp is marked by the mesial and distal developmental grooves.

The Distolingual Cusp (Fig. 92).—It is the presence or absence of this cusp that contributes most to the variations present in the crown.

When present, it is usually diminutive in size, and is without definite form. In many instances nature is apparently attempting to cast it off in precisely the same manner in which she is attempting to add to the first molar by a development of the "fifth cusp," the distobuccal cusp appearing to hang to the distolingual angle of the crown in a manner very similar to the "fifth cusp." When thus situated, it is separated from the body of the crown by a groove, which cannot be considered as being upon the occlusal surface. When located in its normal position, it has for its inner boundary the distolingual groove.

The Fossæ and Grooves of the Occlusal Surface (Fig. 92).—The great variety and *form* common to this surface exert a controlling influence over the size, number, and position of the grooves and fossæ. In the tritubercular class the central fossa alone is present. The developmental grooves, with the exception of the buccal, are not definitely outlined, but, descending toward the fossæ from the central incline, are numerous small ridges divided from each other by a like number of diminutive supplemental grooves. The distal groove is sometimes well defined, and crosses over the oblique ridge, which in this type becomes the distomarginal ridge. When the distolingual cusp is present, all of the ridges and grooves are more pronounced. In this case the central fossa corresponds more closely to the central fossa of the other molars, this resemblance increasing just in proportion as the size of the distolingual cusp increases. The distal fossa, in a vast majority of instances, is present as a mere pit; the size of this fossa is likewise much controlled by the extent of development in the distolingual cusp. Where the distomarginal ridge is supplementary to the distolingual cusp, the distolingual groove lies between the former and oblique ridge. Another peculiarity found only upon the occlusal surface of this tooth is, what appears to be an effort upon the part of the cusps to cluster toward the center. This is common only to those teeth possessing three cusps, and accompanying this form the central fossa shows a number of fantastically arranged grooves and ridges which ascend the cusps, passing over the marginal ridges and breaking them into a number of small tubercles.

Fig. 93.—Upper third molar, occlusal surface, with distolingual cusp and distal fossa poorly defined.

Temperamental Types.—The third molar is probably less influenced by the character and habits of the individual than any other tooth in the mouth. The inclination to a general degeneracy is no doubt favored by civilization. With a constant decline in the functional activity, brought about by modern culinary methods common to civilization, this tooth in a measure becomes useless, and nature is gradually making an effort to cast it off. While there are undoubtedly many individuals possessed of the highest mental attainments with the third molar as fully developed as either the first or the second, this condition is usually confined to those possessed of little intellectuality. If, in general, the temperament of the subject be taken into consideration, the cusp-formation on this tooth will correspond in a certain degree to that on the bicuspids and molars.

CHAPTER IX

A Description of the Lower Teeth in Detail—Calcification, Eruption and Average Measurements—Their Surfaces, Ridges, Fossæ, Grooves, Sulci, etc.

THE LOWER TEETH

In most respects the anatomy of the lower teeth is similar to that of the upper, but we find a slight variation existing between the two sets. As compared to the upper incisors, the crowns of the lower incisors are more slender and somewhat more angular in outline. The roots are more slender, proportionately longer, more flattened laterally, and seldom crooked. The crowns of the lower incisors are probably more constant in form than those of any other teeth, seldom varying except in size. The mesiodistal measurement of the crown of the lateral incisor is a trifle greater than that of the central, a condition exactly the reverse to that of the upper incisors. The labial and the lingual surfaces of these teeth are smooth, and, with the exception of young teeth, show but little trace of the developmental process by the presence of grooves, fissures, etc. The outline of the lower cuspids is almost identical to that of the corresponding teeth in the superior arch, excepting that they are in every way more slender. The bicuspids are proportionately smaller in every direction than those of the upper jaw, their cusps are smaller, and they are seldom found with more than one root. The crowns of the lower molars are somewhat larger than those of the upper, and are provided with five cusps instead of four,* and they are attached to the alveolus by two, instead of three roots. In the incisors, cuspids, and bicuspids the process of development is the same as in the corresponding upper teeth, calcification taking place from the same number of centers. In the molars, however, development may proceed from five centers instead of four, as in the upper molars. The manner of development, and the period at which this action takes place, so nearly corresponds with that of the upper teeth that the process will not be repeated.

* The lower first molar has five cusps in ninety per cent. of cases, while in the second five cusps are present in about fifty per cent.

LOWER CENTRAL INCISOR

Calcification Begins, First Year.
Calcification Completed, about the Tenth Year.
Erupted, Seventh to Eighth Year.
Average Length of Crown, .34.
Average Length of Root, .47.
Average Length over All, .81.

Like the upper central incisor, this tooth has four surfaces, an incisal-edge, and various angles, margins, etc. By the union of the labial and lingual surfaces at the incisal-edge the incisive feature is established and the double incline plane common to incisors produced.

The Labial Surface of the Crown (Fig. 94).—This surface is smooth and convex, its general outline resembling an inverted cone, the base of which is formed by the incisal-edge and the apex by the cervical line. The margins of the surface are, with the exception of the incisal-edge, not so well defined as those of the upper central. Near the incisal-edge the mesial and distal margins pass somewhat abruptly into the respective lateral surfaces, but as the neck of the tooth is approached they are much rounded. The incisive margin is squarely cut, and is nearly at right angles with the long axis of the tooth. The cervical margin is fairly well defined, and is deeply concave in the direction of the root. Except in very young teeth, this surface is seldom much broken by the labial grooves; but in certain types one or more transverse ridges may be found occupying the cervical third. The mesiodistal diameter at the incisal-edge is about one-third greater than at the cervical line, and, while these measurements are likely to vary in accordance with the temperament, this variation is not so pronounced as in the upper incisor. The surface is frequently inclined to flatness near the incisive margin, the general convexity becoming more marked as the cervical line is approached.

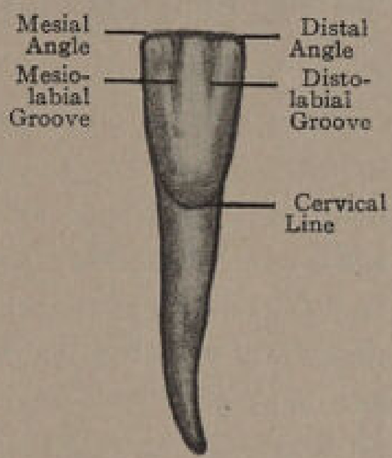


Fig. 94.—Lower incisor, right side, labial surface.

The Lingual Surface of the Crown (Fig. 95).—In general outline this surface resembles the labial, with the exception of the cervical margin, the lines of which are somewhat more acute. The surface presents a marked concavity from the incisal-edge to the cervical ridge, and also a slight transverse concavity near the incisive margin. All of the margins are more definite than those of the labial surface. The mesial and distal margins are formed by the marginal ridges common to these borders, but these ridges are not so well defined as those of the upper incisors. The cervicomarginal ridge is present as a well-rounded band of enamel but is never a well-defined cingulum, or cuspule. The depression between these marginal ridges is so slight that it can scarcely be referred to as a fossa, although usually characterized as the lingual fossa. The lingual grooves are generally more pronounced than the corresponding developmental grooves of the labial surface, but end more or less abruptly before reaching the cervical ridge. The mesiodistal measurements of the surface are a trifle less than the corresponding measurements of the labial surface.

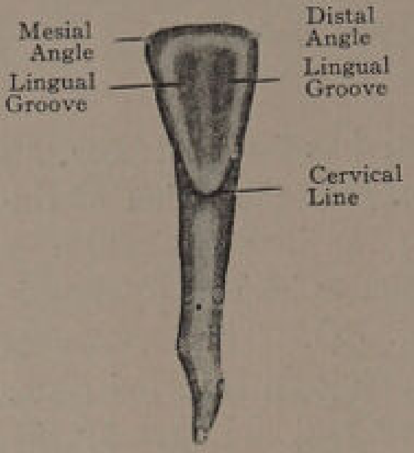


FIG. 95.—Lower incisor, right side, lingual surface.

The Mesial Surface of the Crown (Fig. 96).—The outline of this surface is exactly the reverse of the labial and lingual just described, being a cone, with its base directed downward or in the direction of the root, while its apex is formed by the mesial extremity of the incisal-edge. The cervical margin of the surface, or that represented by the base of the cone, is concave; the labial and lingual margins are rounded over the cervical third and inclined to angularity near the incisal-edge. There is a slight convexity over the entire surface, which is most marked near the center. The lingual half of the cervical portion slopes away to the distal, passing gradually into the lingual surface. By the union of this surface with the incisal-edge and the labial and lingual surfaces, the mesial angle of the crown is formed. This angle is well outlined and reaches out toward the median line, giving to this portion of the crown a prominent appearance. Near the incisal-edge the surface presents a slightly rounded prominence, which provides a point of contact with the corresponding tooth of the opposite side.

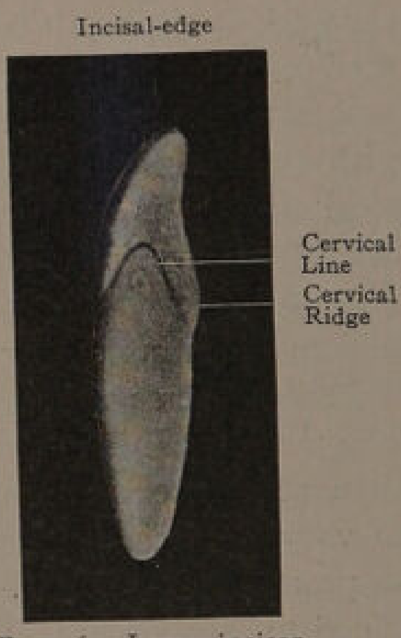


FIG. 96.—Lower incisor, mesial surface.

The Distal Surface of the Crown (Fig. 97).—In a general way this surface closely resembles that of the mesial side of the crown. Near the incisal-edge, the surface is usually more prominent and presents a more marked convexity, and near the cervical margin it is flattened and sometimes slightly concave. The union of this surface with the incisal-edge and the labial and lingual surfaces forms the distal angle of the crown, which, like the mesial angle, is square and well defined. The margins of the surface are in no way different from those of the mesial surface.

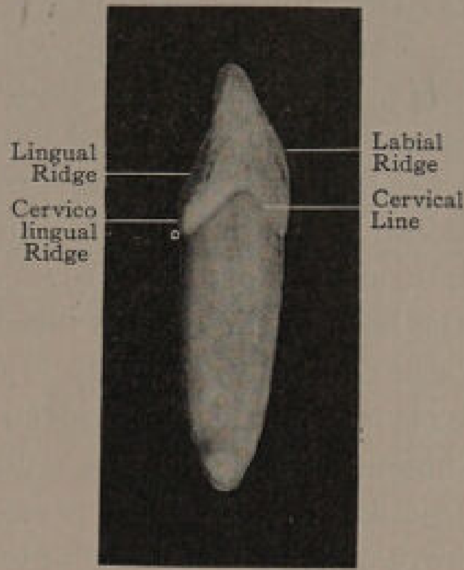


Fig. 97.—Lower incisor, distal surface.

The Incisal-edge.—In the young tooth this incisive margin is thin and generally divided into three distinct parts (Fig. 98) by the developmental grooves, but these disappear so early that they can scarcely be considered in connection with a description of the fully developed tooth; in fact, the incisal-edge of this, as well as that of all the lower incisors, is so susceptible to change by mechanical abrasion that a normal condition is of but short duration. After the disappearance of the primitive lobes, and before further abrasion has taken place, the edge is fairly sharp and placed nearly at right angles with the crown. As in the upper incisors, the incisal-edge is in a line with the long axis of the tooth. The labial margin is slightly convex, while the lingual is irregularly concave to the same extent.

Fig. 98.—Young lower incisor, with incisal-edge showing the lines of development.

The Cervical Margin.—This marginal line, which is marked by the extent of the enamel cap, corresponds closely to that of the upper incisors, dipping down with a graceful concavity on the labial and lingual surfaces with a corresponding convexity on the mesial and distal surfaces. The prominence of this enamel margin, together with the nature of the curvature, is much influenced by the tooth type.

The Neck of the Tooth.—A distinctive feature of this tooth is found in the convergence of its mesial and distal surfaces in passing from the incisal-edge rootward, thus producing a neck much constricted from mesial to distal. When examined from either the mesial or distal surface, this feature is scarcely noted, the crown passing into the root with little more than the cervical line as a mark of separation. The labial and lingual portions of the neck are rounded and narrow, while the two lateral sides are flat and broad.

The Root.—The root of this tooth is usually smaller than that of any other tooth in the mouth. It is much flattened from mesial to distal, while the labial and lingual aspects are rounded and narrow. Besides being flattened and broad, the mesial and distal sides are usually found with a longitudinal depression extending from a point near the base of the root almost to its apex. These surfaces gradually taper from the base to the apex, while the labial and lingual first widen from the base and then gradually taper to the apex. The contour of the root-base is generally reproduced at the apical extremity, although in some instances the latter is a rounded point. While the root of the tooth is usually straight, there is sometimes a tendency for the apical third to have a slight distal inclination.

LOWER LATERAL INCISOR

Calcification Begins, First Year.
Calcification Completed, Tenth to Eleventh Year.
Erupts, Eighth to Ninth Year.
Average Length of Root, .35.
Average Length of Root, .50.
Average Length over All, .85.

The crown of this tooth (Fig. 99) differs from the central incisor in being broader from mesial to distal at the incisal-edge, resulting in a

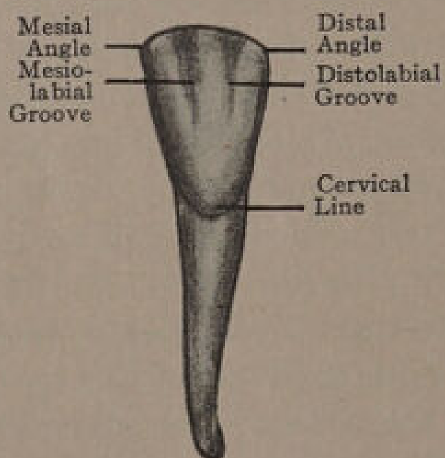


Fig. 99.—Lower lateral incisor labial surface.

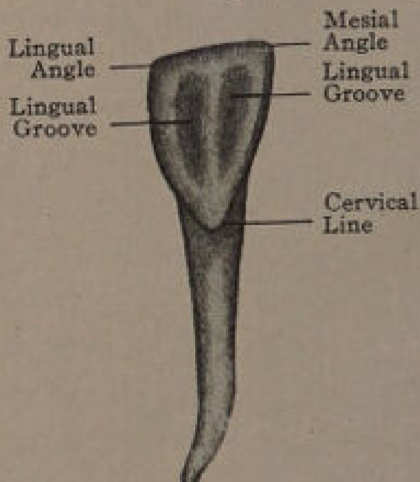


Fig. 100.—Lower lateral incisor, lingual surface.

crown more strongly bell-shaped. The incisal-edge, instead of being at right angles to the long axis of the tooth, slopes to the distal at the expense of the distal angle, which is much rounded, while the mesial angle closely resembles the corresponding angle of the central incisors. The labial and mesial surfaces do not differ materially from the corresponding surfaces of the central incisor, excepting that the lingual more frequently shows the lines of development, and the distal is at variance in having that portion which contributes to the formation of the distal angle extended and prominent. The marginal ridges of the lingual surface are probably more definitely outlined than those of the central incisor, and the crown in general presents a stronger appearance. The neck of the tooth is similar to the neck of the central incisor, as is also the root, with the exception of a slight addition to its length.

LOWER CUSPID

CALCIFICATION BEGINS, THIRD YEAR.
CALCIFICATION COMPLETED, TWELFTH TO THIRTEENTH YEAR.
ERUPTS, TWELFTH TO THIRTEENTH YEAR.
AVERAGE LENGTH OF CROWN, .40.
AVERAGE LENGTH OF ROOT, .60.
AVERAGE LENGTH OVER ALL, 1.00.

There is probably a greater similarity existing between the upper and lower cuspid than any other class of teeth in the mouth. Occupying as they do a prominent position in the dental arch, and being called upon to perform the double function of incising and tearing the food, their crowns are strong and heavy-set, and their roots long and firmly anchored in the alveoli. Like the upper cuspid, the crown of the lower is surmounted by a single cusp, from the summit of which descend a mesial and a distal incisal-edge. There is also a labial, lingual, mesial, and distal surface presented for examination.

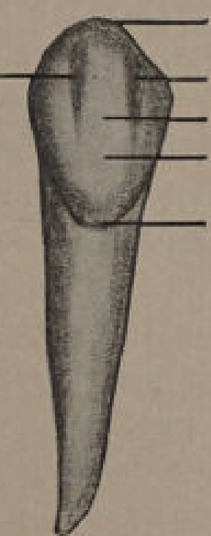


FIG. 101.—Lower cuspid, labial surface.

The Labial Surface of the Crown (Fig. 101).—The crown of the tooth, being a little longer than that of the upper cuspid, gives to this surface the appearance of being more slender, when in reality there is but little difference in the width of the two teeth. This surface is smooth and convex, and, while the labial grooves are usually present, they are not so marked as those found upon the corresponding upper tooth. A pronounced feature of the surface is the labial ridge, which extends from the summit of the cusp to the cervical line, providing additional strength to the crown. Aside from this ridge and the labial grooves, the surface is occasionally broken by one or more transverse ridges over the cervical portion. The margins of the surface closely resemble those of the upper cuspid, the incisive and mesial being definite in character, while the distal is made equally indefinite by the passing of the labial into the distal surface by a gentle curve.

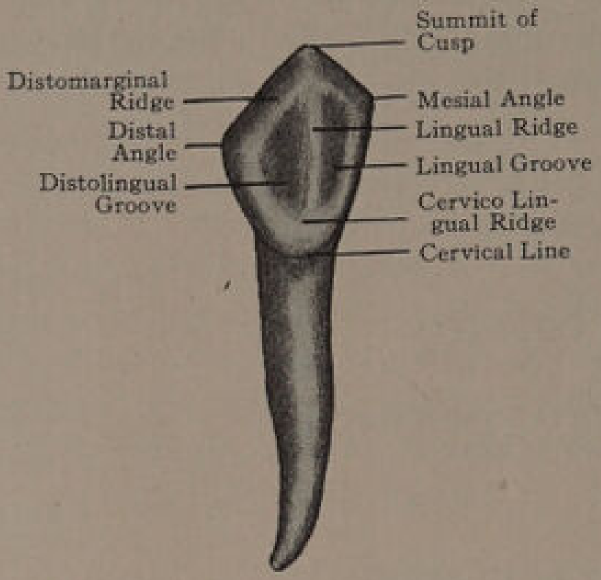


Fig. 102.—Lower cuspid, lingual surface.

The Lingual Surface of the Crown (Fig. 102).—The ridges and grooves of this surface are far less pronounced in character than those of the upper cuspid. The lingual ridge, which divides the surface into two equal parts, extends from the summit of the cusp to the base of the cervical ridge, while the marginal ridges pass rootward from the angles of the crown, and, uniting, form the cervical ridge. The slight depressions between the lingual ridge and the marginal ridges correspond to the lingual grooves of the upper cuspid, but in this tooth partake more of the nature of fossæ.

The Mesial Surface of the Crown (Fig. 103).—A peculiarity found in connection with this surface is the general plane existing between the crown and root-surface. In all other teeth the mesial and distal surfaces are found to bulge somewhat beyond the corresponding surface of the root, but this surface of the lower cuspid is not only usually in a direct line with the mesial surface of the root, but is occasionally inclined to the distal, resulting in a crooked or bent appearance to the tooth. In addition to this individual peculiarity, the surface is flat and passes by a long curve to meet the lingual surface.

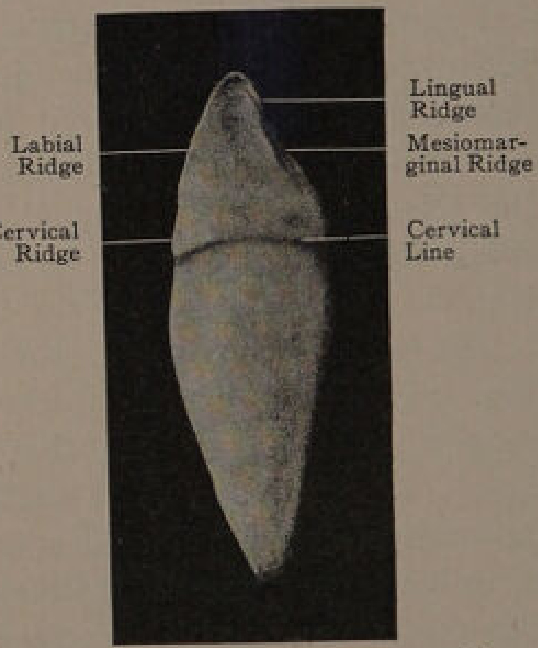


Fig. 103.—Lower cuspid, mesial surface.

The Distal Surface of the Crown (Fig. 104).—This surface is somewhat less in extent than the mesial surface, and, in place of being flat and in line with the root-surface, that portion near the angle of the crown presents a marked convexity, while that near the cervical line is frequently slightly concave. This general form of the surface further assists in producing the distal crook previously referred to. The lingual margin is well defined and somewhat angular, while the surface passes so gradually into the labial that a positive line of demarcation can scarcely be said to exist.

FIG. 104.—Lower cuspid, distal surface.

The Cusp and Incisal-edges.—In most respects these are similar to the corresponding parts of the upper cuspid. The length of the mesial incisal-edge is usually somewhat less than that of the distal, but this difference is seldom so marked as that found in the upper cuspid. The mesial and distal angles of the crown are equally as pronounced as those of the corresponding upper tooth.

The Neck of the Tooth.—This is shown by a fairly well-marked constriction, but the passing of the mesial surface of the crown into the mesial surface of the root is not broken by this circular depression. On account of this latter feature the neck of this tooth is somewhat less pronounced than that of the upper.

The Root of the Lower Cuspid.—The root of this tooth is somewhat shorter and more flattened on its mesial and distal sides than that of the upper cuspid, this lateral flatness frequently amounting to a decided longitudinal depression or groove. As referred to in the description of the crown, the mesial side of the root is continuous in a direct line with this surface of the crown, but as the apical third of the root is approached, there is frequently found a slight distal inclination which affects alike both the mesial and distal sides. The labial and lingual surfaces of the root are abruptly convex and taper very gradually from the cervical line to the apex, while the mesial and distal surfaces taper much more rapidly, the four ending in a slender apex usually flattened from mesial to distal.

THE LOWER BICUSPIDS

In many respects these teeth are similar to the bicuspids of the upper jaw, the chief differences being that they are somewhat shorter and smaller in every respect. Their crowns are much more rounded and the cusps are never so strongly developed. Unlike the upper bicuspids the buccal and lingual cusps are connected by a transverse ridge. The roots are much less flattened from mesial to distal, and are seldom bifurcated.

LOWER FIRST BICUSPID

CALCIFICATION BEGINS, ABOUT THE FOURTH YEAR.
CALCIFICATION COMPLETED, ELEVENTH TO TWELFTH YEAR.
ERUPTED, TENTH TO ELEVENTH YEAR.
AVERAGE LENGTH OF ROOT, .30.
AVERAGE LENGTH OF CROWN, .54.
AVERAGE LENGTH OVER ALL, .84.

In general, the crown of this tooth is much more rounded and smaller in all its measurements than that of the upper first bicuspid. The buccal surface presents a much greater convexity, which results in forcing the summit of the buccal cusp well toward the center of the long axis of the tooth. The mesiodistal and buccolingual measurements of the crown are nearly equal, and about correspond to the maximum length of the crown. As in the upper bicuspids, the development of this tooth is similar to that of the incisors and cuspids, the buccal cusp being derived from three lobes, while the lingual results from a single center.

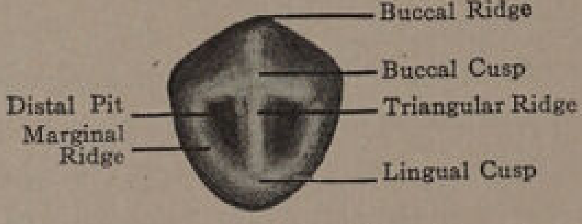


FIG. 105.—Lower first bicuspid, occlusal surface.

The Occlusal Surface of the Crown (Fig. 105).—This surface is so unlike that of the corresponding surface of the upper first bicuspid that a separate description without further comparative reference is required. In general outline the form of a rounded triangle is approached, the buccal margin serving as one side of the triangle, while, by the union of the mesial and distal margins to form the lingual, the remaining sides are established.

The Buccal Cusp.—As previously stated, the summit of this cusp is thrown well toward the center of the surface. Descending from it are four well-defined ridges—the buccal ridge to the buccal surface, the mesial marginal ridge, the distal marginal ridge, and the triangular ridge, the latter descending in a lingual direction to meet the lingual ridge or cusp. This ridge divides the surface into two parts, the center of each being marked by a well-defined pit—the *mesial* and *distal pits*. The mesial and distal marginal ridges are frequently crossed by the buccal grooves, and mark the line of union between the central and two lateral lobes of the buccal cusp. The marginal ridges, one of which begins at the mesial angle and the other at the distal angle, pass to the lingual, where they unite to form the *lingual ridge* or *cusp*.

The Lingual Cusp.—This cusp is seldom well developed, and corresponds to the cervical ridge of the incisors and cuspids. The extent of development in the lobe is extremely variable, in some instances amounting to little more than a continuation of the mesio- and distomarginal ridges while in others a small cusp is present. When this latter condition is present, the triangular ridge of the buccal cusp contributes to its formation. The triangular ridge frequently divides into two or more smaller ridges, which usually end in the mesial pit, but in some instances they continue to the lingual, and divide the lingual ridge into two or more smaller tubercles.

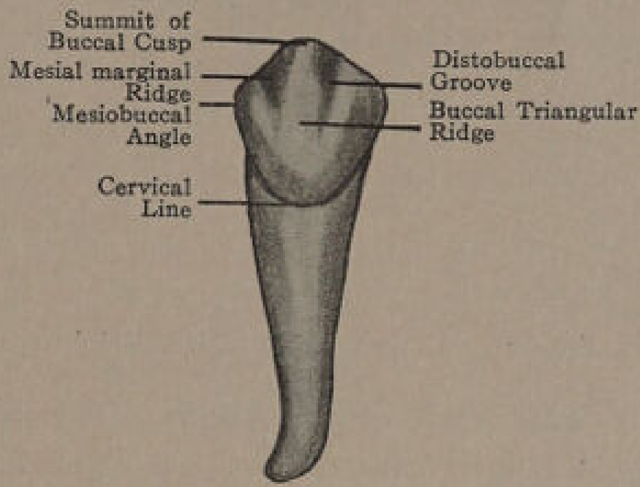


FIG. 106.—Lower first bicuspid, buccal surface.

The Buccal Surface of the Crown (Fig. 106).—This surface is smooth and convex in all directions, and in general outline there is but little variation between it and the corresponding surface of the upper first bicuspid. It is traversed from the point of the cusp to the cervical line with a rounded ridge, the buccal ridge, upon either side of which are the buccal grooves.

Lingual Surface of the Crown.—This surface is more or less extensive in accordance with the character of the lingual lobe. In most instances the measurement from the summit of the cusp or ridge to the cervical line is about one-half that of the same measurements on the buccal surface. From mesial to distal a well-rounded convexity is present, while from the occlusal margin to the cervical line it is straight or only slightly convex. The surface passes so gradually into the mesial and distal surfaces that no definite lateral margins exist.

The Mesial Surface of the Crown (Fig. 107).—In the region of the occlusal margin this surface is prominent, with a marked convexity from buccal to lingual; but as the cervical margin is approached, the surface recedes to the distal, and is flattened or is possessed of a slight general convexity. The occlusal and cervical margins alone are well defined, the buccal being gracefully rounded, while the surface passes to the lingual with a long curve.

FIG. 107.—Lower first bicuspid, mesial surface.

The Distal Surface of the Crown.—There is but little difference between this and the mesial surface; the occlusal portion of the surface is somewhat less prominent, resulting in less of the bell-shaped appearance to this side of the crown.

The Neck of the Tooth.—The neck of this tooth is marked by a well-defined constriction, the enamel of the crown suddenly folding in to meet the cementum of the root at the cervical line, forming a band or ridge which completely encircles the tooth. The amount of constriction appears to be evenly distributed between the various parts, so that, viewed in all directions, the neck becomes a distinctive feature of the tooth.

The Root of the Lower First Bicuspid.—The root is usually straight and tapers gradually from base to apex. In rare instances it is bifurcated, and when thus formed, those portions beyond the point of separation are more or less crooked. In the single root the apical third often curves slightly to the distal. The buccal and lingual sides are convex throughout their entire length, while the mesial and distal may be slightly convex, flattened, or provided with a slight longitudinal concavity. In passing from buccal to lingual the mesial and distal sides converge, thus resulting in a narrowing of the lingual side of the root.

LOWER SECOND BICUSPID

CALCIFICATION BEGINS, BETWEEN THE FOURTH AND FIFTH YEAR.
CALCIFICATION COMPLETED, ELEVENTH TO TWELFTH YEAR.
ERUPTS, ELEVENTH TO TWELFTH YEAR.
AVERAGE LENGTH OF CROWN, .31.
AVERAGE LENGTH OF ROOT, .56.
AVERAGE LENGTH OVER ALL, .87.

In general contour this tooth is similar to the lower first bicuspid, excepting that the crown is somewhat more rounded and the lingual cusp more fully developed, this latter feature causing it to closely resemble the upper bicuspids. The crown is frequently a trifle shorter than that of the lower first bicuspid, but the length of the root generally exceeds that of the latter, making this the longer tooth of the two.

The Occlusal Surface of the Crown (Fig. 108).—The occlusal surface of this tooth presents a greater variety in form than any other tooth of its class. The general outline of the surface is that of a broken circle, in most instances the mesial and distal margins showing almost as much of a convexity as that of the buccal and lingual. The summit of the buccal cusp usually extends well toward the center of the surface, but it is sometimes forced toward the buccal by an increased development in the lingual cusp. The buccal grooves, which cross the mesial and distal marginal ridges of the buccal cusp, are seldom so well defined as those of the first bicuspid, but they occasionally pass over these marginal ridges and form well-marked grooves, which end in the mesial and distal pits. The triangular ridge of the buccal cusp is usually more prominent than in the first bicuspid, and divides the surface into two portions, which are about equal in extent, the center of each portion being provided with a small pit—the mesial and distal pits. As in the first bicuspid, the mesio- and disto-marginal ridges begin at the mesial and distal angles of the crown, pass to the lingual, and, uniting, form the lingual ridge or cusp. The lingual cusp, while generally well developed, is never so prominent as the buccal. The lingual lobe is sometimes divided by a groove which passes from buccal to lingual, thus forming three cusps upon the surface. When this latter condition is present, the mesial and distal grooves are fully outlined from the mesio- and disto-marginal ridges to the center of the surface, where they unite with the groove

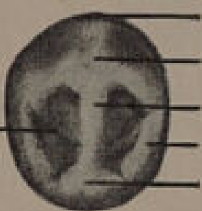


FIG. 108.—Lower second bicuspid, occlusa surface.

previously referred to and form a central pit or fossa. Another form frequently met with is one in which the surface closely resembles that of the upper bicuspids, two well-defined cusps being present, separated from each other by a central groove, which passes from mesial to distal and joins the triangular grooves at these joints. The resemblance to the upper bicuspids is further increased by the presence of two small pits, one on the mesial and one on the distal half of the surface.

The Buccal Surface of the Crown (Fig. 109).—The principal variation between this and the buccal surface of the lower first bicuspid is that it is less extensive and the buccal grooves somewhat less defined. It presents a general convexity, which is most pronounced near the center, between which point and the occlusal margins it is slightly inclined to flatness. The summit of the buccal cusp is usually to the mesial of the center of the occlusal margin, so that the mesial marginal edge is considerably longer than the distal, this fact also resulting in forcing the buccal ridge to the mesial of the center of the surface. The mesial angle of the crown, as observed when looking directly upon the buccal surface, is in a direct line with the mesial side of the root, while the distal angle extends beyond this corresponding line, and gives a prominent or bulging appearance to this section of the crown.

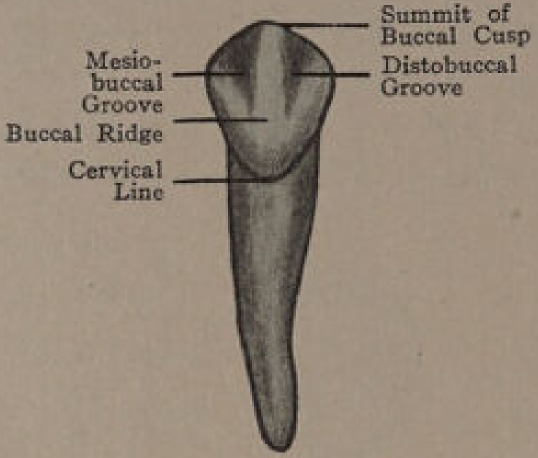


FIG. 109.—Lower second bicuspid, buccal surface.

The Lingual Surface of the Crown.—Proportionately, this surface is more extensive than the corresponding surface of the first bicuspid, this increase being produced by the additional development of the lingual cusp. It is well rounded from mesial to distal, and passes into these surfaces without the existence of a positive line of separation. From the cervical line to the occlusal margin a slight convexity is present. The general outline of the surface is much influenced by the conditions present upon the occlusal surface.

The Mesial Surface of the Crown (Fig. 110).—In the region of the occlusal margins this surface is decidedly convex from buccal to lingual, but in passing toward the cervical line a gradual flatness is apparent, which, however, seldom amounts to a perfect plane. While there is a gradual convergence of this and the distal surface toward the root, it is not so marked as that of the first bicuspid, resulting in less of the bell-shaped appearance to the crown.

The Distal Surface of the Crown.—The description given of the mesial surface applies equally well to this, there being but slight variation existing between the two. Occasionally this surface will present a greater convexity in the region of the occlusal margin, but this is not a constant feature.

FIG. 110.—Lower second bicuspid, mesial surface.

The Neck of the Tooth.—The crown of the tooth being somewhat smaller, and the root proportionately larger and longer than that of the first bicuspid, results in diminishing the amount of constriction at the neck, and for that reason this feature is less defined.

The Root of the Tooth.—As previously stated, the root of this tooth is larger and longer than that of the first bicuspid. The mesial and distal sides are flattened and frequently provided with a longitudinal groove. In some instances it is rather blunt, ending in a heavy, rounded apex; in others it tapers very gradually from the base to the apex, ending in a slim, pointed extremity.

THE LOWER MOLARS

THE LOWER FIRST MOLAR

CALCIFICATION BEGINS, ABOUT ONE MONTH BEFORE BIRTH.
CALCIFICATION COMPLETED, NINTH TO TENTH YEAR.
ERUPTS, SIXTH TO SEVENTH YEAR.
AVERAGE LENGTH OF CROWN, .30.
AVERAGE LENGTH OF ROOT, .52.
AVERAGE LENGTH OVER ALL, .82.

The process of development in this tooth corresponds to that of the upper first molar, calcification beginning upon the various cusps as early as the eighth fetal month, the crown being completely calcified by the fifth year, the roots formed and their apices established by the eleventh year. There is, however, one important difference between the development of this tooth and the corresponding upper tooth; that of calcification taking place usually from *five centers* instead of four, and, as a result, we find the occlusal surface provided with five well-developed cusps separated from one another by five developmental grooves. When compared with the upper first molar, the crown is found to be somewhat less in size; in general outline it is subject to a greater variation and is much more angular in its nature. The mediodistal measurement of the crown is nearly always greater than the buccolingual, and the length of the crown from the occlusal margins to the cervical line is proportionately less than that of the corresponding upper molar.

The Occlusal Surface of the Crown (Fig. 111).—The general outline of the crown is best studied when looking directly upon this surface. Two principal varieties exist: one in which the sides or margins of the surface appear to be flattened or straightened out, and the other when these same margins are gracefully rounded. In either form the buccal line is the longest, so that the mesial and distal lines converge to meet the lingual. This common form gives to the buccal angles an acute character, while the lingual angles are about equally obtuse. The surface is divided into five distinct or developmental portions, each of which is surmounted by a cusp, named, as their location indicates, mesiobuccal,

FIG. 111.—Lower first molar, occlusal surface.

buccal, distobuccal, mesiolingual, and distolingual. Separating these parts are five developmental grooves—the mesial, the distal, the buccal, the lingual, and the distobuccal. The four former cross the marginal ridges from the various surfaces and end in the central fossa, while the latter passes from the distobuccal angle and joins the distal groove, their union being marked by a slight depression or pit—the distal pit. Branching off from the various grooves are a number of supplemental grooves, the presence of which results in the production of a number of smaller ridges.

The Marginal Ridges of the Occlusal Surface.—Properly speaking these are only two in number, the mesiomarginal ridge and the distomarginal ridge. Those margins which correspond to the buccal and lingual ridges of the upper molars are so broken by the various cusps and developmental grooves that a definite marginal ridge scarcely exists, as will be observed by the description of these parts.

The mesiomarginal ridge is strongly outlined, passing from the mesiobuccal to the mesiolingual angle of the crown in the form of a bold angular ridge. In some instances it is broken near the center by the mesial groove passing over it to reach the mesial surface, in others being further divided by numerous small supplemental grooves.

The distomarginal ridge is much shorter and less decided than the mesial, and extends from the distobuccal to the distolingual angle. In nearly every instance it is broken by the distal groove, which crosses it to reach the distal surface.

The buccomarginal ridge is formed by the various ridges which descend in a mesial or distal direction from the three buccal cusps. Near the center the margin is broken by the buccal groove, and it is again broken at its distal third by the distobuccal groove, both of which pass over it to reach the buccal surface of the crown. This is much the longest margin of the surface, and in its entirety presents a gradual buccal convexity.

The linguomarginal ridge is principally made up of the distal incline from the mesial cusp, and by the mesial incline from the distal cusp. Near the center it is broken by the lingual groove, which passes over it to reach the lingual surface. This margin, unlike the buccal, is not always convex, but in many instances is almost a straight line, extending from the mesial to the distal angle.

The Cusps (Fig. 111). *The Mesiobuccal Cusp.*—This is usually the largest, though not always the longest, cusp of the group. It is bounded by the mesial and buccal surfaces and by the mesial and buccal grooves, which together form the mesiobuccal triangular groove. Descending from the summit of this cusp to the distal is a well-defined ridge—a part of the buccomarginal ridge—while in a mesial and lingual direction the descending ridges contribute to both the bucco- and mesiomarginal ridges. Descending toward the center of the surface and ending in the central fossa is the mesiobuccal triangular ridge.

The Buccal Cusp (Fig. 111).—This cusp, which is placed a little to the distal of the center of the buccal surface, is separated from the mesiobuccal cusp by the buccal groove, and from the distobuccal cusp by the distobuccal groove. It is about one-half the size of the mesiobuccal cusp, and a trifle less in length. Descending from it are two ridges, one in a mesial and one in a distal direction, which form a portion of the buccomarginal ridge; descending to the buccal surface is the buccal ridge, while the central incline gives place to a fourth ridge—the buccotriangular ridge.

The Distobuccal Cusp (Fig. 111).—This cusp is much the smallest of the five, and is located at the distobuccal portion of the crown, in some instances being nearest the buccal surface, in others forced to the distal by an increase in the size of the buccal cusp. It is separated from the buccal cusp by the distobuccal groove, and from the distolingual cusp by the distal groove. The ridges which descend from it contribute to both the bucco- and disto-marginal ridges, and descending toward the distal pit is the distobuccal triangular ridge.

The Mesiolingual Cusp (Fig. 111).—This cusp is second in size, and frequently the longest and most pointed. It has for its boundaries the mesial and lingual surfaces, and the mesial and lingual grooves. The ridge which descends from it in a mesiobuccal direction assists in forming the mesiomarginal ridge, while that which passes to the distal forms a part of the linguomarginal ridge. In the direction of the central fossa a pronounced ridge is present—the mesiolingual triangular ridge—which is often supplemented by one or more smaller ridges running in the same direction.

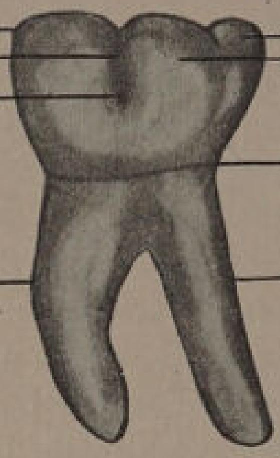


FIG. 112.—Lower first molar, buccal surface.

The Distolingual Cusp (Fig. 111).—This cusp usually occupies the distolingual portion of the crown, although sometimes being forced well toward the lingual by the distobuccal cusp. It is separated from the mesiolingual cusp by the lingual groove, and from the distobuccal by the distal groove. Two of the ridges which descend from it assist in forming the linguo- and disto-marginal ridges, while the one which descends the central incline is the distolingual triangular ridge. The central inclines of the mesiobuccal, buccal, mesiolingual, and distolingual cusps contribute to the formation of the central fossa, while the buccal, distobuccal, and distolingual central inclines assist in forming the distal pit or fossa.

The Buccal Surface of the Crown (Fig. 112).—This is the most extensive of the lateral surfaces of the crown. It is convex from mesial to distal, and also from the occlusal margin to the cervical line. The width of the crown from the mesial to the distal angle is always somewhat greater than that at the cervical line, the difference being governed by the typal form of the tooth. A little to the mesial of the center of the surface is the buccal groove, which, after crossing the buccomarginal ridge, is usually quite deep; but as it proceeds in the direction of the root it gradually disappears, or it may end abruptly in a well-defined pit —the *buccal pit*. The *distobuccal groove* enters the surface near the distobuccal angle, and gradually becomes less pronounced as it passes rootward. It is seldom so well defined as the buccal groove, and usually ends when about half-way to the cervical line. The occlusal margin is made irregular by the presence of the three buccal cusps; the cervical margin is nearly straight from mesial to distal, and is surmounted throughout by a strong enamel fold, the cervicobuccal ridge. The mesial margin is longer than the distal, but neither of them is well defined.

FIG. 113.—Lower first molar, lingual surface.

The Lingual Surface of the Crown (Fig. 113).—This surface is smooth and convex in every direction. It is generally divided into two portions, a mesial and a distal, which are nearly equal in extent. This separation is formed by the *lingual groove*, which is sometimes deep and sulcate, at others shallow, and not infrequently entirely wanting. The surface is nearly one-third less in extent than the buccal, the convergence of the mesial and distal surfaces in passing to the lingual accounting for this difference. The occlusal margin is formed by the double incline of the two lingual cusps; the cervical margin is either straight or slightly concave in the direction of the occlusal surface, while the mesial and distal margins are rounded and poorly defined.

The Mesial Surface of the Crown (Fig. 114).—This surface is inclined to flatness, with a slight bulging near the center, which marks the point of contact with the approximate tooth. It is usually smooth, and unbroken by developmental or other grooves, although the mesial groove occasionally traverses it after crossing the marginal ridge from the occlusal surface. Near the center of the cervical third a slight concavity is often present. The margins of the surface are somewhat irregular, the occlusal margin being made irregularly concave by the ridges which descend from the two mesial cusps; the cervical margin is slightly concave in the direction of the occlusal surface, and, while the buccal margin inclines to the lingual as the occlusal surface is approached, the lingual is almost perpendicular.

The Distal Surface of the Crown (Fig. 115).—Unlike the mesial, this surface is possessed of a decided convexity in every direction. It is surmounted by a portion of the distobuccal and distolingual cusps, and is frequently broken by the distal groove, which reaches it after crossing the marginal ridge from the occlusal surface. The occlusal margin is irregularly formed of the marginal ridges which descend from the distobuccal and distolingual cusps; the cervical margin is usually straight, while the buccal and lingual are rounded and in definite.

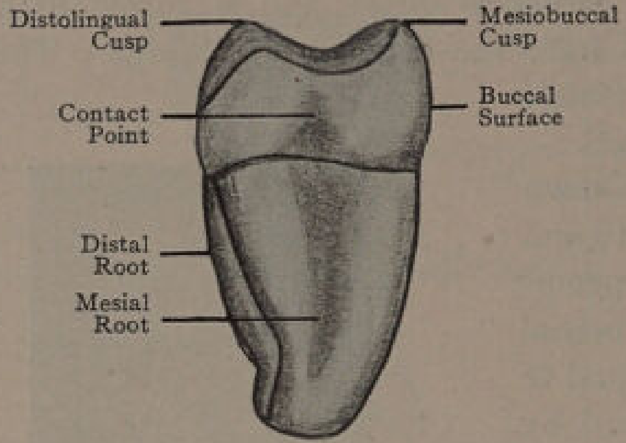


FIG. 114.—Lower first molar, mesial surface.

The Neck of the Tooth.—One characteristic feature of this tooth is the greater circumference of the crown at the occlusal margin over that at the cervical line, giving a flaring appearance to the crown, and resulting in the production of a neck which is much constricted.

This is particularly noticeable when looking upon the buccal surface of the tooth; but when looking upon the mesial or the distal surface, this feature is not so pronounced, although the rather heavy fold of enamel which surmounts the cervical line contributes much to the formation of the neck from these aspects.

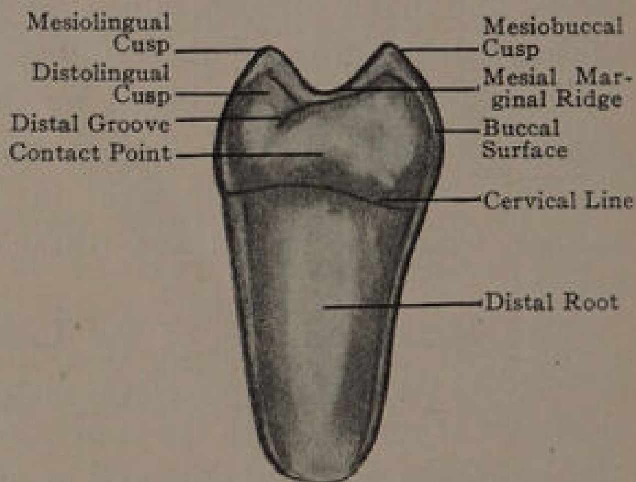


FIG. 115.—Lower first molar, distal surface.

The Roots of the Tooth.—The roots of this tooth are two in number—one of which is placed beneath the mesial, and the other beneath the distal half of the crown—and are named the *mesial root* and the *distal root*. The fact that the point of bifurcation is constantly in close proximity to the neck or crown of the tooth is a sufficient reason for the statement that two roots exist, rather than a single root with two branches. The roots are both much flattened from mesial to distal, and broad at the base from buccal to lingual.

The mesial root is usually the larger and longer of the two. After leaving its base it generally inclines to the mesial, but beyond the center of its length it is provided with a distal turn, which in some instances amounts to a decided crook. The center of the mesial side is occupied by a longitudinal depression, as is also the distal side, making this part of the root thin, giving the appearance of an effort to bifurcate, which condition is occasionally present. The buccal and lingual sides of the root are rounded and smooth, and taper gradually to the apex, which is somewhat broadened from buccal to lingual.

The distal root is usually straight, with a more gradual taper throughout, ending in an apical extremity more pointed than that of the mesial root. A longitudinal depression is also present upon both the mesial and distal sides, but is never so pronounced as that upon the the mesial root. The buccal and lingual sides are convex and smooth. The root possesses little or no inclination to bifurcate.

LOWER SECOND MOLAR

CALCIFICATION BEGINS, ABOUT THE FIFTH YEAR.
CALCIFICATION COMPLETED, SIXTEENTH TO SEVENTEENTH YEAR.
ERUPTS, TWELFTH TO SIXTEENTH YEAR.
AVERAGE LENGTH OF CROWN, .27.
AVERAGE LENGTH OF ROOT, .50.
AVERAGE LENGTH OVER ALL, .78.

This molar differs in so many particulars from the lower first molar that a separate description will be called for. The principal variation is usually found in the absence of the fifth lobe or cusp,* resulting in the production of an occlusal surface much less complicated.

The Occlusal Surface of the Crown (Fig. 116).—When the crown is studied by looking directly upon this surface, the variations between this and the first molar are readily noted. Four equally proportioned cusps are observed, separated from each other by four developmental grooves. A single pit or fossa is present, the four grooves arising from this one point. In general outline two principal varieties exist: one in which the opposite sides of the crown are nearly of the same length, and parallel with each other, with the angles rounded; the other, in which either the buccal or lingual margin is the longest, with the mesial and distal margins converging one way or the other, as the case may be. The marginal ridges are formed in a manner similar to those of the first

* When five cusps are present, the anatomy of this surface does not differ from that of the first molar.

molar, with the exception of the distal portion of the buccal ridge, which is not broken by a developmental groove. Each marginal ridge is divided near its center by one of the grooves of development, the mesial groove crossing the mesiomarginal ridge, the buccal groove crossing the buccomarginal ridge, the lingual groove crossing the lingual ridge, and the distal groove passing over the distal ridge. In many instances numerous supplemental grooves are present, which in turn form a number of smaller ridges. The four *cusps* are the *mesiobuccal*, *distobuccal*, *mesiolingual*, and *distolingual*. In a general way they are similar to the cusps of the first lower molar, excepting that they are somewhat larger and probably less pointed and less angular. Each cusp is provided with a number of ridges, which descend from the summit to the base, two of these contributing to the formation of the marginal ridges, one passing to the buccal or lingual, and one, the triangular ridge, descending the central incline of each cusp. The names given to these various ridges are identical with those of the first molar.

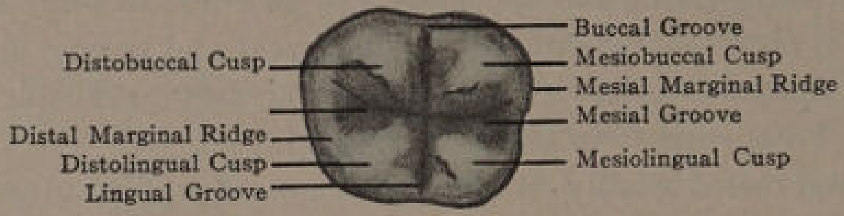


FIG. 116.—Lower second molar, occlusal surface.

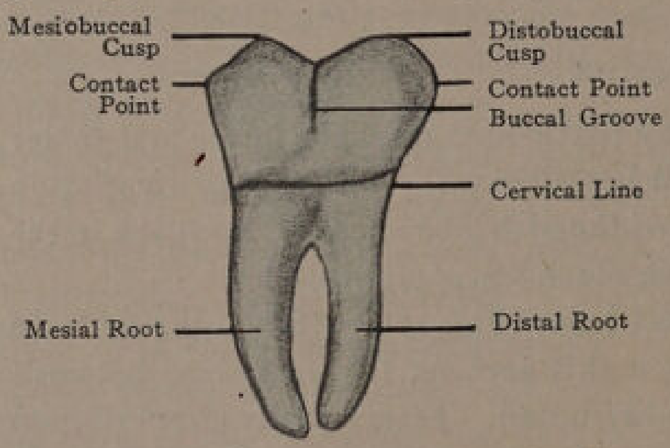


FIG. 117.—Lower second molar, buccal surface.

The Buccal Surface of the Crown (Fig. 117).—The principal difference between this and the corresponding surface of the first molar is that produced by the absence of a fifth cusp, the surface being divided into two parts instead of three. The single division is caused by the buccal groove, which reaches the surface after crossing the buccomarginal ridge from the occlusal surface. The position of this groove is usually a little to the mesial of the center of the surface. Like the buccal groove of the first molar, it may disappear gradually as it passes toward the cervical line, or it may end in a well-marked pit—the buccal pit.

The Lingual Surface of the Crown.—This surface so closely resembles the corresponding surface of the first molar that it is somewhat difficult to distinguish one from the other. The occlusal margin may be a trifle less irregular, and in some instances more extensive, than the buccal surface, this latter feature seldom occuring in the first molar.

The Mesial Surface of the Crown (Fig. 118).—This surface corresponds to the mesial surface of the first molar, being flattened or

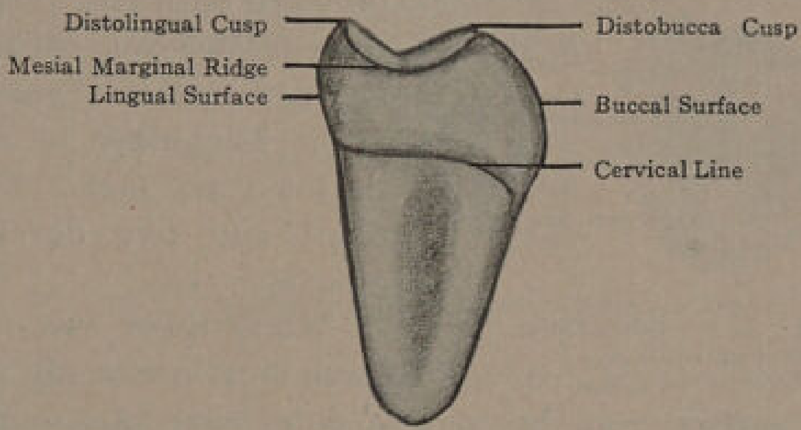


FIG. 118.—Lower second molar, mesial surface.

slightly convex from buccal to lingual, with an inclination to a slight depression or concavity near the cervical margin.

The Distal Surface of the Crown.—On account of the absence of the buccal cusp, this surface is less complex than that of the first molar. It is convex in all directions; in most instances smooth, in others broken by the distal groove, which reaches it after crossing the distomarginal ridge from the occlusal surface.

The Roots of the Tooth.—Like the first molar, these are two in number, a mesial and a distal. They are much less constant in form, are often nearer together, and in some instances united. When the two roots exist—which may be considered the normal condition—they are less flattened upon their mesial and distal sides, with the longitudinal depression wanting or but slightly apparent. These roots, therefore, are more rounded in general, taper more gradually from neck to apex, and end in a rounded apex, which is often provided with a slight distal curve.

LOWER THIRD MOLAR

CALCIFICATION BEGINS, EIGHTH TO NINTH YEAR.
CALCIFICATION COMPLETED, EIGHTEENTH YEAR.
ERUPTS, SIXTEENTH TO TWENTIETH YEAR.
AVERAGE LENGTH OF CROWN, .26.
AVERAGE LENGTH OF ROOTS, .36.
AVERAGE LENGTH OVER ALL, .62.

This tooth is probably subject to a greater variety in form than any other. There are, however, two varieties which are most frequently met. In one the crown is similar to the lower second molar, being provided with four cusps, which are separated from one another by four developmental grooves (Fig. 119). The other is similar to the lower first molar, having five cusps and five developmental grooves.

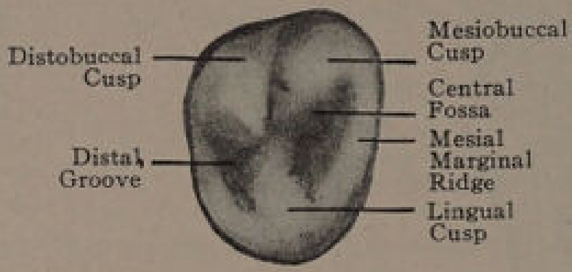


FIG. 119.—Lower third molar, occlusal surface.

While these two forms are those most commonly met with, the occlusal surface may be so broken by numerous supplemental and developmental grooves that even six or eight well-defined cusps may be present. Whatever complications may exist upon the occlusal surface, a central fossa is usually present, from which radiate the various developmental grooves. When the central fossa is absent, the space which it should occupy is usually taken up by a rounded cusp, by the presence of which the grooves are prevented from uniting, and their course is much distorted. Along with these variations, the tooth is subject to much variety in size. In some instances the crown is one-third less in circumference than that of either the first or second lower molars, while in others it is a trifle greater. The increase in the size of the crown is generally accompanied by an increase in the number of cusps. One feature very common to the crown is its inclination to the circular form, almost resulting in the absence of the angles common to molars in general. The marginal ridges are, of course, subject to the ever-varying conditions to be found upon the occlusal surface; in

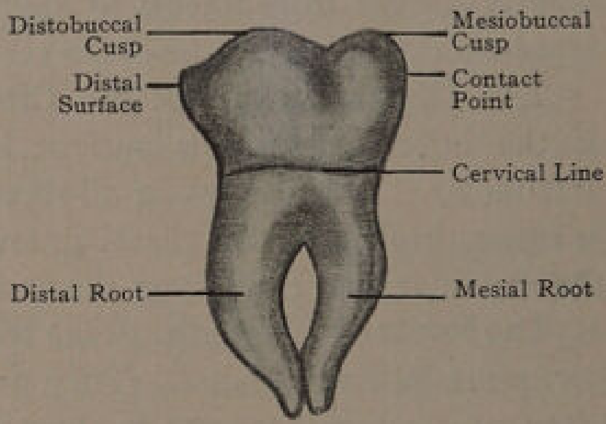


FIG. 120.—Lower third molar, buccal surface

general, they are poorly defined, and are frequently crossed by numerous small supplemental grooves, dividing them into many minute tubercles. The latter are smooth and strongly convex, with their general outlines much influenced by the number of cusps.

The Roots of the Tooth.—While this tooth is strongly inclined to have two roots like the other lower molars, this condition is by no means

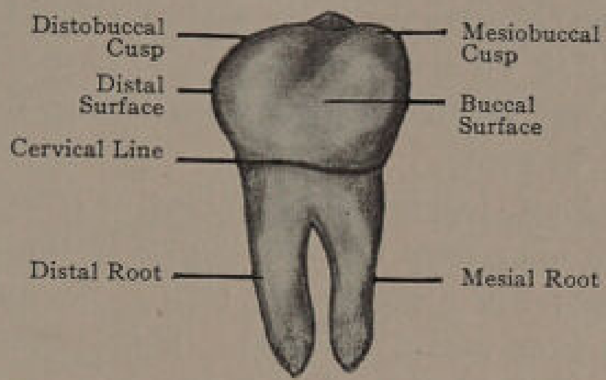


FIG. 121.—Lower third molar, buccal surface. A common form.

the common one. Like the crown, the roots are probably more variable than those of any other tooth. A single conic root may be present, or a mesial and a distal root may exist; again, the mesial root may bifurcate, thus resulting in three. In some instances, four, or even five, branches may be given off from a common base. When more than two roots

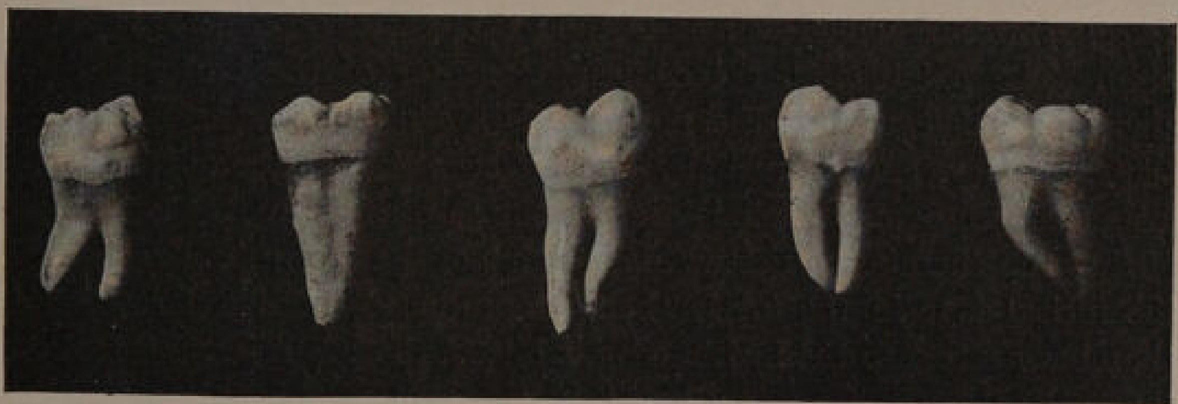


FIG. 122.—Types of lower third molars.

are present, they are usually much twisted or crooked, and, while generally inclined to the distal, are liable to branch in various directions.

A better idea of the variations in this tooth may be had from the accompanying illustration (Fig. 122).

CHAPTER X

The Pulp-cavities of the Teeth

In the preceding chapters the study of the teeth has been confined to their external forms; it will now be necessary to learn something of their internal anatomy, and for this purpose various dissections of each individual tooth must be made.

Dissections.—First, longitudinal sections of each tooth should be made by sawing or filing from labial to lingual in the anterior teeth, or from buccal to lingual in the posterior teeth. Second, a longitudinal section by sawing from mesial to distal. Third, numerous transverse sections by sawing through the crown or root at various points.

These dissections will expose to view a central cavity with outlines closely corresponding to those of the tooth itself. This is called the *pulp-cavity*, and in the vital tooth contains the formative and life-sustaining substance of the dentin, the *dental-pulp*. The pulp-cavity is divided into two principal parts, that portion within the crown of the tooth being the *pulp-chamber*, while that traversing the root is the *pulp-canal*. At the apex of the root the canal ends in a small foramen, the *apical foramen*,* which transmits the blood-vessels and nerves to the pulp. The pulp-chamber occupies the center of the crown and is always a single cavity; the pulp-canals are prolongations from this central cavity, and are usually one for each root, although in some instances two or more canals are present in a single root. The form of the pulp-chamber varies with the shape of the crown, the outline of the incisal-edge in the incisor being reproduced in that part of the chamber nearest to the incisal-edge, while in the bicuspids and molars the occlusal surface is reproduced on the wall of the pulp-chamber, immediately beneath it, the lateral walls corresponding to the various sides of the tooth. In the incisors and cuspids the pulp-chamber passes so gradually into the pulp-canal that a positive line of demarcation between the two is not observed. In the bicuspids and molars the canals may be readily distinguished by a sudden constriction and branching out of the cavity into the various roots, which prolongations gradually decrease in size until the apical foramen is reached. The size of the pulp-cavity is much influenced by the age of the tooth, its func-

* In many instances two or more foramina are present.

tional activity, character of the occlusion, etc. The tooth-pulp, as the formative organ of the dentin, gradually decreases in size as the tooth develops (see Development of the Teeth), and as a result of this action the youngest teeth are provided with the largest pulp-cavities. At the time of eruption of a tooth, the diameter of the pulp-cavity is about equal to one-half the diameter of the crown, while the length of the canal must, of necessity, accord with the extent of root-calcification. As the growth of the tooth proceeds, the diameter of both the chamber and canal is gradually diminished; this gradual reduction in size is continued during the life of the tooth, and if permitted to proceed until old age, the chamber and canal may become almost or entirely obliterated. It must be remembered that while the diameter of the root-canal is diminished with the growth of the tooth, its length increases, continuing to do so until the time of complete root-calcification. During the period of root-development the diameter of the root-canal is greatest at the free or apical end of the root, at which point it presents a funnel-shaped opening. As the root continues to calcify, this funnel-shaped extremity of the canal advances in the direction of calcification, and finally, as the formative process nears completion, the mouth of the funnel gradually disappears, and the apical foramen is established. The various lobes of the teeth are penetrated by a prolongation of the pulp-cavity, these being called the *horns or processes of the pulp-chamber*. The depth to which the horn penetrates the lobe varies in accordance with the form of the latter. If the tooth is one provided with long, penetrating cusps, the horns of the pulp-chamber will also be long, but if the cusps be poorly formed, the horns of the chamber will be short. In the anterior teeth, when the lobal construction is outlined by well-marked developmental grooves, the horns of the pulp-chamber will be three in number and directed toward the incisal-edge. These are most marked in young teeth, and gradually disappear as age advances. The functional activity of the teeth also serves to materially reduce the size of the pulp-chamber. Thus, when opposing teeth occlude squarely and firmly against each other, with more or less rubbing or sliding during mastication, the external surface is prone to rapid abrasion, and, as a direct result of this external irritation, the pulp-chamber undergoes a corresponding alteration by a rapid growth of dentin about its walls.

THE PULP-CAVITIES OF THE UPPER TEETH

Upper Central Incisor.—Figure 123 shows a number of labiolingual sections presenting the relative size and shape of the pulp-cavity in the upper central incisor at various ages. In No. 1 the condition existing at about the sixth year, or at a time immediately prior to the eruption of the tooth, is shown. The tooth-crown is fully formed and calcified; the cervical line may be observed, as well as a small portion of the root-wall. The pulp-chamber, which is represented by the dark portion of the cut, occupies about one-third of the diameter of the crown as its greatest width. The pulp-chamber at this age, when viewed in this direction, forms almost a perfect cone, the base of which is directed upward or toward the future extremity of the root, and its apex downward in the direction of the incisal-edge of the tooth. The apex of the

1 2 3 4 5

FIG. 123.—The pulp-cavity in the upper central incisor, from the sixth to the tenth year.

cone may end somewhat abruptly, or it may be lengthened into a slender, horn-like projection, extending well toward the incisal-edge. No. 2 represents the same tooth about the seventh year, or at a time shortly after its eruption. The pulp-chamber has become slightly reduced in its basal diameter, while but little change has taken place in the apex. That portion of the pulp-cavity above the cervical line represents a part of the future pulp-canal. At this age the canal is a direct continuation of the conic pulp-chamber, ending above in a broad, funnel-shaped extremity. No. 3 shows the condition of the cavity about the eighth year. The diameter of the pulp-chamber is considerably diminished, the apex has slightly receded, and the horn-like projection has partly disappeared. The increase in the length of the canal is about 3/16 of an inch over its length at seven years. The two parallel sides of the canal have lengthened proportionately, and the funnel-shaped extremity is reduced in diameter owing to the gradual narrowing of the roots-wall. No. 4 gives the relative size of the pulp-chamber and canal at the ninth year, or at a time when root-calcification is nearing completion. The decrease in the capacity of the chamber is readily apparent; the horn-like projection has disappeared and the parallel sides of the canal are partly extended into the chamber, thus reducing the length of the cone. In the canal a greater reduction has taken place in its diameter, while its length has increased about ¼ of an inch over that at eight years, and the diameter of the funnel-shaped opening is but little greater than that of the body of the canal. No. 5, which represents a section of the tooth about the tenth year, shows calcification in the root completed, and the apical foramen established. A glance at the illustration will show the gradual decrease in the capacity of the pulp-cavity and the completion of its growth in an apical direction. At this stage of development the fan-shaped extremity of the canal gradually disappears, and for the first time in the life of the tooth the canal partakes of the external root form throughout its entire extent.

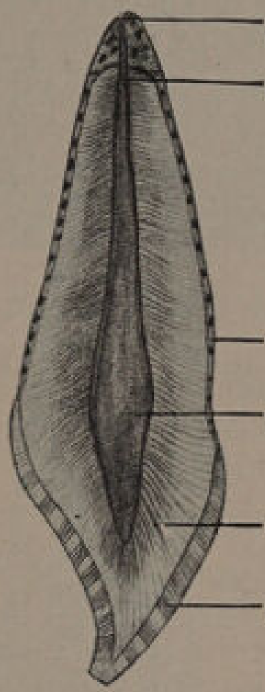


FIG. 123.—Upper central incisor longitudinal section labial to lingual.

Figure 123 represents the size and form of the average pulp-cavity in the adult upper central incisor in longitudinal section from labial to lingual. In its entirety it represents a double cone, with a common base near the cervical line, the pulp-chamber forming one cone and the pulp-canal the other. At this common base the cavity assumes its largest diameter, which measurement is approximately equal to one-fourth the labiolingual diameter of the tooth. The extent and form of the lower cone, or that represented by the pulp-chamber, varies in the adult tooth with the tooth type. A further study of the pulp-chamber and canal may be made by a mesiodistal section made through the long axis of the tooth (Fig. 124). The outline of the cavity, viewed in this way, closely follows the outline of the crown and root of the tooth. There is no distinct division between the chamber and the canal, the former gradually blending into the latter. The outline of the entire cavity is that of a single cone, with its base directed toward the incisal-edge and its apex in the direction of the apex of the root. The lower margin of the pulp-chamber, or that nearest the incisal-edge of the crown, is broad from mesial to distal and thin from labial to lingual. This margin in the average adult tooth is about on a line with the center of the labial surface of the crown, and the lateral walls of the cavity as they pass upward converge slightly, and finally blend into the walls of the canal at a point somewhat beyond the cervical line. During the early life of the tooth the margin of the chamber nearest the incisal-edge presents three well-defined horns, corresponding to the three rudi-

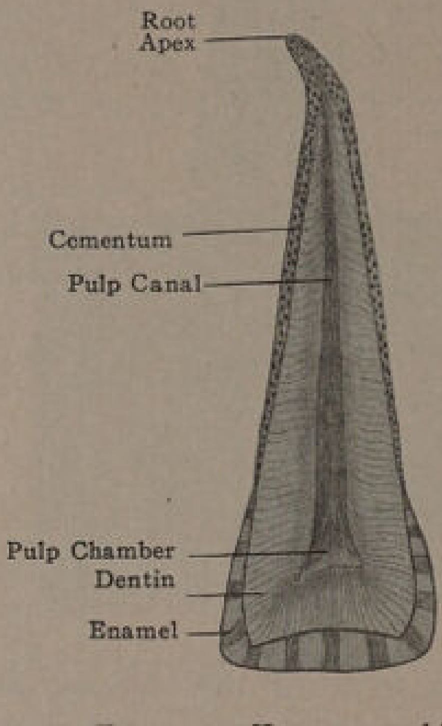


FIG. 124.—Upper central incisors section mesial to distal.

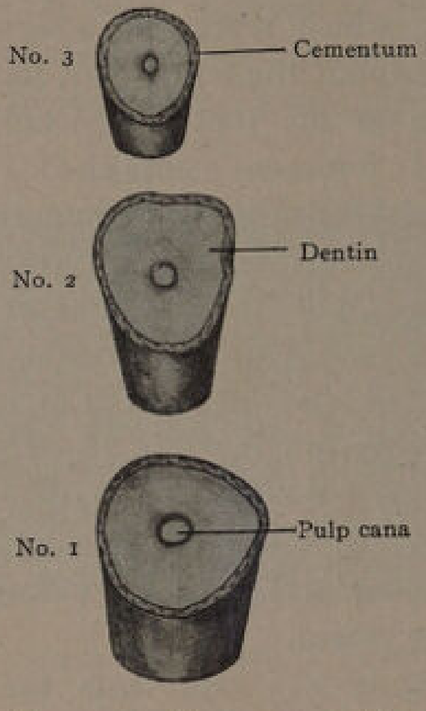


FIG. 125.—Transverse sections of root.

mentary lobes found upon the incisal-edge at this period. These horns rapidly disappear, and are seldom found after the fifteenth year. In certain tooth types, however, the mesial and distal horns may continue present until adult age, and even into middle life, but when this occurs it is not the result of the temporary tooth form, but is occasioned by the permanent angular outline of the crown.

Figure 125 represents a number of transverse sections of an upper central incisor, showing the outline and relative size of the pulp-canal in passing from the base of the crown toward the apex of the root. No. 1 shows the outline of the canal at the cervical line; No. 2 represents the condition ⅛ of an inch nearer the apex of the root; No. 3 is from the region of the apex.

Upper Lateral Incisor.—The pulp-cavity in the upper lateral incisor is so nearly identical with that of the central that it will only be necessary to call attention to one or two points which are at variance. Figure 126 shows the five stages as represented by the growth of the tooth. In

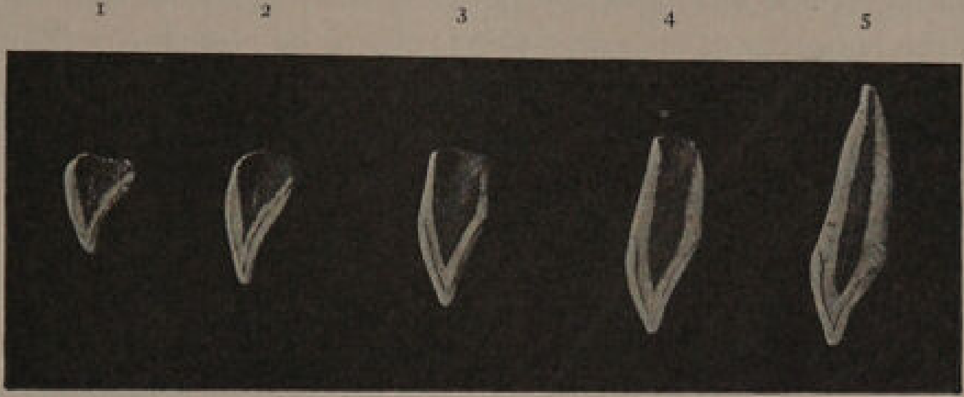


FIG. 126.—Pulp-cavity in the upper lateral incisor, from the sixth to the tenth year.

general it will be observed that the cavity is much smaller than that of the central incisor, but this difference is to be accounted for in the smaller proportions of the tooth. No. 1 shows the condition of the crown and pulp-cavity about the sixth year, the pulp-cavity occupying a large portion of the partly calcified tooth-crown. No. 2 represents the conditions present at the seventh year, or about the time of the eruption of the tooth. The pulp-chamber at this age resembles a perfect cone, the base of which reaches to the root-walls, and faintly outlines the beginning of the future pulp-canal. In No. 3, at eight years, the length of the root has increased about 3/16 of an inch, and the parallel sides of the walls of the pulp-canal have made their appearance. In No. 4, at nine years, by the growth of the root the canal has considerably increased in length and at the same time much decreased in diameter, while in No. 5, at ten years, the root is completely formed, the apical foramen established, and the maximum size of the entire pulp-cavity in the fully formed tooth shown.

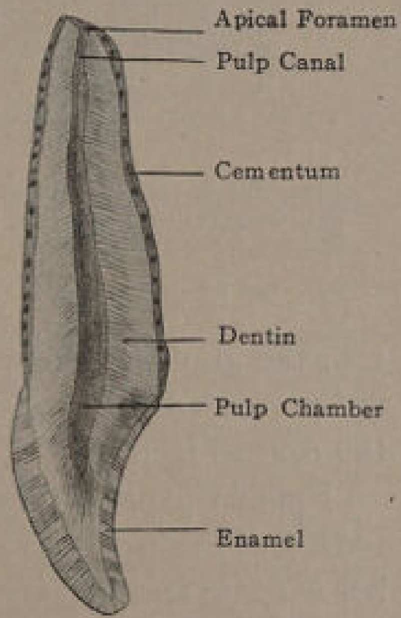


FIG. 127.—Upper lateral incisor longitudinal section. labial to lingual.

Figure 127, shows the average condition of, the pulp-cavity in the upper lateral incisor at adult age. In a mesiodistal section—figure 128—a close resemblance to the pulp-cavity in the central incisor will be noticed. While the pulp-cavity is smaller than that of the central incisor, it is usually a trifle larger in proportion to the size of the tooth. Owing to the marked constriction at the neck of this tooth, there is occasionally found a slight line of distinction between the pulp-chamber and canal, but in the majority of instances this is not to be observed. The horns of the pulp-chamber are in every respect similar to those of the central incisor, excepting when they exist permanently, in which case the mesial horn is usually the longest. By the transverse sections shown in figure

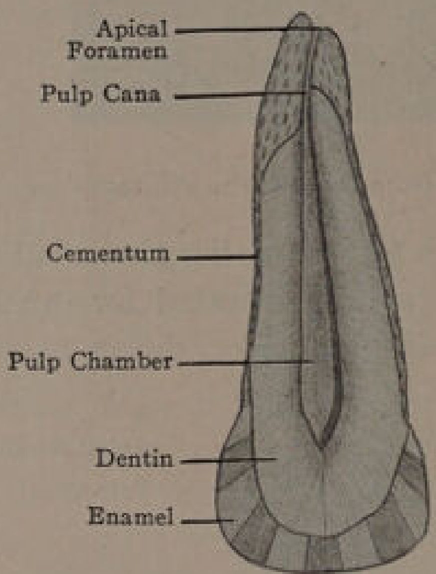


FIG. 128.—Upper lateral incisors, longitudinal section, mesial to distal.

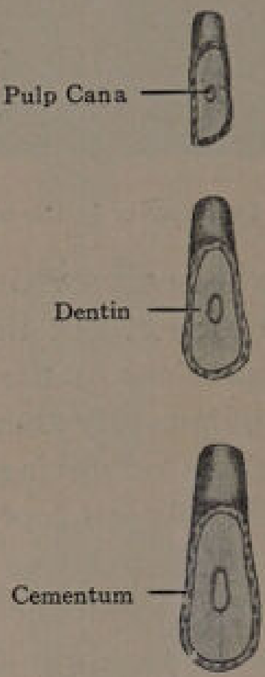


FIG 129.—Transverse sections of root.

129, the gradual decrease in size and change in form in the root-canal are presented, the sections being similar to those made in the root of the central incisor.

Upper Cuspid.—The pulp-cavity of this tooth is in general similar to that of the incisors, excepting that the coronal extremity of the chamber is conic and inclined to a horn-like projection which penetrates the single cusp of the tooth-crown in the direction of its summit. Figure 130 represents a number of labiolingual sections. No. 1 shows the condition of the pulp-cavity about the seventh year, or fully five years before the eruption of the tooth. The pulp-chamber partakes of the cone shape previously referred to, but the margins, instead of being straight lines, are somewhat bowed or concave, thus conforming more closely to the outline of the crown. The central horn of the chamber is proportionately longer than that of the incisors, in correspondence with the cusp of the tooth. At this age the formative process has barely extended to the root-walls; therefore, the width of the cavity is about equal to its length. In No. 2, at eight years, an increase in the capacity of the chamber over that of the incisors is shown, this being the result of the greater bulk in the tooth-crown. The cone-like outline of the chamber is somewhat broken by an effort of its margins to follow the outline of the crown. In No. 3, at nine years, the principal change has taken place in the canal, which has lengthened fully 3/16 of an inch, and the funnel-shaped extremity, instead of joining with the pulp-chamber direct, is continued below by two parallel walls to the true beginning of

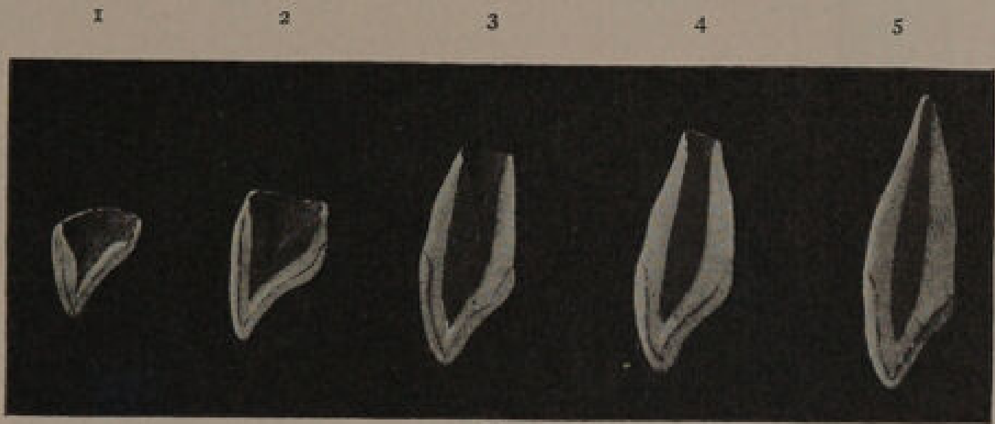


FIG. 130.—Pulp-cavity in the upper cuspid, from the seventh to the twelfth year.

this cavity. At ten years, No. 4, a more marked transformation has taken place in both portions of the cavity. The diameter of the chamber at the cervical line has diminished, as has also the length of the cone. The increase in the length of the root, which has been proportionately greater than that of the preceding year, has extended the length of the canal about 3/8 of an inch. The walls of the canal are no longer parallel with each other, but are inclined to follow the root-outlines. The funnel-shaped opening is much reduced both in length and breadth. No. 5 represents the condition at the time of the eruption of the tooth, or about the twelfth year. The general outline of the pulp-cavity is that of a double cone, with a common base at a point nearly corresponding to the cervical line. The diameter in both the chamber and canal has considerably decreased, while the central horn in the former has further receded. The calcification of the root externally is about complete and the foramen formed. In this particular the cuspid differs from the incisors, and in fact from all other teeth, in having its root-calcification about completed and the apical foramen established at or soon after the time of its eruption. Figure 131 gives an idea of the capacity of the pulp-cavity in a young upper cuspid. The coronal extremity of the pulp-chamber is but little inclined to follow the outline of the mesial and distal incisal-edges. The chamber passes into the canal without a mark of separation, and the latter gradually diminishes in diameter as the apex of the root is approached. At its point of beginning the canal is sometimes inclined to flatness from

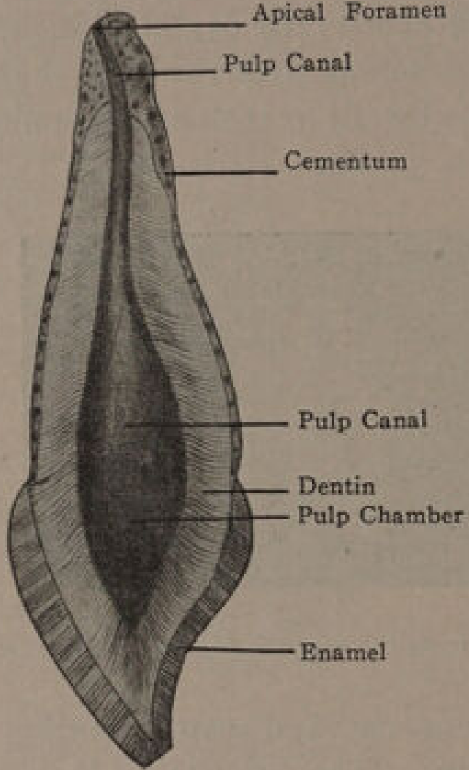


FIG. 131.—Upper cuspid longitudinal section, lateral to lingual

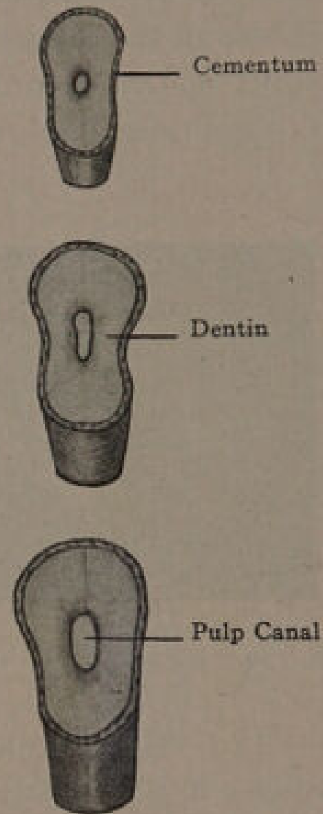


FIG. 132.—Transverse sections of root.

mesial to distal, but in passing toward the apex this tendency disappears, and it becomes more circular in outline. In Fig. 132 represents transverse sections through the root of the tooth at various points between the cervical line and the apex of the root.

Upper First Bicuspid.—The study of the pulp-cavity in this tooth differs in many particulars from that of the incisors and cuspids. First, the line of distinction between pulp-chamber and the root-canal or canals is, in most instances, definitely marked by the bifurcation of the roots and a corresponding branching of the pulp-cavity into two fine canals, one of which occupies the center of each root. This division of the cavity brings thecenter of the pulp-chamber almost on a level with the cervical line. In figure 133, No. 1 shows the partly calcified crown of the upper first bicuspid at the seventh year. A portion of the pulp-chamber alone may be studied at this period, and this is found to be somewhat irregular in outline, with a broadened, funnel-shaped opening above, and two small, cone-like projections below, pointing into either cusp of the crown. These latter projections are the horns of the pulp-chamber, and are named in accordance with the cusp which they occupy. In very young teeth it is not unusual to find these horns penetrating the dentin almost to the enamel-wall. No. 2, at eight years, shows the crown fully calcified and the outline of the base of the roots established. The horns of the pulp-chamber have slightly receded, and the branching of the canals is made manifest by the central deposit of dentin. In No. 3, at nine years, the capacity of the pulp-chamber is much decreased, and appears to have receded bodily rootward. The roots are calcified

1 2 3 4 5

FIG. 133.—Pulp-cavities of the upper first bicuspid, from the seventh to the twelfth year.

to about one-third their full length, and the canals which traverse them are each provided with the funnel-shaped opening at their free calcifying extremities. In No. 4, at ten years, the decrease in the size of the pulp-chamber is not only caused by the deposit of dentin upon the occlusal and lateral walls, but from the direction of the roots as well. The diameter of the root canal is much less than at nine years, but the walls are as yet parallel. No. 5 shows the roots fully formed and the apical foramina established, which condition occurs about the twelfth year. The horns of the pulp-chamber have receded somewhat, and the center of this cavity is now almost on a level with the cervical line. The canals have assumed the form of the roots themselves, and their diameter is much diminished. The illustration shows the proportionate maximum size of the chamber and canals in this tooth after completion of surface calcification. It will be observed that the foramina are proportionately smaller than those of the incisors and cuspids at a corresponding period, this condition resulting from the smaller diameter of the roots.

Figure 134, illustrates the approximate size and form of the pulp-chamber and canals at adult age, and attention is called to the appearance of the horns of the pulp-chamber. It will be observed that the horn which penetrates the buccal cusp is larger and more pointed than that directed toward the lingual cusp; this condition is fully explained by the buccal cusp being proportionately larger and longer than the lingual. The foregoing description applies only to the two-rooted bicuspids, but as many of these teeth have but one root, an additional description will be necessary. When a single root is present, many varieties in the outline of the pulp-cavity will be presented; this variation, however, seldom affects the capacity or form of the pulp-chamber. Two distinct canals may exist in the single root, branching off from the chamber, one from the buccal and one from the lingual portion. These canals gradually taper in the direction of the apex of the root, and may end in a single foramen, or in distinct foramina. Occasionally the canals will unite before reaching the root-apex and continue as a single canal ending in a single foramen, or they may communicate at one point and again diverge and finally end in separate foramina. In some instances the pulp-canal appears to be a direct continuation of the pulp-chamber, extending throughout the length of the root in the form of a flattened canal, with its greatest diameter from buccal to lingual and similar to the upper second bicuspid see Figs. 135 and 137. When two separate canals exist in the single root, the outward appearance of the root indicates a near approach to two roots; when the single flattened canal is present, the root is also flattened and shows no sign of bifurcation. Reference has been made to the horns of the pulp-chamber, and in this connection it will be well to speak of the extent to which they may exist. In that type of tooth provided with long penetrating cusps the horns will dip well down into the cusp occasionally to the full depth of the dentin, and

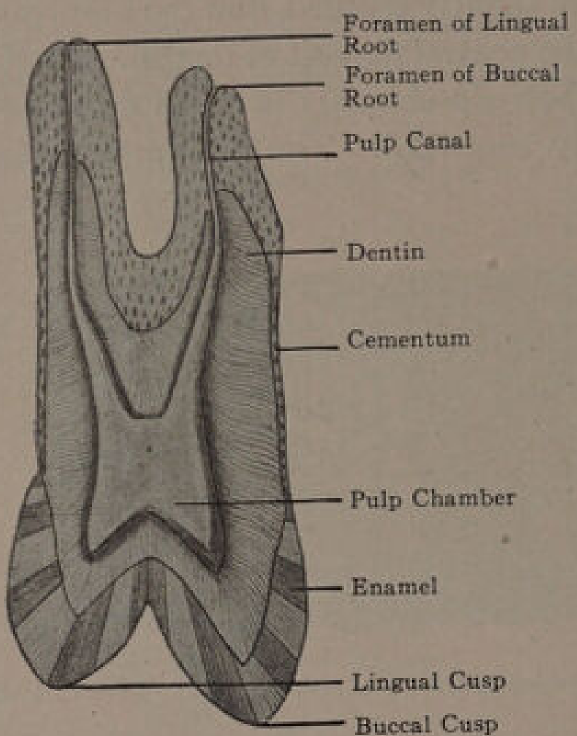
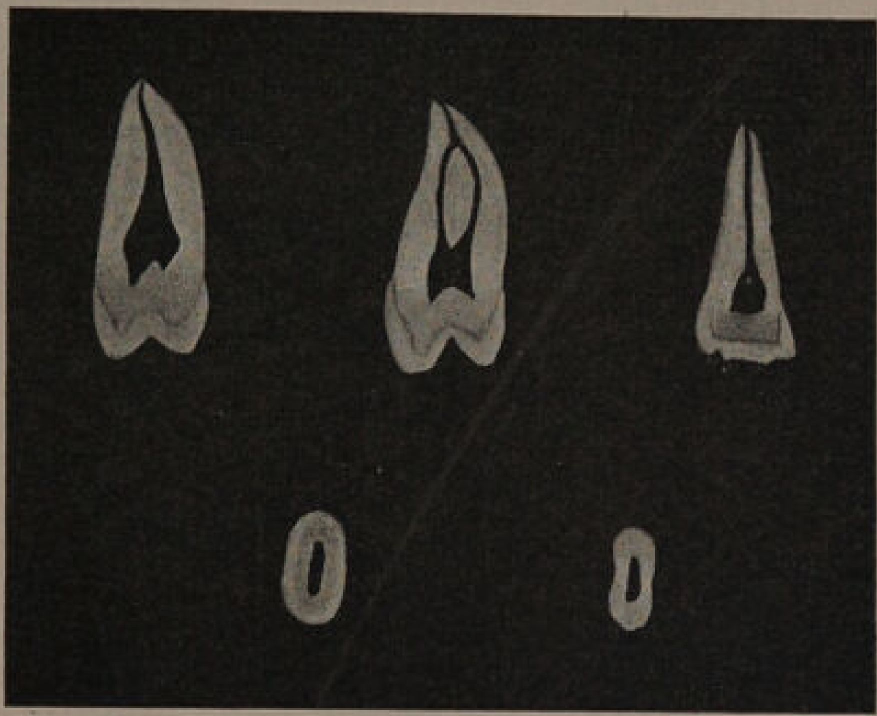


FIG. 134.—Upper left bicuspid longitudinal section buccal to lingual.

in rare instances may penetrate the enamel. In those teeth lacking in cusp-formation the length of the horns will be correspondingly reduced, and may be entirely wanting. In the two-rooted upper first bicuspid the floor of the pulp-chamber, or that part of the cavity directed root-



A B

FIG. 135.—Section of upper second bicuspid.

ward, is prominent and rounded in the center, from which point it gradually slopes toward the entrances to the canals, one of which arises from the extreme buccal margin, and the other from the extreme lingual margin.

1 2 3 4 5

FIG. 136.—Pulp-cavities in the upper second bicuspid, from the seventh to the twelfth year.

Upper Second Bicuspid.—The pulp-cavity of this tooth is in many respects similar to that of the first bicuspid, the principal variations being in the horns of the chamber, which are proportionately smaller in correspondence with the diminution in cusp-formation. There is usually no positive line of demarcation between the chamber and canal, the latter being quite large, and broad from buccal to lingual. The extent of the pulp-chamber is sometimes well defined by the presence of two root-canals, similar to those described in connection with the first bicuspid. In rare instances the tooth may possess two roots, each of which would be traversed by a canal. Figure 135 represents the various stages of the development of the pulp-cavity, as shown by a longitudinal section from buccal to lingual. No. 1 shows the condition at seven

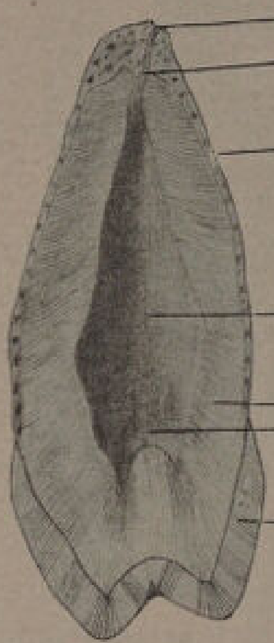


FIG. 137.—Upper second bicuspid longitudinal section buccal to lingual.

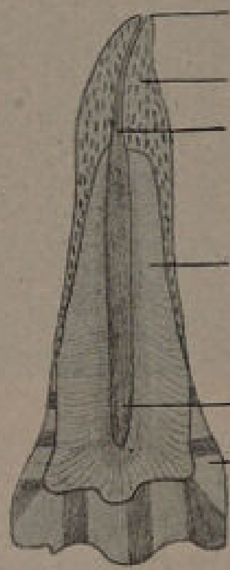


FIG. 138.—Upper second bicuspid mesiodistal section.

FIG. 139.—Shows transverse section of the root.

years, or at a time when a portion of the crown only is calcified, in consequence of which the pulp-chamber alone can be studied at this period. The buccal and lingual horns of the chamber may be observed penetrating the dentin in the direction of their respective cusps. No. 2 shows the advance made in the formative process by the eighth year, or at a time immediately prior to the eruption of the tooth; the outline of the chamber is completed and the walls of the future pulp-canal faintly outlined. At this period there has been but little change in the horns of the pulp-cavity. No. 3 shows the condition of the tooth at the ninth year, or at the beginning of its eruptive period. The diameter of the chamber has somewhat decreased, the horns have slightly receded, the funnel-shaped extremity of the cavity has advanced beyond the cervical line, and is now confined to the canal alone. No. 4 represents the condition of the pulp-cavity about the tenth year. A gradual decrease in the diameter of both the chamber and canal is observed, and the horns of the pulp-cavity are growing less. The length of the root having increased nearly one-quarter of an inch, we find a corresponding addition to the length of the canal. No. 5 shows the maximum size of the pulp-cavity in the upper second bicuspid, which condition accompanies the completion of the external calcification at the twelfth year. As previously stated, the cavity, in its entirety, presents no line of separation between the chamber and canal, but gradually tapers from its broadened base in the crown to its ending at the apex of the root. In this tooth, as well as in all those previously described, the apical foramen at the time of completion of root-calcification is comparatively large, and readily penetrated during operations upon it. Figure 136 illustrates a number of sections of an upper second bicuspid at maturity. The same figure also presents two transverse sections, A being at the cervical line, B midway between the cervical line and apex of the root.

PULP-CAVITIES OF THE UPPER MOLARS

The internal anatomy of the molars being much more complicated than that of the teeth previously described, it will be found necessary to make a number of dissections in various directions in order to obtain a comprehensive idea of the location and form of the different parts of the pulp-cavity. The line of demarcation between the pulp-chamber and canals is always definite, the former occupying a central position in the crown and seldom extending beyond the cervical line, while the latter are given off from the floor of the chamber and penetrate the various roots, their entrances being marked by small funnel-shaped openings in the floor of the chamber. In the matured tooth the form of the pulp-chamber usually corresponds to the external outline of the tooth crown. The lateral walls of the chamber are four in number, and are named according to their location—mesial, distal, buccal, and lingual. The average thickness of these walls at maturity is about equal to the diameter of the pulp-chamber. In that type of tooth common to the lymphatic temperament where there is but little constriction at the neck, resulting in the various sides of the tooth-crown being nearly parallel with each other, the pulp-chamber is nearly quadrilateral in form; but in those teeth marked by a decided constriction at the neck, most marked in the nervous temperament, the extent of surface covered by the floor of the chamber is much less than that occupied by the occlusal portion. In the former class, the entrances to the various canals are much farther apart than in the latter. The occlusal wall is usually much thicker than the lateral walls, and is penetrated by the horns of the pulp-chamber, one of which extends into each cusp. As in the bicuspids, the extent to which the horns penetrate the cusps is controlled by the prominence of the latter. The floor of the pulp-chamber is irregularly rounded, being high in the corner and gradually falling away in the direction of the canals. The entrances to the root-canals, three in number, are placed in the form of an irregular triangle, called the *molar triangle*. The mesial side of the triangle is usually the longest, the distal next in length, and the buccal the shortest. In young teeth the entrances to the canals are usually in the form of funnel-shaped openings, and comparatively easy of access, but after maturity may disappear and be but little larger than the canals themselves. To properly study the position occupied by the entrance to the canals on the floor of the pulp-chamber, a transverse section of the tooth should be made at a point somewhat above the cervical line, at the same time preserving both the crown and the roots of the tooth for comparison. The entrance to the lingual canal, which is usually the largest and most readily accessible, may be located by a line drawn through the center of the occlusal surface of the crown (Fig. 140) from buccal to lingual, A, and by another line drawn from mesial to distal almost parallel with the linguomarginal ridge, passing through the summits of the mesiolingual and distolingual cusps, B; the point at which these two lines intersect will mark the approximate location of the lingual canal. The entrance to the mesiobuccal canal may be located by a line drawn from the inner side of the mesiobuccal angle to a corresponding position near the distobuccal angle, C. This should be intersected by a line drawn from the summit of the mesiobuccal cusp to the summit of the mesiolingual cusp, D, the point at which these two lines cross marking the entrance to the mesiobuccal canal. The location of the entrance to the distobuccal canal is found by the line, C, which is intersected by another line, E, drawn from the summit of the distobuccal cusp to a corresponding point on the distolingual cusp. The nearer the tooth-crown approaches to the quadrilateral, the nearer will the molar triangle approach the equilateral.

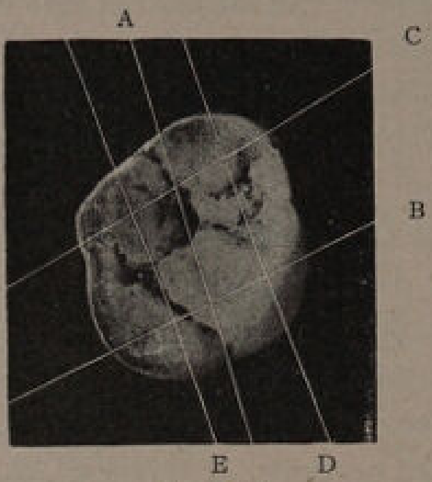


FIG. 140.

Upper First Molar.—In a simple longitudinal section of this tooth, the pulp-chamber and two of the root-canals only will be shown, but this will be sufficient to pursue the study with intelligence. Figure 141 shows a number of longitudinal sections, made in such a manner as to expose the lingual canal, usually the largest, and the mesiobuccal canal. No. 1 illustrates the approximate size and form of the pulp-chamber at the fifth year. At this period the chamber occupies a large proportion of the center of the tooth-crown. Two of the four horns are seen, one of which penetrates the mesiobuccal cusp, and one, the mesiolingual cusp. In many instances the horns of the molars are quite slender, penetrating the dentin to a greater depth than shown in the illustration

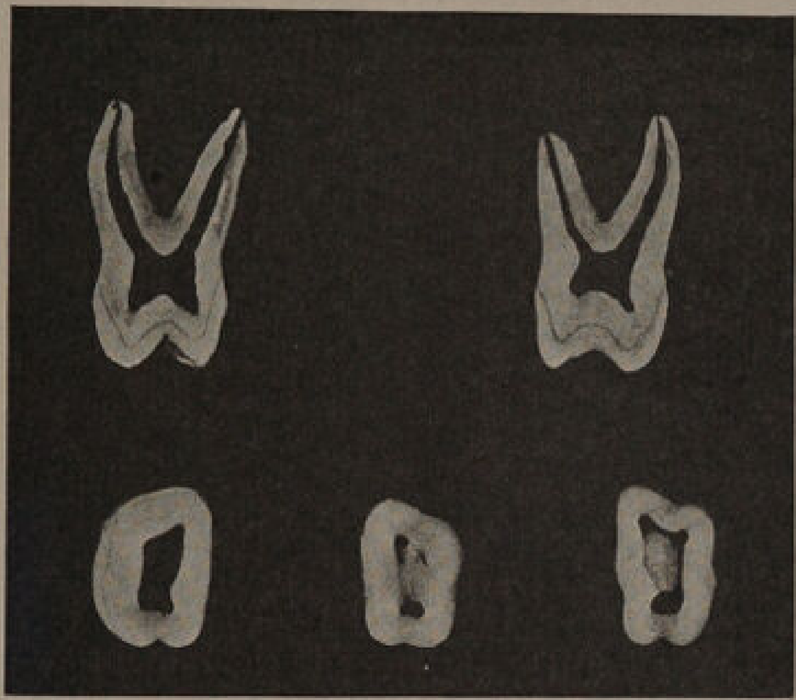
FIG. 141.—Pulp-cavity of upper first molar, from the fifth to the ninth year. Lingual and mesiobuccal canals.

in the form of minute hair-like projections, which in some instances reach almost to the enamel walls.

No. 2 illustrates the condition of the pulp-cavity at the sixth year, or at the time of eruption. The outline of the pulp-chamber is completed, and the floor has begun to make its appearance by a central deposit of dentin. It will be observed that the lateral walls of the chamber are somewhat less in thickness than the occluding wall, a condition which will become more pronounced as the tooth develops. With the beginning of the formative process in the floor of the chamber we find the branching of the roots established, and the beginning of the canals outlined. The canals at this period are quite similar to those of the bicuspid, being provided with a funnel-shaped extremity, which extends from the free calcifying margins of the roots to the floor of the chamber. No. 3 shows the change which has taken place at the seventh year. While the pulp-chamber is somewhat reduced in size, but little change is noticeable in its outline. By this time the floor of the chamber has become an important factor in the tooth development. By the constant lateral extension of this central deposit of dentin the floor of the chamber is gradually spread out, this alteration being at the expense of the entrances to the root-canals, which become reduced in diameter, as the floor is extended. The horns of the chamber are slightly less prominent, but this part of the cavity has the appearance of having receded bodily rootward. The roots have advanced somewhat beyond the point of trifurcation, and a definite outline has been given to the canals. At this period the diameter of the root-wall is about equal to the diameter of the pulp-canal. Along with the gradual decrease in the diameter of the roots, there is observed a corresponding decrease in the width of the funnel-shaped extremities of the canals.

At the eighth year, No. 4, a gradual reduction in the capacity of both the chamber and canal is noted. Accompanying the above condition there is found a corresponding increase in the thickness of the surrounding walls. The horns of the pulp-chamber are much reduced in size, and the form of the chamber more closely resembles that of the general contour of the tooth-crown. The increase in the length of the roots is proportionately greater than that of previous years, in consequence of which the length of the canals is increased to a greater degree. In No. 5 the maximum size of the chamber and canals is apparent, which condition takes place about the ninth year, or at a time when calcification of the tooth is completed externally. In some instances, owing to the additional length of the lingual root, the apical foramen may not be established before the tenth year. At this latter period it is safe to assume that all three canals have completed their longitudinal extent, and the foramina, although proportionately large, have been established, so that a more definite description of each canal may be given. The *lingual canal* (Fig. 142, A) is usually the largest, and branches off from the floor of the chamber, near the mesiodistal center of the extreme lingual margin, the entrance in the average tooth being well defined by a circular, funnel-shaped opening. The direcion of this canal is usually upward and slightly inward, until the apical extremity is approached, at which point it is inclined to the buccal. The circular form presented at the beginning of the canal is generally continued throughout its entire length, in this respect differing from the two buccal canals. The average length of the lingual canal is about ½ of an inch. The *mesiobuccal* canal (Fig. 142, B) branches off from the floor of the chamber, at its extreme mesiobuccal angle, and the entrance, instead of being funnel-shaped and easy of access, is flattened from mesial to distal, and frequently difficult to enter. This flattened form continues throughout its course, which for the distance of ⅛ of an inch is in a buccal and mesial direction; beyond this point it is usually inclined to the buccal, until the upper third of the root is reached, where it turns rather abruptly to the distal. This canal is generally a trifle shorter than the lingual, averaging about 3/8 to 7/16 of an inch. The *distobuccal* canal (Fig. 142, C) branches off from the floor of the chamber at the extreme distobuccal angle. In those teeth which most nearly approach the quadrilateral form, the entrance to this canal will be farther from the center of the tooth, the molar triangle in this instance

B C



D E F

FIG. 142.—Pulp-cavities of upper first molar.

being almost an equilateral. It sometimes happens that the entrance to this canal is directly in the floor of the pulp-chamber, near to, but not against, its buccodistal angle. The entrance is usually abrupt, seldom being funnel-shaped, making it by far the most difficult of access. It is inclined to be circular in form, and more or less tortuous in its course. Immediately above the point of beginning it is inclined toward the buccal and distal; near its center it may incline slightly to the mesial, and finally, at its upper third, turns somewhat abruptly in a distobuccal direction. This canal is usually the shortest of the three, its average length being about 3/8 of an inch.

Figure 142 also illustrates a number of transverse sections of this tooth, D being made at the cervical line, looking toward the crown, E looking toward the roots, while F represents a transverse section at a point immediately above the floor of the pulp-chamber.

Upper Second Molar.—In many respects the pulp-chamber of this tooth is similar to that of the first molar, but there are a few variations which must be briefly described. First, the outline of the tooth-crown being much more flattened from mesial to distal, a corresponding variation is noted in the form of the pulp-chamber, increasing the length of the mesial side of the molar triangle, and decreasing the length of the buccal and distal sides. The chamber is more or less flattened from mesial to distal, making it somewhat oblong from buccal to lingual. Second, on account of a reduction in the prominence of the cusps, the horns of the cavity are usually somewhat less pronounced than those of the first molar. Third, the floor of the cavity is less convex, and slopes more gradually toward the entrances of the various canals. In a general way, the rules given for ascertaining the approximate location of the entrances to the canals in the first molar apply to this tooth. The comparative size and form of the pulp-chamber and canals during the development of the tooth are shown in figure 144,

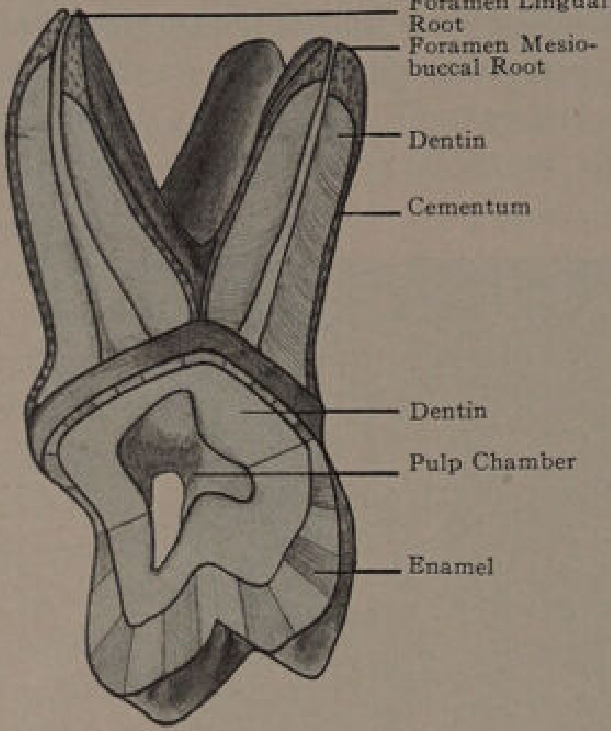


FIG. 143.—Upper first molar longitudinal section of roots and crown.

FIG. 144.—Pulp-cavities in the upper second molar, from the ninth to the eighteenth year.

extending from the ninth to the sixteenth or eighteenth year, at which latter period the crown and roots of the tooth are fully calcified externally.

Upper Third Molar.—In this tooth the conditions are so variable that a description of the pulp-cavity taken from a single tooth would be insufficient. In the majority of instances the outline of the tooth-crown approaches the triangular form, and in consequence the pulp-chamber is triangular rather than quadrilateral or oblong. The mesial border of the chamber is the longest, the distal next in length, and the buccal the shortest of the three. The horns are generally less in number and much less pronounced than those of either the first or second molars. The floor of the chamber may be broken by irregularities similar to those previously described, or it may be entirely absent, this latter condition occurring when the tooth has but a single root accompanied by a single canal. The various stages of development having been given in connection with the general description of the tooth, no attempt will be made to describe this by longitudinal sections, the complications in root-form making such a proceeding impracticable. Instead of so doing, the space will be devoted to a brief description of the variety of pulp-canals found in this tooth. Probably the most frequent

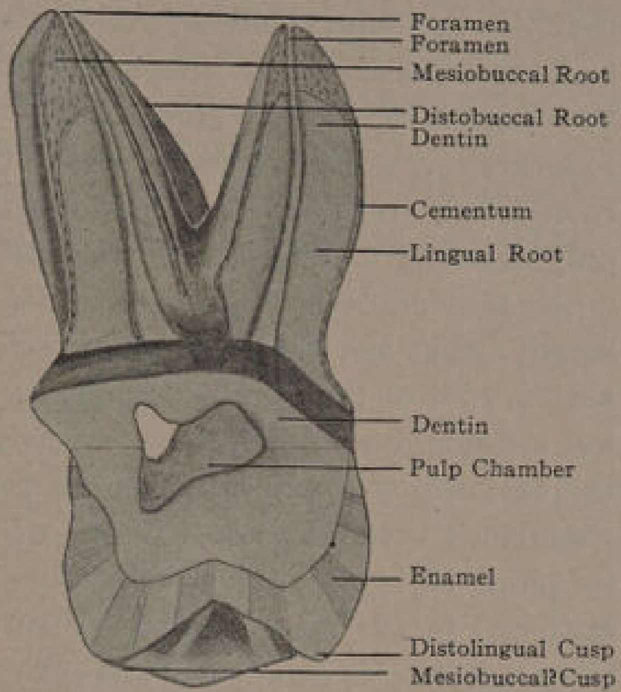


Fig. 145.—Upper second molar longitudinal section of crown and roots.

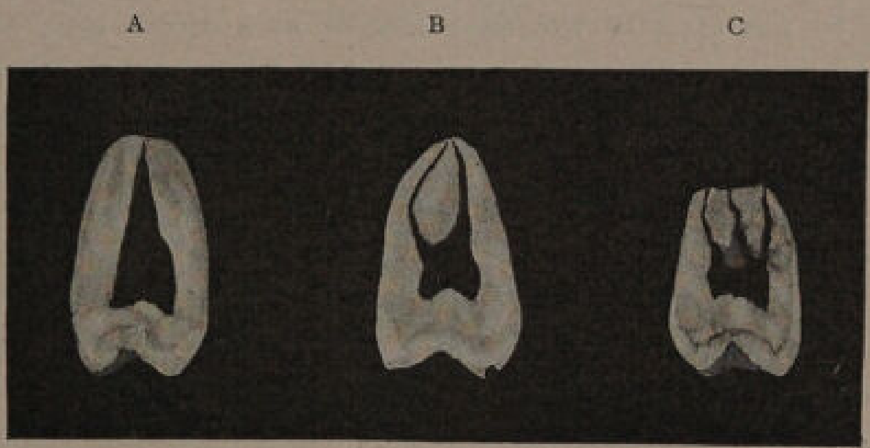


Fig. 146.—Longitudinal sections, upper third molar, slightly enlarged.

condition is that which resembles the first and second molars—*i.e.*, three canals branching off from the chamber in as many different roots, two to the buccal and one to the lingual. When the three canasl exist, the entrances to them will be well beyond the cervical line, where they will be found clustered much closer together than those of the first and second molars, this difference in their location being so marked that the diagram previously given cannot be depended upon in an attempt to locate them. The usual course of these canals is first slightly mesial, then distal, and finally in a distolingual direction. On account of the pulp-chamber extending well beyond the cervical line, the canals are much shorter than those of the first or second molars, their average length being less than ½ of an inch. Another form frequently met with is that of the flattened single canal, occurring when the tooth has but a single root, which shows no signs of trifucating (Fig. 146, A). In this instance the pulp-chamber gradually passes into the canal, and the chamber is without a floor. Such a canal is shaped like the chamber at its point of beginning; but as it passes toward the apex it becomes flattened in the direction of the smallest diameter of the root. But little difficulty is experienced in entering such a canal, and usually it is readily followed to its apex. Another condition frequently met with in the single-rooted third molar is that of one or more canals branching off from the floor of the chamber, their course through the root-substance being without regard to the external contour of the root (Fig. 146, B). These canals, which may exist to the number of five or six, are usually very minute, and in some instances may pass from the floor of the chamber to the apex of the root almost in a direct line, and end in distinct foramina, or they may take a tortuous course, and when near the apex unite, ending in a single foramen. When the tooth is provided with four, five, or even six small roots, as sometimes occurs, each root will be traversed by a minute canal, the entrances to these being variously placed about the floor and lateral margins of the pulp-chamber (Fig. 146, C). In all operations upon this tooth it must be recalled that it is the last to be calcified, and consequently the canals and foramina are proportionately larger than in the other teeth; at the same time, it possesses one operative advantage over the others—*i.e.*, (with the single exception of the cuspid), being fully calcified at or about the time of its eruption.

PULP-CAVITIES OF THE LOWER TEETH

The outline of the pulp-cavities of the lower teeth, like those of the upper, corresponds to the general tooth contour. The comparative size of the cavity at various stages of tooth development will not be repeated in this description, the conditions being similar to those in the upper teeth (see also Development of the Teeth).

Lower Incisors.—The pulp-cavities of the lower central and lateral incisors are so nearly alike that a single description will answer for both.

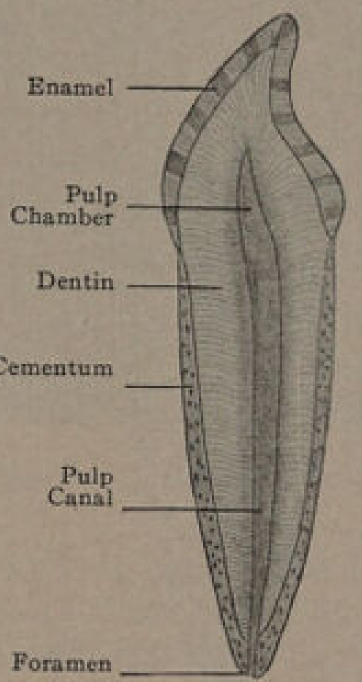


FIG. 147.

Figure 147, represents a labiolingual section of a lower incisor, showing the most frequent form of the pulp-cavity. The tooth from which the section was prepared was one about middle life, the cavity in younger teeth being proportionately larger, while a gradual decrease in diameter would be noted with advancing age. There is no mark of distinction between the pulp-chamber and canal, so that an imaginary separation would have to be made at the cervical line, or slightly below that point. Taken in its entirety, the cavity presents the form of a double cone, the common base of which is slightly to rootward of the cervical line. The chamber penetrates the crown fully half-way to the incisal-edge, at which point it ends in a thin, fan-like margin (best observed in mesiodistal section), while the canal gradually decreases in size until the apical foramen is reached. Although this is the most common form of the pulp-cavity in the lower incisors, it is by no means the constant condition. The tooth is not infrequently provided with a medium-sized pulp-chamber, which extends somewhat below the cervical line beyond which point it branches into fine canals, which are continued separately until the apical third of the roots is approached, when they again unite, and finally end in a single foramen.

Lower Cuspids.—The pulp-chamber and canal in this tooth, while usually conforming to the general contour of the tooth, are frequently

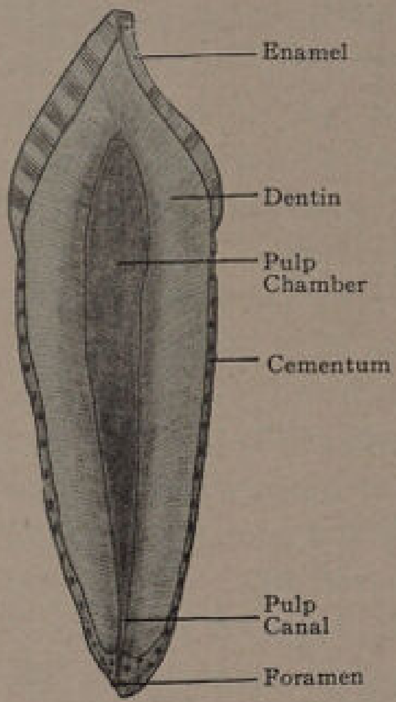


FIG. 148.

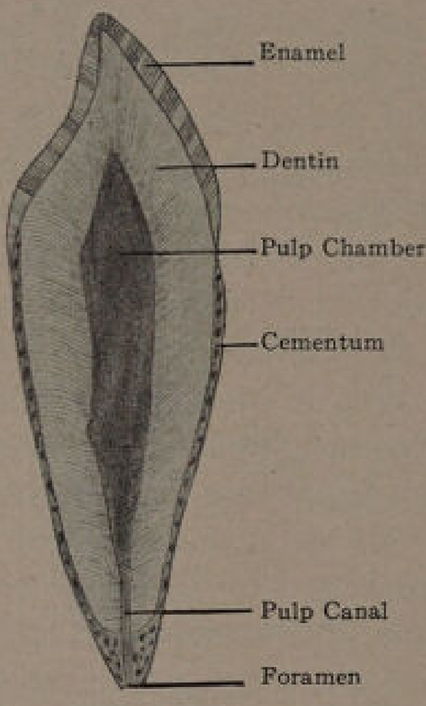


FIG. 148A.

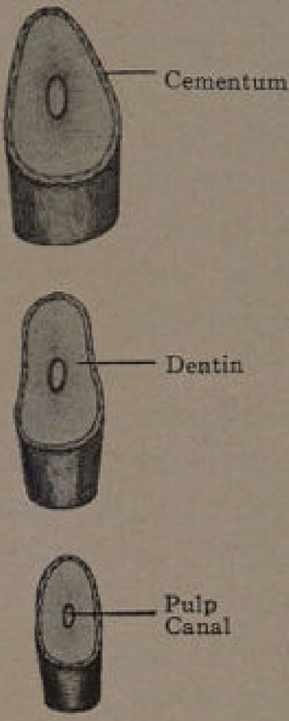


FIG. 149.

found to vary greatly, both in outline and in size. The most common form, however, is that shown in Figs. 148 and 148A, a labiolingual section of an adult tooth. The chamber and canal have no line of demarcation, and unite at a common base considerably below the cervical line, the former penetrating the crown of the tooth to a point about midway between the cervical line and the summit of the cusp, at which point it ends in a sharp, hair-like projection. Accompanying this common form there is much variation in size, even in teeth of the same age. The root of this tooth is in most instances circular, in which case the canal will be similarly formed; but occasionally the root will be much flattened from mesial to distal, and as a result of this the canal will also be much flattened. The canal of this tooth is seldom divided. Fig. 149, shows a number of transverse sections, which will give an idea of the form of the cavity at various parts of the tooth root.

Lower Bicuspids.—The pulp-cavities of these teeth may be best described collectively, thus affording an opportunity for comparison.

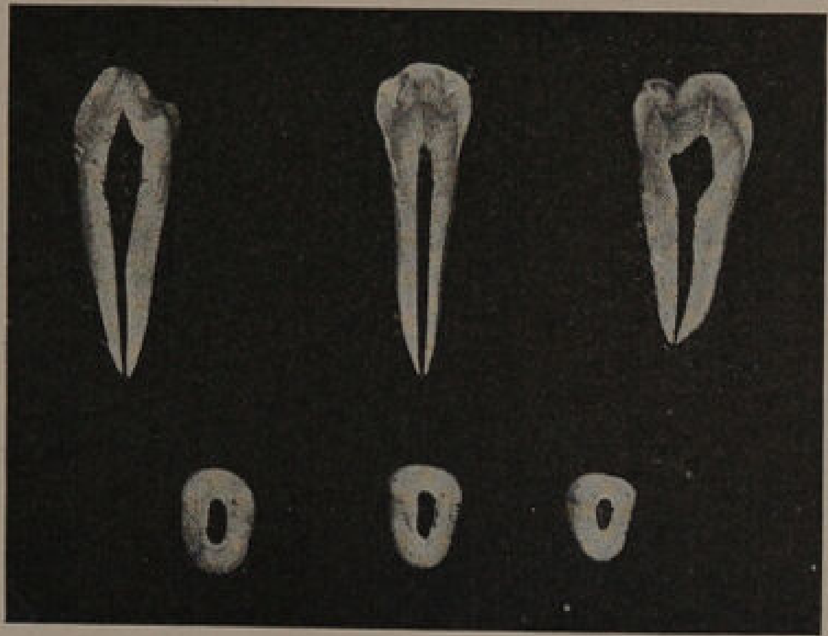


Fig. 150.—Sections of lower bicuspids.

Unlike the upper bicuspids, it is seldom that the canals are definitely separated from the chambers. That part of the cavity within the crown, however, is usually quite wide from buccal to lingual, and unites with the canal by a long funnel-shaped constriction. The center of the pulp-chamber may be considered as being about on a level with the cervical line. In the first bicuspid the pulp-cavity is provided with a single horn, which extends with more or less prominence in the direction of the buccal cusp. That part of the chamber facing the lingual cusp is usually rounded off. In the second bicuspid the occlusal wall of the pulp-chamber generally presents a different form; two well-defined horns are usually present, of which the buccal is the longest; or the chamber may be prominently rounded at these points. The pulp-chamber of the second bicuspid is generally larger than that of the first. The canals of these teeth are usually circular throughout, and are readily penetrated until the apical third is reached, beyond which point they are extremely small. In some instances the canal divides near the center of the root, and is continued as two canals, ending in distinct foramina, or, after separating, they may again unite, and end in a single foramen. In Figs. 150 and 151 the average size and form of the canal in these teeth is shown by a number of mesiodistal and transverse sections.

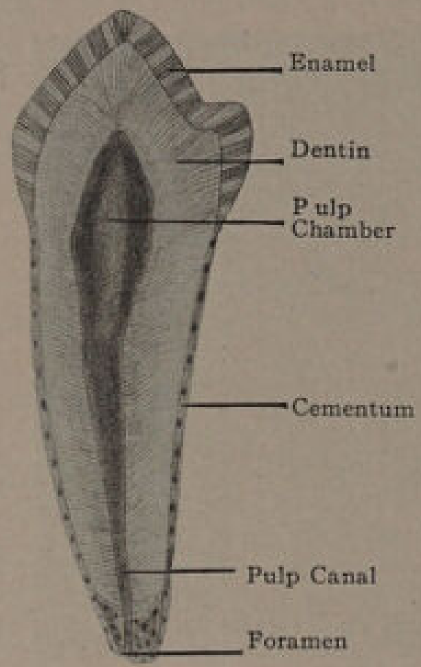


FIG. 151.—Showing first bicuspid. Longitudinal section buccal to lingual.

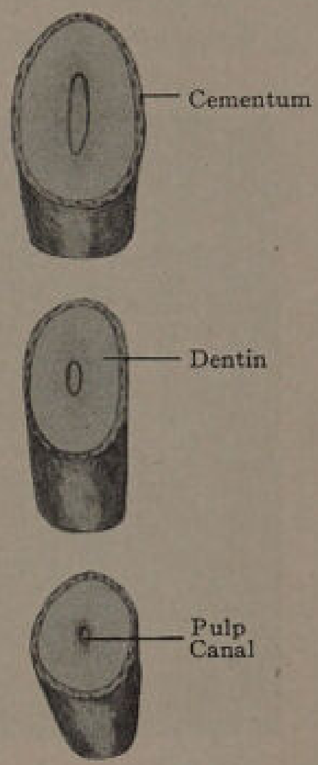


FIG. 152.—Shows transverse sections of the root.

Lower Molars.—The form of the pulp-chambers of the lower molars corresponds to the general outline of the crown, and the form of the root-canals is similar to the general contour of the roots. The pulp-chambers approach the quadrilateral form; the buccal and lingual sides are somewhat the longest, the mesial next in length, and the distal, usually slightly rounded, is the shortest. The occluding wall is convex rootward, sloping in the direction of the various cusps, each of which is penetrated by a horn. Like the horns of these pulp-chambers in general, the extent to which these penetrate the cusps is influenced by the age, type, and functional activity of the organ. The floor of the cavity is convex in the direction of the occlusal surface, but this convexity is principally from mesial to distal. From the summit of this convexity the floor slopes to the entrances of the canals, the opening into which is inclined to be funnel-shaped rather than abrupt. The lateral walls of the chamber are much inclined to follow the general contour of the crown. The horns of the pulp-chamber are usually more pronounced in the first than in the second molar, and still less clearly defined in the third than in the second. The roots of the first molar being somewhat further apart than those of the second, the floor of the chamber in the former is slightly more extensive than in the latter. To study the pulp-cavities of these teeth a longitudinal section should be made through the center of the tooth from mesial to distal. Fig. 153, A, shows such a dissection through the first molar, and illustrates the average size and form of the chamber and canals at adult age. The canals join the chamber by a funnel-shaped opening, and but little difficulty

A B C

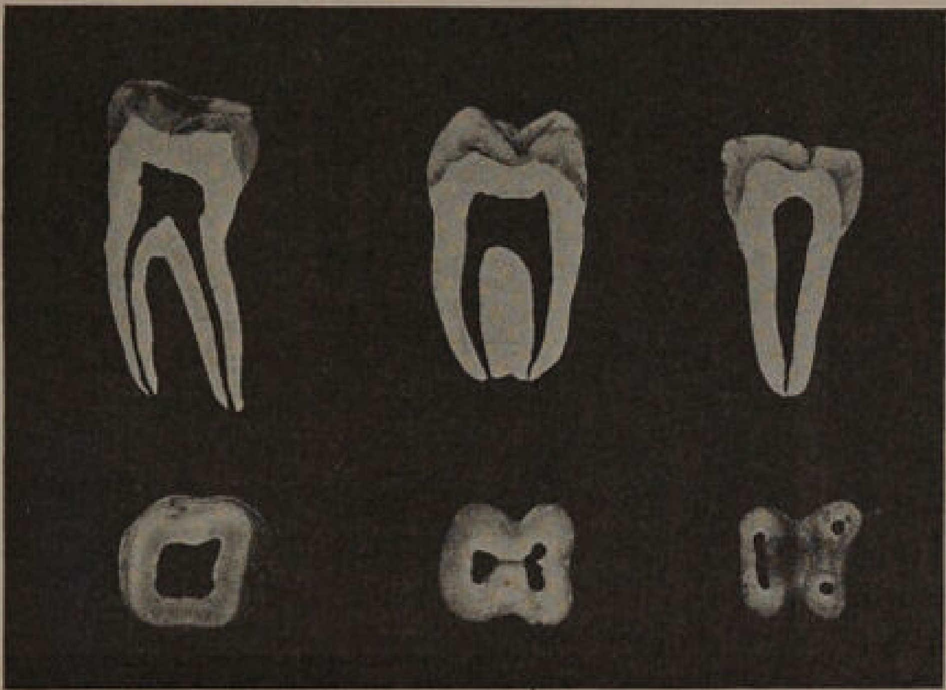


FIG. 153.—Sections of lower molars, enlarged about one-third.

will be found in effecting an entrance, but to follow them to their apices will be more perplexing. The roots of this tooth being much flattened from mesial to distal, the canals are also flattened in this direction, but broad from buccal to lingual. The entrances of these canals may be found at the extreme mesial and distal margins of the pulp-chamber, and usually extend from the buccal to the lingual walls of the cavity. It is not uncommon for the mesial canal to divide soon after leaving the chamber, and continue as two canals, ending in separate foramina (Fig. 153, B). This condition is seldom present in the distal canal, which is usually straight from its mouth to the apical foramen. The capacity of the pulp-chamber is usually a trifle less than that of the first molar, and the entrances to the canals are somewhat nearer together. In other respects the cavity is similar to that of the first molar. Fig. 153 also shows a number of transverse sections through a lower molar, and gives an idea of the size of the canals at various parts of the roots. In some instances the roots of the second molar coalesce, in which case a single root-canal may be present. In the third molar the most common form

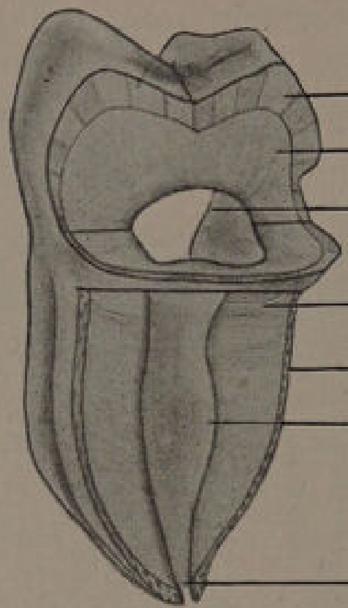


FIG. 154.

of the pulp-cavity is one similar to that of the first, but both the chamber and canals are smaller. Unlike the pulp-cavity of the corresponding upper tooth, this tooth is not subject to so much variation, although it is sometimes found with a single root traversed by a single canal, which may be accompanied by a rather large pulp-chamber. Fig. 154 shows sections on the crown and root of a lower second molar.

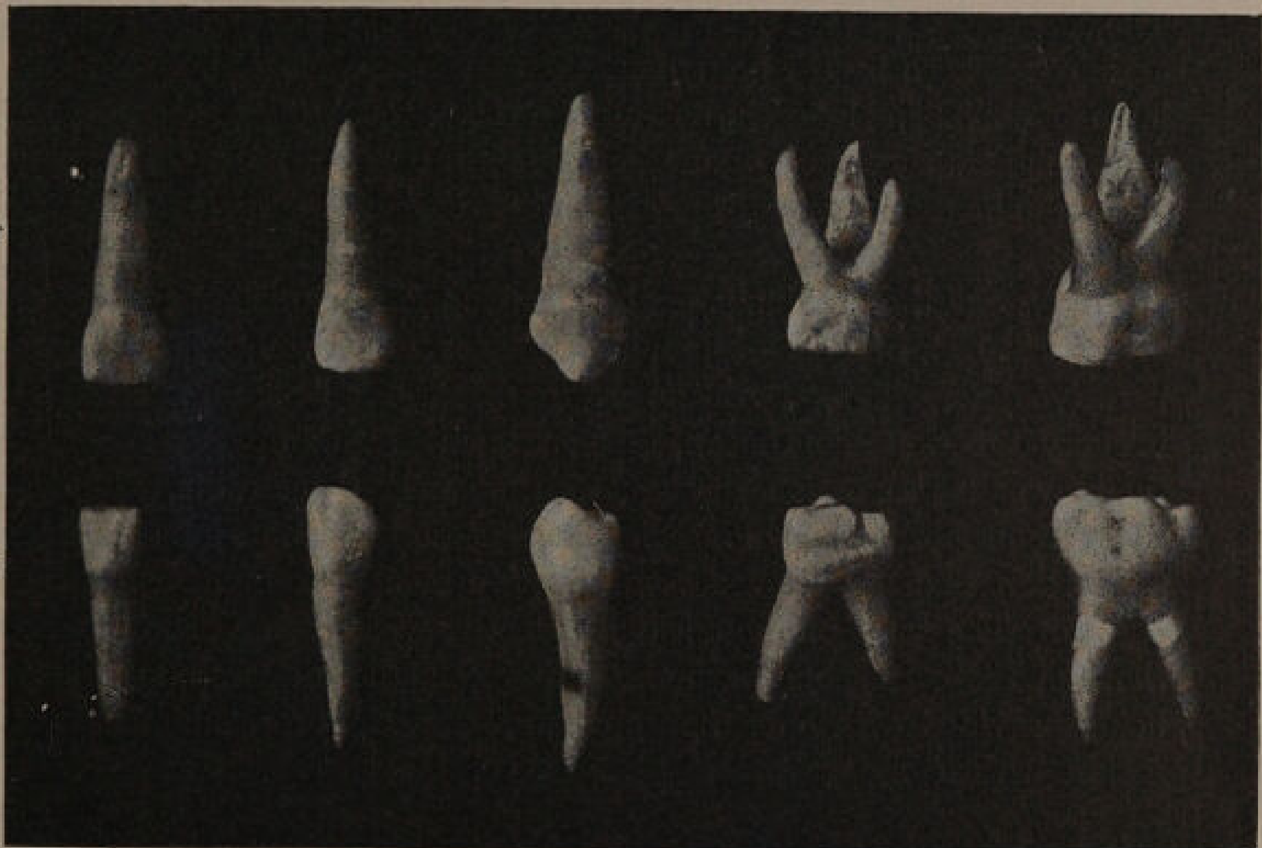
CHAPTER XI

The Deciduous Teeth, Their Arrangement, Occlusion, Etc.; Calcification, Eruption, Decalcification, Shedding Process, and Average Measurements; Their Surfaces, Grooves, Fossæ, Ridges, Sulci, and Pulp-Cavities.

THE DECIDUOUS TEETH

Central Incisor Lateral Incisor Cuspid First Molar Second Molar

Upper



Lower

Central Incisor Lateral Incisor Cuspid First Molar Second Molar

FIG. 155.—The deciduous teeth, upper and lower, from the left side of the mouth.

As implied by the word deciduous, these teeth are temporary in their nature, and, after subserving the purposes of early childhood, are thrown off by an operation of the economy to give place to the permanent organs. The shedding process takes place in the incisors between the seventh and eighth years, in the molars from the tenth to the eleventh years, and in the cuspids about the twelfth year. This shedding process, however, does not indicate the period at which the degeneracy of the tooth begins, for, in a year or two after the root is completely formed and the apical foramen established, decalcification begins at the apical extremity and continues in the direction of the crown until absorption of the entire root has taken place and the crown is lost from lack of support. Decalcification in the incisors begins between the fourth and fifth years, in the molars from the seventh to the eighth years, and in the cuspids about the ninth year.

The deciduous teeth are *twenty in number*, ten in each jaw, and may be classified as follows: *Four incisors, two cuspids, and four molars.* The incisors, central and lateral, occupy the central portion of the arch, are placed two upon each side of the median line, and are succeeded by the four permanent incisors, which finally occupy the same position. The cuspids are located immediately to the distal of the lateral incisors, and are replaced by the permanent cuspids. The first and second molars come next in the arch, but, unlike the anterior teeth, are followed by permanent successors of another class, the first and second bicuspids, the permanent molars erupting posteriorly to these as the jaw increases in length.

In general the deciduous teeth resemble their permanent successors, yet there are a number of minor differences which will require a comparative description. Both the crowns and the roots are much smaller in every direction than those of the permanent teeth, but the diameter of the crowns is proportionately greater than that of the roots, while the roots are proportionately longer. The fact that the roots are smaller in proportion than the crowns is productive of a neck much more constriced. The roots of the deciduous teeth are the same in number as those of the corresponding permanent teeth, the incisors and cuspids being provided with one, the upper molars with three, and the lower molars with two.

THE OCCLUSION OF THE DECIDUOUS TEETH

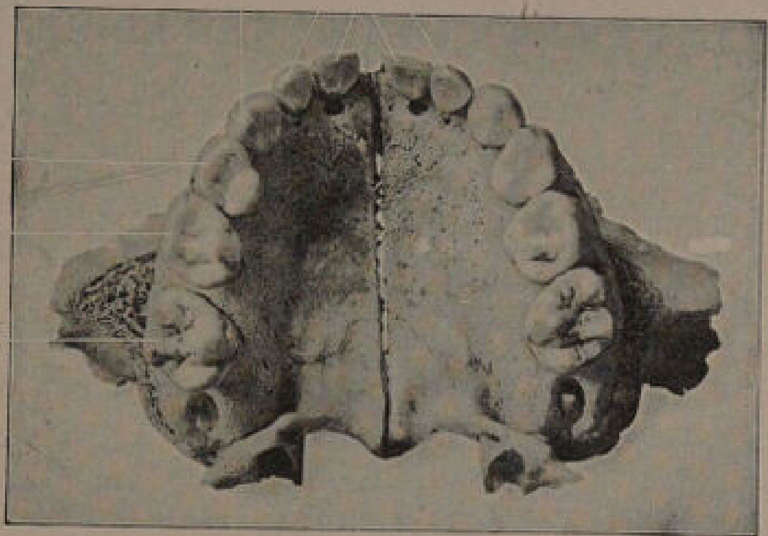


FIG. 156.—The upper dental arch about the seventh year.

The arrangement of the deciduous teeth in the jaws is similar to that of the permanent organs, the upper teeth describing the segment of a larger circle than the lower, in consequence of which the upper teeth close over or outside of the lower. The character of the occlusion in the deciduous teeth is not subject to so much variation as that found in connection with the permanent set, this being accounted for by the more constant form in the crowns of the former. The relations existing between the upper and lower deciduous teeth when in contact is such that each tooth, with the exception of the lower central incisor and the upper second molar, occludes with two teeth of the opposite jaw, the upper central incisor being opposed by the entire incisal-edge of the lower central and the mesial third of the lower lateral; the upper lateral coming in contact with the remaining two-thirds of the lower lateral and a portion of the mesial half of the lower cuspid, this arrangement continuing throughout the series. The foregoing description of the occlusion of the deciduous teeth is applicable to but a small part of their transitory existence. Soon after they are fully erupted and have assumed their respective positions in the arch, the increase in the size of the bone is sufficient to create a slight space or diastema between the teeth, which condition is soon followed by a greater separation through the protrusion of the anterior teeth, caused by the growth and approach of the permanent teeth from behind.

The calcification of the deciduous teeth is similar to that of the permanent, the process in the incisors and cuspids beginning along the incisal-edges in three distinct lobes, while in the molars a center of calcification is provided for each cusp (see Development of the Teeth).

THE DECIDUOUS TEETH IN DETAIL

UPPER CENTRAL INCISOR

Fig. 157.

Calcification Begins, about the Fourth Fetal Month.
Calcification Completed, Seventeenth to Eighteenth Month after Birth.
Erupts, Sixth to Eighth Month after Birth.
Decalcification Begins, about the Fourth Year.
Shedding Process Takes Place, about the Seventh Year.
Average Length of Crown, .23.
Average Length of Root, .39.
Average Length over All, .62.

This tooth, as well as all of the deciduous teeth, presents for examination numerous surfaces, margins, and angles, these being the same in name and location as those of the permanent teeth.

Fig. 158.

The Labial Surface of the Crown (Fig. 158).—This surface is smooth and generally convex, but with an inclination to flatness near the incisive margin. The mesial margin is slightly convex in the direction of the length of the tooth, and rounded from labial to lingual. The distal margin is decidedly convex from the incisal-edge to the cervical line, in many instances forming almost a complete semicircle, which is usually at the expense of the distal angle of the crown. The cervical margin is deeply concave in the direction of the root, and the incisive margin is straight over its central portion and rounded or angular at its extremities. The labial grooves are seldom so well defined at those upon the permanent incisors.

The Lingual Surface of the Crown.—In some instances this surface is smooth and concave near the incisal-edge and convex over the cervical portion, with the marginal ridges well defined. In other cases it is concave from the incisal-edge to the cervical ridge, being provided with a longitudinal ridge in the center, a slight depression upon either side, and marginal ridges poorly defined. In the former instance the lingual fossa is present; in the latter it is absent. The *mesial* and *distal* surfaces of the crown are both smooth and convex, the former being inclined to flatness over its cervical third—a condition which is seldom present in the latter. The mesial angle is alone well defined, the incisal-edge passing into the distal surface with a long, gradual sweep, thus in a measure destroying the distal angle. The neck of the tooth is marked by a decided constriction, which is principally produced at the expense of the crown alone. The root of the tooth, when compared with the root of the permanent central incisor, is much longer in proportion to the length of the crown. In some instances it is flattened from mesial to distal, these two sides converging as they pass to the lingual; in others it is flattened from labial to lingual. Generally speaking, it is a simple cena, but is occasionally provided with a slight mesial curve near its apical third, and it is sometimes curved slightly from labial to lingual.

UPPER LATERAL INCISOR

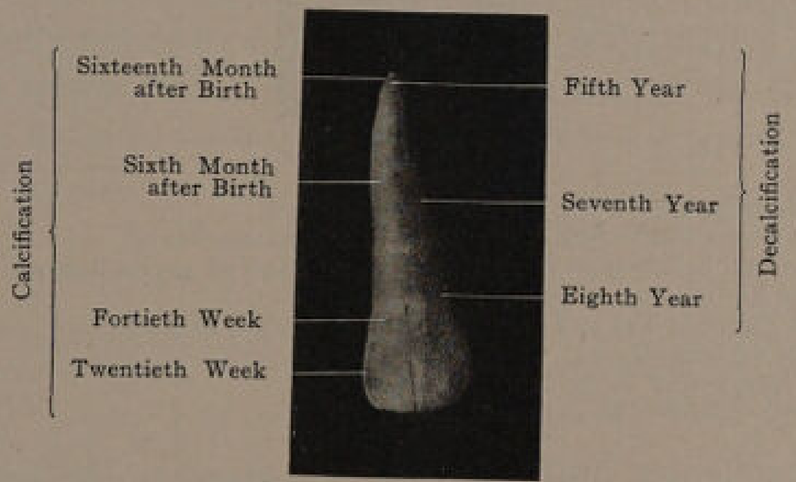


Fig. 159.

Calcification Begins, about the Fourth Fetal Month.
Calcification Completed, Fourteenth to Sixteenth Month after Birth.
Erupts, Seventh to Ninth Month after Birth.
Decalcification Begins, about the Fifth Year.
Shedding Process Takes Place about the Eighth Year.
Average Length of Crown, .25.
Average Length of Root, .45.
Average Length over All, .70.

The various surfaces of this tooth so closely resemble those of the central incisor that a separate description will be unnecessary; in a gen-

Fig. 160.—Upper lateral incisor, labial surface.

eral way, however, there are a few minor points of difference. The tooth is smaller in every direction excepting in its length, which is generally equal to and frequently greater than that of the central incisor. The diameter of the root is but little less than that of the central, while the mesiodistal measurement of the crown is about one-third less, in consequence of which the neck of the tooth is not so well defined. The angles of the crown are more rounded than those of the central incisors.

UPPER CUSPID

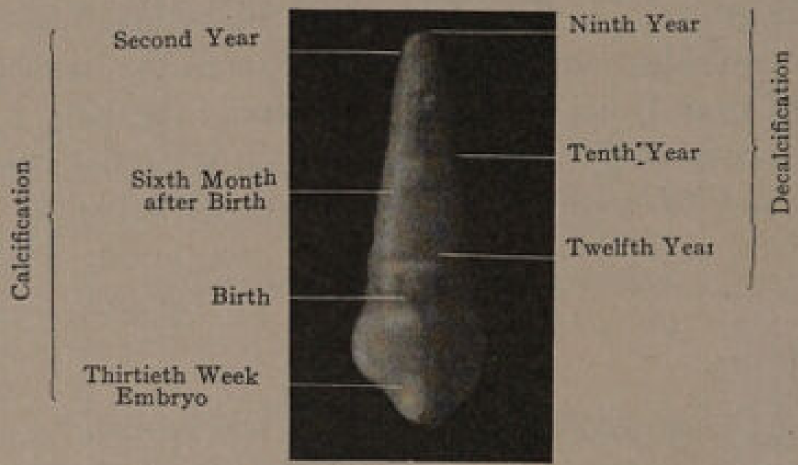


Fig. 161.

Calcification Begins, about the Fifth Fetal Month.
Calcification Completed about Two Years after Birth.
Erupts, Seventeenth to Eighteenth Month after Birth.
Decalcification Begins, about the Ninth Year.
Shedding Process Takes Place, about the Twelfth Year.
Average Length of Crown, .25.
Average Length of Root, .53.
Average Length over All, .78.

Like the permanent cuspid, the general contour of this tooth is that of a double cone, the lines of which are somewhat broken. The greatest mesiodistal extent of the crown is from angle to angle, and this measurement about corresponds with the width of the crown of the central incisor.

The Labial Surface of the Crown (Fig. 162).—This surface is strongly convex from mesial to distal, and slightly so from the incisal-edge to the cervical line. It is bounded by five margins: mesial, distal, cervical, mesio-incisive, and disto-incisive. The mesial and distal margins are rounded and smooth, the cervical well outlined by the cervical line and base of the cervical ridge, while the two incisive margins are formed by the mesial and distal incisal-edges. The labial grooves are thrown well toward the lateral margins, and are usually more distinct than those upon the incisors. The labial ridge is prominent.

The Lingual Surface of the Crown.—This surface is generally divided into two portions by the lingual ridge, which extends from the summit of the cusp to the base of the cervical ridge. On either side of this ridge are the lingual grooves but which appear more in the form of small fossæ. The marginal ridges are fairly well defined.

FIG. 162.—Upper cuspid, labial surface.

The Mesial and Distal Surfaces of the Crown.—The extent of these two surfaces is frequently much interfered with by the slope of the mesial and distal incisal-edges, which may be so long that the angles of the crown are forced well toward the cervical line, in some instances almost obliterating these two surfaces. When the incisal-edges are shorter, these surfaces present a marked general convexity. While the summit of the cusp will always be found to be in a direct line with the long axis of the tooth, there is in nearly every instance a difference in the length of the incisal-edges, and, unlike the permanent cuspid, the mesial is usually the longer. The neck of the tooth is much constricted and the root straight and conic.

THE UPPER MOLARS

Upper First Molar.

FIG. 163.
CALCIFICATION BEGINS, ABOUT THE FIFTH FETAL MONTH.
CALCIFICATION COMPLETED, EIGHTEENTH TO TWENTIETH MONTH AFTER BIRTH.
ERUPTS, FOURTEENTH TO FIFTEENTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, SIXTH TO SEVENTH YEAR.
SHEDDING PROCESS TAKES PLACE, ABOUT THE TENTH YEAR.
AVERAGE LENGTH OF CROWN, .20.
AVERAGE LENGTH OF ROOT, .39.
AVERAGE LENGTH OVER ALL, .59.

The contour and lobate construction of the crown of this tooth is peculiar to itself, being dissimilar to any other class of teeth in the mouth. Calcification takes place from three centers, two for the buccal and one for the lingual half of the crown. The general form of the crown may best be studied by an examination of the occlusal surface.

The Occlusal Surface of the Crown (Fig. 164).—The outlines represented are those of an irregular quadrilateral, of which the buccal and mesial sides are the longest. The angles of the quadrilateral are somewhat variable, the mesiobuccal being acute, the mesiolingual obtuse, while the two distal angles are rounded right angles. The surface is surmounted by three cusps, a mesiobuccal, a distobuccal, and a lingual. These various cusps are separated from one another by three developmental grooves—the mesial, the distal, and the buccal. The marginal ridges are sharp and well defined, this being particularly true of the buccal and lingual, which resemble incisal-edges. The mesio-marginal ridge begins at the mesiobuccal angle, and, after making a long distal curve, ends in the mesial incline of the lingual cusp. The center of the surface is deeply and irregularly concave, producing the central fossa, and descending from the various ridges and cusps surrounding it are numerous supplemental grooves and ridges. The

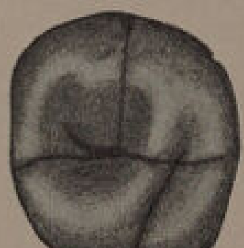


FIG. 164.

various developmental grooves are not inclined to cross the marginal ridges, although in some instances one or two may be found to do so.

The Buccal Surface of the Crown (Fig. 165).—This surface is generally smooth and convex, with an excessively developed cervical ridge, which is particularly prominent at its mesial extremity. The buccal groove is in the form of a slight depression, and the buccal ridges, common to all molars, are scarcely to be observed. The mesial, occlusal, and cervical margins are distinctly outlined, while the distal margin is obliterated by the gradual passing of this surface into the distal surface.

The Lingual Surface of the Crown.—This surface is circular in outline, decidedly convex and smooth, and is seldom broken by grooves and ridges. It is most prominent near the center, from which point it slopes in every direction. The cervical ridge is not so pronounced as that of the buccal surface, but there is a sudden rounding of the surface in a cervical direction to meet the lingual root.

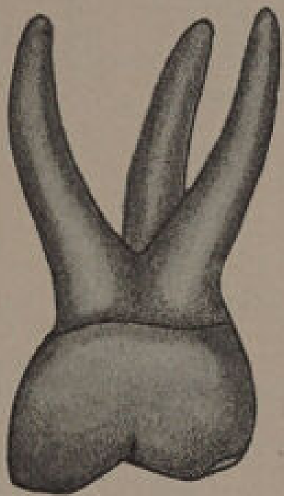


Fig. 165.—Upper first molar, buccal surface.

The Mesial Surface of the Crown.—This surface is probably more extensive than any of the others; it is inclined to flatness, with a slight conic convexity over its occlusal third, and a slight concavity near the cervix. The buccolingual measurement of the surface is nearly twice as great as that from the occlusal margin to the cervical line. It is much more prominent near the occlusal margin, so that a **V**-shaped space usually exists between it and the distal surface of the cuspid.

The Distal Surface of the Crown.—The extent of this surface is much less than that of the mesial; it presents a general convexity, and is seldom broken by grooves or ridges, although occasionally the distal groove crosses its occlusal margin. Like the deciduous teeth previously described, the neck of the tooth is marked by a decided and abrupt constriction, this form appearing to arise from the heavy enamel folds which are present near the cervical line, rather than from any marked constriction in the base of the roots themselves.

The roots of the tooth are three in number—a mesiobuccal, distobuccal, and a lingual; of these, the latter is usually the largest and longest. The two buccal roots are much flattened from mesial to distal, while the lingual is compressed in the opposite direction. The apical ends of the roots are much separated from one another, the triangle which these points form being almost twice the size of the triangle formed by the base of the roots. The apical ends are usually provided with a central curve.

Upper Second Molar.

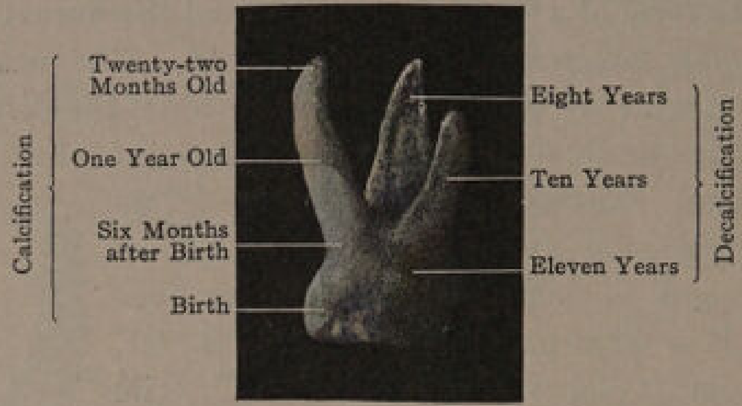


FIG. 166.

CALCIFICATION BEGINS, BETWEEN THE FIFTH AND SIXTH FETAL MONTHS.
CALCIFICATION COMPLETED, TWENTIETH TO TWENTY-SECOND MONTH AFTER BIRTH.
ERUPTED, EIGHTEENTH TO TWENTY-FOURTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, SEVENTH TO EIGHTH YEAR.
SHEDDING PROCESS TAKES PLACE, ELEVENTH TO TWELFTH YEAR.
AVERAGE LENGTH OF CROWN, .22.
AVERAGE LENGTH OF ROOT, .46.
AVERAGE LENGTH OVER ALL, .68.

The most remarkable feature about the crown of this tooth is its close resemblance to the crown of the upper permanent first molar. The various surfaces are almost identical, the developmental process, and consequently the cusp-formation, is the same, the marginal and other ridges common to the occlusal surface correspond, and both the central and distal fossæ are present, together with the various developmental grooves. A description of the crown will, therefore, be unnecessary; suffice it to say that it is much smaller in every direction and is somewhat more constricted at the neck. The roots are the same in name and number as those of the first permanent molar, but they are more widely separated at their apical extremities. In general form they are smaller than those of the upper first deciduous molar.

FIG. 167.—Upper second molar, buccal surface.

FIG. 168.—Upper second molar occlusal surface.

THE LOWER DECIDUOUS TEETH

A description in detail of the lower incisors and cuspids would practically be a repetition of that given of the corresponding upper teeth, and for that reason will be passed with a limited reference to each. The lower molars being in many respects unlike the upper, they will require a separate description.

Lower Central Incisor (Fig. 169).

CALCIFICATION BEGINS, ABOUT THE FOURTH FETAL MONTH.
CALCIFICATION COMPLETED, SIXTEENTH TO EIGHTEENTH MONTH AFTER BIRTH.
ERUPTED, SIXTH TO EIGHTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, ABOUT THE FOURTH YEAR.
SHEDDING PROCESS TAKES PLACE, ABOUT THE SEVENTH YEAR.
AVERAGE LENGTH OF CROWN, .19
AVERAGE LENGTH OF ROOT, .35.
AVERAGE LENGTH OVER ALL, .54.

This is the smallest of the lower teeth, in this respect being at variance to the upper central, which is larger than the lateral. The mesiodistal diameter of the crown is but little less than that from the incisal-edge to the cervical line. The mesial and distal angles are similar, both being pointed and square. The cervical ridge is quite pronounced and the neck much constricted.


FIG. 169.—Lower central incisor, labial surface.

The **root** is usually straight and tapers gradually from base to apex. It is broader on the labial than on the lingual side, and the mesial and distal sides are but little flattened.

Lower Lateral Incisor (Fig. 170).

CALCIFICATION BEGINS, ABOUT THE FOURTH FETAL MONTH.
CALCIFICATION COMPLETED, TWELFTH TO FOURTEENTH MONTH AFTER BIRTH.
ERUPTED, SEVENTH TO NINTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, ABOUT THE FIFTH YEAR.
SHEDDING PROCESS TAKES PLACE ABOUT THE EIGHTH YEAR.
AVERAGE LENGTH OF CROWN, .19.
AVERAGE LENGTH OF ROOT, .39.
AVERAGE LENGTH OVER ALL, .58.

This tooth is larger than the central incisor, and closely resembles the upper lateral both in size and form. The crown is more rounded in its nature than that of the central, forming a greater general convexity to the labial surface, and less concavity to the lingual. The mesial angle of the crown is fairly well defined, while the distal is usually much rounded by a long, circular sweep of the incisal-edge to meet the distal surface.

FIG. 170.—Lower lateral incisor, labial surface.

The mesial surface of the crown is flattened and somewhat prominent at the angle, while the distal surface is strongly convex. The labial grooves are but slightly visible, while the corresponding lingual grooves are quite pronounced. The neck of the tooth is even more marked than that of the lower central incisor. The root is long and tapering, slightly flattened from mesial to distal, with a decided longitudinal groove on both the mesial and distal sides. The labial and lingual sides are rounded, and there is an inclination to crookedness, which is usually from mesial to distal.

Lower Cuspid (Fig. 171).

CALCIFICATION BEGINS, ABOUT THE FIFTH FETAL MONTH.
CALCIFICATION COMPLETED, ABOUT TWO YEARS AFTER BIRTH.
ERUPTED, SEVENTEENTH TO EIGHTEENTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, ABOUT THE NINTH YEAR.
SHEDDING PROCESS TAKES PLACE, ABOUT THE TWELFTH YEAR.
AVERAGE LENGTH OF CROWN, .23.
AVERAGE LENGTH OF ROOT, .45.
AVERAGE LENGTH OVER ALL, .68.

The principal variations between this tooth and the upper cuspid are observed in the diminished mesiodistal measurement of the crown, together with it being somewhat less angular in outline. The ridges and grooves common to the various surfaces are not so marked as those of the upper cuspid, resulting in a smoothly formed crown throughout. The root is larger in proportion to the size of the crown than that of its upper opponent, thus producing a neck much less constricted. It is usually straight, or provided with a slight distal inclination near its apical extremity, and much flattened from mesial to distal, these two sides converging to the lingual, forming a rounded triangular outline.

FIG. 171.—Lower cuspid, labial surface.

Lower First Molar (Fig. 172).

CALCIFICATION BEGINS, ABOUT THE FIFTH FETAL MONTH.
CALCIFICATION COMPLETED, EIGHTEENTH TO TWENTIETH MONTH AFTER BIRTH.
ERUPTED, FOURTEENTH TO FIFTEENTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, SIXTH TO SEVENTH YEAR.
SHEDDING PROCESS BEGINS, ABOUT THE TENTH YEAR.
AVERAGE LENGTH OF CROWN, .24.
AVERAGE LENGTH OF ROOT, .38.
AVERAGE LENGTH OVER ALL, .62.

Upon making an examination of the occlusal surface of this tooth it will be observed that the crown is made up of four irregularly formed lobes, separated from one another by four well-defined grooves. Each lobe is provided with a cusp, more or less prominently developed. Between the various cusps are two fossæ—one occupying the distal two-thirds of the surface (the distal fossa) and the other the remaining or mesial third (the mesial fossa). The outline of this surface, which represents the contour of the crown in general, is that of an oblong square, with its angles more or less rounded, and having a slight variation in its parallel lines. Each lobe denotes a separate center of calcification, and the four grooves the lines of union between the various parts.

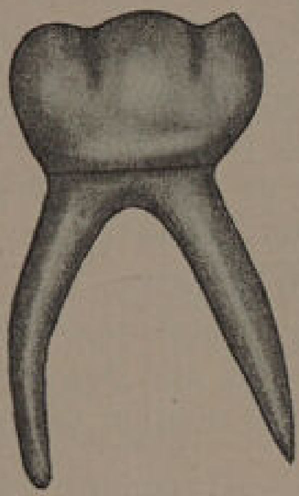


FIG. 172.—Lower first molar, buccal surface.

The Mesiobuccal lobe is somewhat irregular in contour and is frequently the largest of the four. It assists in forming the mesiobuccal angle of the crown and the greater part of the mesial fossa. Descending from this cusp to the lingual is a pronounced triangular ridge, which is made continuous by uniting with a similar ridge from the corresponding lingual cusp. By this union a transverse ridge is established, separating the mesial from the distal fossa. The central boundary of this lobe is formed by the mesial groove, which arises from the distal fossa, passes over the transverse ridge to the mesial fossa, from which it continues to the lingual, and by the buccal groove, which branches off from the mesial somewhat to the distal of the transverse ridge, passing over the buccomarginal ridge to the buccal surface.

The Distobuccal Lobe.—This cusp is general smaller than the mesiobuccal, and is more pointed and more regular in outline. It assists in forming the distobuccal angle of the crown, and by its central incline forms about one-third of the distal fossa. Its boundaries are formed by the buccal, mesial and distal grooves, the latter beginning in the distal fossa, and passing over the distomarginal ridge to the distal surface.

The Mesiolingual Lobe.—In the recently erupted tooth the summit of this cusp is long and pointed, and frequently remains the most pronounced of the four. It is triangular in outline, and, as above referred to, furnished a triangular ridge, which, by uniting with a like ridge from the mesiobuccal cusp, forms the transverse ridge. By its central incline it assists in forming the mesial fossa. Its boundaries are formed by the mesial groove and the lingual groove, the latter arising near the center of the distal fossa, passing to, and sometimes crossing, the linguomarginal ridge.

The Distolingual Lobe.—This is usually the smallest of the four. It is inclined to be rounded, rather than angular, and in some instances is poorly developed. It assists in forming the distolingual angle of the crown, as well as a portion of the distal fossa. Its central boundaries are formed by the lingual and distal grooves.

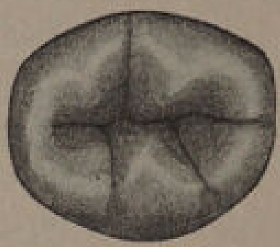


FIG. 173.—Occlusal surface.

The marginal ridges of the surface are abruptly but irregularly formed, ascending and descending the various cusps in a manner similar to those previously described.

The Buccal Surface of the Crown (Fig. 172).—This surface is smooth and generally convex, with a mesiodistal measurement about twice as great as that from the cervical line to the occlusal margin. The surface is most prominent over its cervical third, forming a well-rounded and bold cervical ridge, a feature strongly characteristic of this tooth. The distal center of the surface is broken by the buccal groove, which usually ends near the center in a shallow depression or pit.

The Lingual Surface of the Crown.—This surface is much less extensive than the buccal. It is smooth and convex throughout, and is broken near its distal center by the lingual groove, which gradually disappears as it passes rootward. The cervical ridge is not so prominent as that of the buccal surface.

The Mesial and Distal Surfaces of the Crown.—These are slightly convex in every direction, the former passing, by a gradual sweep, into the lingual surface, destroying the angularity of the crown at this point, while the latter passes more abruptly, forming an acute angle. These surfaces are both prominent near the occlusal margin, making the point of contact with adjoining teeth near the surface. The bold cervical ridge of the buccal surface is discontinued or greatly diminished upon these surfaces, both of which are inclined to pass very gradually into the base of the roots.

The **roots** of this tooth are the same in name, position, and number as those of the lower permanent molars. They are much flattened from mesial to distal, the center of their flattened sides being further compressed by a deep longitudinal groove, which extends from the base to the apex of each root. In passing from the base of the roots to their apices they become more widely separated, until these extremities are much wider apart, proportionately, than those of the permanent molars.

Lower Second Molar (Fig. 174).

CALCIFICATION BEGINS, BETWEEN THE FIFTH AND SIXTH FETAL MONTHS.
CALCIFICATION COMPLETED, TWENTIETH TO TWENTY-SECOND MONTH AFTER BIRTH.
ERUPTED, EIGHTEENTH TO TWENTY-FOURTH MONTH AFTER BIRTH.
DECALCIFICATION BEGINS, SEVENTH TO EIGHTH YEAR.
SHEDDING PROCESS TAKES PLACE, ELEVENTH TO TWELFTH YEAR.
AVERAGE LENGTH OF CROWN, .21.
AVERAGE LENGTH OF ROOT, .44.
AVERAGE LENGTH OVER ALL, .65.

The anatomy of this tooth being almost identical to that of the lower first permanent molar, it will be unnecessary to enter into a description in detail. The lobes, and consequently the grooves, are the same in position, name, and number, and a similar developmental process is recorded. The tooth is not characterized by a prominent cervical ridge, such as is found upon the lower first molar, the crown passing very gradually into the root-base with neck moderately constricted.

FIG. 174.—Lower second molar, buccal surface.

THE PULP-CAVITIES OF THE DECIDUOUS TEETH

A few general remarks in reference to these cavities, in connection with the information to be derived from the accompanying chart and its annexed description, will sufficiently instruct the reader, without the necessity of treating each tooth individually. The pulp-chambers and canals, like those of the permanent organs, assume the form of the external contour of the tooth, the crown being provided with a central cavity, the pulp-chamber, partaking of outlines closely resembling those of the crown, while the root is traversed by the pulp-canal, likewise conforming to the shape of the

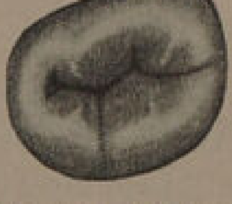


FIG. 175.—Occlusal surface.

root. One very important distinction between the pulp-chambers and canals of the deciduous teeth and those of the permanent organs is that the former are proportionately larger. It must also be noted that

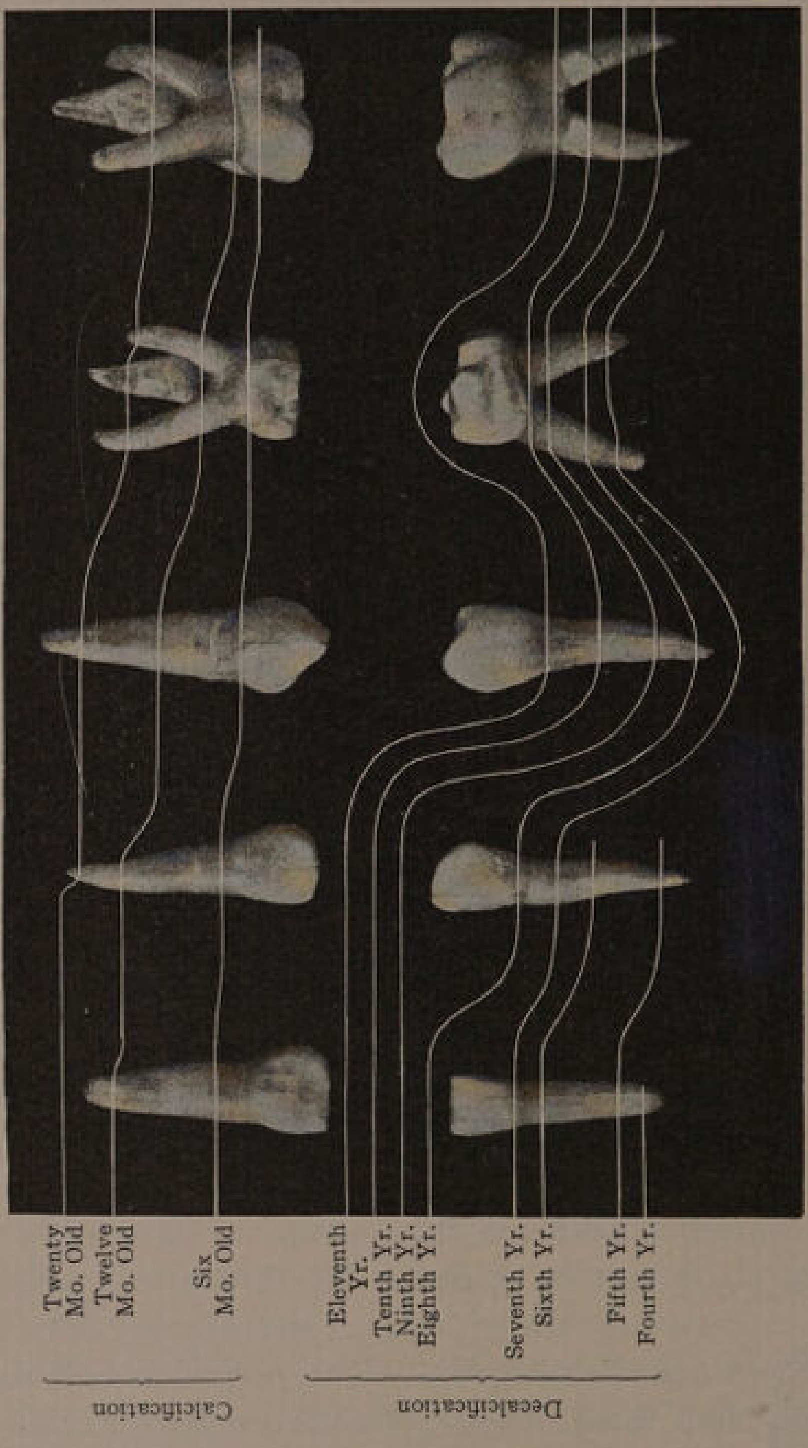


FIG. 176.—Chart showing calcification and decalcification of the deciduous teeth and the consequent length of the pulp-canal at various periods.

the apical foramina in these teeth are so transitory in their nature that there remains but a very brief period during which the canals may be said to be fully formed. It will be recalled that in a very short time after the roots have become completely calcified, decalcification begins, and this process of degeneracy continuing without interruption until the roots are completely absorbed.

With the canals proportionately larger than those which occupy the roots of the permanent teeth, the foramina during their very limited existence are also much larger, and much more readily penetrated. With these ever-changing conditions in the pulp-canals of the deciduous teeth, it is of importance that a definite knowledge of what takes place should be acquired, and it is for this purpose that the accompanying chart has been prepared (Fig. 176).

PART II.—HISTOLOGY AND HISTOGENESIS

CHAPTER I

General Cytology; General Embryology; and Histogenesis

The foregoing pages have been devoted to the description of the face and oral cavity, so far as they can be studied with the naked eye, either by close inspection, superficially as it were, or after their component parts have been made manifest by dissection. That part constitutes what is commonly known as *gross* or *macroscopic anatomy.*

Similar to all other regions of the body, however, the functions of the individual parts composing the face and the oral cavity, in health, and the pathological processes which take place in them when they are diseased, are dependent on the normal or pathological condition of the minute structure or *tissues*, of which these parts are composed. These minute structures cannot be seen with the naked eye, they must be examined with the aid of a microscope, and this part of study is therefore known as *microscopical anatomy* or *histology*—the science of tissues.

The minute structures of the face and oral cavity, generally speaking, in no way differ from the structures of other parts of the body, but here, more than in any other region of the body, the anatomy as well as the histology of the parts cannot be well understood, unless their gradual formation or development—*embryology*—is studied. To enable the student of dentistry to understand more intelligently the details of the parts in which he is most interested, it is therefore essential to have a more or less thorough knowledge of the broad principles underlying, not only the mature structural arrangements of the human body, but also the development of the organs—*organogenesis*—as well as the development of the tissues of which these organs are composed—*histogenesis*.

In submitting parts of different organs of the body to a more close examination with the microscope, we find revealed a great variety of more or less complex textural arrangements, each characteristic of the part examined, and adapted to the function which the given part has to fulfill. Some tissues we find consisting of either very thin or more or less coarse *fibers* running parallel to each other in a compact fashion and forming firm or elastic bands; others we find showing the same kind of fibers loosely arranged and interlacing with each other, thus forming more or less typical networks. In some instances we find similarly formed elements, so-called *cells*, joined together in a mosaic-like fashion and forming either coverings of surfaces or various tubes or sacs. The majority of organs consist of fibers and cells, modified and combined together in either a simple or more or less complex manner. We also observe that the substances filling the spaces between the fibers and cells, the so-called *ground substances*, vary in their consistency; it may be a fluid or a semifluid, it may be of a more or less firm nature, or it may be very hard. Notwithstanding this great variation, however, all the tissues of which the animal body is composed can be grouped into five distinct classes, each one of which has its well-defined characteristics of structure, which makes it specially adapted to the various functions which it has to fulfill in the animal economy. These classes comprise the *elementary tissues*, which by their various modifications and combinations form all the organs of the body. They are the following: (1) *Epithelial tissue.* (2) *Connective tissue.* (3) *Muscular tissue.* (4) *Nervous tissue.* (5) *Blood and lymph.*

Before we attempt to describe the individual elementary tissues, it is necessary to become familiar with some features which are common to all of them. This can be best accomplished by giving a brief history of the beginning and gradual development of our knowledge on the subject.

The principal features in the minute structure of animals are the same as of plants, and it may be justly stated that animal histology took its origin from the histology of plants. In 1667 Robert Hooke published the results of his microscopical investigations of a piece of cork. He found that it consists of a number of small boxes or cells, and thus the name *cell* was introduced into histologic nomenclature. In 1838 the botanist *Schleiden* published the results of his elaborate studies of plant structures, and established the fact that, no matter how widely individual plants and parts of plants differ from one another in their general appearance, in their minute structure they reveal themselves as constituting aggregations of cells, or modifications of such. He, however, laid particular stress upon the fact that each cell contains a substance, semifluid in nature, which constitutes the essential, life-carrying part of the cell, which by later investigators was named *protoplasm.* Furthermore, he found that within the protoplasm there can always be distinguished a kernel-like body, which was named *nucleus.*

Inspired by personal contact with Schleiden, the anatomist *Schwann* undertook extensive examinations of various tissues of animal bodies. In 1839 he published the results of his investigations and established the fact, that no matter how widely various animals and organs of animals differ in regard to their general appearance, in their minute structure they always present aggregations of cells, or modifications of such.

This conformity in the results of the investigations of Schleiden and Schwann has revealed the most interesting as well as the most important fact, that just as all chemical compounds have as their ultimate units the atoms or the molecules, so all living tissues have as their ultimate units the cells. This forms the foundation for all considerations of

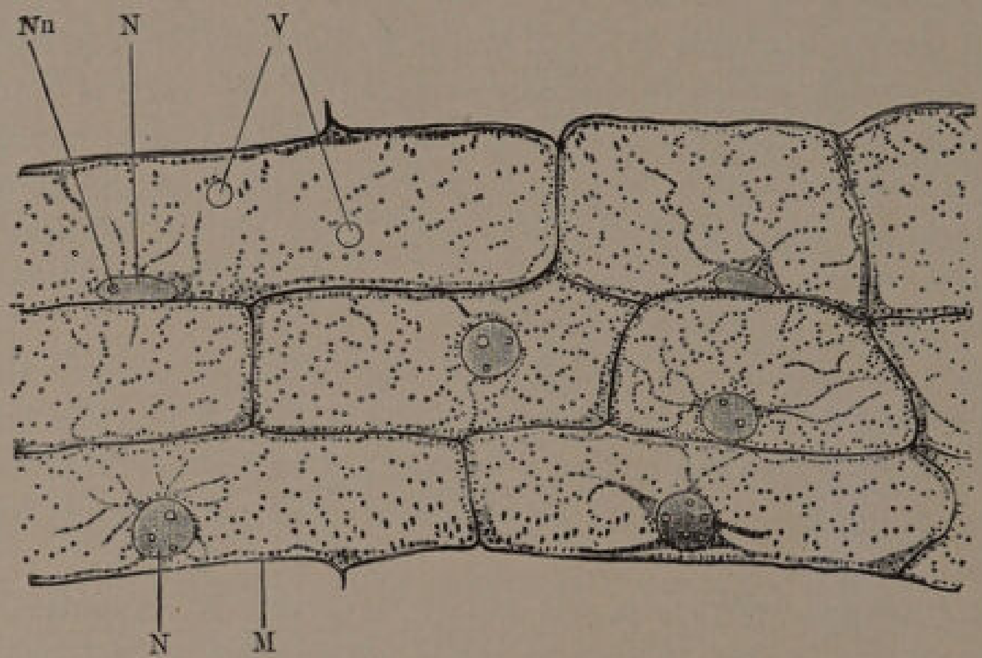


FIG 177.—Cells from bulb of a fresh onion forming a membrane. *M*, Cell membrane; *N*, nucleus seen from the surface; *Nn*, nucleus; *V*, vacuoles, ×240. (*After Stirling.*)

plant and animal histology up to the present time, notwithstanding the recent advancement in our knowledge of the structure and life of the cell itself.

According to the views of Schleiden, Schwann and their contemporaries, a cell consists of: (1) a cell-membrane; (2) a substance contained within—a protoplasm; and (3) a small kernel-like body—a nucleus.

Continuous extensive studies of the structure of cells in various animal tissues have, however, very soon revealed the fact that while in all cells there can always be demonstrated a protoplasm and a nucleus, the presence of a cell-membrane is an exceedingly rare occurrence, and that this part, therefore, cannot be considered as an essential one in the structure of a cell. It was also found that there may be a number of other structural elements present in one or the other kind of cells, but by their absence the individuality of the cell is by no means lost. The establishment of these facts naturally led to a change in the conception of the cell-structure, and in 1861 a distinguished investigator, *Max Schultze*, narrowed down the definition of a cell to *a mass of protoplasm containing a nucleus*, and this definition is generally accepted as the most appropriate one up to the present time.

Another very important point pertaining to the conception of the cell has attracted the attention of all well-known investigators for a long time, namely, the origin of cells in general, and the formation of new cells in the different tissues for substituting old ones when they are worn out or lost through injury or disease. It was at one time believed that cells may originate spontaneously by transformation from organic or inorganic chemical compounds. By persistent investigations it was however gradually determined that the so-called *spontaneous generation* is much less frequent than had at first been supposed, and at present the belief in the formation of cells in that way is given little credence. It is definitely established that all varieties of animal cells, no matter to which class of tissues they may belong, always originate from preexisting cells of the same kind. Furthermore, it was ascertained that while the different tissues of the animal body can be easily distinguished from one another in their mature state, there are great similarities between them in the early periods of the development of the animal. These similarities become the more pronounced the further back we trace them to their starting-point, and find that all tissues collectively take their origin from the same source, namely, from the *ovum* or *egg*, which, according to our present knowledge, is also nothing other than a single cell.

The polymorphism of cells, or the great variety of cell-forms, which was observed in the animal body, has naturally suggested the assumption that the structure of cells with their essential and accessory parts is by no means a simple one, and further investigations have proved this to be correct. The study of cells and tissues has been greatly facilitated by the discovery of various substances, animal as well as vegetable, and particularly chemical compounds, which, when brought in contact with the tissues, show a distinct chemical affinity to the different parts of it and possess the ability of staining them in a distinct characteristic manner. Some of these substances stain the protoplasm of the cells and are therefore called *protoplasmic stains*, others stain the nucleus and are therefore called *nuclear stains*. By application of these staining materials it was made possible to reveal the details in the structure of the various cells, and in the following we will give a description of the minute structure of the cells, as it is generally accepted, and may be observed in one or the other kind of physiologically differentiated cells during the various stages in their life-history.

According to the statement made above, the essential parts of a cell are the *protoplasm* and the *nucleus*. The term *protoplasm* is however used in modern histology to designate the substance of the whole cell, while the substance of the cell-body surrounding the nucleus is termed *cytoplasm;* the substance of the nucleus is sometimes termed *nucleoplasm*, but most frequently simply *nucleus*. We will also use these terms in our description.

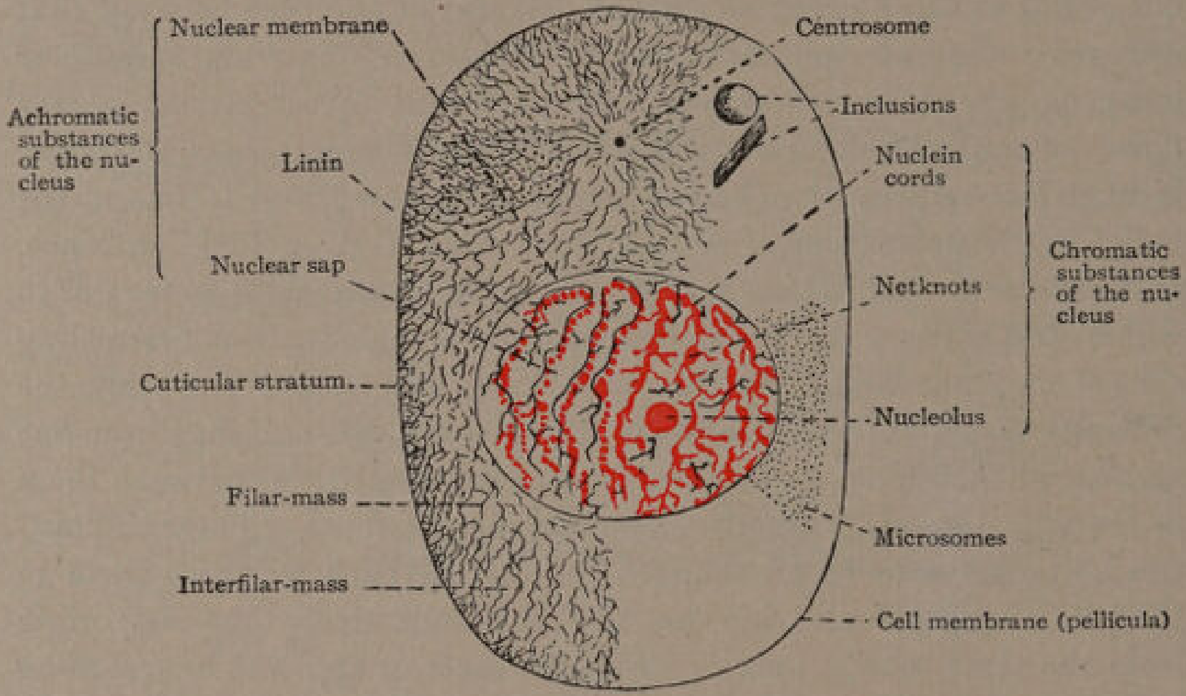


FIG. 178.—Scheme of a cell. Microsomes and filar-mass only partly sketched. (*Stohr*.)

Cytoplasm.—The structure of the cytoplasm has been described differently by different investigators, and several theories have been advanced in that respect. Some have described it to be of an homogeneous nature; others found it to be reticular; again, it was claimed to be granular; by some it is supposed to be foam-like. Thanks to experimental research-work carried out within recent years, it is now positively known, that the most important of all vital manifestations of the cells—*metabolism*—takes place in the cytoplasm, and this being the case the various stages of the process naturally manifest themselves in the structure of the cytoplasm. In this, and in the diversity of the methods used in preparing tissues for examination, must be sought the cause for the difference in the results obtained. There is a general agreement among histologists, however, that even when fresh, unstained tissues are examined there can be recognized in the cytoplasm two different parts, one forming a reticulum or network and called *spongioplasm;* the other, a substance more homogeneous in character, which fills out the spaces of the network and is called *hyaloplasm.* The reticulum or the spongioplasm may at times show a bead-like structure, thus presenting a *granular* appearance. The hyaloplasm may also be not entirely homogeneous, but contain very fine granules which are known as *microsomes.* There may be also found in the cytoplasm various foreign inclosures, such as particles of pigment, droplets of oil, some apparently empty spaces known as vacuoles, etc. All such inclosures are collectively known as *meta-*, *para-* or *deutoplasm.* There is also very often seen a condensation of the peripheral part of the cytoplasm, constituting what is called an *ecto-* or *exoplasm*, which without any sharp lines of demarcation passes into the more central part, called *endoplasm.* A *cell-wall* or *-membrane* must be considered as a highly specialized part of the exoplasm.

Nucleus.—In the great majority of instances, the nucleus is a spherical or oval body, situated usually either in the center of the cell or nearer to one pole of it than to the other, and varies in size generally in proportion with the size of the cell. In general its structure may be said to be somewhat similar to that of the cytoplasm, as it also consists of a reticulum or network, and a substance, more fluid in nature, filling the meshes of it. The network of the nucleus is however more complicated in its structure. By means of staining the specimens with so-called nuclear stains it has been revealed that the nuclear network consists of two different substances, first, of an exceedingly delicate, non-stainable reticulum, apparently very similar to the one of the cytoplasm, and called *linin;* secondly, of a substance which has the form of threads, or of a network, or of a mass of granules, and has the power of absorbing very actively certain dyes. This latter substance has therefore received the name *chromatin substance* in contradistinction to all other substances of the nucleus, which are not affected by the dyes, and therefore known as *achromatin substance.*

The nucleus is separated from the cytoplasm by a distinct line of demarcation, which is known as *nuclear membrane.* This may however disappear at times, thus making possible an interchange of the substance of the nucleus with that of the cytoplasm. It generally takes place during the process of the so-called cell-division, of which we will speak later.

Nucleolus.—This is a small body found in the center of the nucleus in the great majority of cells. In some instances, as for example in nerve cells, it becomes very conspicuous. The significance of the nucleolus in the cell-life is, however, not as yet well established.

Centrosome.—This is a minute body observed in cells in close relation to the nucleus and generally situated just outside of the nuclear membrane. It consists of a more homogeneous substance and contains in its center a small dot, the centriole. The centrosome can not always be seen, but it becomes very conspicuous during a certain period of activity of the cell, namely, during cell-multiplication, when it plays a very significant rôle.

Other constituents of cells have been mentioned already.

VITAL MANIFESTATIONS OF CELLS

In animals consisting of but one cell, the so-called unicellular organism, all life functions are naturally exerted by this one cell. The results of microscopic and experimental investigations of the last half century have, however, led to the conviction that the life activities of all the familiar higher animals, in health as well as in disease, are dependent on the activities of the cells of which they consist. It is for that reason that, while the study of the details of this subject belong to the domain of physiology, some of the more important points of it are also generally considered in connection with the description of cell-structure. The most conspicuous vital characteristics of cells are the following:

Metabolism.—Of all the vital activities of cells, this is the most essential one. It represents the sum total of all those physico-chemical processes taking place in cells which have as their ultimate result the maintenance of the life and individuality of the cells. It therefore embraces the process of taking into the body material suitable for its nutrition; the process of converting some of it into a part of its own substance to replace that which became worn out; transformation of another part into various kinds of energy; finally, the elimination of substances, not suitable for further use, as waste-products.

Growth.—Newly-formed cells are generally not of the same size as mature cells, therefore a part of the substances assimilated by young cells is used up by them for the increase of their size. This goes hand in hand with the shaping of the cell until it becomes identical with the one from which it originated.

Irritability.—This is a faculty of living cells to respond to various influences; mechanical, chemical, thermical, etc. It generally results in those peculiar manifestations of the cells to which they are specially adapted, for example, secretion, motion, etc.

Conductivity.—This is the ability of cells to convey and transmit impulses from one part of the cell to another and from one cell to another.

Motion.—This is the property of cells to change their relative position to the surrounding media. It occurs in three different forms:

1. *Amœboid Motion.*—Similarly to the *amœba*, cells may send out thin or thick projections from their body, called *pseudopodia*, and if such projections become attached to some foreign object and the rest of the body is drawn after it, there results a creeping motion. Cells endowed with such motion are known as *wandering cells*. In some instances such cells may, by means of their processes, surround foreign bodies and either incorporate them by assimilation into their own body-substance, or deposit them by expulsion into various other localities. Such wandering cells are known as *phagocytes*.

2. *Ciliary Motion.*—Some cells, usually those columnar in shape, have one of their free surfaces beset with a number of delicate, transparent, hair-like processes called *cilia*, which are constantly lashing forward and backward (reminding of the blades of grass in a field, when acted upon by a strong wind) producing a strong current, thus sweeping along various small substances.

3. *Contractile Motion.*—This is generally observed in fiber-shaped cells, such as are found in muscles. It consists of a shortening of the fibers in the direction of its long axis. The result is an approximation of the two ends of the fiber and consequently an approximation of the parts to which the two ends are attached.

Reproduction.—While all the just mentioned cell-properties either serve to maintain their own individuality, or are the manifestations of their function in the animal economy, *reproduction* is the property of cells to form new cells similar to their own, a kind of *rejuvenation*, as it were. The object of this is either to substitute new cells for the ones which have become worn out and cast off, or, by adding new ones to their own ranks, increase their functional ability.

The studies of the structural changes which take place in cells during cell-reproduction, have been pursued with great zeal and enthusiasm during the last four or five decades, because it was through these studies that the true and complex structure of cells was revealed. We will therefore consider this phenomenon in its details at this point.

The cell-structure as described on page 238, is considered as the one which presents the cell in its so-called *resting state*, and the changes which have been observed in it during the process of reproduction are the following:

In the first place, the *centrosome*, whether it has previously been visible or not, becomes very distinctly defined, and divides in two, which gradually separate from one another, and ultimately pass to opposite

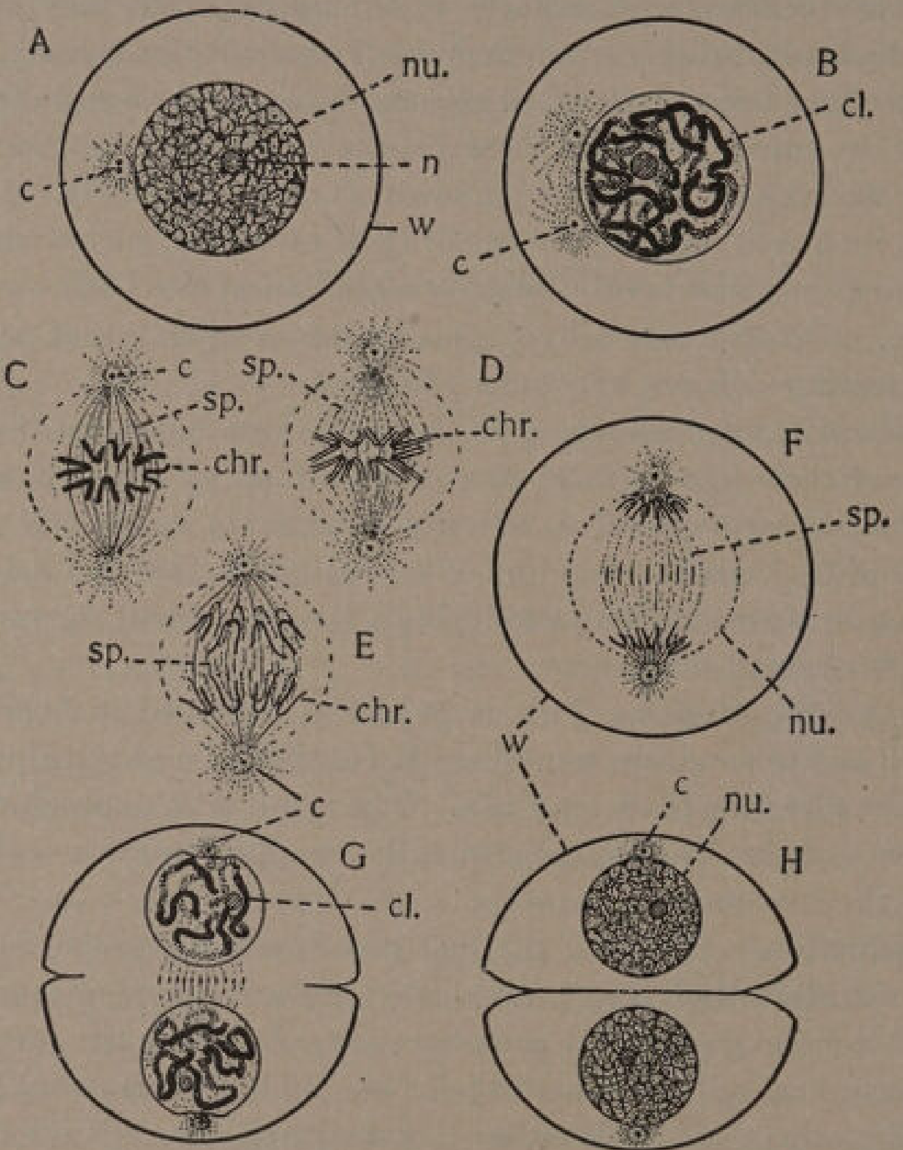


FIG. 179.—Diagram of indirect or mitotic *cell-division; A*, cell with nucleus in *resting* stage; *B*, cell with nucleus in *skein* stage and with *centrosomes* separating; *C*, formation of *chromosomes; D*, longitudinal *splitting* of the chromosomes; *E*, *separation* of the chromosomes; *F*, *diaster* stage; *G*, *H*, formation of the *two daughter* cells; *c*, centrosome; *cl*, chromatin thread; *chr.*, chromosomes; *nu*, nucleus; *n*, nucleolus; *sp.*, nuclear spindle; *w*, cell wall. (*After Galloway*.)

poles of the cell; they remain connected with each other however by means of finely drawn-out non-stainable fibers, known as the *achromatic spindles*.

In the meantime the *nuclear membrane* disappears and the chromatin substance of the nucleus, whatever be its form during the resting stage, assumes the form of a continuous, densely coiled-up thread, which is known as the *close skein*. This coil gradually becomes in a measure entangled, and is then known as the *loose skein*.

The next step is one of the most significant ones in the whole process. The whole chromatin thread becomes broken up into a number of segments known as *chromosomes*, and it is a very important fact that, while the number of chromosomes varies in cells of animals of different species, there is always an *equal number* of them in cells of animals of the same species. The chromosomes become arranged in the equatorial plane of the spindle in a somewhat star-like fashion, and this is then spoken of as the *monaster stage*. Next, a splitting of each individual chromosome in its longitudinal direction takes place, and in this way the number of chromosomes becomes doubled, each one consisting now of a pair, or presenting a twin-chromosome, as it were. The two chromosomes of each pair gradually separate from one another and one of each pair ultimately passes to opposite poles of the spindle, near the centrosome. Here they also assume a star-like arrangement, and we have there what is known as the *diaster-stage*. The chromosomes are generally regarded at the present time as the bearers of *heredity*.

The changes, which take place in each one of the stars, from now on present simply the reverse of those described above for the formation of the monaster, *i.e.*, the individual chromosomes become united with one another, thus forming two skeins. At first the skeins are loose, then a condensation takes place and two close skeins are formed. Finally, around each one of them a membrane is formed, and there appear *two* nuclei similar to the one from which they originated.

While this final shaping of the nuclei is going on, the cytoplasm of the cell becomes constricted half-way between the two nuclei, and when this is completed a division has thus taken place, and we have *two* cells instead of the original *one*.

The various investigators have laid particular stress on one or the other stage during the process of cell-multiplication. Accordingly, various names have been given to the same process, they all have their justification and are in use as synonyms. Taking into consideration the ultimate result of the process, it is called *cell-division*. In view of the fact that the changes are most conspicuously going on in the nucleus, it has been spoken of as *karyokinesis*. Because the chromatin substance of the nucleus assumes the form of a thread, the process is called *mitosis*. Finally, as this form of cell-division is accomplished in a rather complicated round-about way, it is also known as *indirect cell-division*.

While the process of cell-division just described is the most frequently met with, there can be observed a more simple one, which leads to the same end. Without any preliminary rearrangement in its structure, the nucleus of the cell becomes elongated, then it assumes a *dumb-bell* shape, finally the connecting neck becomes broken across and thus two so-called daughter nuclei are formed which gradually separate from one another; in the meantime a *constriction* of the cytoplasm takes place, and as a result there appear two cells instead of one. For the reason that in this form of cell-division the nuclear substance does not assume any thread-like arrangement, and the end is accomplished in a

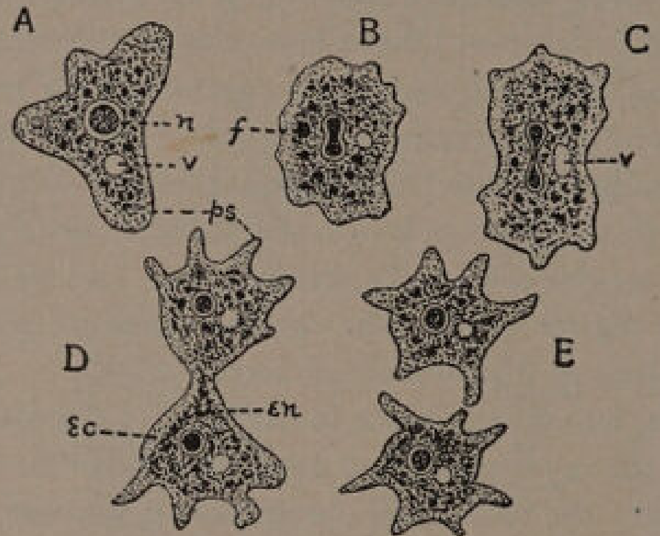


FIG. 180.—Direct cell-division (*Amœba*).—*A*, active specimen with pseudopodia; becoming spherical preliminary to division; *C*, beginning of elongation and constriction; *D*, later stage; *E*, daughter cells forming pseudopodia; *ec*, exoplasm; *en*, endoplasm; *f*, food particle; *n*, nucleus; *ps*, pseudopodium; *v*, vacuole. (*After Galloway*.)

rather simple manner, this process is called *amitosis* or *direct cell-division*. This process has been observed in the white corpuscles of the blood, occasionally in the liver, and not infrequently in pathologic conditions; it is assumed that this mostly occurs in cells having a lowered vitality. There is however much to be learned yet in regard to this question.

ORGANS AND TISSUES

All through the animal kingdom, with the exception of the unicellular organisms, we observe, among the various elements of which they consist, the manifestation of a phenomenon commonly known as *division of labor*. We find groups of cells united together in various fashions to perform a certain function, and such aggregations of cells, specialized to fulfill well-defined duties in the economy of the organism, are called *organs*. Only among the lower animals, however, do we find that the organs consist of only one kind of cell. Higher in the scale of animal organization, we find the organs exhibiting more and more complexity in their make-up. They consist of groups of various kinds of cells, and the individual groups present very little similarity to each other, sometimes becoming modified to such an extent that it is very difficult to recognize the cellular nature of them. While the name *organ* conveys the idea of a physiological unit, the texture of it is known as *tissue*. If the tissue presents an aggregation of elements, similar in character, we speak of *simple tissues;* and where we have an aggregation of elements of various kinds, we speak of *complex tissues*.

To gain a proper understanding of the characteristic appearance of the various simple tissues, their various modifications, combinations and transformations in forming that multitude of structures, which is observed in a mature organism, it is necessary to trace them to their first beginning, or *histogenesis*.

We have stated elsewhere that an animal body takes its origin from the egg, *ovum*, which is nothing else but a single cell. While ova of various types of animals differ in size, they all have relatively the same structure and are all specialized for the same purpose—to produce a new individual. The changes which an ovum undergoes in course of its development into a new individual are in all cases principally the same, and therefore the knowledge gained from the study of one form serves us, in a general way, to understand all others. The study of these consecutive changes constitutes the subject of *General Embryology* and *Histogenesis*.

General Embryology and Histogenesis

In all animals with sexual mode of reproduction, the cell from which the whole organism ultimately develops is itself a product of the union of two highly differentiated and specialized cells; one, supplied by the male individual and formed in the testicle—the *spermatozoon;* the other, supplied by the female individual and formed in the ovary—the *ovum*. These two so-called *elements of reproduction* are derived by transformation of special cells in the body, the so-called *germinal cells*, which are set aside, as it were, for the purpose to be eliminated from the body at certain periods and used as a foundation for the propagation of the species. The process of entrance of the spermatozoon into the ovum, and the ultimate union and fusion of the two elements is known as the *fertilization.* Before this fertilization can take place, however, the ovum has to undergo a preliminary process called *maturation,* which consists in the elimination of half of the quantity of its nuclear substance in form of two small bodies, expulsed at one of the poles of the ovum, and therefore called *polar bodies.** The fertilized ovum is that cell from which a new being gradually develops; and while the mode of development varies somewhat in its details in different species of animals, the general principles of the process always remain the same. In the following we endeavor to give a short general account of the essential points

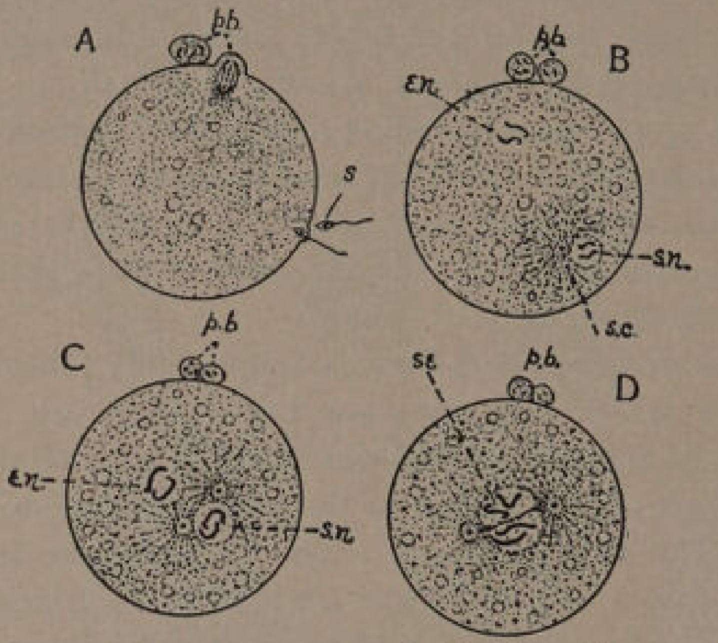


FIG. 181.—Four stages in the maturation and fertilization of the ovum (partly diagrammatic). *A*, formation of the polar bodies and entrance of the spermatozoon; *B*, the male and female pronuclei; *C*, nuclei coming together; *D*, pronuclei uniting to form segmentation nucleus; *e. n.*, egg nucleus; *p. b.*, polar bodies; *s*, spermatozoon; *s. c.*, sperm centrosome; *s. n.*, sperm nucleus; *s.e.*, segmentation nucleus produced by the union. (*After Galloway.*)

in the development of the ovum, but for the details of it we must refer to the various text-books on embryology.

After a short period of rest, the fertilized ovum begins to undergo the so-called process cleavage or *segmentation.* By means of karyokinesis it divides into two halves, producing *two* cells. Each of these cells in turn again divides, giving rise to *four* cells, and this is succeeded by another division, forming *eight* cells, and by repeated division of this kind there arises a solid mass of smaller cells called *morula* or mulberry mass, from its resemblance to a berry. As the cells increase in number, the mass also increases in size by the absorption of nutriment, and a

* By expulsion of the *polar bodies* the number of chromosomes in the ovum is reduced to one-half of it; the fusion with the spermatozoon, which is also supplied only with half the number of chromosomes, the normal quantity is restored and the *fertilized ovum* thus contains heredity bearing substance from both its progenitors.

gradual arrangement of the cells in a definite fashion takes place, varying however with the character of the ovum. They may arrange them-

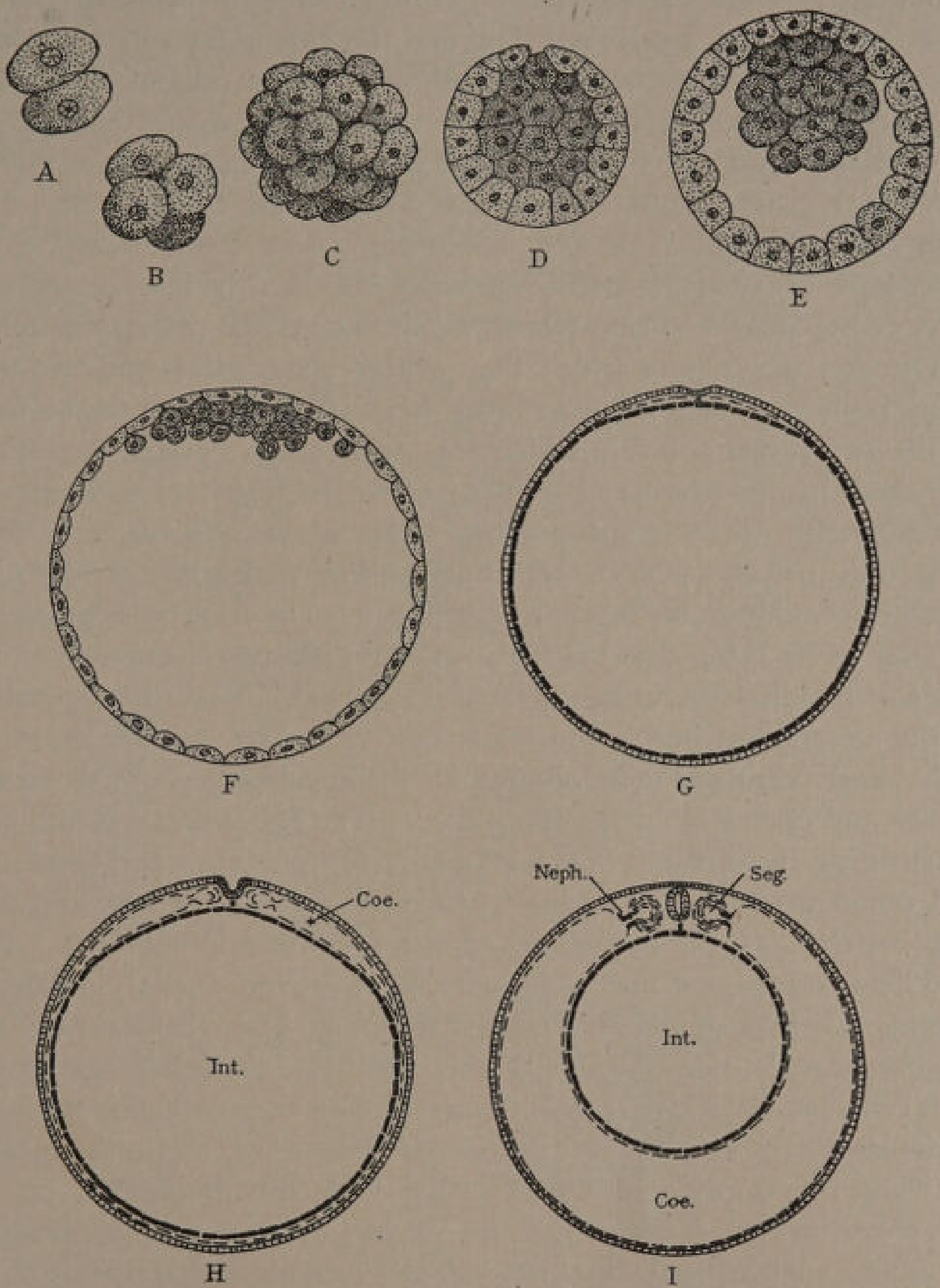


FIG. 182.—Diagrams showing the development of the germ layers. (*After van Beneden and Stöhr.*) *A*, Two-celled stage; *B*, four-celled stage; *C*, morula stage; *D* to *I*, transverse section of various stages of the blastoderm.

selves in the form of a layer of cells spherically surrounding the so-called segmentation cavity; or they may be spherically arranged around a mass of yolk; or they may form a disk-like arrangement, floating as it were on a spherical mass of yolk. In any case we observe the cells to be cylindrical in shape and, lying side by side in regular fashion, form a somewhat skin-like arrangement. This is therefore called the *blastoderm*, which means a germinal skin, and the individual cells are named *blastomeres*. The continuous multiplication of the cells of the *blastoderm* results in either an infolding (invagination) or a splitting off (delamination) of some of the cells, which by their own gradual multiplication form a distinct continuous layer of cells beneath the first one. It is then generally spoken of as a *two-layered* blastoderm, of which the outer layer is called *ectoderm* or epiblast, and then the inner layer *entoderm* or hypoblast. These two layers are called the primary germinal layers, and the cells of which they consist show great similarities in many respects. Very soon, however, some of the cells, on the surfaces of the two primary layers which face each other, detach themselves therefrom by the process of splitting off or delamination and lodge in the gradually widening space between the layers. As the number of these cells increases also through their own multiplication, it very soon becomes possible to distinctly recognize a *third layer* of cells, which, on account of its being situated between the other two, has received the name of middle layer or *mesoderm* or mesoblast. With the formation of the mesoderm, the blastoderm is said to consist of three *germinal layers*, and with this the foundation for the development of the various tissues and organs is finally established. The resemblance of the cells constituting the different layers gradually becomes more and more lost, and differentiation then begins to take place. Through all the consecutive changes, the derivatives of the *ectoderm* and *entoderm* retain the characteristic tendency to be arranged in groups of cells lying closely side by side in a simple or stratified fashion. The derivatives of the *mesoderm* are, on the contrary, characterized by a looser arrangement of their cells, some of which remain connected with one another by means of protoplasmic prolongations or processes, while others retain the faculty of wandering away and intermingling with the derivatives of the other two layers. Each of the three layers gives rise to well-defined structures adapted to distinct physiological functions, but none of them can in this respect be substituted by another, without producing abnormal conditions in the organism.

CHAPTER II

Elementary Tissues: Epithelial Tissue, Connective Tissue, Muscular Tissue, Nervous Tissue, Blood and Lymph

The differentiation of the three layers of the blastoderm into various tissues goes on parallel with the development of the body in general, and with the growing complexity of organization along the scale of the

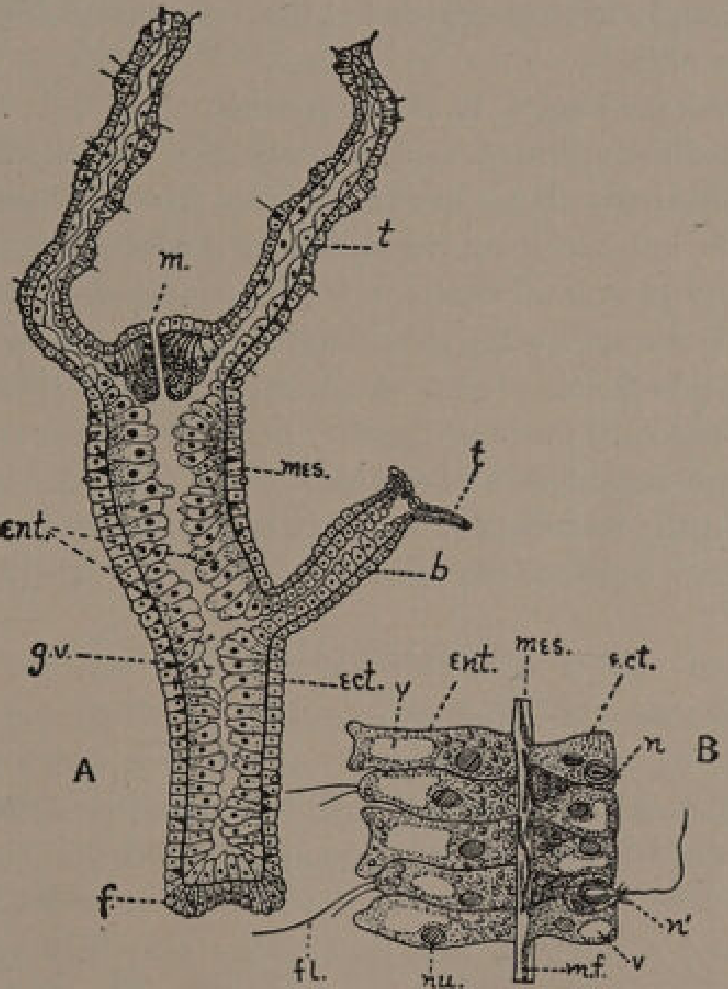


FIG. 183.—*A*, Diagram of a longitudinal section through the body of a Hydra; it presents the structure of an animal, in which the walls consist of only two layers of cells specialized to perform all the function. *B*, a small portion of the wall more highly magnified. (*After Galloway*.)

animal kingdom, the number of varieties of tissues as well as their complexity also increases. On page 234 we have already indicated, however, that we can resolve all the various tissues into five well-characterized typical groups, which are known as elementary tissues. These are:

(1) epithelial tissue, (2) connective tissue, (3) muscular tissue, (4) nervous tissue, (5) blood and lymph.

Among the lower animals there are some which resemble to a considerable extent the early embryonic stages of higher animals. Their walls consist of two layers of cells, which resemble one another very much, and are transformations respectively from the ectoderm and entoderm. They are endowed with the ability to perform all functions which characterize living bodies and represent that typical group of cells known as epithelial tissue. Accordingly, in the higher animals, also, the principal functionating parts of the various organs, including the nervous system, are by various transformations derived from the ectoderm or entoderm, and are either epithelial tissue proper or highly specialized modifications of it.

The mesoderm begins to develop when the other two layers are already well differentiated, and, accordingly, the tissues which take their origin from that layer are found very sparingly, or not at all, in lower animals, but become more and more conspicuous as we ascend in the complexity of animal organization. It gives rise mainly to tissues which, while not constituting the principal parts in the texture of various organs, are nevertheless of very great importance to them and form indispensable auxiliary parts of them. These are the connective tissues, muscular tissue and blood and lymph. Some epithelial formations take their origin in the mesoderm also, but their number is very limited.

We will now consider the individual tissues in detail.

I. EPITHELIAL TISSUE

Epithelial tissue is found as coverings of all surfaces of the body, those directly exposed to the air as well as those which form variously shaped cavities and communicate with the air indirectly through narrow or wide openings. The cells composing the epithelial tissue are known as *epithelial cells*. These are definite in outline, show very clearly a cytoplasm and a nucleus, and lie side by side in a regular fashion. There is just enough substance—so-called *intercellular substance*—between the individual cells to hold the cells together. Three principal forms of cells are generally met with: (1) the flattened or *squamous*, (2) the cylindrical or *columnar*, and (3) the many-sided or *polyhedral*. If a single layer of cells is present, it is known as *simple epithelium;* if there are two or more superposed layers of cells present, it is spoken of as *stratified epithelium*. In simple squamous epithelium the cells are flattened or scaly and the nuclei are round and also flattened. In the stratified squamous variety, which is the one most frequently met with, only the superficial layers are squamous, while the deeper ones are more irregular, and may gradually become columnar.

In columnar epithelium there is quite a variety in the outline of the cells. In simple columnar epithelium the cells may be either long—*high columnar*—or of a medium size—*cuboidal*—or very short—*low columnar*. They may be beset on their free surfaces with numerous minute hair-like processes, which are constantly vibrating during life and are known then as *ciliated epithelium*. In the stratified variety also the superficial layer only may be typically columnar, while the others may be of a different shape. Among a continuous superficial layer of columnar epithelium, there may be found scattered here and there cells which have somewhat the shape of a conical cup and contain in their cytoplasm mucus in various states of formation. From time to time a contraction of their cell-body takes place, and their content, which is of a mucous character, is poured out upon the surface. Owing to their shape, these cells are called *goblet cells*.

The polyhedral epithelium may be found in various localities in the body. If the body of the cells contains some pigment granules, it is known as *pigmented epithelium*. When polyhedral or columnare pithelium is forming the constituting part of the so-called glandular organs, it is known as *glandular epithelium*. A very conspicuous variety of epithelial cells of various shapes is represented in the so-called *neuro-epithelium*, which is specialized for the creation and perception of the special senses.

Epithelial tissue never contains blood-vessels; their nutrition takes place by the absorption of nutritive juices through the clefts between the cells, or the cement-substance. It is obvious that when a stratified epithelium consists of a large number of layers, the superficial ones may receive very little nourishment or none at all, which accounts for the constant exfoliation of cells from the surface skin and other parts.

II. CONNECTIVE TISSUE

Connective tissue is the most widely distributed tissue in the animal body. It holds the individual parts of other tissues together; it connects the various tissues with one another, and at the same time keeps them separated from one another; it gives firmness to the body as a whole, and a support for the various organs within it; it forms variously constructed channels for the distribution of the nutritive material to the various parts of the body. With the variety of functions just enumerated there is a corresponding variety of forms in which connective tissue is found represented in the body.

We have stated above that connective tissue takes its origin from the mesoderm. With the advance in the differentiation of the ectoderm and entoderm the derivatives of these two layers gradually become separated from one another, and the changes of the mesoderm follow closely in their steps. It becomes split into two secondary layers, one of which attaches itself to the derivatives of the ectoderm, ready to serve them with the above-enumerated functions, and is called *parietal mesoderm*, while the other plays the same rôle in regard to the derivatives of

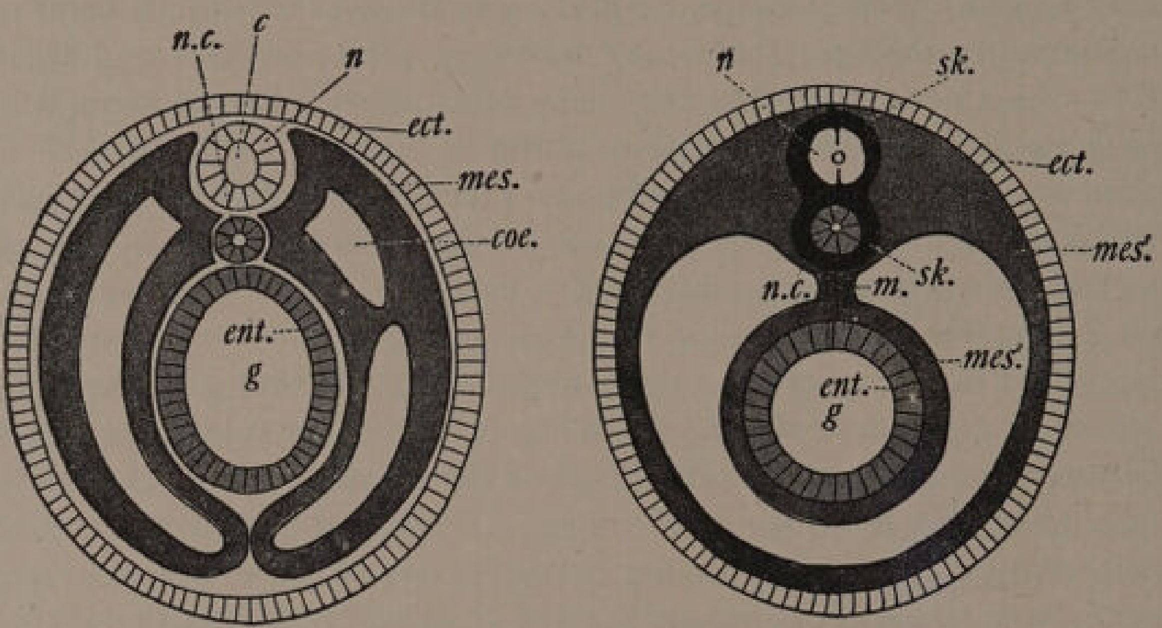


FIG. 184.—Diagrams of transverse sections through the body of an embryo of a vertebrate. It shows the relation of the three germinal layers. *ect.*, Ectoderm; *ent.*, entoderm; *mes.*, mesoderm; *coe.*, coelom or body cavity; *sk.*, beginning of skeleton; *n.*, beginning of spinal cord; *g*, lumen of the gut. (*After Galloway.*)

the entoderm, and is called *visceral mesoderm*. The gap, which remains between these two secondary layers, is known as the *body-cavity* or *coelom*. The characteristic feature of the mesoderm tissue is that the cells do not lie side by side and form continuous layers, but are separated from one another, sometimes quite considerably, and the spaces between the cells are occupied by a substance somewhat gelatinous in consistency which is called *intercellular substance* and is obviously a product of the cells themselves. The cells are stellated or spindle-shaped, and their thinned-out processes unite and interlace with one another, forming a network. The formation of the various forms of connective tissue from the mesoderm in course of development is due mainly to the differentiation and various chemical changes which that *intercellular* substance or *matrix* undergoes. In view of the fact that the intercellular substance constitutes the predominating part in connective tissue, it is the feature upon which the classification of this tissue is based, and we can distinguish five well-defined characteristic groups: (1) *mucous* or *embryonic connective tissue*, (2) *ordinary* or *fibrous connective tissue*, (3) *cartilage*, (4) *bone*, (5) *dentin*.

Mucous or Embryonic Connective Tissue.—This tissue closely resembles in its structure the mesoderm tissue in earliest stages of the embryo, as described above. It consists of a semi-gelatinous, mucoid matrix, and within it are scattered stellate or spindle-shaped cells, and here and there thin fibers. The latter present mainly the elongated and anastomosing processes of the cells, some of them, however, are undoubtedly products of the matrix itself, by a process that reminds somewhat of coagulation. This tissue is found at birth in the umbilical cord as the so-called jelly of Wharton; in the adult human body it is found in the pulp of the teeth and in the vitreous humor of the eye.

Ordinary or Fibrous Connective Tissue.—This tissue is present in the skin and mucous membrane, in the intermuscular tissues, in tendons, in fascia and aponeuroses, and in the tissues connecting various organs. It is composed of a meshwork of fine fibers of *two* kinds. The first, which makes up the greater part of the tissue, is formed of very fine, *white*, structureless fibers arranged closely in bundles and bands crossing and intersecting in all directions. The second variety, or the *yellow*, elastic fiber, has a much sharper and darker outline, not arranged in bundles, but is intimately mingled with the white fibers by twisting around and among its filaments. These are known as the elementary connective-tissue fibers. The size of the connective-tissue bundles depends upon the number of elementary fibers present, and by a variation in the arrangement of the bundles variety in the character of the fibro-connective tissue is produced in different localities. When the fibrous connective tissue is formed into an unbroken mass, as in mucous membrane, the minute bundles are collected into smaller or larger groups (the *trabeculæ*), and these are in turn associated into groups. In the skin and mucous and serous membranes, the trabeculæ of the connective-tissue bundles are separated, and, by crossing and recrossing one another, form a dense, fan-like structure. In other tissues, as the tendons and fascia, the bundles are arranged in parallel layers. In the submucous tissues the connective-tissue fibers are loosely woven, the fibers crossing and intermingling, with the intervening spaces unusually large, resulting in a loose, flabby tissue. Two varieties of fibrous connective tissue are distinguished—namely, (*a*) *Compact* or fibrillar connective tissue, forming bands of either white fibers, or yellow elastic fibers, or mixed fibers; and (*b*) *loose* or *areolar* connective, forming a network or *reticulum*. Modifications of the loose variety are found represented in *adipose* tissue and *lymphoid* tissue.

The fibrous connective-tissue cells are few in number, of several varieties, and variously shaped, being flattened, stellate, or apparently distorted by pressure from surrounding cells or fibrous bundles. In the mucous membrane the cells are oblong and somewhat flattened, having many branches which reach out and, uniting with like processes from neighboring cells, form a network. Other connective-tissue cells are comparatively larger, oval or rounded in form, granular in appearance, rich in protoplasm, and are known as *plasma-cells*. The body of connective-tissue cells, besides containing a nucleus, frequently contains pigment-granules; these are known as *pigment-cells*. These are seldom found in mucous or serous membranes, being principally confined to the integument. Fat-globules may also be found in fibrous connective tissue, and when of considerable size unite and form a rounded cell, called a *fat-cell*. Numerous fat-cells uniting, and well supplied with blood-vessels and nerves, form *adipose* tissue, or fat. Fat-cells are frequently found in areolar tissue as well. When fibrous connective tissue is immediately contiguous to epithelium, it becomes somewhat modified and a new membrane is formed, called the *basement membrane*, or *membrana propria*. This membrane is a thin, transparent, structureless layer, and, when in connection with those mucous membranes provided with a layer of vascular fibrocellular tissue, may appear as the formative substance out of which successive layers of epithelial cells are generated. In the ducts and glands—for example, the salivary glands—the basement membrane forms the proper walls of the tubes, and the cells here generated, and corresponding to the epithelial cells of the coarser mucous membranes, are known as *gland-cells*, rather than epithelial cells. This, however, is a distinction without a perceptible difference, the location and function as secreting cells being alike in each.

Cartilage.—Cartilage is a semi-opaque, non-vascular tissue, white in color, and composed of a matrix containing nucleated cells. The matrix is somewhat elastic and rather dense. The cells are simple in form, being spheric or slightly inclined to angularity. The variation in the character of cartilage is due rather to the difference in the character of the matrix than to the cellular structure, the principal variation in the cells being in their size. The cells lie in the spaces or lacunæ of the matrix, which they completely fill. Investing the free surface of most cartilaginous tissue (articular cartilage excepted) is a thin but tough and firm fibrous membrane—the *perichondrium*. This membrane is well supplied with blood-vessels and nerves, and is essential to the growth and maintenance of the cartilage. There are three varieties of cartilage—namely, hyaline cartilage, elastic cartilage, and fibrocartilage.

Hyaline cartilage is of a faint pearly-blue color, slightly transparent, and is found investing the articular ends of the bones—for example, the condyles of the mandible; also forming the costal and nasal cartilages, as well as those of the trachea, bronchi, and a part of the larynx. Hyaline cartilage is distinguished by a granular or homogeneous matrix. The cells, which contain a nucleus with nucleoli, are usually grouped together in patches, and are somewhat irregular in outline, appearing flattened near the free surface of the tissue in which they are placed, and inclined to be perpendicular to the surface in the more deeply seated portions. The matrix is dimly granular in appearance, resembling ground glass, and receiving its name from this fact. That part of the cartilage close to the perichondrium is supplied with cells much smaller than those occupying the lacunæ in the substance of the mass, and the growth of the cartilage is most active in this part. Lining each lacuna is a delicate membrane (the capsule), which primarily is but partly filled out, but as the cell or cells increase in size, this membrane is carried to the walls of the lacuna. Articular hyaline cartilage is non-vascular, being nourished by the blood-vessels of the bone beneath.

Elastic cartilage is of a dull-yellow color, and is sometimes called yellow cartilage. It is not present in the mouth, but occurs in the external ear, in the epiglottis, and in part of the larynx. Its structural composition is quite similar to hyaline cartilage, but may be distinguished from it by a network of fine elastic fibers which pentrate the matrix. The cells are rounded or oval, containing nuclei and nucleoli.

Fibrocartilage is yellowish or milky white in color, and is much more widely distributed throughout the body than the elastic variety. It is present in the temporomandibular articulation. Like those previously described, it is composed of cells and a matrix, the latter being made up of fibrous connective tissue arranged in bundles, and for this reason it is scarcely deserving the name of cartilage, only that in other portions continuous with it cartilage-cells may be found in abundance. Between the strata of the fibrous bundles are numerous nucleated cells, which are oval and more or less flattened, and each enveloped in a delicate capsule.

Cartilage is further classified into two divisions—*temporary* and *permanent*—the former term being applied to that kind of cartilage which in the fetus and in youth is destined to be converted into bone (for example, Meckel's cartilage, see page 376); the latter class including all those cartilages which are generated as such, and continue to serve in that capacity. Temporary cartilage closely resembles the hyaline variety, being formed of a matrix, in the lacunæ of which, the cells are located. These cells, however, are not grouped together as in hyaline cartilage, but are more uniformly distributed throughout the matrix.

Bone.—Bone is mainly composed of tricalcium phosphate and cartilage. The matrix of osseous tissue has a distinguishing feature produced

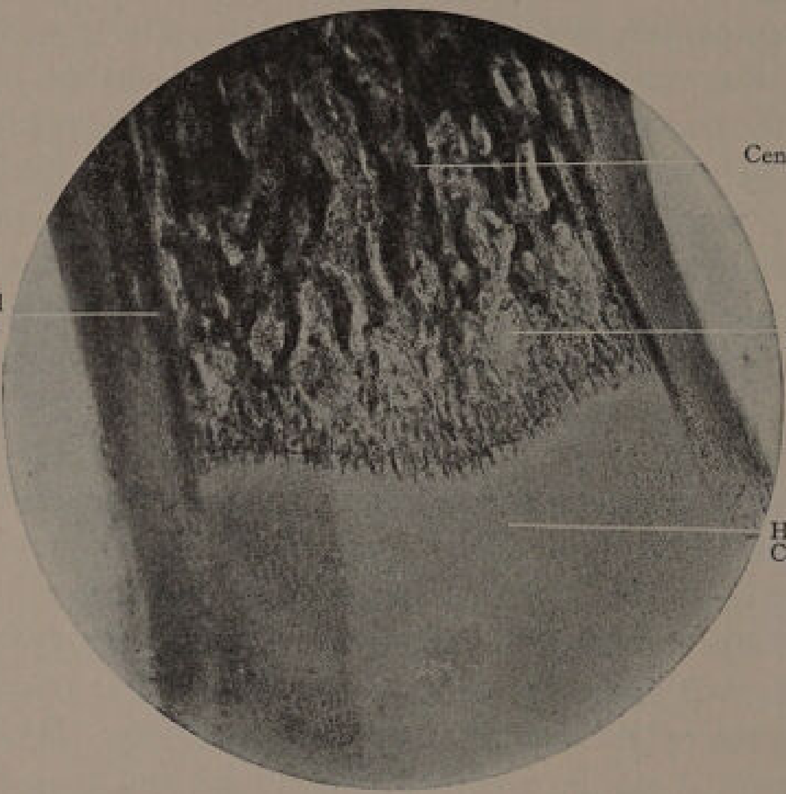


FIG. 185.—Developing bone. × 40.

by the blending of organic and inorganic substances, resulting in hardness, solidity, and elasticity. The combination of organic and inorganic elements in bone is of such a nature that either part may be removed without destroying the other. The matrix is composed of the salts of lime, especially phosphate, and of slendor fibrils united by a cement-substance into bundles of various sizes. The cement-substance is chiefly composed of insoluble lime-salts, principally carbonates and phosphates. These two kinds of structure are found to be present in different parts of the same bone, forming a dense or compact, and a spongy or cancellated tissue. The former occur in the shaft of long bones and in the outer layer of flat or irregularly formed bones. Cancellated bone-substance occurs in the extremities of the long bones and in the interior of flat and irregular bones. The irregularly formed maxillary bones give place to both kinds of bony structure; the external layer of the maxillæ and the body and rami of the mandible are composed of compact tissue, while the interior of these bones and the condyloid processes of the mandible are spongy or cancellated. When examined by the microscope the bony substance is found occupied by numerous little spindle-shaped spaces—*lacunæ*. Branching out from these in various directions are minute canals—*canaliculi*—which anastomose with similar canals from neighboring lacunæ. In the maxillary bones

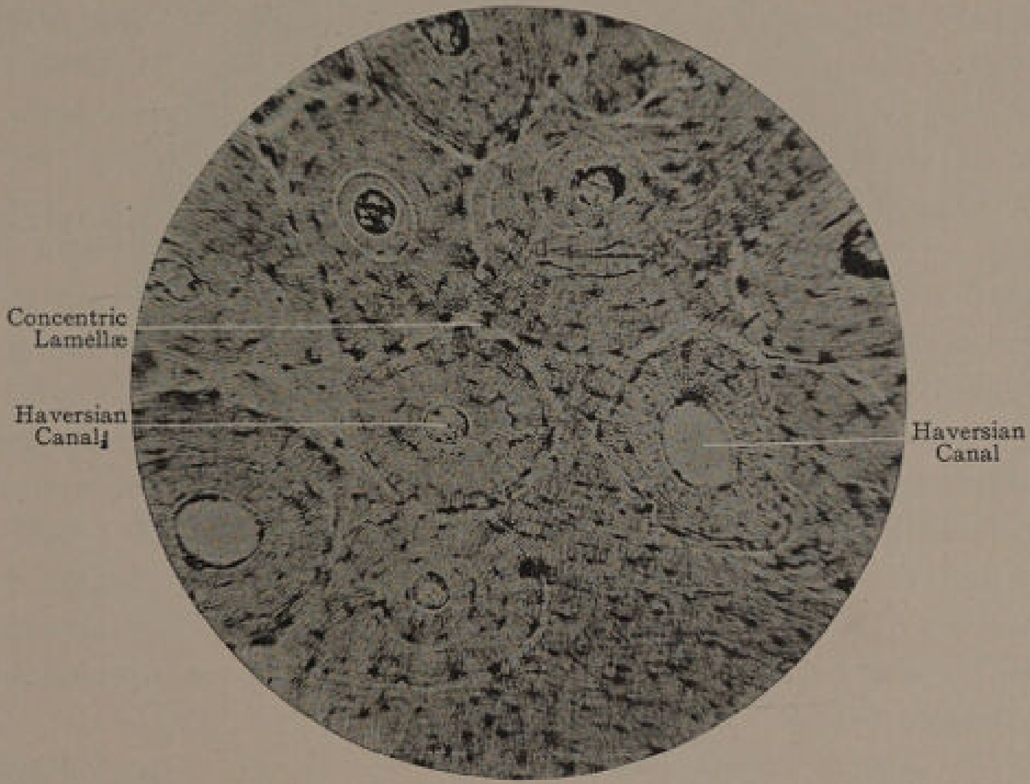


FIG. 186.—Transverse section through shaft of long bone. × 30.

no other canals than these may be visible, but if a transverse section be cut through one of the long bones, an additional space makes its appearance (Fig. 186). These spaces are known as *Haversian* canals. They are circular in outline and appear as a center for a small, circular district mapped out by concentric layers, the lacunæ and canaliculi following the same concentric plan, and through each other communicating with the Haversian canals. The general direction of the Haversian canals is longitudinal with the long axis of the long bones, and in the flat or irregular-shaped bones they are somewhat irregular in formation and ramify in various directions. In the osseous matrix each lacuna contains a bone-cell. These are nucleated, protoplasmic cells.

In developing bone, these cells, which do not completely fill the lacunæ, are connected by numerous branches or processes passing through the canaliculi; in older bone very few processes are observed.

There are two processes by which bone may be prepared for histological examination, one which results in the destruction of the organic elements, and the other which removes the inorganic elements. In the former process the organic matter is removed by simply drying the

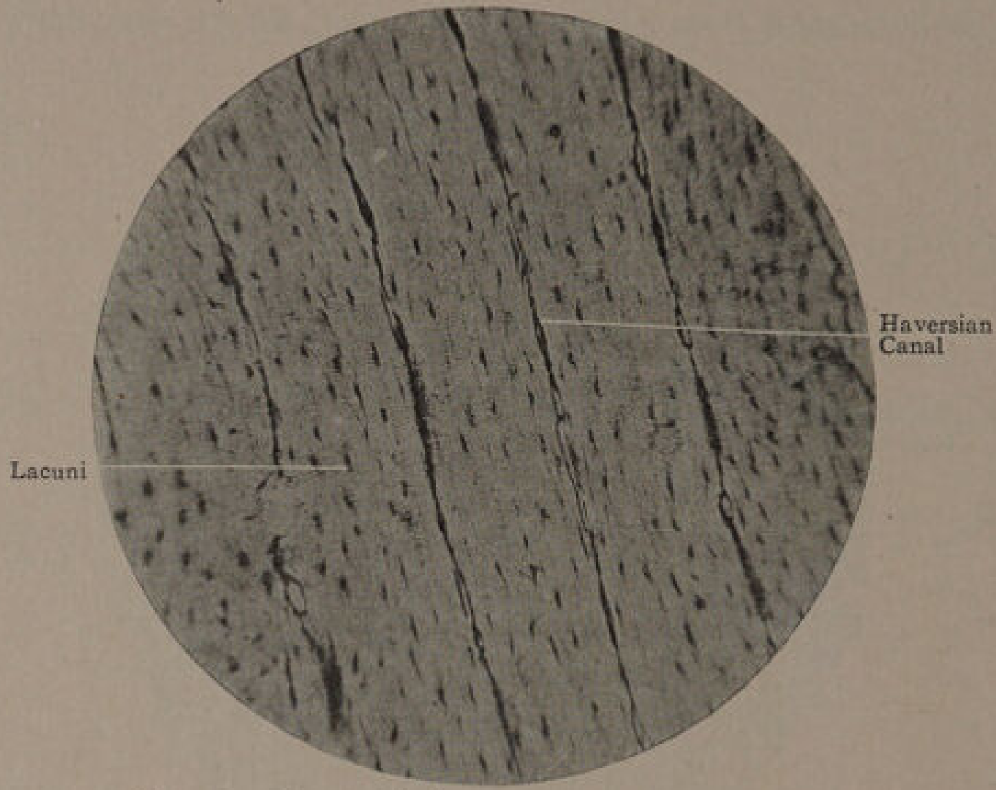


FIG. 187.—Longitudinal section of long bone. × 30.

structure, after which thin sections may be prepared and carefully examined under the microscope, when the Haversian canals, lacunæ, and canaliculi will be seen forming a complete concentric network. In the latter method the inorganic substance is removed by immersing a fresh bone in dilute picric acid, or nitric, which readily decalcifies it, and when properly prepared sections are placed under the microscope the organic contents of the lacunæ and canaliculi alone are visible.

The concentric laminæ of bone is held together by numerous delicate rods or processes named *Sharpey's fibers*, these delicate fibers passing through the laminæ to perform this office.

Periosteum and Bone-marrow.—The interstices of spongy bone are filled with a soft mass—the bone-marrow—and the external surface of the bone is covered by a fibrous membrane—the *periosteum*. This membrane is absent where bones are joined to each other by ligament or cartilage, and over articular surfaces. The periosteum is a compact connective-tissue brmemane. It consists of two layers: an *outer*, fibrous layer rich in blood-vessels, which forms the connection with adjacent structures; an *inner* or osteogenetic layer containing few blood-vessels, loose in texture, but rich in elastic fibers and spheric connective-tissue cells, with oval nuclei. These are the formative cells of bone and are called *osteoblasts*. These cells appear in the lower strata of the inner layer, or the layer in contact with the bone, and are especially numerous during the period of development. Through the blood-vessels of the bone the marrow, internally, is placed in communication with the periosteum externally; small branches given off from the numerous arteries and veins of the periosteum enter the Haversian canals, upon which they pass to the canaliculi, thus communicating with the blood-vessels of the marrow. In like manner numerous nerves enter the substance of the bone, first passing into the Haversian canals, after which they become closely associated with the minute blood-vessels and are distributed to the periosteum and bone-marrow. The bone-marrow, besides filling the interstices of the spongy substance, is also found occupying the central cavity of long bones, and in the larger Haversian canals. The marrow is of two varieties, distinguished by its color, being either red or yellow. Red marrow is found in the flat bones including the maxillæ, the vertebræ, and ribs, while yellow marrow occurs in the long bones of the extremities. Red marrow is composed of a delicate connective-tissue network supporting, besides the marrow-cells, a few fat-cells and giant-cells. In the long bones the yellow marrow is surrounded by a connective-tissue membrane lining the medullary canals. Marrow-cells and giant-cells are present in abundance. Marrow is very vascular and contains many osteoblasts.

Dentin.—This structure, as well as cementum, which in many particulars closely resembles bone, will be fully considered in connection with the histology of the tissues of the teeth.

III. MUSCULAR TISSUE

Muscular tissue consists of elongated or *fiber-cells* and according to the structure of these fibers it is divided into three classes—*non-striated*, *striated* and *cardiac*.

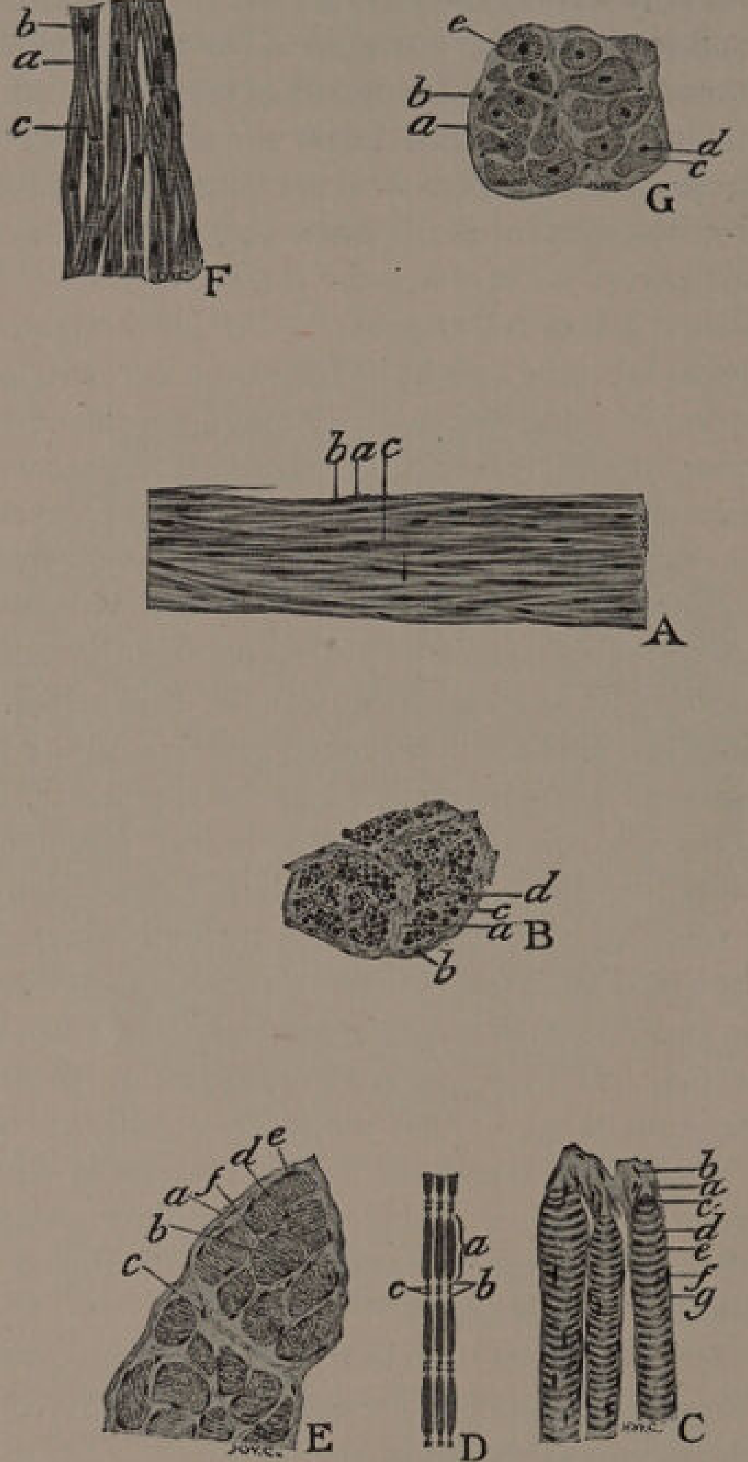


FIG. 188.—A.—Longitudinal section of smooth muscle fibers—*a.* muscle fiber; *b.* nucleus; *c.* fibrous tissue between fibers. B.—Cross-section of smooth muscle fibers—*a.* perimysial connective tissue; *b.* blood-vessel; *c.* nucleated fiber; *d.* nonnucleated fiber. C.—Longitudinal section of voluntary muscle fibers.—*a.* sarcolemma; *b.* nucleus; *c.* end of muscle fiber; *d.* dark bands; *e.* intermediate disc; *f.* nucleus; *g.* lateral disc. D.—Diagrammatic section of cross and long striations.—*a.* dark disc; *b.* lateral discs; *c.* intermediate disc. E.—Cross-section of voluntary muscle—*a.* perimysium; *b.* endomysium; *c.* nucleus of perimysium; *d.* fibrillæ; *e.* nucleus of muscle; *f.* sarcolemma. F.—Longitudinal section of cardiac muscle fibers—*a.* muscle fiber; *b.* nucleus; *c.* branch. G.—Cross-section of cardiac muscle fibers—*a.* perimysial sheath; *b.* nucleus of sheath; *c.* muscle fiber; *d.* nucleus; *e.* radial plates of fibrillæ. (*Radasch.*)

Non-striated, Smooth, or Involuntary Muscular Tissue.—This tissue consists of contractile fiber-cells which are elongated, spindle-shaped, and cylindric, with exceedingly elongated extremities, which become shorter and thicker through contraction. They are quite variable in length ($\frac{1}{10}$ to $\frac{1}{450}$ of an inch), and are composed of a pale, homogeneous-looking protoplasm, each inclosing an elongated or rod-shaped nucleus. The muscular fibers are firmly bound together by a cement-substance, forming fasciculi, which in turn are collected into strata or membranes, which may be disposed parallel, or crossing and recrossing, forming an intricate network. The connective-tissue septa provide a passageway for the larger blood-vessels, while the capillaries penetrate the fasciculi forming a complicated network with oblong meshes. Involuntary muscular tissue is not found in the mouth except in the ducts of the salivary glands. They form the main constituent part of the middle layer or coat of blood-vessels and are particularly abundant in the arteries.

Striated or Voluntary Muscular Tissue.—Striated muscular tissue is composed of long, cylindric fibers, which are regularly transversely striated. In most instances their extremities are attached to bones by means of tendons, as, for example, the cheek- and lip-muscles. The fibers are grouped together by fibrous connective tissue into various sized bundles, forming *fasciculi*. There is much variation in the length of the fibers composing the fasciculi in different muscles. In most instances the fasciculi which serve to make up the bundles of a single muscle continue parallel with one another throughout their length. Surrounding the whole muscle is a layer of connective tissue called *epimysium;* this penetrates between the individual bundles and forms a covering for each of them, which is called the *perimysium,* and passing from this into the substance of the bundle is a still more delicate connective tissue, the *endomysium,* which separates the individual fibers from one another. The former structure carries the larger blood-vessels and nerve-fibers, while the latter supports the capillaries.

Each muscular bundle may again be divided into smaller bundles, which in turn are ensheathed in a similar manner and further divisible, so continuing until the primitive fasciculi, or so-called muscular fiber, is reached. Striped muscular fiber consists of a structureless, elastic sheath, the *sarcolemma,* which structure represents the cell-membrane, and closely invests a number of filaments or fibrils. Besides the fibrillæ, there is contained within this fine, structureless, transparent membrane the *sarcoplasm,* a faintly granular substance resembling protoplasm, but not identical with it. This substance serves in the capacity of a matrix for the fibrillæ. The *nucleus* is found beneath the sarcolemma. The fibrillæ are arranged parallel to one another, being supported by the sarcoplasm. It will thus be seen that each fiber of a striated muscle comprises the sarcolemma, the muscle-nuclei, the fibrillæ, and, finally, the sarcoplasm, filling all the interstices, first between the fibrillæ of each muscle-column, between the columns of each group, and between the groups themselves. The disposition of the sarcoplasm may be most favorably studied by a cross-section through the fibers, appearing as a delicate but clear network, within the meshes of which are the muscle-columns. Striated muscular fibers are usually tapering off and becoming thinner toward their extremities. In rare instances they are branched at their ends. This condition is present in the tongue, the extremities of the fibers passing transversely into the oral mucous membrane, where they become further subdivided. The striated or voluntary muscles make up the muscular tissues of the lips, cheeks, tongues, and soft palate.

Cardiac or Involuntary and Striated Muscular Tissue.—This tissue is found only in the heart. The fibers are short, striated and have a central nucleus.

IV. NERVOUS TISSUES

Until within recent times it has been stated that the nervous tissue consists of two histologic elements known as *nerve-cell* and *nerve-fiber;* that these two elements differed not only in their mode of origin, but in their structure and physiologic endowments. At the present time it is believed that the entire nervous system consists of an infinite number of definite independent morphologic units, which, through having a common origin and a similarity of structure, have, nevertheless, different functions in different parts of the body. This neurologic unit has been termed the *neuron*, and, as represented schematically in figure 192, may be said to consist of: First, the nerve-cell, or neurocyte; second, nerve-process, or axon; third, the end-tufts, or terminal branches. Each of these three main portions of the neuron presents a variety of secondary features which are related to their functional activities.

The Nerve-cells, or Neurocyte.—The nerve-cells are found in the cortex of the brain, in the interior of the spinal cord, in the various ganglia of the cerebrospinal and sympathetic nervous systems, and in the organs of special sense. All neurocytes are the modified descendants of independent oval or pear-shaped cells (the *neuroblasts*), originating from the epithelial cells which form the medullary tube. The neurocyte is at first smooth, devoid of processes, and endowed with ameboid movement. In the course of development the cells project a greater or less number of processes and assume a variety of shapes and sizes, in accordance with variations in functions; thus, the cells may be spheroid, pyramidal, spindle-shaped, stellate, etc. The body of the cell consists of a protoplasmic basis, more or less granular, containing a well-defined nucleus and nucleolus. A centrosoma has also been found in the nerve-cell in many situations. There is no evidence, however, of the existence of a cell-membrane. From the body of the neurocyte there arises one or more protoplasmic processes, which, passing outward in various directions, divide and subdivide into a greater or less number of branches, which are collectively known as *dendrites* or *dendrons*. The ultimate subdivisions and terminations of a dendrite, though forming an intricate feltwork, always end free, never anastomosing with one another. Arising from the cell-body, the dendrites resemble in appearance and structure the cell-protoplasm, or cyto-plasm. In the *cortex of the cerebrum* and in the *cortex of the cerebellum* the dendrites are characterized by short,

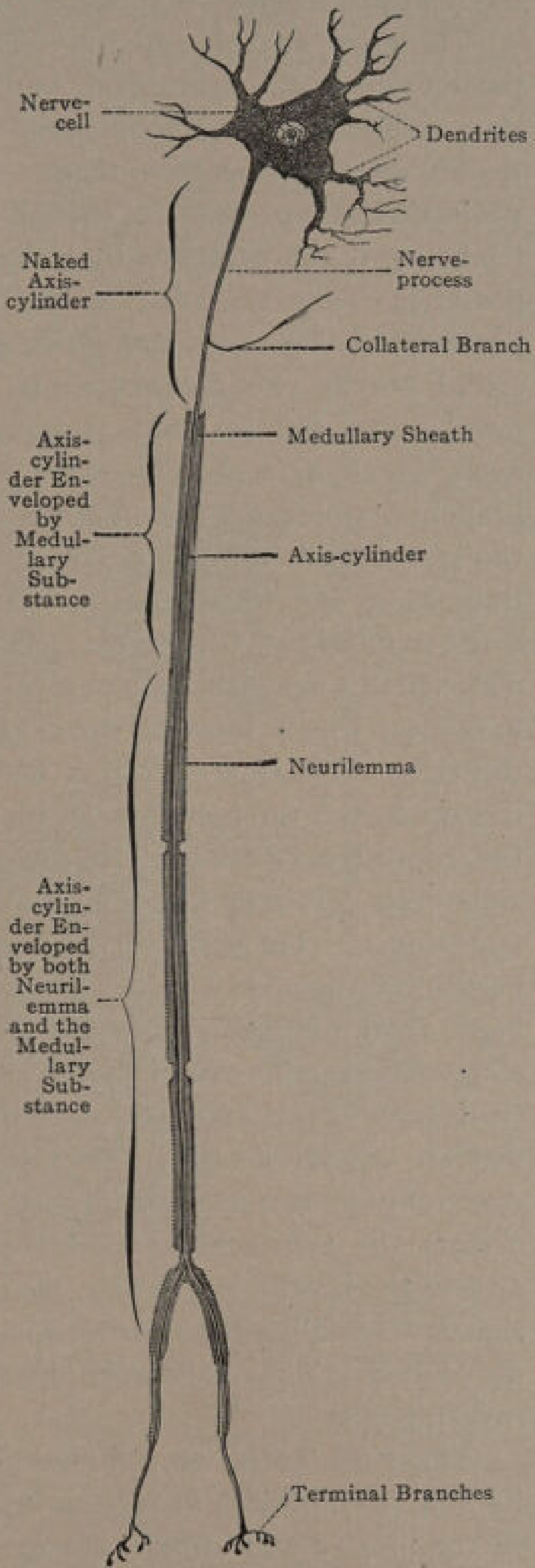


FIG. 189.—Diagram of a Neuron. (*From Stöhr's "Histology."*)

lateral projections known as lateral buds or gemmules, which impart to the dendrite a feathery appearance.

The Axon, or Nerve-process.—The axon is the first outgrowth of the protoplasm of the neuroblast, but with the development of the neurocyte it becomes so differentiated from the dendrites that it can be readily distinguished from them. It usually arises from a cone-shaped projection of the cell-body, though occasionally it arises from a dendrite itself. It is characterized by a short, regular outline and a hyaline appearance. The majority of the cells, especially in the mammalia, possess but one axon, though in the developing ganglion-cells of the spinal nerves two distinct axons are present. In their subsequent development the two axons appear to blend together to form but a single axon, which, at a short distance from the cell, again divides into two branches, which pursue opposite directions, one passing directly into the spinal cord, the other toward the periphery. The axon may continue as an individual structure for an indefinite distance, varying from a few millimeters to 100 cm. In the former instance the axon, at a distance of a few millimeters from the cell, breaks up into a number of branches, which form an intricate feltwork in the neighborhood of the cell. This type of cell is not widely distributed, being confined largely to the cerebellum. In its course the axon, more especially in the central nervous system, gives off a number of side-branches or collaterals, which do not differ from the axon itself, either in structure or appearance. The axon of the peripheral nerves, especially the spinal nerves, are devoid of collaterals throughout their extent, except, perhaps, in the immediate neighborhood of the cell. The more or less elongated axon becomes inclosed at a short distance from the cell with a thick layer of fatty material, forming a medulla or myelin, inclosed by a delicate cellular sheath (the neurilemma), and thus constitutes what is commonly known as a medullated nerve-fiber. In the central nervous system the neurilemma is frequently wanting. In the sympathetic system the myelin is wanting, though the axon is inclosed by a delicate sheath resembling the neurilemma, thus constituting a non-medullated nerve-fiber. The collateral branches are provided with similar investments.

The End Tufts, or Arborizations.—Each axon, as it approaches its final termination, breaks up into a number of branches, which vary in complexity and appearance in different regions. They are always free from any medullary investment, and appear to be formed by the splitting of the axon into a number of fine filaments, which remain independent of one another. In peripheral organs, as muscles, glands, and blood-vessels, the tufts are in direct organic connection. In the central nervous system the end-tufts are in more or less intimate relation with the dendrites of other neurons.

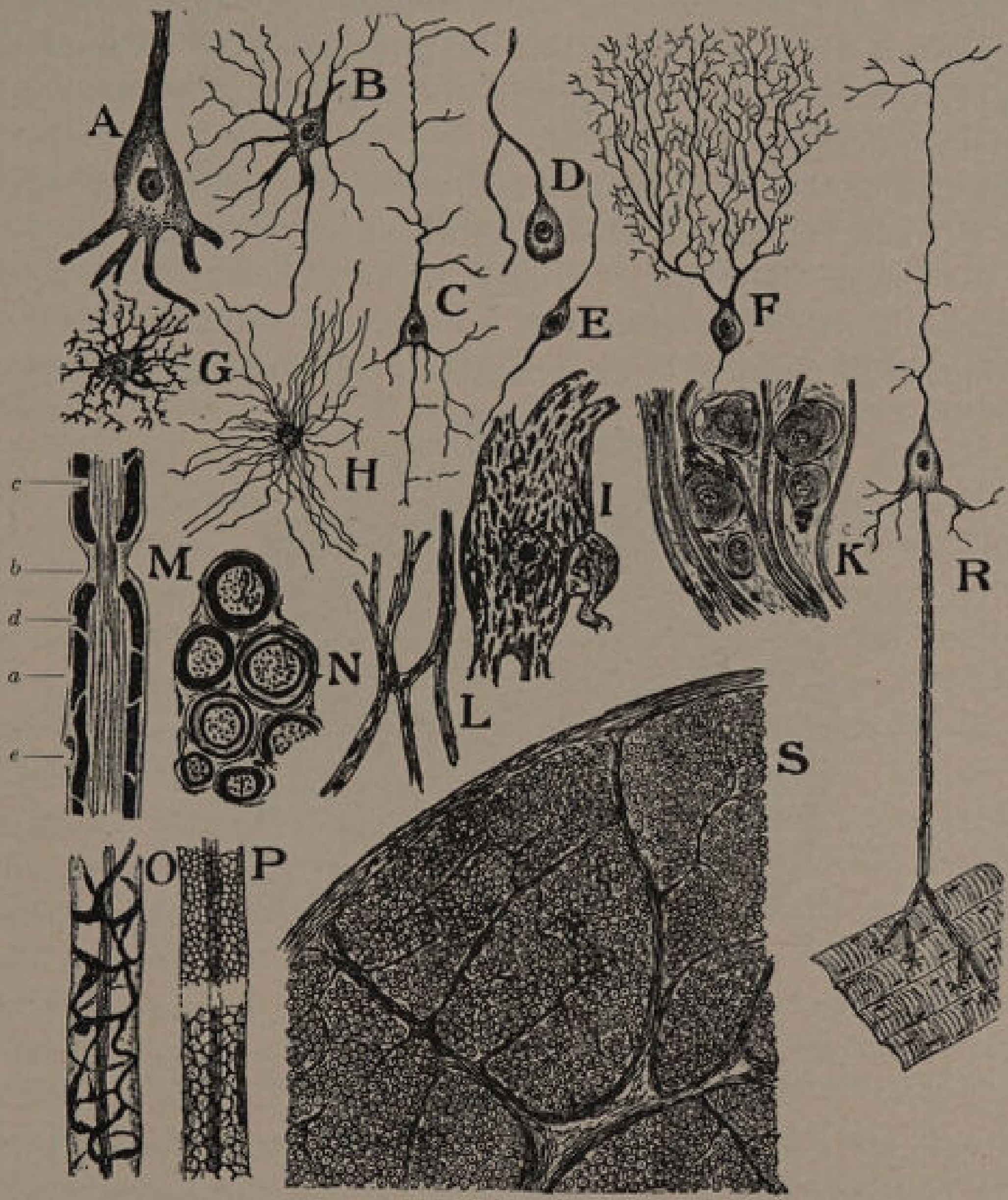


FIG. 190.—A. Multipolar cell from cerebral cortex; B. multipolar cell from spinal cord; C. pyramidal cell from cerebral cortex; D. unipolar cell; E. bipolar cell; F. cell of Purkinje, antler cell; G. mossy cell; H. spider cell; I. cell from spinal cord of an ox, showing pigment granules; K. ganglion; L. sympathetic or amyelinated fibers; M. longitudinal section of myelinated nerve fiber—*a*. neurilemma; *b*. myelin sheath; *c*. axis cylinder; *d*. node of Ranvier; *e*. nucleus; N. cross-section of osmicated nerve fibers; O. myelinated nerve fiber of a guinea-pig, showing the reticulum; P. myelinated nerve fibers of a toad, showing reticulum (neurokeratin); R. motor neuron, showing nerve cell, dendrites, axis cylinder and ending of latter in a muscle; S. cross-section of nerve trunk. (*Radasch.*)

Nerves.—Nerves are to be regarded, therefore, as groups of axons, with their medullary investments connecting the peripheral organ with the central nervous system.

The nerves are arranged in two great systems—the cerebrospinal and the sympathetic. In the cerebrospinal nerves the conducting media—the nerve fibers—are arranged in parallel or interlacing bundles, and these are further grouped into nerve-branches or nerve-trunks. The bundles are connected by intervening fibrous connective tissue (the *epineurium*), and through this the principal blood-vessels ramify to supply the nerve-trunks, together with a plexus of lymphatics and numerous fat-cells and plasma-cells.

The size of the nerve-bundles, or *funiculi*, is regulated according to the size and number of nerve-fibers which they contain. Investing each funiculus, or primary bundle of nerve-fibers, is a connective-tissue sheath—the *perineurium*. The fibers composing this sheath are arranged in lamellæ, being separated from one another by lymph-

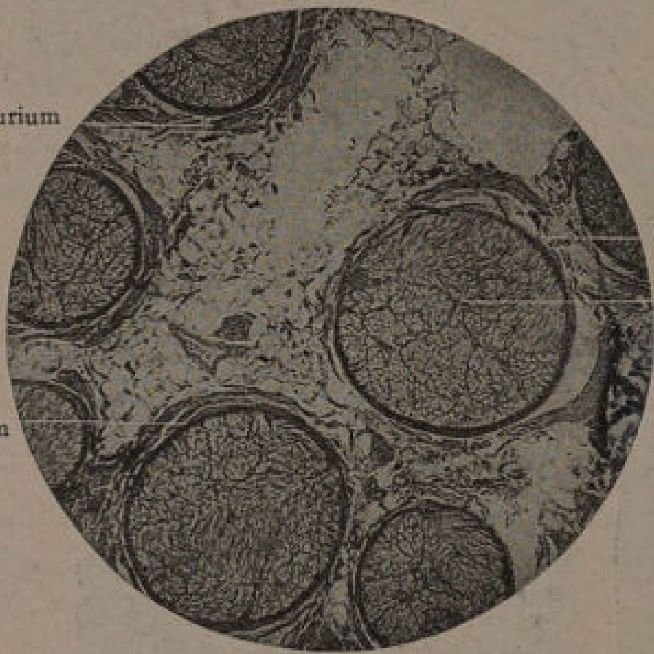


FIG. 191.—Transverse Section, Bundles of Nerve-fibers, Human Median nerve. × 30.

spaces variable in size, through which communication is afforded the lymphatics of the epineurium. Within the bundles the nerve-fibers are held together by fibrous connective-tissue—the *endoneurium*. The epineurium holds together and envelops the several funiculi of the nerve-trunk, the perineurium investing each funiculus, or primary bundle of nerve-fibers, and the endoneurium extending among and around the individual fibers. Nerve fibers are divided into two classes—which classification is dependent upon the presence or absence of a medullary sheath or covering—into the *medullated* or *white*, and the *non-medullated* or *gray*. The *medullary sheath*, or white *substance* of Schwann, is a bright, fatty substance (the myelin) surrounding the axon, or *axis-*

cylinder, the conducting or central part of a nerve-fiber. Between the medullary sheath and the axis-cylinder there is present a small amount of albuminous fluid. Closely surrounding the medullary sheath, and foaming the outer boundary of the nerve-fiber, is the *neurilemma*, or *sheath of Schwann*. Between this delicate, structureless membrane and the medulla there are placed at intervals oblong nuclei, surrounded by protoplasn; these are the *nerve-corpuscles*. Besides the division of nerve-fiber into *medullated* and *non-medullated*, each division is susceptible of further subdivision, dependent upon the presence or absence of the neurilemma. Non-medullated nerve-fibers without a neurilemma are composed of an axis-cylinder only; they are cylindric or band-like in form, transparent, and show faint, longitudinal striations. Nonmedullated nerve-fibers with a neurilemma are composed of an axis-cylinder surrounded by a neurilemma, and are homogeneous throughout their extent.

Medullated nerve-fibers are those which are partly, but never entirely, invested by a medullary sheath. They may or may not possess a neurilemma; in the former instance they consist of an axis-cylinder and a medullary sheath only. The axis-cylinder, or essential part of the nerve-fiber, is cylindric of band-like, occasionally exhibiting a delicate, longitudinal striation, which appearance is due to its being composed of a primitive fibrillæ.

The nerve-cells or ganglia-cells are found in the ganglia as well as along the course of the nerves. They are composed of granular or faintly striated protoplasm, inclosing a characteristic nucleus within which is a nucleolus. They differ greatly in form as well as in size, the spheric, spindle-shaped, and irregularly stellate forms being the most common. In the latter numerous processes are given off, forming the stellate outlines. The cells are variously named, according to the number of processes. If one process is present, the cell is termed a *unipolar* cell; it two, a *bipolar;* and if a number of processes exist, they are named *multipolar*. The processes are of two varieties—the axis-cylinder process and the branched protoplasmic process. The various forms are most readily distinguished in the multipolar cells. The axis-cylinder process is readily characterized by its hyaline appearance and unbroken outline. The protoplasmic processes are thicker, granular, and striated.

V. BLOOD AND LYMPH

It is rather difficult to conceive that blood and lymph may be spoken of as representing one of the elementary animal tissues. The conception of an elementary tissue, as exemplified in the four tissues just considered, carries with it the idea of some well-defined stationary structure. Blood and lymph, on the contrary, present fluids which uninterruptedly stream along within closed channels—the blood-vessels and lymph-vessels. A closer study of the development and structure of blood and lymph, however, reveals a very close relation and great similarity of their cellular elements to those of the other elementary tissues. On the other hand, we must take into consideration that blood and lymph constitute the medium by means of which nutrient and building material is carried to all remotest, as well as minutest parts of the body, and in exchange receives and carries away the waste products. Now, it is quite obvious that the distribution of blood and lymph throughout the body can only take place when the free motion of its constituent parts is not handicapped by a tenacious or solid intercellular substance. It can only be accomplished because the intercellular substance is a fluid. If a quantity of blood is drawn and exposed to the air it coagulates, which means, that the fluid intercellular substance becomes fibrous, and as the density gradually increases its real similarity to other elementary tissues becomes very evident. While, thus, blood and lymph present conspicuous peculiarities, it is nevertheless justifiable to consider them as a distinct elementary tissue. We may define it as: "a tissue like all other tissues, consisting of cells and intercellular substance, but in which the intercellular substance is a fluid."

Development.—Blood and lymph, as well as the channels in which they originate in the *mesoderm*, form groups of cells especially predetermined for that purpose. Some of the cells become joined together by means of their protoplasmic processes in a chain-like fashion, and gradually becoming flattened, form continuous epithelium-like layers known as *endothelium* or *mesothelium*, which ultimately become arranged into the shape of *tubes*. Other cells of the same group do not exhibit any processes of their cytoplasm, they are more or less spherical in outline, and while the formation of the tubes is going on, these cells remain separated from one another and become imprisoned, as it were, within the latter. The gradually developing tubes are the future *blood*-and *lymph-vessels*, and the cells inclosed within the latter are the future *blood*-and *lymph-cells* or *corpuscles*. Between the individual corpuscles there gradually forms an intercellular substance, which becomes differentiated into a fluid known as *blood* and *lymph plasm* and thus a possibility for the cells to stream along within closed channels and fulfill the duties assigned to them in the economy of the body, becomes established.

We also observe, however, that many of the cells belonging to the same group do not meet the fate of the cells just described but retain an independent individuality. Some of them become endowed with a vital characteristic peculiar to one of the lowest unicellular organisms—the ameba, which is known as *ameboid motion*. Owing to this faculty, these cells are constantly changing their place and travel along between

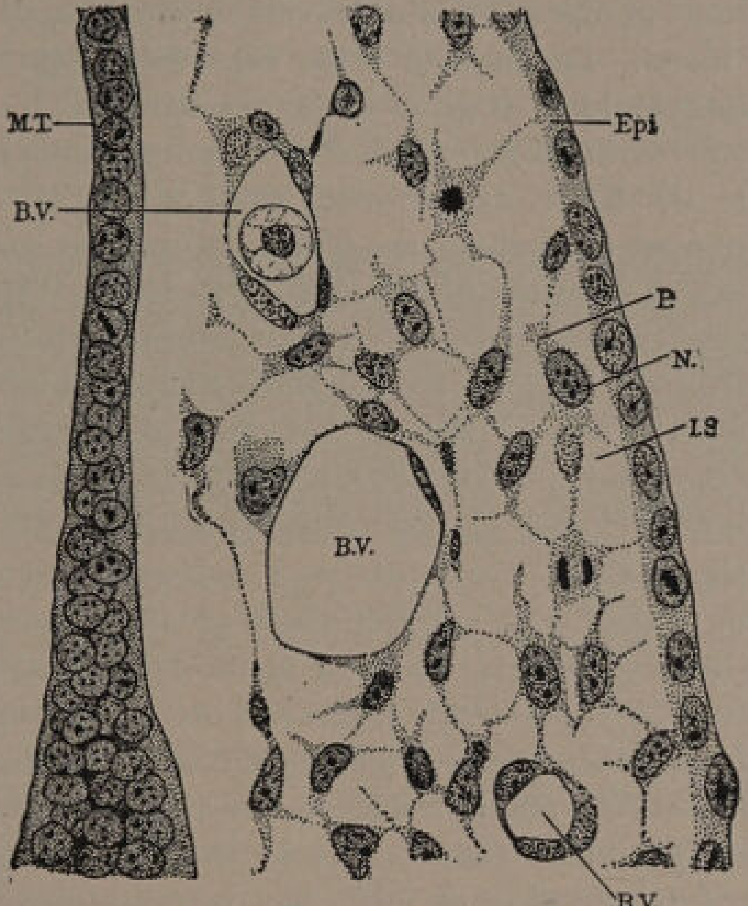


FIG. 192.—Section from the head of a rabbit embryo of ten and one-half days, 4.4 mm., to show Mesenchyma. (*Stohr*.) Epi. and M.T., Ectodermal epithelium of the epidermis and medullary tube, respectively. N., Nucleus; P., protoplasm; and I. S., intercellular substance of a mesenchymal cell. Two of these cells show mitotic figures. B.V., Blood-vessel, lined by endothelium. One of the blood-vessels contains an embryonic red blood corpuscle.

the cells in the variously differentiated tissues, and are therefore known as *wandering* or *migratory* cells. Some of the migratory cells are able to incorporate into their cytoplasm various substances of inorganic or organic nature, as well as whole living micro-organisms. They may either digest them or in traveling along, carry these substances and incidently deposit them in other localities, sometimes quite remote from the place where they have been picked up. These cells are known as *phagocytes*, and are of great significance in the body economy.

Some of these migratory cells are identical with the cellular elements found in the lymph, and are therefore known as *lymphoid* cells. These cells are found distributed throughout the body and, in various localities they aggregate into larger masses and form the so-called *lymphoid tissue* and *lymphoid organs*, of which we will speak later.

Structure.—We have to keep in mind that the ultimate rôle of blood and lymph is to keep up the interchange of substances in the body, which in a general way takes place as follows: The lymph absorbs the ultimate products of digestion, and delivers them, through the thoracic duct, to the blood. Laden with these substances, the blood passes through the lungs and here it gives off the deleterious CO_2 to the atmosphere and receives in exchange a corresponding amount of O. It then passes to the heart, and through the activity of that organ it becomes distributed throughout the body. Now, just as the function of the blood differs from the function of the lymph so these two tissues differ in their structure. The active elements in the process of absorption taking place in the lymph are the above-described migratory cells. They constitute the cellular elements of the lymph and are therefore known under the common name of *lymphocytes.* The active elements in the process of exchange of gases taking place in the blood are cells containing a chemically active substance *hemoglobin*, which is the cause of the red color of the blood, and these cells are therefore known as the *red corpuscles* or *erythrocytes.* In view of the fact, however, that the lymph, as stated above, ultimately enters and becomes a component part of the blood it is obvious that the blood must contain the active elements of both, and we actually find in the blood two kinds of cellular elements, which are correspondingly called: (*a*) *colored* or *red blood corpuscles* or *erythrocytes* and (*b*) *colorless* or *white* blood-corpuscles or leucocytes. The average number of these per cubic millimeter is 5,000,000 red corpuscles to 8,000–10,000 white corpuscles, making a ratio of 500:1.

Erythrocytes.—The red blood-corpuscles are usually described as colored, non-nucleated, biconcave, circular discs, of 7.5–8 micr. or $\frac{1}{3200}$ inch, in diameter. When blood is at rest, the corpuscles show a decided tendency to stick together in clumps or be piled up in columns known as *rouleaux.* The main characteristics of the erythrocytes have always been, and still continue to be, a matter of investigation and discussion, and the following points must be noted.

The color is due to the iron-containing chemical compound, which is known as *Hemoglobin.* When examined singly, the corpuscles have a rather greenish-yellow tint, but when aggregated in larger quantities, and suspended in their natural medium, the blood-plasm, they appear red.

In regard to shape, there is hardly any doubt that the form of circular *biconcave disks* is greatly predominating. Some, however, present a *cup-shape;* we also see some of a *spherical* or *globular* shape, and a very conspicuous form is the one known as *crenated.* This variety of forms of the red corpuscles can be explained without difficulty if we take into consideration the condition of the fluid in which they are suspended. It is obvious that when the density of the plasm is decreased the corpuscles will become more permeated with the fluid and will expand. This expansion may cause a bulging out only on one side of the disc and will produce a *cup-shape,* or it may cause a bulging out on both sides and the *globular* form will be the result. On the other

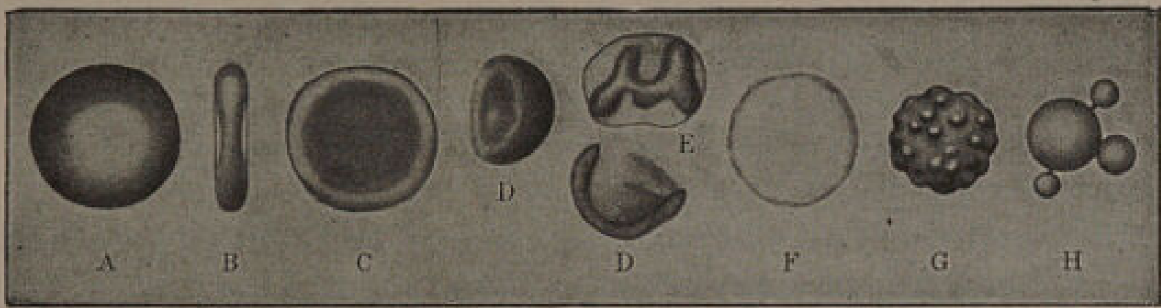


FIG. 193.—Red corpuscles in various conditions. (*Stohr.*) A, Biconcave disc as seen with objective lowered and C, with objective raised. B, Seen on edge. D, Cup-shaped form. E, Irregular contractions and distortions. F, Corpuscles from which the hemoglobin is removed. (*Shadows.*) G, Crenated form. H, Extrusions from the corpuscle.

hand, if the density of the plasm is increased, by evaporation for example, the surface tension of the corpuscles will be decreased, an irregular shrinkage will take place and the *crenated* form will result.

In regard to the nucleus, we have to state that, while the colored blood-corpuscles of lower animals are nucleated, those of human blood and blood of other mammals are, when examined in the adult, always non-nucleated. This fact made it rather doubtful, whether these corpuscles can be considered as cells, as it is not compatible with our definition of a cell as: a mass of protoplasm containing a nucleus. The study of the development of the blood has, however, entirely cleared up that point. We have stated above, that blood and lymph, as well as the channels in which it flows, originate in the mesoderm, from cells specially destined for that purpose, which are therefore known as *angioblasts.* Those of the angioblasts, which later become the cellular elements of the blood are known as *hematoblasts* and are like the rest of the mesoderm cells, nucleated. A number of these hematoblasts become gradually colored through formation of hemoglobin within the cells and are then known as *erythroblasts.* These cells still contain a nucleus, but gradually the latter disappears and they become moulded into the well-known *erythrocytes*. The exact process of the disappearing of the nucleus is not positively established as yet; some investigators are of the opinion that the nucleus becomes extruded from the cell and may be found as a distinct small corpuscle within the blood, others think that the nucleus becomes entirely dissolved and no traces of it are left. Be that as it may, the fact established beyond doubt is, that all red corpuscles possess a nucleus in the early stages of their life-history and therefore must be considered as true cells, which have undergone important modification. Deprived of the nucleus, the red blood-corpuscles have lost their ability to produce new cells, and consequently new corpuscles can only be supplied by gradual transformation from undifferentiated *hematoblasts*. This process takes place throughout the entire life of the organism, mainly in the bone-marrow, and it is in this locality where we can observe and study the erythrocytes in all stages of their development.

Leucocytes.—The white blood-corpuscles are colorless *spherical* bodies, which are constantly present in blood, but owing to the fact that they are colorless and their number is very much smaller than the number of the red, they are not so easily detected. These corpuscles present all attributes of true cells and have always been considered as such. We can distinguish in them a cytoplasm and a nucleus, and a great majority of them manifest *ameboid movement*. Due to the latter faculty they can make their way out or in through the thin walls of the fine blood channels and creep about as wandering cells among other cells of the tissues. During their excursions some may incorporate various particles which they are liable to meet with and also extrude them here and there on the route which they cover, thus acting as *phagocytes*.

Within the last few decades, the migratory activity of the leucocytes and their phagocytic action became to be considered as one of the most important factors in carrying and transmitting disease-producing germs. They are also considered as factors of great importance in curing, as well as preventing, disease, by holding up these germs, destroying them and removing the débris from the body. It is due to this fact mainly, that the white blood-corpuscles have attracted the attention of many distinguished investigators, and many interesting and important facts have been revealed. It was in these studies particularly that the great importance of using various dyes for microscopic examinations has been very clearly demonstrated, since it was the application of the various stains which led to the most important discoveries in this domain. We know at present, that the cells of the blood which are known collectively as *leucocytes*, are not all of the same kind. They differ in size as well as in structure and the following classifications and nomenclature is in vogue at present.

1. One classification is based upon the size of the cells and the character of the nucleus, and there can be distinguished four varieties of cells from this point of view.

(*a*) *Small Mononuclear Leucocytes.*—As the name indicates, these cells contain only one nucleus and are of small size. They are also known as small lymphocytes, and constitute about 20 per cent. of all leucocytes in the blood.

(*b*) *Large Mononuclear Leucocytes.*—They are also known as large lymphocytes, and their number is only about 1 per cent.

(*c*) *Polynuclear* or *Polymorphonuclear Leucocytes.*—As the name indicates, these cells have several nuclei, and the shape of the latter varies. This is the predominating form among the leucocytes of the blood, and constitutes about 70 per cent.

(*d*) *Transitional Leucocytes.*—Under this heading are grouped leucocytes with a structure somewhat midway between the others. They constitute about 7 per cent.

2. Another classification is based upon the presence or absence of various granules in the cytoplasm. These granules can be distinguished only when various stains are applied and manifest a difference in their affinity to the various dyes. This method of studying blood for leucocytes constitutes at present every-day work, we might say, of a clinical examination. There have been many forms of leucocytes described and quite a number of names are used. It is beyond the scope of this book to describe them all, but we think that it is necessary that the readers should be familiar with the principal points of this subject. To understand the classification given below it is necessary to keep in mind the following point. The anilin dyes used for microscopic examination are procured in form of powders, which present chemical compounds known as salts and are soluble in water or alcohol or in both. Like other salts, they consist of a base and an acid and it has been found that in some dyes the basic principle has the staining qualities, in others the acid principle has the staining qualities, while in a third group the staining qualities are due to both. We therefore distinguish three kinds of stains: (*a*) basic stains, (*b*) acid stains, (*c*) neutral stains. On the other hand it has been conclusively demonstrated that some of the

granules in the cytoplasm are stainable with basic stains, and these are therefore called *basophilic* granules, others are stainable with acid stains and are therefore known as *acidophilic* granules, and still others are stainable with both and are known as *neutrophilic* granules. With these facts kept in mind, the following classification will be conceived without difficulties.

(*a*) *Acidophiles.*—Leucocytes with granules stainable with acid stains. They are also known as *Eosinophiles*, because the stain used when they were first described was *eosin*.

(*b*) *Basophiles.* (Coarse).—They are also called "mast cells."

(*c*) *Basophiles.* (Fine).—They are identical with the large mononuclear leucocytes.

(*d*) *Neutrophiles.*—They are identical with the polymorphonuclear leucocytes.

It is now a very well-established fact that various diseases are characterised by the predominance in the blood of the patients, of one or the other of the various forms of leucocytes. It has also been found that in the same disease the character of the leucocytes as a predominating feature may differ during the various stages of the disease. These facts are undoubtedly of great significance, but the causes underlying them are still a mystery.

Blood-platelets.—Besides the erythrocytes and leucocytes, there has been observed in the blood a third form of corpuscles, which are known as *blood-platelets*. These are very minute circular discs, which are considered to be of importance as factors in blood coagulation, and are therefore also called *thrombocytes*. In regard to their structure the statements of the various investigators differ very materially, and also in regard to their origin many views have been expressed. While some investigators consider the platelets as distinct independent cellular elements, others look upon them as disintegrated fragments of erythrocytes or of leucocytes. Some see in them the expelled nuclei of erythrocytes, others consider them as constricted and discarded protoplasmic parts of leucocytes. We must say, that notwithstanding the great amount of research work done and quite considerable literature accumulated, the mystery surrounding these corpuscles still remains unsolved.

CHAPTER III

Circulatory Organs, Glands

In the previous chapters we have described the elementary tissues and have pointed out that each one of these tissues is differentiated to perform a well-defined function in the economy of the organism as a whole. The functions of the individual tissues, however, become manifest only when two or more of the elementary tissues are associated to form more or less complex units known as *organs*.

ORGANS OF CIRCULATION

The organs of circulation consist of a system of tubes of various sizes known as *blood-vessels*, and a central apparatus which furnishes the motive power for propelling the blood within these tubes—the *Heart*.

If we consider, for example, the blood circulation in the lower teeth, we find that the blood starting from the heart takes its course first to the aortic arch. Here it is distributed among vessels of smaller caliber, one of these being the common carotid artery. From this channel, the blood is again distributed into arteries of still smaller diameter, and a part of it enters the inferior dental artery which also branches off into a number of still smaller vessels which carry the blood to the *pulps* of the individual teeth. Here we find the blood circulating in a network of fine vessels known as *capillaries*. The walls of these capillaries are very thin and therefore a close contact of the blood with the tissues takes place. Becoming laden with the waste materials of the tissues, the blood is returned to the heart through blood-vessels known as *veins*, which gradually increase in size until the heart is reached.

Of the three kinds of blood-vessels mentioned; the first,

1. *Arteries* carry the blood from the heart to the tissues; the second,

2. *Veins* carry the blood back to the heart from the tissues, while the third,

3. *Capillaries* distribute the blood among the tissues thus enabling it to perform the important function assigned to it.

Conforming to their functions, the three kinds of blood-vessels show marked differences in their structure, which variations may be best understood by referring to the mode of development.

Some cells in the mesoderm become arranged in a simple squamous epithelium-like fashion, known as *endothelium*, and form tubes consisting of a single layer of *endothelium* or *mesothelium*. The walls of the capillaries consist practically of a single layer of *endothelial cells*, but as the caliber of the tubes increases the walls become strengthened

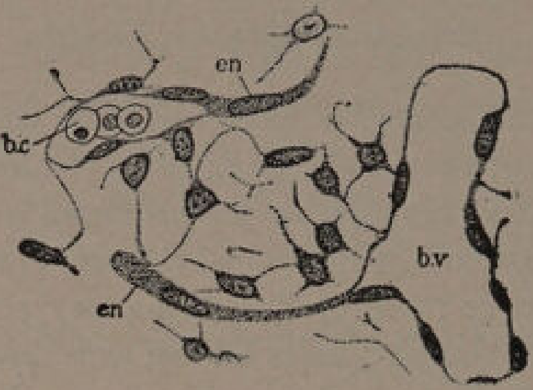


FIG. 195.—Blood-vessels from a rabbit embryo of thirteen days, developing as endothelial sprouts (en) from pre-existing vessels (bv); b.c., blood corpuscle within a vessel. (*Stohr.*)

with a few strands of connective tissue. The inner lining of all parts of the circulatory apparatus show the same kind of an *endothelial lining*, and the differences which are manifest, are found only in the tissues which surround this lining and give the tube more strength, firmness and elasticity, depending on the size of the blood vessels, the

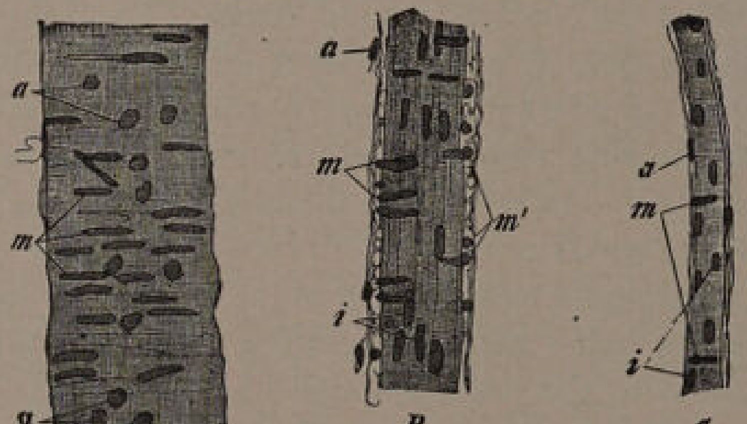


FIG. 196.—Small arteries of man. (*Stohr.*) Nuclei of endothelial cells; *m*, nuclei of circular muscle fibers, at *m'* seen in optical cross-section; *a*, nuclei of connective tissue. In *A*, since the endothelium is out of focus, its nuclei are not seen. × 240.

amount of blood it contains and the degree of pressure which it exercises upon its walls. If we take as typical, a medium sized artery, we generally recognize three coats.

1. *The inner coat* (*intima*) which consists of a single layer of *endothelial cells* resting upon a *subendothelial* connective tissue and a strand of elastic tissue known as the *inner elastic lamina*.

2. *The middle coat* (*media*) which consists of several layers of *smooth*, short, circularly arranged *muscle fibers* interwoven with connective-tissue fibers, mostly of the elastic variety.

3. *The outer coat* (*adventitia*) which consists of *connective tissue* which ultimately blends with the connective tissue surrounding the artery as a whole.

Veins have, broadly speaking, the same structure as arteries but some difference is shown in the *relative quantity* of one or the other

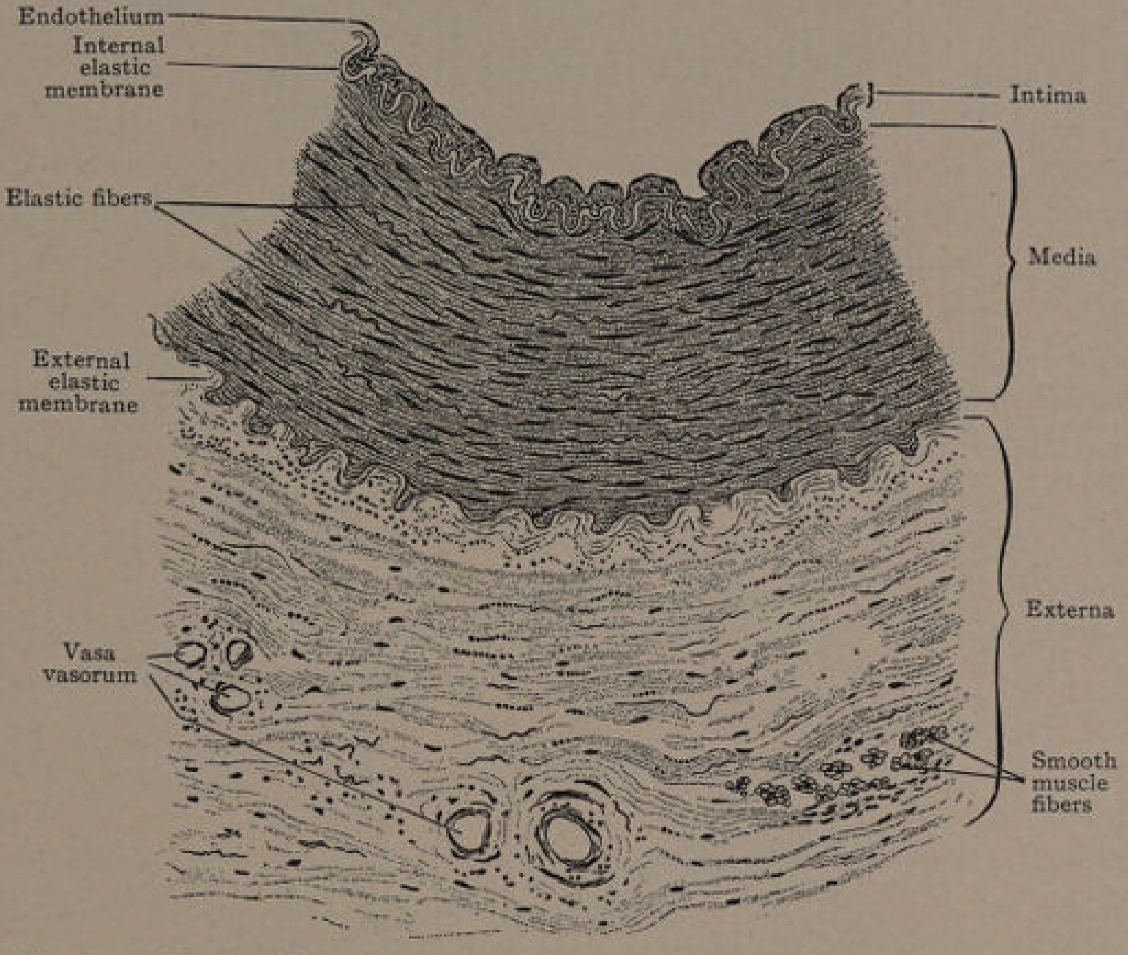


FIG. 197.—Portion of a cross-section of the brachial artery of man. × 100. (*Stohr.*)

elementary tissues. In a medium-sized vein, we generally find the walls thinner, and the inner elastic lamina of the intima is much thinner or is entirely wanting. The media shows less muscle fiber and more connective tissue. The adventitia shows the same structure as that of the arteries, but is considerably thicker.

While arteries and veins constantly have blood passing through them, their tissues are not nourished from this source, but receive the blood supply needed for their metabolism by means of special blood-vessels situated within the outer connective-tissue layer (*adventitia*) which are known as *vasa vasorum.*

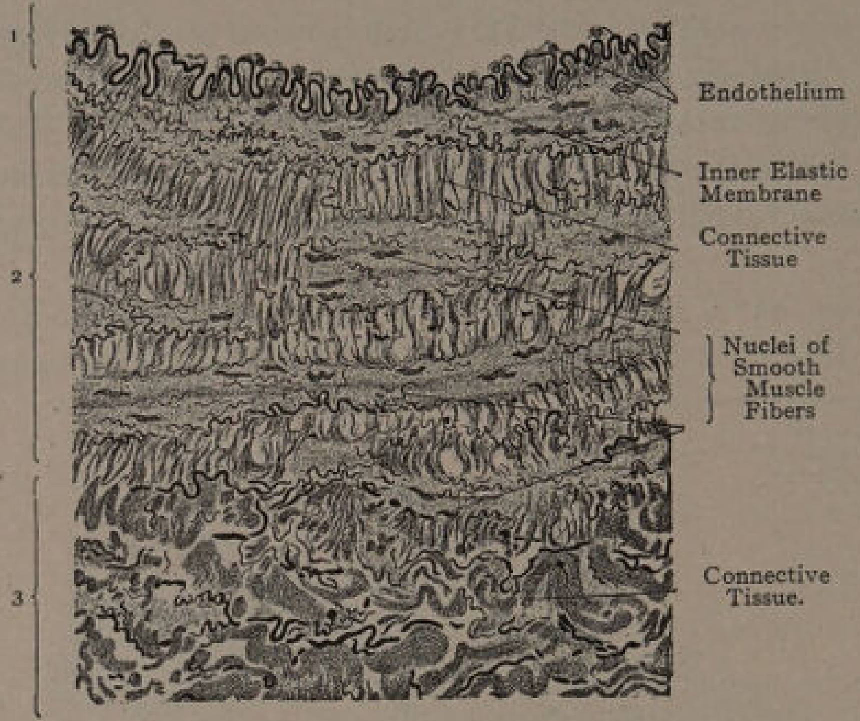


FIG. 198.—Part of a cross-section of a vein from a human limb. × 230. (*Stohr.*) The elastic elements are shown very black. 1, Intima; 2, media; 3, externa. (The middle of the three objects labeled nuclei of smooth muscle is apparently an elastic fiber.)

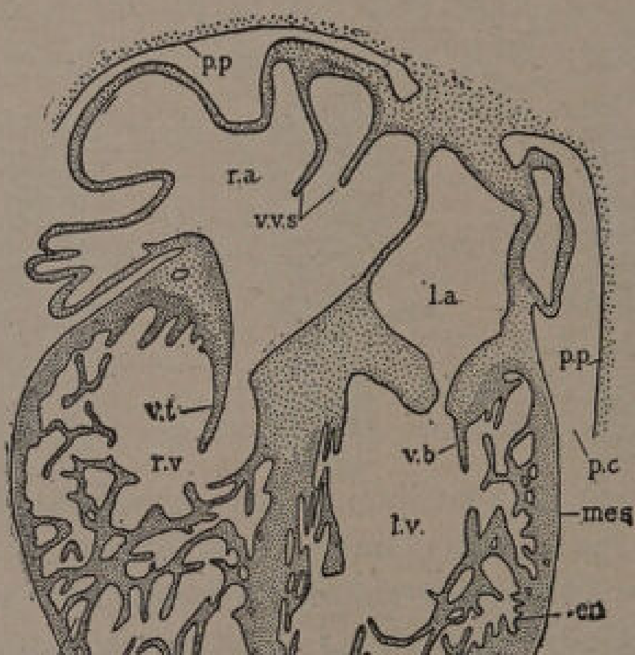


FIG. 199.—Section of the heart. (*Stohr.*) ca, Capillaries; en, endothelium; l.a., left atrium; l.v., left ventricle; mes., mesothelium (of the epicardium, or visceral pericardium); p.c., pericardial cavity; p.p., parietal pericardium; r.a., right atrium; r.v., right ventricle; si., sinusoids; v.b., bicuspid valve; v.t., tricuspid valve; v.v.s., valve of the venous sinus.

If we now examine the structure of the heart, we find the following:

1. *The inner lining* as a continuation of the inner lining of the blood-vessels, consisting of a layer of endothelial cells and subendothelial connective tissue corresponding to the intima and known as *Endocardium*.

2. *The middle coat* (*myocardium*) which forms the bulk of the heart, and consists of many layers of muscular tissue running in various directions and showing a special structure of the so-called *cardiac muscle*.

3. *The outer coat* (*epicardium*) shows some peculiarities, inasmuch as it consists of a layer of endothelial cells and some subendothelial connective tissue forming the so-called *Epicardium*. This layer when it reaches the roots of blood-vessels, turns back again and forms the so-called *Pericardium*. In the heart and in a number of veins, the endocardium bulges out in the form of folds and forms the *valves*. As to the nourishment of the heart, the same that was said in regard to the blood-vessels, applies, namely that while all the blood passes through the heart, the supply of blood for the metabolism of the heart tissue itself, is carried on by special vessels, the so-called *coronary arteries* and *veins*, which therefore correspond to the vasa vasorum of the blood-vessels and are located in a position corresponding with the latter, namely, the connective tissue of the outer layer, the epicardium, beneath the endothelium.

GLANDS

Broadly speaking, glands are organs consisting of one or more elementary tissues but in which the epithelial tissue takes the leading part in performing the function of the given organ. The function of glands is to produce various substances of great importance to the economy of the organism; and the epithelial cells in the glands are the elements which are specialized and adapted to do the work of *secreting* these substances. In lower animals we find distributed among other epithelial cells individual secreting cells which are known as *unicellular glands*. In higher animals we also find in various localities individual cells which are endowed with the faculty of secretion, and these cells are known as *goblet cells*. As a rule, however, glands consist of groups of cells united together for the common function of secretion. The secreting cells are arranged in the form of *tubes* or *sacs* and the substances which they produce are conveyed to the surface through outlets known

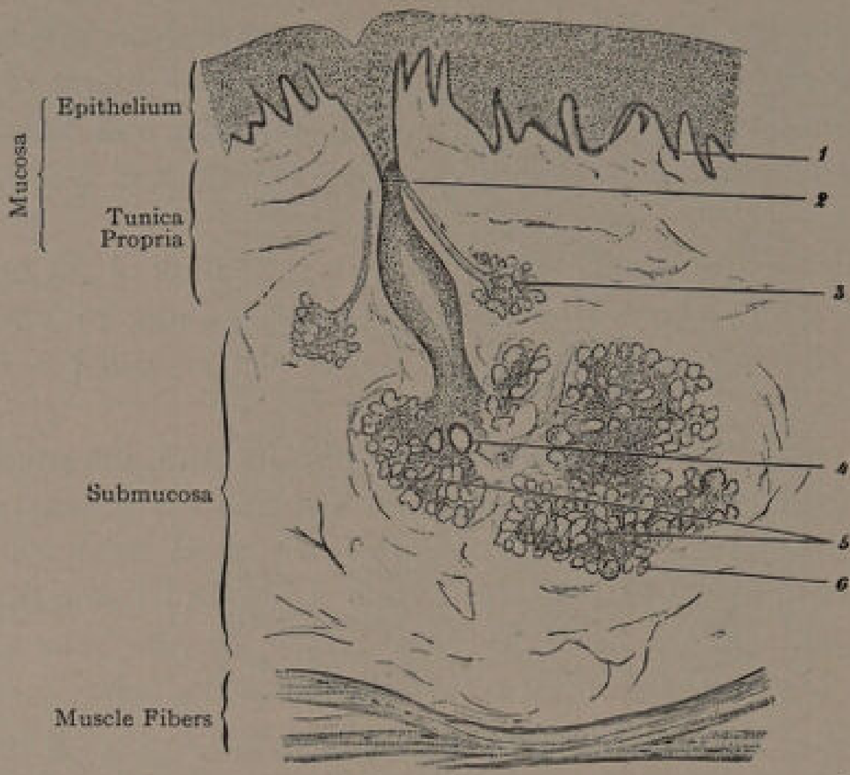


FIG. 200.—Vertical section through the mucous membrane of the lip of an adult man × 30. (*Stohr.*) 1, Papilla; 2, excretory duct; the lumen is cut at only one point; 3, accessory gland; 4, a branch of the excretory duct in transverse section; 5, gland bodies grouped into lobules by connective tissue; 6, a gland tubule in transverse section.

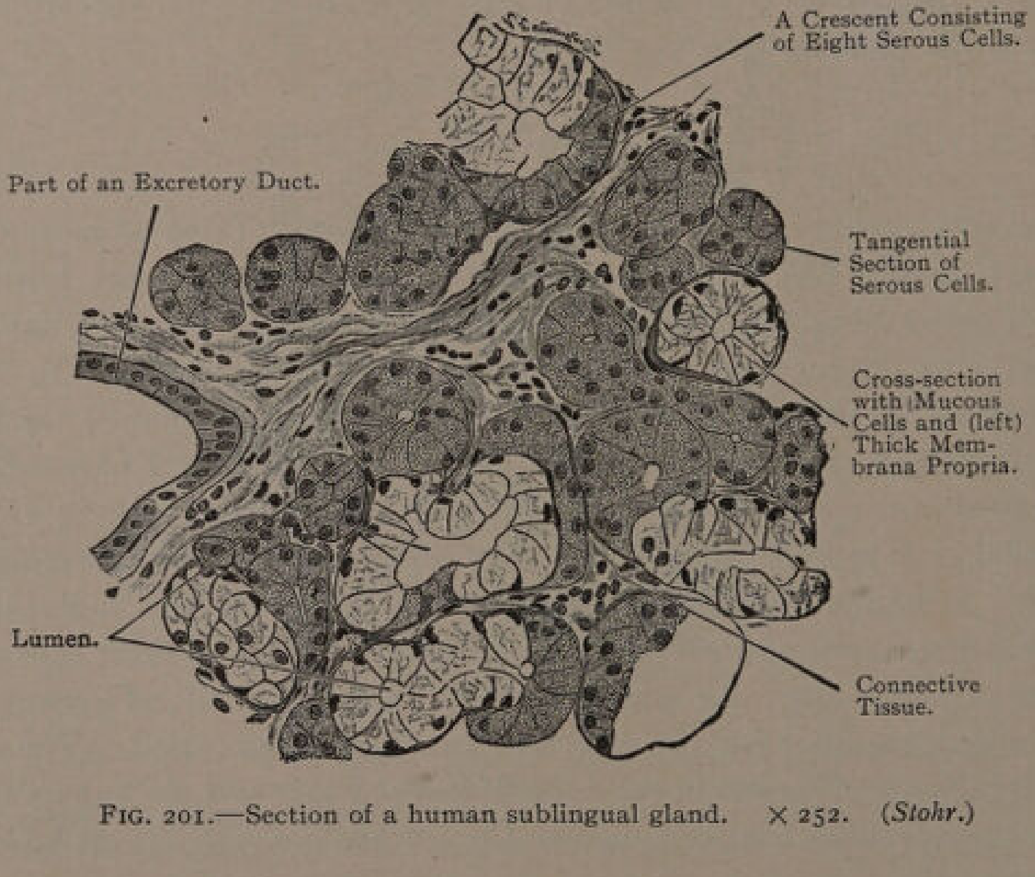


FIG. 201.—Section of a human sublingual gland. × 252. (*Stohr.*)

as *ducts*. Owing to the fact that the secreting cells in glands are arranged in a variety of shapes, the following classification is in vogue:

I. Tubular Glands.
(*a*) *Simple*; (*b*) *compound*.
II. Saccular *or alveolar* Glands *or racemous glands*.
(*a*) *Simple*. (*b*) *compound*.
II. Tubulo-alveolar Glands.

Glands are situated either within the surface coverings themselves as for example in the mucous membrane of the digestive tract, or they are imbedded in connective tissue beneath the mucous membrane

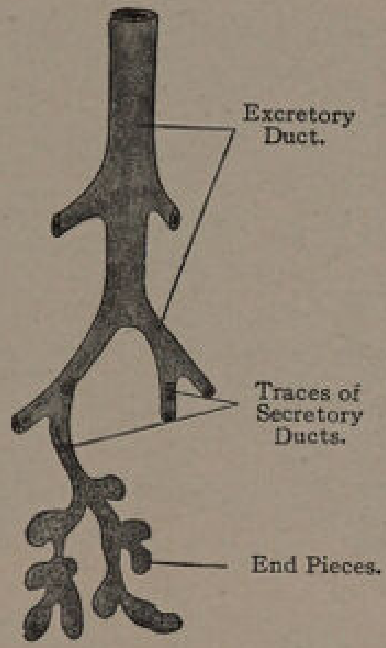


Fig. 202.—Diagram of the human sublingual gland. (*Stohr*.)

known as submucosa as for example in the skin or in the mucous membrane of the mouth. A number of glands are located as separate bodies imbedded among other important organs, as for example the various salivary glands, and communicate with the surface by means of long ducts. A description of the various glands in detail will be found in the following chapters.

Beside the type of glands just described, there are a number which produce substances of very great importance in the economy of the body, but these substances are not conveyed to the surface and therefore these glands have no direct outlets in the form of ducts and are known as *ductless* or *internally secreting glands*. The substances produced by these glands come in close contact with the blood through the walls of the capillary blood-vessels distributed throughout the texture of these organs and are taken into the blood and thus become distributed throughout the body. The glands belonging to this group are the *thyroid bodies*, the *parathyroids*, the *adrenal* and the *hypophysis*. The significance of these organs and their products is still a subject of considerable discussion.

There is also a third group of organs, which have long been classified as glands and even at present are occasionally considered under that heading, the so-called *lymph glands*. It has been stated on page 263 that the so-called *lymphoid* cells aggregate in larger quantities within the meshes of areolar tissue and form the lymphoid tissue. In some localities we find more dense aggregations of lymphoid cells which are

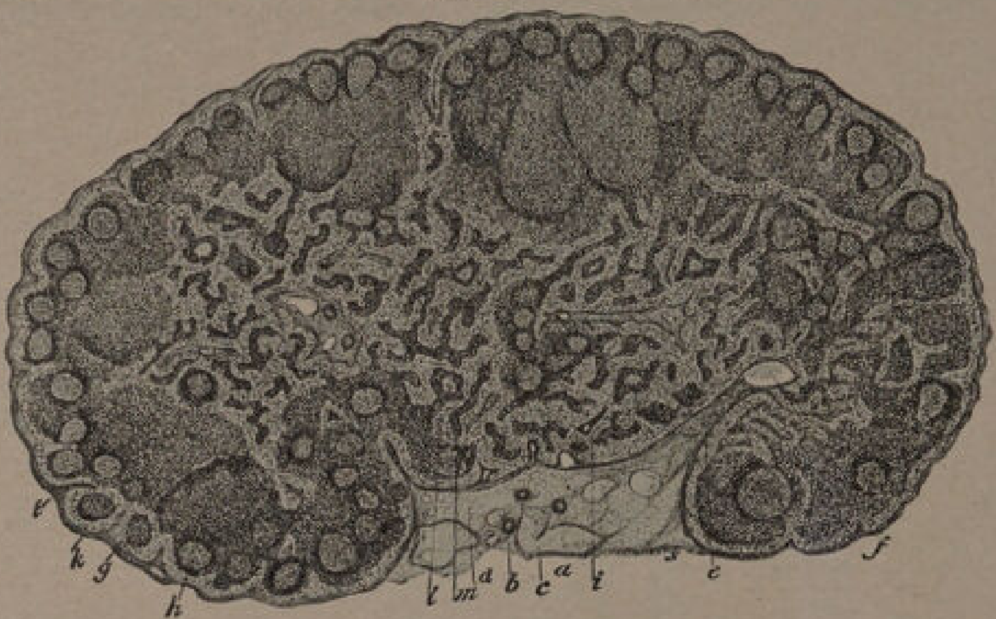


FIG. 203.—Longitudinal section of lymph node. (*Radasch.*)
a, Hilus; *b*, arteriole; *c*, venus sinuses; *d*, adipose tissue; *e*, secondary, nodule of cortex; *i*, vein of medulla; *g*, subcapsular lymph sinus; *h*, germinal center of secondary nodule; *f*, *i*, trabeculæ; *k*, capsule; *l*, lymph sinus; *m*, medullary cord.

known as *lymph follicles*. In the center of the follicle, the cells are more loosely arranged and quite a number of mitotic figures can be observed. This indicates that multiplication of cells is taking place and therefore the lymph follicles are considered as the main localities where lymph cells originate in the adult. In various regions of the body are found interposed in the lymphatic circulation a number of lymph follicles grouped together and surrounded by a connective-tissue capsule, and these are known as *lymph nodes* or incorrectly *lymph glands*. As examples of such nodes may be mentioned: *cervical nodes*, *parotid nodes*, *lingual nodes*, *submaxillary nodes*, etc. If we recall, however, that under the name gland we understand as epithelial organ the cells of which are endowed with the power of secretion it is obvious that, when this name is applied to an organ consisting of lymphoid cells which never secrete, it is a misnomer.

CHAPTER IV

The Mucous Membrane of the Mouth; of the Lips; of the Cheeks; of the Gums; of the Roof of the Mouth, Hard and Soft Palate; of the Floor of the Mouth; the Tongue

HISTOLOGY OF THE TISSUES OF THE MOUTH

Mucous Membrane of the Mouth.—The term "membrane" in a general sense is one applied to thin layers of tissue, somewhat elastic and of a whitish or reddish color. Such tissues are found lining either closed cavities or canals which open externally, absorbing or secreting fluids, and enveloping various organs. The simple membranes are of three varieties, being either mucous, serous, or fibrous. The mucous membranes are so called from the clear viscid fluid (mucus) which they secrete. They line the various cavities or tracts of the body which communicate with the exterior. The three grand divisions of mucous membrane are those lining the digestive, respiratory, and genito-urinary passages. Lining the entire cavity of the mouth we find the beginning of the digestive tract, being continuous with, in many respects similar to, the skin on the exterior and performing similar functions within. It is soft, smooth, and velvety, of a bright pink color, and quite vascular; it is covered on the exterior by a layer of epithelial cells overlying the vascular parts. Immediately beneath this is a network of fibrous connective tissue forming the proper mucous membrane, and still deeper is a third layer, somewhat loose in texture, but composed of fibrous connective tissue, the submucous membrane. The oral mucous membrane, at its point of beginning on the contiguous surface of the lips, is endowed with keen sensibility; it is dry, bright red in color, and plentifully supplied with vascular papillæ, in many of which are sensory nerve terminals. Distributed along the line of junction between the integument and the mucous membrane are numerous sebaceous follicles, which, however, are devoid of hair-bulbs. The characteristic dryness of this surface gradually becomes changed to a mucus-secreting one, as that part of the membrane lining the interior of the lips is approached. Distributed over the surface of the labial mucous membrane are a number of minute openings, the mouths of the labial glands, which lie immediately beneat ı the membrane. The buccal mucous membrane, or that lining the cheeks, is similar to that covering the internal surface of the lips. It is penetrated at various points by the mouths of the buccal glands, which, in general, are smaller and less numerous than the labial glands. In the region of the second molars the membrane is broken by four or five openings of larger size, which communicate with the molar glands. The mucous membrane covering the hard palate is thick and firm, less brilliant in color than that covering the cheeks and lips, and firmly bound down to the periosteum. Running from before backward at the median line, the membrane is formed into a slight fold, the median

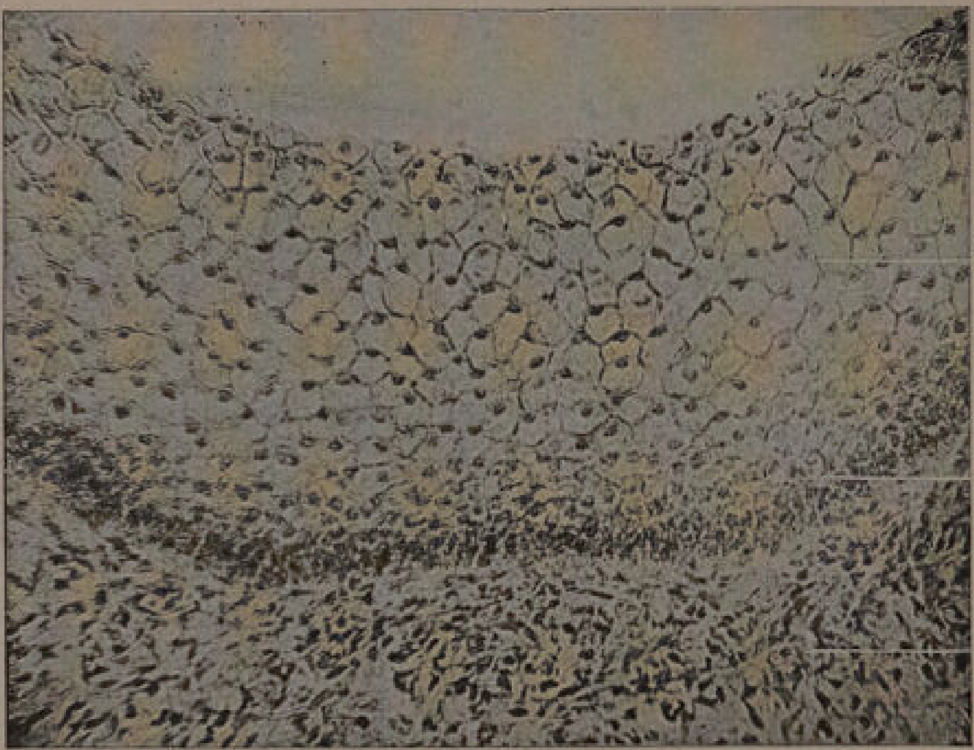


FIG. 204.—Vertical section, mucous membrane of the mouth, human embryo. × 150.

raphe, while near the anterior portion of the palate are a number of fantastically arranged folds, the *rugæ* (see General Description of the Mouth). The thin but rather dense fibrous aponeurosis forming the soft palate is covered anteriorly by the oral mucous membrane. Suspended from the center of the free margin of the soft palate is the uvula, which is likewise covered by mucous membrane, and from the base of this, on either side, are two muscular folds, which extend outward and downward, forming the anterior and posterior pillars of the fauces. The mucous membrane covering the tongue has already been described in connection with that organ. From the mouth the digestive mucous membrane passes through the fauces, pharynx, and esophagus to the stomach, and is so continued throughout the whole digestive tract. Other prolongations also pass into the ducts of the salivary glands.

The mucous membrane lining the cavity of the mouth consists of two parts—the epithelium and the tunica propria; beneath the latter, and forming the deeper part of the mucous membrane, is the submucosa.

The epithelium of the mouth is a thick, stratified, squamous epithelium, the most superficial cells being scale-like or horn-like. The cells are arranged similar to those in the epiderm, the lower layers are columnar in form, and contain very little pigment.

The tunica propria is a somewhat dense feltwork of interlacing connective-tissue bundles, interspersed with elastic fibers. The tunica propria penetrates the epithelium in the form of cylindric or conic papillæ, which differ in length with the variation in the thickness of the epithelium. As the mucosa is usually thickest in the lips, gums, soft palate, and uvula, accordingly the papillæ are of the greatest length in these parts. The tunica propria passes into the submucosa so gradually that a positive line of demarcation cannot be established.

The submucosa consists of a bundle of fibrous connective tissue with but few elastic fibers. This structure is somewhat loose in texture and is loosely attached to the underlying periosteum. Over the major portion of the gums and the entire hard palate the submucosa is attached to the bones of the mouth through the medium of their periosteal covering. It is in this loosely constructed tissue that the glands of the mucous membrane are situated. These are for the most part branched, tubular, mucous glands. Besides adipose tissue in the form of groups of fat-cells, striped muscular tissue is present in the submucosa. In some parts of the mouth this tissue forms a conspicuous portion—namely, in the sphincter muscle of the lips (orbicularis oris); also in the soft palate, uvula, and pillars of the fauces.

The blood-supply to the mucous membrane of the mouth is principally distributed in two systems, the larger vessels to the submucosa and the capillaries to the tunica propria. The larger vessels break up and send a dense network of capillaries through its substance and to the numerous papillæ which extend into the epithelium. Numerous veins ramify through the superficial part of the tunica propria. The lymphatics form two networks, the submucosa giving place to the coarser vessels, while the fine vessels are distributed to the tunica propria.

Nerve-supply to the Mucous Membrane of the Mouth.—In the submucosa the medullated nerve-fibers form a wide-meshed reticulum, from which numerous primitive fibrillæ pass to the tunica propria, where they terminate or continue as non-medullated nerve-fibers, and penetrate the papillæ of the epithelium, forming networks.

Mucous Membrane of the Lips.—Beginning as a direct continuation of the integument or external covering of the lips, the labial covering, including the integument, may be divided into three parts—namely, a cutaneous portion (best described in this connection), a transitory portion, and a mucomembranous portion.

The *cutaneous* portion, covered by a thin epidermis, consists of a double layer of somewhat flattened epithelium. Immediately beneath this is a thin, cellular, mucous layer, the cells composing it being spheroid in form, and containing nuclei which are proportionately large. Subjacent to this is the cutis, composed of fasciculi of fibers intersecting and closely woven together, the principal fibers passing toward the free border of the mucous membrane covering the contiguous surface of the lip. These fibers are for the most part connective-tissue fibers, intermingled with elastic-tissue fibers. Numerous small, vascular papillæ are found upon the surface of the cutis; these are cylindric or conic in form, and project for some distance into the rete mucosa—the lower layers of living cells of the epidermis. Equally distributed at various depths in this tissue are numerous hair- and sebaceous follicles. The general direction of the hair-follicles in the upper lip is downward, while those occupying the lower lip are turned upward. Other than the distinction noted by the difference in color of the parts, the cutaneous portion may be distinguished from the transitional mucous membrane by the absence of hair-follicles and sebaceous glands in the latter.

The *transitional* portion of the mucous membrane of the lips is outlined externally by the outer border of the red portion of the lips, and internally by that prominent part of the labial convexity which comes in contact with the opposing labial fold, leaving the transitional portion exposed to view when the lips are in occlusion. The epithelial layer of this surface does not begin where the hair-follicles cease to exist, a slight interspace appearing upon the cutaneous portion which is devoid of these follicles. At its line of beginning the transitional portion of the labial mucous membrane is quite thin, but rapidly increases in thickness in passing toward the mucomembranous portion. Superficially the cells are much flattened, closely associated with one another, and devoid of nuclei. The cells of the middle and deeper layers are oblong or spheric, and provided with irregularly shaped nuclei. The chief fibrous tissues of the transitional portion, which are thinnest at the point where the hair-follicles cease to exist, are united into flexiform fasciculi, which are separated at various points to give passage to numerous minute blood-vessels. The fibrous tissues increase in thickness as the muco-membranous portion is approached. Numerous thin and somewhat elongated papillæ are distributed over the surface of the transitional portion.

The *mucomembranous* portion of the mucous membrane of the lips includes all that portion covering the labial folds within the mouth, beginning at the line of occlusion on the contiguous surface and extending to the gums. The epithelium is much thicker than that previously

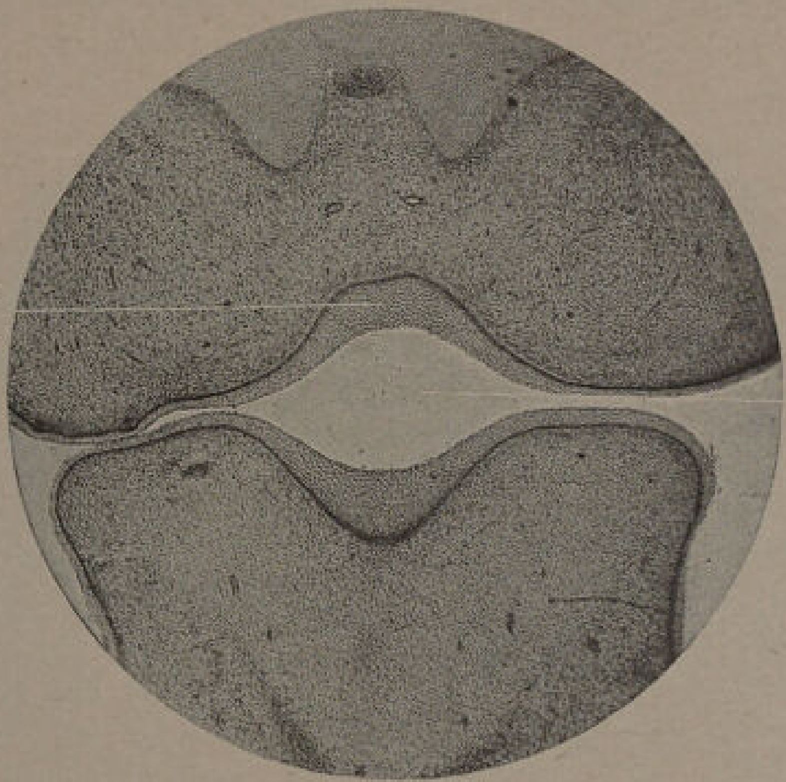


FIG. 205.—Vertical transverse section through head of human embryo, about the sixth week, showing, single common buccal cavity. × 30.

described and presents the characteristic layers common to stratified, squamous epithelium. Superficially the cells are flattened and tubular, provided with nuclei of similar form. In the middle layer the cells are flattened and oblong, followed in the deeper layer by irregularly formed nucleated cells. A variety of fibers make up the structure—one class fine in texture and united into fasciculi, intermingled with elastic fibers, together with another set of coarse, strongly looped fibers. Whenever the fibers of the tunica propria assume a definite general direction, they are horizontal, passing from right to left and encircling the buccal orifice. The tunica propria is beset with numerous conic papillæ which project into the epithelium; these are longest where the epithelium is thickest. The mucous membrane forming the labial frena is covered by an epithelial layer which is much thinner than that distributed to other parts of the lips. The fibers in these are irregularly distributed, and the papillæ are small and not so numerous. The coronary arteries and their accompanying veins course through the lips near the junction of the transitional with the mucomembranous portion of the mucous membrane.

Mucous Membrane of the Cheeks.—The mucous membrane of the cheeks presents but little variation in its structure from that of the

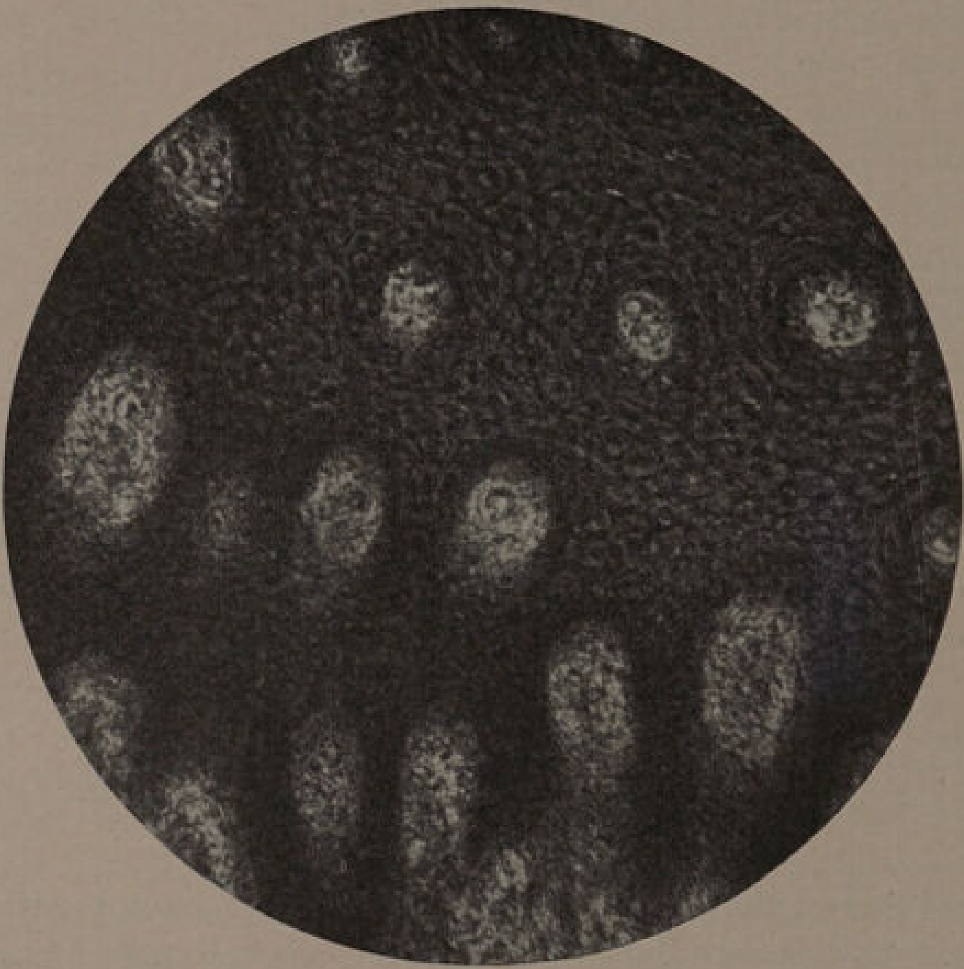


FIG. 206.—Section through the mucous membrane of the cheek, showing the papillæ of the mucosa in transverse section.

mucomembranous portion of the labial mucous membrane. The buccal epithelium is the same in structure and thickness as that of the lips, excepting the disposition of cells in the middle layer, where they are greater in number and more closely associated, being somewhat distorted by contact. The papillæ, which project from the mucosa into the epithelium, are somewhat broad at their base, with elongated extremities, the height of which is quite variable, in some instances penetrating well into the epithelium, at others merely entering its deeper layer. At the anterior portion of the cheek, or that in the region of the angle of the mouth, the mucous membrane, by its submucous portion, is in immediate contact with the fibers of the buccinator muscle, and throughout the entire surface of the cheek it is closely associated with this muscle. The membrana propria is dense immediately beneath the epithelium, but as the buccinator is approached it becomes much less so.

Mucous Membrane of the Gums.—The gingival mucous membrane, on account of the numerous tendinous fasciculi which enter into its

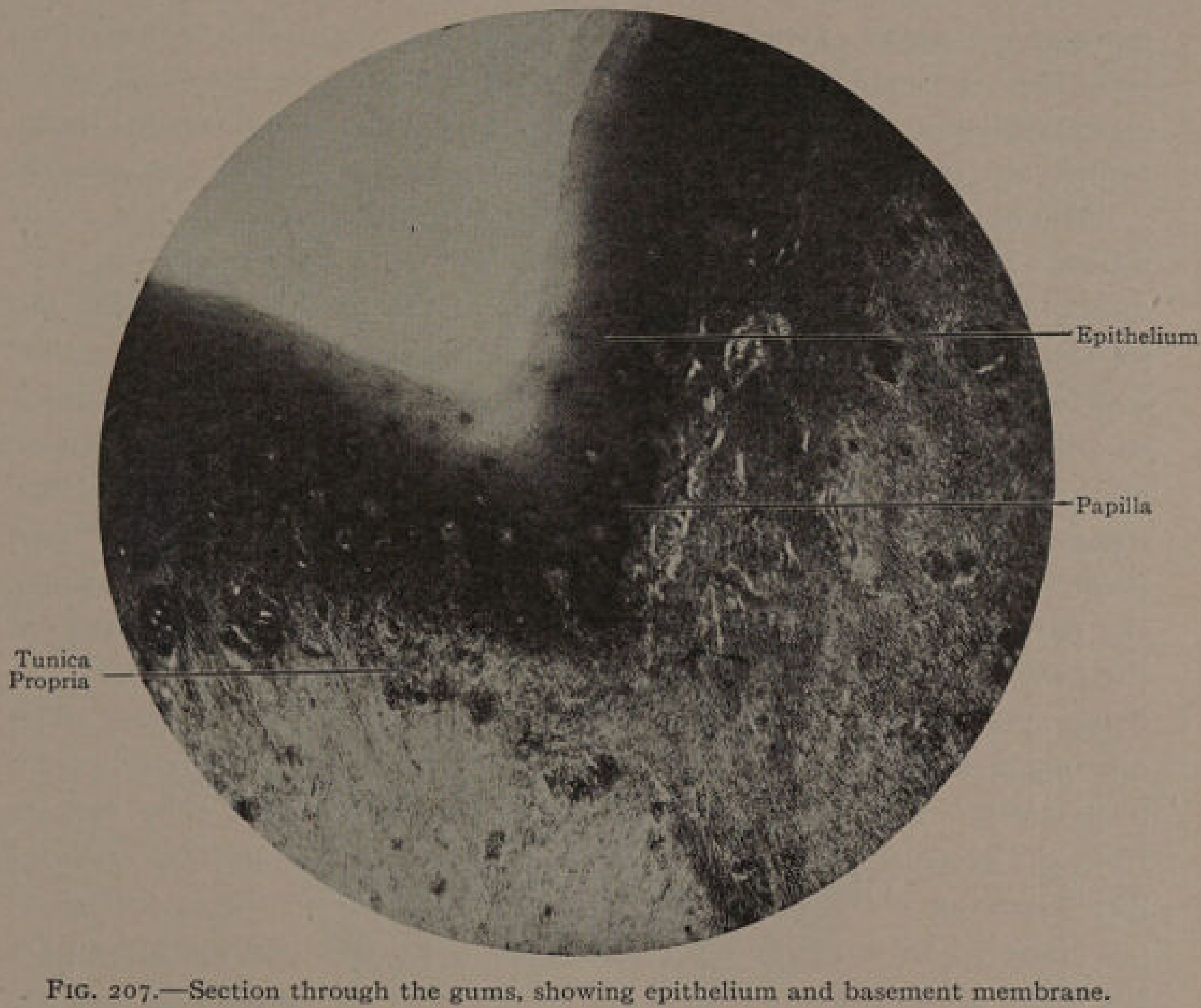


FIG. 207.—Section through the gums, showing epithelium and basement membrane.

construction, is extremely dense and tough, these characteristics being more strongly manifest here than in any other portion of the oral mucous membrane. These qualities are especially pronounced about the gingival margins and over the major portion of the alveolar walls, being closely bound down to the bone by direct prolongations of the tendinous fasciculi of the periosteum which penetrate the membrane. As the gingival mucous membrane passes into that of the lips and cheeks it gradually becomes less dense. The epithelium of the mucous membrane of the gums is composed of lamina of tessellated and ribbed cells. The superficial cells are the flattened cells of pavement epithelium; subjacent to this they become thicker and deeply ribbed, while the deepest cells are conic or cylindric with conic extremities. The tissue composing the tunica propria is made up of flattened fasciculi of connective tissue, the fibers of which run parallel with one another. Numerous elastic fibers are also present. Three sets of fibers are to be distinguished in the mucous membrane of the gums—those which run vertically, those which pass in a horizontal direction, and those which radiate or are distributed fan-like. Of the first-named, the fibers extend from above downward; in the second class they pass from right to left parallel with the surface; the third class, including those fibers which are reflected from the alveolodental membrane, are distributed in fasciculi about the margins of the alveoli.

Mucous Membrane of the Roof of the Mouth. *Hard Palate.*—The mucous membrane covering the hard palate is, in very many respects, dissimilar to that surrounding the necks of the teeth and forming the palatogingival margins. Like the mucous membrane of the gums, that overlying the hard palate is dense and tough. The papillæ of the tunica propria, which penetrate the epithelium, are not so numerous as those upon the gums. In the posterior third of the hard palate they are somewhat more numerous and generally a little more prominent than those in the anterior portion. In the median raphe and over the rugæ, the papillæ are especially sparingly distributed. The epithelium is of the pavement variety, somewhat thinner in front than behind, the cells being more freely distributed at some points than at others. The mucous membrane of the hard palate is less in thickness anteriorly than posteriorly. The distribution of the fibers is such that they radiate from the alveolar borders toward the center of the palate, the anterior fibers passing obliquely backward, while those from the lateral walls pass parallel with one another to the median line. For the most part the fibers are broad and form a plexus between the epithelium and the submucous tissue. The submucous tissue is sparingly distributed over the central portion of the hard palate, but laterally is somewhat more abundant, containing a few fat-cells.

Soft Palate, Uvula, and Fauces.—Passing backward from the posterior margin of the hard palate, the mucous membrane overlies the fibrous aponeurosis of the soft palate and its median and lateral prolongations—the uvula and pillars of the fauces. The epithelium is of the laminated pavement variety, with the deeper cells larger than those placed superficially. The substance of the mucous membrane is composed of fasciculi of connective tissue, intermingled with a plexus of elastic fibers. The fibers are distributed in three principal directions—from side to side, or horizontally, longitudinally, and obliquely. The oblique fibers are instrumental in forming the submucous tissue of both the soft palate and uvula. Numerous conic papillæ project from the tunica propria into the epithelium; these are larger and more numerous on the uvula than on the soft palate. The tunica propria is somewhat variable in thickness to accommodate the glands, which are more or less numerous, and present in greater numbers in one instance than in another. In general the membrane as a whole is thinnest along the margin of the hard palate, gradually increasing in thickness as the free border is approached. The folds of mucous membrane forming the pillars of the fauces present no peculiarity differing from that of the soft palate, save a more generous supply of elastic fibers.

Mucous Membrane of the Floor of the Mouth.

The Tongue.—The entire unattached surface of the tongue is covered

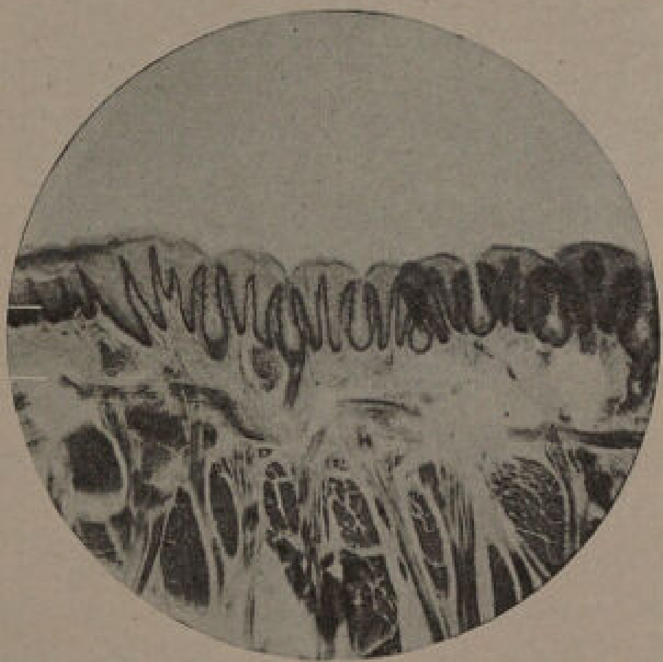


FIG. 208.—Longitudinal section through mucous membrane of the human tongue. × 20.

by a reflection of the mucous membrane of the floor of the mouth. In this organ the general structure of the mucous membrane does not vary from that of other oral mucous membrane, being composed of an epithelium, a tunica propria, and a submucosa. The mucous membrane covering the dorsum of the tongue however presents special characteristics, which differ from that of the under surface and the floor of the mouth in general. In the former location the papillary elevations of the tunica propria are conspicuously developed, and with their covering of stratified, scaly epithelium cause the peculiar furred appearance. Three classes of papillæ are distinguished, named, in accordance with their form, filiform papillæ, fungiform papillæ, and circumvallate papillæ.

The filiform papillæ, which are very numerous over the entire dorsum and sides of the tongue, are conic and frequently prolonged into numerous horn-like processes, known as secondary papillæ. As elevations from the tunica propria they are composed of well-defined fibrillated tissue, intermingled, with numerous elastic fibers. The pavement epithelial cells are found overlapping one another, and pro-

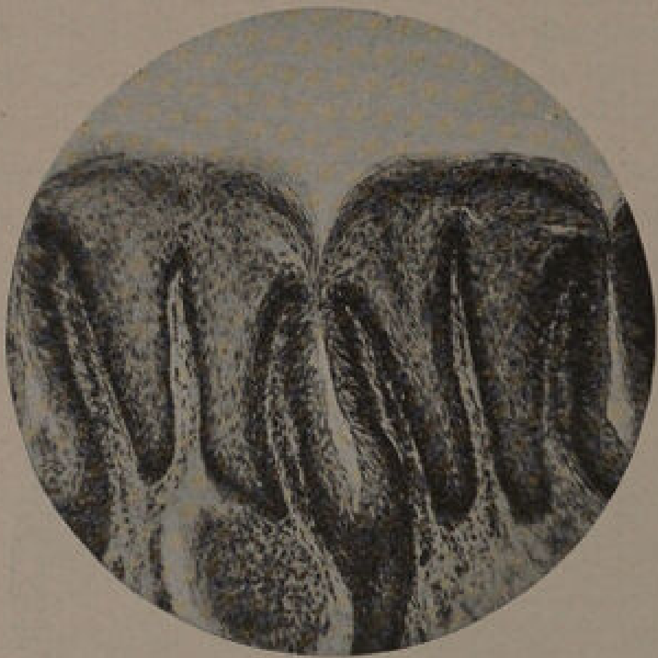


FIG. 209.—Longitudinal section of the mucous membrane of the human tongue, showing the fungiform and secondary papillæ. × 80.

vided with processes which project beyond the papillæ.

The fungiform papillæ are also distributed over the entire dorsum and sides of the tongue, but are somewhat less numerous than the filiform variety. They appear as well-defined elevations, and are connected with the tunica propria by a constricted portion or neck. The entire free or rounded surface of these papillæ is beset with secondary papillæ. The epithelium is slightly thinner than that over the filiform papillæ, this being the principal distinguishing feature. The numerous capillaries produce a rich red color, plainly observable through the transparent epithelium. Connective-tissue bundles make up the bulk of these papillæ, few elastic fibers being present.

The circumvallate papillæ are placed on the posterior portion of the dorsum of the tongue, and are few in number (eight to sixteen). They are much larger than those already described, and in general resemble modified fungiform papillæ. They are flattened and broad, and differ from the fungiform by having a circular furrow or wall surrounding them. Secondary papillæ are present on the free surface only, the sides, and in some instances the walls surrounding them, being occupied by the end organs of the special sense of taste—the taste-buds. Other taste-buds are found upon the lateral margins of the tongue posteriorly, nestled in a group of parallel folds of mucous membrane—the papillæ foliata. The connective tissue within these papillæ is similar to that in

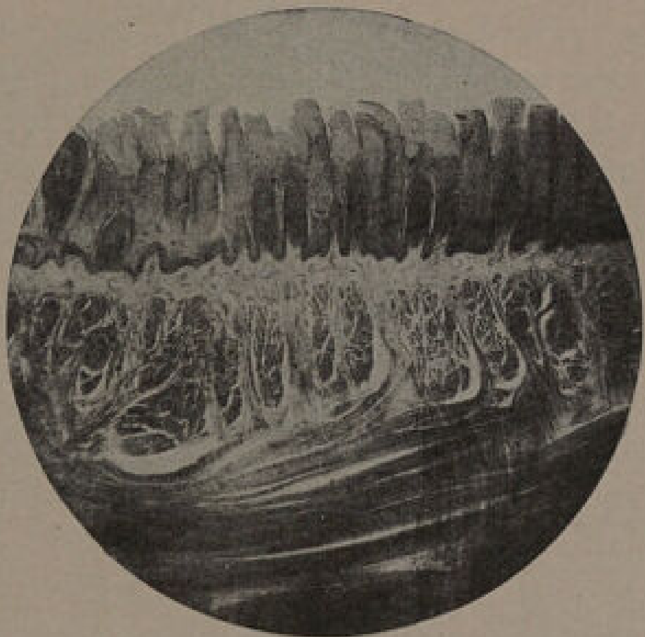


FIG. 210.—Section through epithelium, near the tip of the tongue. × 40.

the fungiform papillæ. On other parts of the tongue, or those portions not occupied by these specially constructed papillæ, the epithelium is similar to that in other parts of the mouth. The tunica propria is less in thickness in and about the tip of the tongue, and is intimately connected with the subjacent muscular structure. As the root of the organ is approached, the tunica propria becomes thicker and more dense. The submucosa is especially intimately connected with the underlying parts at the margins and tip of the tongue. The extreme portion of the root of the tongue has its mucous membrane particularly modified by a special aggregation of adenoid tissue—developed lymph-nodules. These are large and readily perceptible to the naked eye. They are provided with a central opening, which dips down into a well-defined vault or crypt, which is lined by a reflection of the stratified oral epithelium.

Blood-supply to the Mucous Membrane of the Mouth.—The oral mucous membrane derives its supply of blood from numerous branches of the external carotid artery—namely, the superior and inferior coronary, buccal, lingual, transverse facial, pterygopalatine, and the alveolar. Entering the submucosa, the minute terminal branches of these arteries are distributed parallel to the surface, and by anastomosis form plexuses from which other minute branches are given off to supply the papillæ of the tunica propria. After coursing through the papillæ the blood is discharged into a similar venous plexus, and thus conveyed from the parts. In a like manner the mucous membrane and papillæ of the tongue are supplied, branches of the lingual artery conveying the blood to the parts. The dorsalis linguæ supplies the mucous membrane of the dorsum of the tongue and pillars of the fauces, while the ranine artery by its minute branches supplies the remaining mucous membrane. Each papilla is entered by two or more arterial terminals, which divide, anastomose, and finally send off capillary branches to the secondary papillæ.

Nerve-supply to the Mucous Membrane of the Mouth.—The distribution of the nerve-fibers to the oral mucous membrane is approximately similar in all parts. The fibers, which are of the medullated variety, are first distributed to the submucosa, forming a wide-meshed reticulum. From this fibers are given off to the tunica propria, terminating in end-bulbs, or, after losing their medullary sheath, are distributed to the epithelium, where their free extremities lie between the epithelial cells. The nerves of the mucous membrane of the tongue (the glossopharyngeal and lingual branch of the fifth) may have their endings similar to those in other parts of the mouth, or they may be intimately associated with the taste-buds.

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CHAPTER V

Other Structures Within the Mouth—The Gums—The Alveolodental Membrane—Glands, Ducts, Etc.

The Gums (*Gingivæ*).—The gums are formed by a layer of tough fibrous vascular tissue, covering the alveoli, closely attached to their periosteum, and provided with a free margin (gingival margin), which

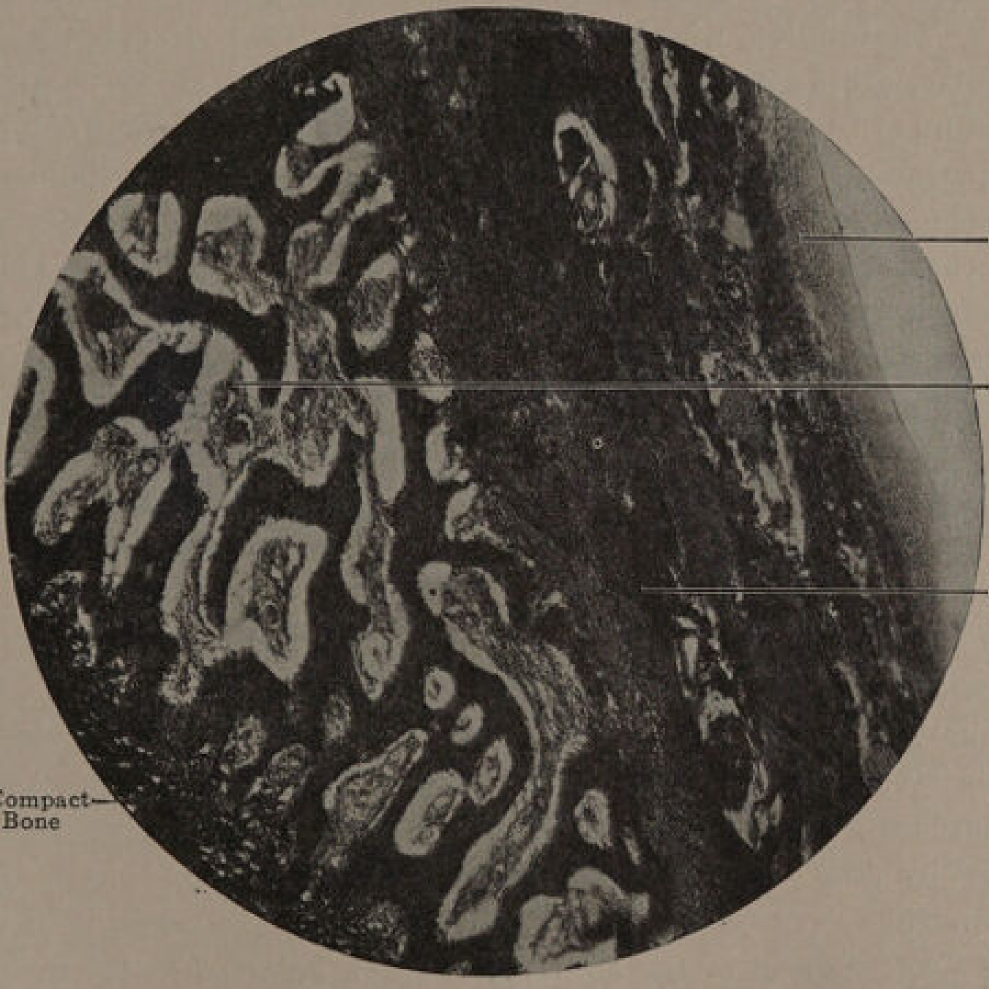

Fig. 211.—Section through gingivæ and alveolus.

is closely molded but not attached to the necks of the teeth. They are covered on both aspects by the general mucous membrane of the mouth, that overlying the labial and buccal surfaces being reflected from the lips and cheeks, the palatal surface being continuous with that of the hard palate, and the lingual surface reflected from the under surface of the tongue and floor of the mouth. In the immediate region of the necks of the teeth the gums are especially thin and hard, being closely adherent to the periosteum and alveolodental membrane in this region. In passing toward the base of the alveolar walls the tissue becomes less firmly attached to the underlying structure, and, when finally passing into the mucous membrane of the cheeks and lips, is quite loose and flabby. This condition also prevails on the lingual aspect, but the palatal surface remains more or less firm throughout, the entire mucous membrane overlying the roof of the mouth being similar in structure and attachment to that portion overlying the alveolus. In various situations about the labial, buccal, and lingual surfaces of the gums small slender folds of mucous membrane are found extending to the surrounding tissues. These folds, which act as a bridle or curb to the adjacent movable parts, are known as the *frena* of the mouth. The principal frena are found at the median line, and are three in number—the frenum labium superioris, frenum labium inferioris, and the frenum linguæ. The two former extend from the inner surface of the lips to the gums, to which their extent of attachment is somewhat variable. The frenum labium superioris is usually much larger than the frenum labium inferioris, and its attachment to the gum frequently extends almost to the gingival border. The frenum linguæ extends from the under surface of the tip of the tongue to the lingual surface of the gums. This is a much stronger fold than those connected with the lips. Similar bridles are found in the buccal region, usually near the bicuspid teeth, but they are much smaller than those at the median line. The *gingival margins*, or that portion of the gums embracing the necks of the teeth, present much variety in outline. Instead of encircling the neck of the tooth in a direct line, the margins are made up of a series of semicircles. Using the incisive region for reference, the labial and palatal margins are concave rootward, while the interproximate spaces are partly or completely filled by gum tissue, having the outline reversed or convex in the direction of the crowns of the teeth. The gingival margin is also termed the "free margin of the gum," this name better describing its extent. As previously stated, the gums are attached to the periosteum and peridental membrane, but in most instances, and particularly before the adult period, the free margins of the gums extend beyond the alveolodental membrane, the limit of which is formed by the cervical line. That portion of the gingival margin beyond the cervical line is in close contact with the neck of the tooth, but is not adherent to it, the connecting medium, the alveolodental membrane, not being present to complete the attachment. The curvature of the gingival margins, and the nature of the tissues which enter into their construction, are usually considered as strongly indicative of the temperament of the individual. Thus, in the bilious temperament the margins are inclined to angularity and the tissues rather thick and firm. In the sanguine type the outline formed is almost a perfect semicircle, and the tissues are of moderate thickness and firmness. In the nervous type the curvature is strongly parabolic, and the tissues firm and delicate. In the lymphatic the tissues are loose and thick, and the curvature is broad and poorly defined. In some instances the interproximate spaces are completely filled by the gingivæ; in others the space is only partly occupied by these tissues. The former condition is present when the proximate surfaces of the teeth are nearly or quite parallel with each other, thus reducing the capacity of the space. The latter condition is present when the crowns of the teeth are bell-shaped and the interproximate spaces extensive. The labial and buccal surfaces of the gums are more or less broken by numerous prominences and depressions, all of which accord with the variations upon the surface of the bone beneath.

Some distinction should be made between the gingival line and the cervical line, the former referring to the free margin of the gum, and not a fixed line, while the latter refers to that positive line established on the tooth by the union of the enamel and cementum.

The Alveolodental or Peridental Membrane.*

This membrane invests the roots of the teeth, and at the same time lines the wall of the alveoli. Being reflected from the periosteum covering the outer alveolar walls, it enters the alveolar sockets as a single membrane, affording nourishment to the bone on one side and to the cementum of the tooth on the other. It is a connective tissue of moderate density, and is rich in its nerve- and blood-supply. The general direction of its fibers is transverse, being attached at one extremity to the alveolar wall and at the other to the cementum of the root. The connective-tissue fibers are not merely attached to the surface of the calcified structure, but the strength of this attachment is greatly increased by the passage of the fibers into the substance of the bone at one extremity and into the cementum at the other. In general, the membrane is more closely adherent to the cementum than to the bone,

* For full histological description see page 357.

usually clinging to the former when removed from its socket. The nature of the articulation between the tooth-root and the alveolar socket, to the production of which this membrane chiefly contributes, is one peculiar to itself. While there is no marked mobility, there is, nevertheless, sufficient elasticity in the intervening membrane to provide against the severe concussions and lateral strains incident to mastication, the former being provided for by the general elasticity, while the latter is cared for by specially distributed fibers, which serve to return the tooth to its normal position when slightly rotated or laterally displaced. This elasticity is greatest in youth and up to the meridian of life, after which time it gradually becomes less pronounced. The membrane is thickest about the apical ends of the roots, filling in the so-called *apical space*, and in the cervical region, *dental ligament*, and the distribution of the fibers at these points is somewhat different from those about the body of the root. In the former location they are spread out fan-like from the apex of the root to attach themselves to the surrounding alveolar wall, while in the latter they pass longitudinally over the alveolar margins to unite with the periosteum of the parts. By the complex arrangement of the special fibers forming the dental ligaments they serve to lift the tooth from its socket when depressed from the forces of mastication, and also right the tooth when slightly notated by the same forces. In conjunction with the functions already mentioned, the alveolodental membrane is the medium by

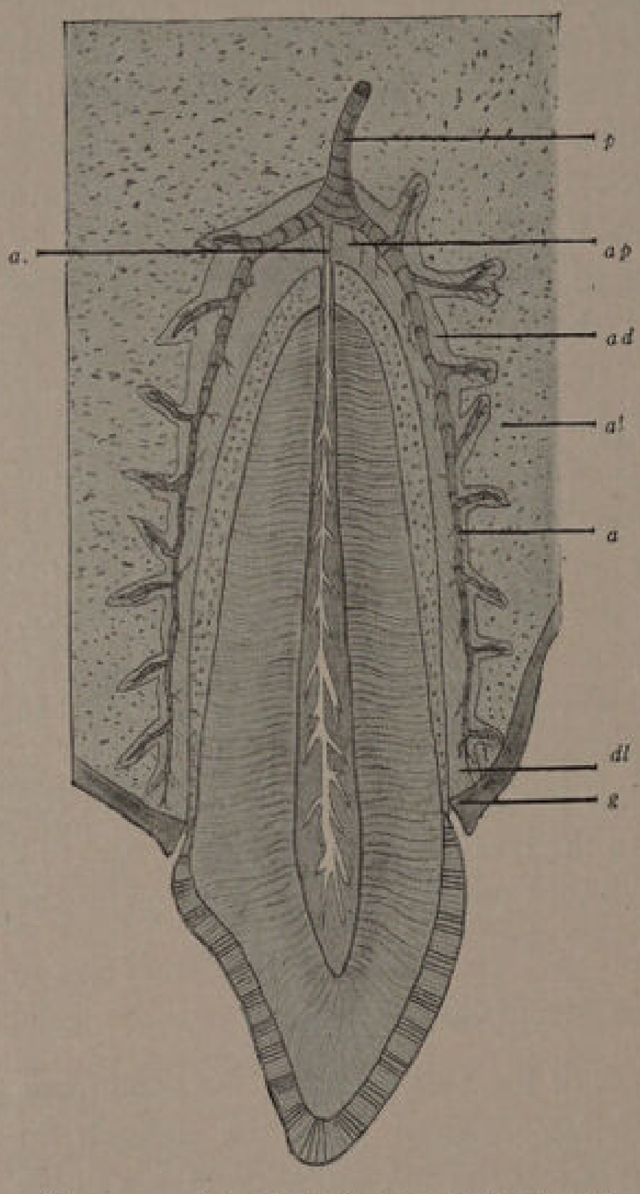

FIG. 212.—Alveolodental membrane tooth root and alveolus in longitudinal section *a*, arteries: *a.p*, apical space: *a.d*, alveolodental membrane: *a.l.* alveolus; *d.l.* dental ligament: g.;gingivae.

which all sensations originating on the tooth-surface are taken up and conveyed to the brain, making it the organ of the sense of touch to the tooth. In a normal tooth sensations of pain alone are conveyed through the nerves of the pulp. The nerves of the membrane act in precisely the same manner as do other sensory-nerve terminals, being influenced by the slightest touch applied to the surface of the tooth-crown.* In certain conditions of defective hearing the alveolodental membrane may be made to assist this function by the use of an instrument made for the purpose known as a dentiphone.

Blood-supply to the Alveolodental Membrane.—A very clear idea of the blood-supply to this membrane may be obtained from figure 212.

After entering the apical space by one or more arterial branches, the thickest portion of the membrane is gained where a number of smaller twigs are given off, one or more of which enter the pulp-canal of the tooth-root through the apical foramina supplying the pulp, while the others ramify through the substance of the alveolodental membrane, supplying the cementum while further minute branches are given off which penetrate the walls of the alveolus and anastomose with the arteries which supply the alveolar mucous membrane, in this manner providing a generous peridental blood-supply. Further on we shall see (see Development of the Teeth), that the blood-supply to the parts during the saccular stage of tooth development is alike distributed to the base of the pulp and to the follicular walls. After the completion of the development process this distribution is but little changed, the blood-vessels accommodating themselves to the alterations incident to the generation of the parts.

The Nerve-supply to the Alveolodental Membrane.—The nerve-supply to this membrane is distributed in a manner similar to the blood-supply, being derived from filaments given off from the dental nerves and entering the tooth-socket by the side of the blood-vessels, and by numerous filaments which reach the structure by passing through the many minute canals in the substance of the alveolar walls and the intervening septa.

GLANDS AND DUCTS

Glands of the Mouth.—The glands of the mouth, like the glands of other parts of the body, are composed almost entirely of epithelium, and may, therefore, be classed with the epithelial tissues. Glands exist in two principal forms—tubular and saccular (alevolar). The former

* For a minute description of the mucous membrane of the mouth see Part II, page 277.

occur either singly or in groups, and are further subdivided into simple tubular and compound tubular glands. A like condition is present in the saccular glands and similar terms are employed to qualify them—simple saccular glands and compound saccular glands.

A *simple tubular gland* is one composed mainly of a simple tube-like structure; a *compound tubular gland* is one composed of a number of smaller tubes emptying into a single duct.

A *simple saccular gland* is one formed by a sacculation of serous or mucous membrane into a single, simple sac, or by branched saccules having an excretory duct (alveolar system); a *compound saccular gland* is composed of a combination of branched saccules.

In the larger glands a sheath is formed by the surrounding connective tissue, from which numerous septa are given off to the interior of the gland, dividing it into compartments varying in size. These are known as *gland-lobules*. The connective-tissue walls of the gland-lobules carry the larger blood-vessels and nerves. Most glands are divided into two essential parts—the gland-follicle and the excretory duct—the former being specialized for the secretory function, while the latter, by communicating with the surface, conveys the secreted substance to that point.

The gland-follicles are composed of a layer of gland-cells, usually simple in character, surrounding the follicular walls. External to these is a specially modified connective tissue, forming the basement membrane, or membrana propria. The appearance of the gland-cells and their nuclei is continually changing, being thus influenced by their functional activity.

The excretory ducts consist of a wall of connective tissue and elastic fibers, lined by a columnar epithelium, either simple or stratified. In some instances the arrangement of the excretory ducts is much complicated, being divided into secretory tubes, which in turn are subdivided into smaller tubules—intercalated tubes.

As to function the smaller glands of the mouth are either *serous* or *mucous*, and, as they differ in the character of their secretions, so they differ in structure. The mucous glands are the most numerous, and are found beneath the mucous membrane of the lips, in the same membrane lining the cheeks, the hard and soft palate, the tonsils, and at the back of the tongue. These glands are quite variable in size, but are all of macroscopic proportions, appearing when examined in this manner as minute whitish bodies. The secretions from the glands are poured into the mouth through small ducts which pass in various directions through the substance of the mucous membrane. Beginning as a single duct for each gland, they pass to the submucous tissue, here branching into two or more smaller ducts terminating in alveoli, the number and size of these depending upon the size of the gland with which they are connected. The glands are variously named according to their location, those occupying the lips being known as *labial glands;* those of the cheeks, the *buccal glands* and *molar glands;* those of the palate, the *palatal glands*, etc. The mucous glands, although differing in size, are similar when histologically considered.

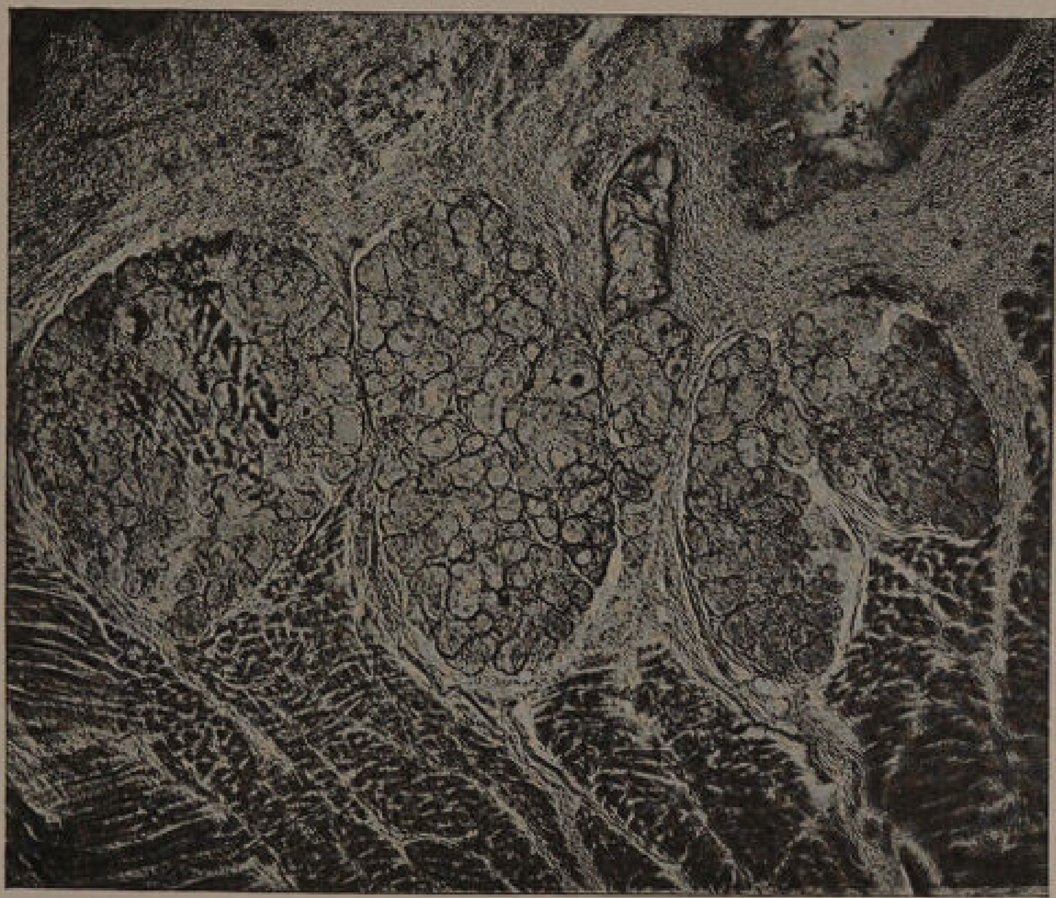

FIG. 213.—Section showing muscular and glandular tissue of the tongue. × 40.

The Glands of the Lips (*Labial Glands*).—The glands of the lips are situated in the submucosa, and are first observed immediately within the line of labial occlusion, at which point the thickness of the epithelium becomes somewhat definite and general. These glands are variable in size, but all are sufficiently large to be observed without the aid of the microscope. They are of the compound tubular variety, and communicate with the surface through an excretory duct, which throughout the greater part of its extent is lined with stratified, scaly epithelium.

In passing from the surface toward the gland-follicle, the main duct takes a spiral course obliquely through the tunica propria, and upon reaching the submucosa gives off numerous branches and twigs which terminate in the individual acini. The larger branches from the main duct are lined with stratified squamous epithelium, while the smaller twigs are provided with columnar epithelium. In many instances the main excretory duct, in its passage through the tunica propria, receives the principal duct from small accessory ducts. The framework of the labial glands is formed by the flexiform tissue composed of fasciculi of fine connective-tissue fibers belonging to the submucous layer, together with delicate, coiled elastic fibers. This framework gives support to a minute system of capillaries and small nerve-fibers supplying the acini. The acini are so arranged that those belonging to a large duct are united into a lobule by the submucous connective-tissue fasciculi, and these in turn are formed into lobes. By a continuation of the same fasciculi and fibers which limit a lobe, and in the meshes of which the acini are situated, a sheath to the excretory duct is formed. Besides the branched, tubular, mucous glands of the lips, there are occasionally found, located near their margins, sebaceous glands.

The Glands of the Cheeks (*Buccal Glands, Molar Glands*).—The glands of the cheeks are also situated in the submucous layer of the mucous membrane. They, like the labial glands, are of the compound tubular variety, and when microscopically examined are found to be similar in structure. They are somewhat larger than the labial glands and proportionately less numerous. The chief duct from each of these glands usually opens with a narrow mouth on the surface of the oral mucous membrane, and in its passage through the tunica propria takes a vertical or oblique direction. In the submucosa the chief duct branches into two or more smaller ducts, taking up alveoli. As the buccal glands are somewhat larger than the glands of the lips, they are composed of a greater number of ducts and alveoli. In the region of the third molars, another set of mucous glands open into the mouth, known as the *molar glands*. They are placed between the buccinator and masseter muscles, are similar in construction, and secrete a like fluid to those previously described, being larger than the buccal and smaller than the labial glands.

The Glands of the Hard and Soft Palate (*Palatal Glands*).—The mucous glands of the hard palate are situated in the submucosa and closely associated with the periosteum. They are compound tubular glands, and in all essential particulars are similar to the labial and buccal glands. They are quite numerous (200 to 300), isolated in the anterior portion, but are grouped into a single row or into two rows posteriorly. The glands are freely distributed in each lateral half, but are absent at the median line.

In the soft palate the glands are of the same character, somewhat variable in size, the largest being found in the uvula. The excretory ducts from these glands vary in diameter, in the nature of their fibrous structure, and in the direction taken in passing to the surface. Over the surface of the soft palate the mouths of these ducts are represented by minute orifices slightly smaller than the body of the duct, but in the

FIG. 214.—Section through base of tongue, showing serous glands.

uvula the opposite condition is present, the mouth of the duct being wider than the body. The course taken by the excretory duct is seldom a direct one, but after receiving all tributary branches passes obliquely through the tunica propria, and before entering the epithelium turns at an abrupt angle, and so continues until the surface is reached. The ducts are lined by a simple columnar epithelium, which in some instances is ciliated; the walls of the tubes consist of gland-cells and a structureless membrana propria. In some instances the surface epithelium may be reflected for a short distance and partly serve in the capacity of a lining to the tubular walls.

The Glands of the Tongue (*Lingual Glands*).—In this organ two varieties of glands are found, occurring both in the mucous membrane and in the superficial muscular strata, being principally distinguished by the nature of their secretions. The gland-cells of the one set are mucigenous, secreting mucin; these are the mucous glands. The other set is productive of a serous fluid, thin, watery, and containing albumin; these are the serous glands.

The mucous glands of the tongue are found along the lateral margins and over the root of the organ, being most numerous in the latter situation. They are of the compound tubular variety, and in most particulars are identical with the mucous glands of other parts of the oral cavity. The ducts are lined with ciliated columnar epithelium, and the walls of the duct consist of a homogeneous membrana propria and gland-cells. The glands found in the root of the tongue are frequently seen with their excretory ducts opening into the follicular crypts. The tubules consist of a structureless membrana propria and numerous gland-cells, the latter varying in appearance according to their function or functional activity. The crypts of the follicles constitute reservoirs for the acinous glands, and these receptacles frequently extend for some distance beneath the surface, receiving at various points the main excretory ducts from the mucous glands. These saccular-like reservoirs are lined by a well-defined capsule surrounded by a fibrous sheath, internal to which is an epithelial covering, a prolongation of the common epithelium of the mouth. Between these two layers are a number of minute, closed lymph-follicles placed in a single layer. The mucous glands on the lateral walls of the tongue are, for the most part, situated near the middle or posterior portion. The ducts from these glands usually open directly toward the cheek, but in rare instances they pass obliquely downward and open near the floor of the mouth. At the tip of the tongue, buried beneath the mucous membrane and some of the muscular fibers, may be found a pair of mucous glands (Nuhn's) which open by free orifices on the under surface. At the root of the tongue, flat, lenticulated elevations of the mucous membrane are present, beneath which is imbedded conglobate, glandular substance. These show a central orifice leading to a small pit lined with tessellated epithelium.

The serous glands of the tongue are compound tubular glands, and are found in the region of the circumvallate papillæ, closely associated with the taste-buds. The excretory ducts, lined with a simple or stratified columnar epithelium, the latter sometimes ciliated, open near the base of the papilla, or between the papilla and its wall. The tubules are similar to those in the mucous glands, consisting of a delicate, structureless membrana propria and gland-cells. The gland-cells are composed of a frail, transparent protoplasm, containing rounded nuclei.

The Salivary Glands (Fig. 215).—The chief salivary glands are six in number, three on each side. They are named *parotid*, *submaxillary*, and *sublingual;* the former, secreting true, thin, watery saliva is a true salivary gland, while the latter two are known as mixed, or muco-salivary glands, secreting both mucus and saliva. These glands each consists of an excretory duct, branching frequently in a tree-like manner into smaller ducts, lined throughout with a layer of epithelial cells. From the smaller ducts terminal branches are given off, which in turn are lined with epithelium. The other portions of the glands are invested by columnar epithelium, and arranged in grape like fashion about the main excretory duct, and consequently belong to the group of racemose glands. The terminal branches or alveoli attached to the smaller excretory ducts are so numerous that they become much compressed from pressure, and the grape-like appearance is more or less destroyed, and but little space is left for interstitial tissue. Each gland is inclosed in a fibrous connective-tissue capsule, and from this numerous septa of fibrous trabeculæ pass to the interior and divide the glandular substance, first into lobes, these being subdivided into lobules, the lobules by further subdivision forming the alveoli. The glandular connective tissue is loose in texture, containing many elastic fibers and lymphoid cells. Fine bundles of fibrous tissue, together with branched connective-tissue corpuscles, constitute the connective-tissue matrix between the alveoli.

The Ducts.—Entering the interior of the gland, the chief duct divides into a number of large branches, one of which passes to each lobe, each of these giving off several branches which connect with the several lobules. Upon close examination the central tube of each lobule is observed to throw off several small tubes—the intralobular tubes. Following these are the intermediate tubules, which continue into the terminal compartments. The chief excretory duct consists of a double layer of cylindric epithelium and fibro-elastic cartilage. Close beneath the epithelium is a compact membrana propria. The intralobular tubes are each provided with a distinct lumen. The walls are composed of a membrana propria lined by a layer of columnar epithelium, the cells of which contain a central round nucleus.

The Parotid Gland.—This gland is the largest of the three, and is placed a little below and in front of the ear, having the following boundaries: Anteriorly, by the ramus of the mandible; posteriorly, by the styloid and mastoid processes of the temporal bone; above, by the root of the zygoma, and below, by a line drawn backward from the angle of the jaw. While the extent and outline of the gland is somewhat variable, its position is approximately that outlined in figure 215. Its superficial surface, somewhat lobulated, is in close relation to the skin and fascia, while deeply it penetrates well into the neck by two processes,

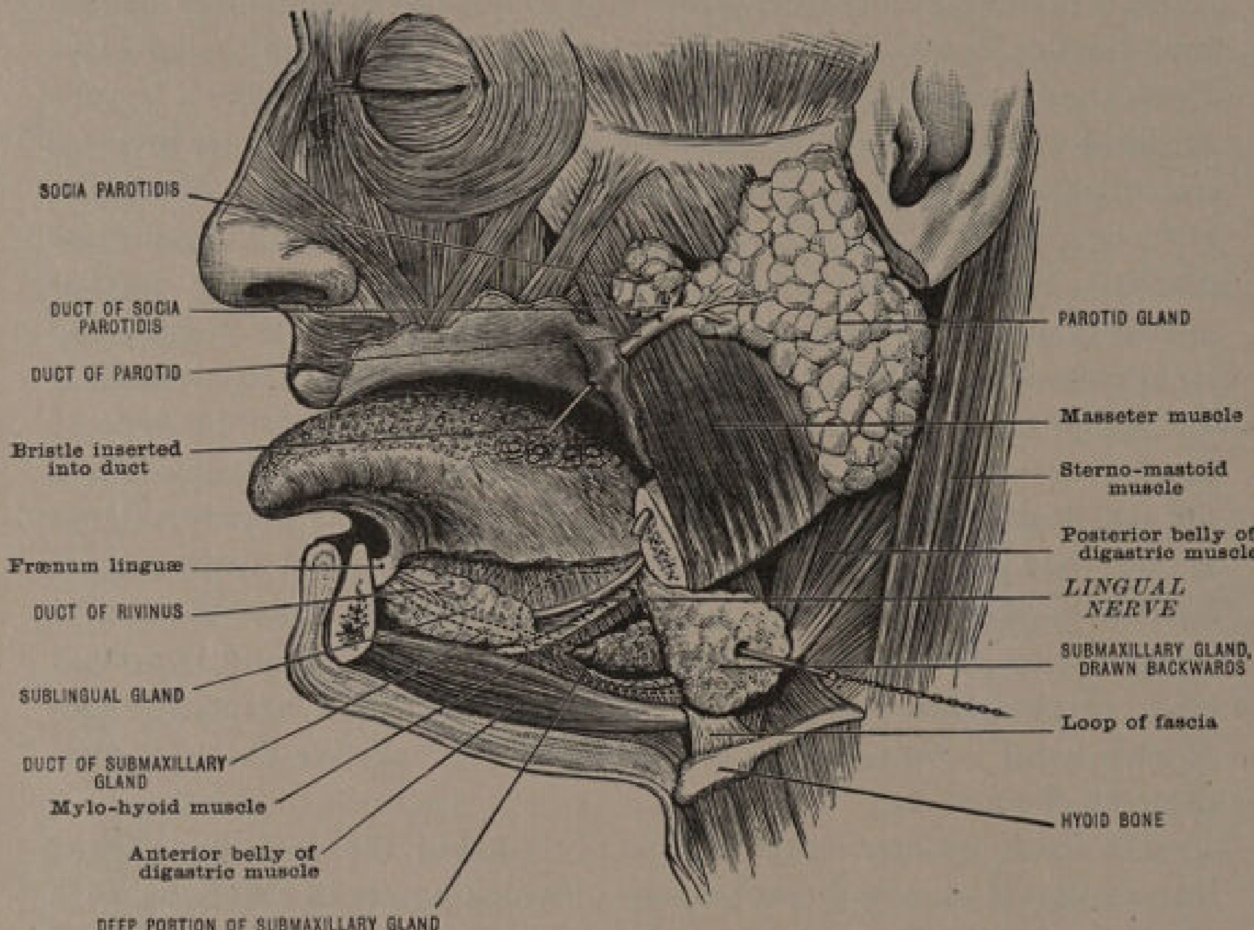

FIG. 215.—The salivary glands. (*Morris.*)

one of which passes behind the styloid process and beneath the mastoid process of the temporal bone and the sternomastoid muscle, while the other passes in front of the styloid process. Given off from the body of the gland and extending in vuaris odirections are a number of processes or lobes, one extending forward between the two pterygoid muscles, and known as the pterygoid lobe; another passing into the glenoid cavity, the glenoid lobe; while a third passes deeply between the carotid vessels, and is called the carotid lobe. In many instances there is an additional lobe, which is detached from the body of the gland, known as the *socia parotids*. When present, this lobe is placed over the parotid duct and empties into it. Passing through the substance of the gland are a number of arteries and veins, principal among which are the external carotid, transverse facial, and internal maxillary, the gland receiving its blood-supply by branches from these. The internal carotid artery and internal jugular vein lie close to its internal surface. The facial nerve and its branches and the great auricular nerve pass through the gland from before backward, and supply its substance with nerve-force. The weight of this gland is from one-half to one ounce.

The Parotid Duct.—Leading from the gland to the mouth is the parotid or Stenson's duct. After passing through the fat of the cheek and the fibers of the buccinator muscle, the duct comes in contact with the deep layer of the oral mucous membrane. After passing between this structure and the cheek tissues for a short distance it enters the mouth opposite the crown of the upper second molar, the orifice of the duct appearing on the surface of the mucous membrane in the form of a small papilla, which may be readily observed with the naked eye. The duct is composed of a double layer of cylindric epithelium and fibrous tissue, intermingled with elastic fibers. The main duct divides and passes into the intralobular tubes, beyond which are the intermediate tubules. The intralobular tubes are lined by columnar cells, while the intermediate tubules are lined by elongated, spindle-shaped cells. The salivary cells lining the acini are different in character from those in the submaxillary and sublingual glands. The parotid gland is a true salivary gland, and the serous gland-cells composing its epithelial lining are disposed in a single layer. The cells are columnar or pyramidal in form and composed of a dense protoplasm, containing a spheric nucleus.

The Submaxillary Gland.—This gland, which receives its name from occupying a position near the lower border of the mandible, is somewhat smaller than the parotid. It is situated beneath the mylohyoid ridge, and occupies the anterior part of the submaxillary triangle, extending upward to occupy the submaxillary fossa on the lower border of the mandible. Superficially, it is covered by the skin and a few muscular fibers and the deep fascia. The facial vein and branches of the facial nerve pass over its superficial surface. Deeply, it is in relation with the mylohyoid and hyoglossus muscles, and also with the mylohyoid artery and nerve. The gland receives its blood- and nerve-supply from the arteries and nerves which penetrate it. This gland is separated from the sublingual gland by the mylohyoid muscle, and weighs about two drams.

The Submaxillary Duct.—The submaxillary duct, otherwise known as Wharton's duct, passes forward and inward, opening into the cavity of the mouth on the summit of a small papilla near the frenum linguæ. The duct, which is nearly two inches in length, first passes through the adjacent muscular tissue, and finally beneath the oral mucous membrane to its outlet. Like the parotid duct, it is lined by a reflexion of the oral mucous membrane. The excretory duct, like the main duct of the parotid gland, is composed of a double layer of columnar epithelium, external to which is a layer of cellular connective tissue, the whole being surrounded by a thin stratum of muscular fibers placed longitudinally. The intralobular tubes are lined by a specialized, elongated, cylindric epithelium, which, in the intermediate tubules, becomes clothed with cubic cells. The acini are lined either with serous gland-cells similar to those lining the acini of the parotid gland or with mucous gland-cells, the former being most constant in their presence. The two kinds of acini are uninterruptedly connected. In most instances there are but a few mucous acini present within the lobule, but occasionally they are found in abundance. The submaxillary is a mixed or mucosalivary gland.

The Sublingual Gland.—This is the smallest of the salivary glands, and is also named from its location beneath the tongue. Its position is beneath the tip of the tongue and the mucous membrane covering this part of the floor of the mouth. It rests in the sublingual fossa of the mandible, meeting with its fellow at the median line, and extending as far back as the mylohyoid muscle, which separates it from the submaxillary gland. The gland is supplied with blood from the sublingual and submental arteries, and with nervous energy from the gustatory nerve. The weight of this gland is about one dram.

The Sublingual Gland.—The excretory duct (Rivini's duct) is similar in structure to the chief excretory duct of the submaxillary gland. The intralobular tubes are lined with columnar epithelium. The intermediate tubules are not positively known to exist, and it is quite probable that the intralobular tubes pass directly into the terminal compartments. The acini are composed of a membrana propria and gland-cells, both mucous and serous. The former are much more numerous than in the acini of the submaxillary. The membrana propria is composed of stellate connective-tissue cells. This gland is also a mixed or mucosalivary gland.

Blood-vessels and Lymphatics in the Salivary Glands.—The lobules of the salivary glands are richly supplied with blood-vessels. The many arterial branches break up into numerous capillaries, which, forming a dense network, surround the acini, being supported by the interalveolar connective tissue. The lymphatic vessels accompanying the intralobular tubes are in communication with numerous lymph-spaces which exist between the interalveolar connective tissue and the walls of the acini. The substance of the gland is further supplied with blood by numerous plexuses of lymphatics which are carried or supported by the interlobular connective tissue.

Nerve-supply to the Salivary Glands.—The nerve-fibers distributed to the salivary glands are both of the medullated and non-medullated variety, and other nerve-tissue in the form of ganglion-cells is present. The medullated nerve-fibers are abundantly numerous, and are distributed to all parts of the gland. In many respects the fibers are peculiarly constructed. They are extremely delicate, made so by the frail nature of this medullary sheath; they divide and give off so many branches as to almost give them a feathery fineness. This peculiarity is especially noticeable toward their extremities, where the fibers lie between the alveoli and give off minute branches in all directions. The nerve-fibers are placed in close relation to the tubes and tubules, which they freely encircle; they perforate the membrana propria and break up into finer subdivisions, from which they are distributed to the exterior of the epithelial cells. In the alveoli two kinds of nerve terminations are found. The primitive fibers branch between the alveoli and are distributed to the membrana propria, upon entering which numerous branches are thrown off which pass to the epithelial cells beneath. The non-medullated fibers, which are much less numerous, are composed of an extremely delicate fasciculi of transparent fibers resembling axis-cylinders, and invested by a sheath of connective-tissue cells containing nuclei. The distribution of these fibers is similar to the medullated fibers, encircling the tubes and penetrating the membrana propria, being similarly distributed to the alveoli.

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CHAPTER VI

Tissues of the Teeth—Enamel; Dentin; Cementum; the Tooth-Pulp—The Alveolodental Membrane

TISSUES OF THE TEETH

Enamel.—The enamel, which forms a cap-like covering of varying thickness over the entire crown of a tooth, is a vitreous, hyaline sub-

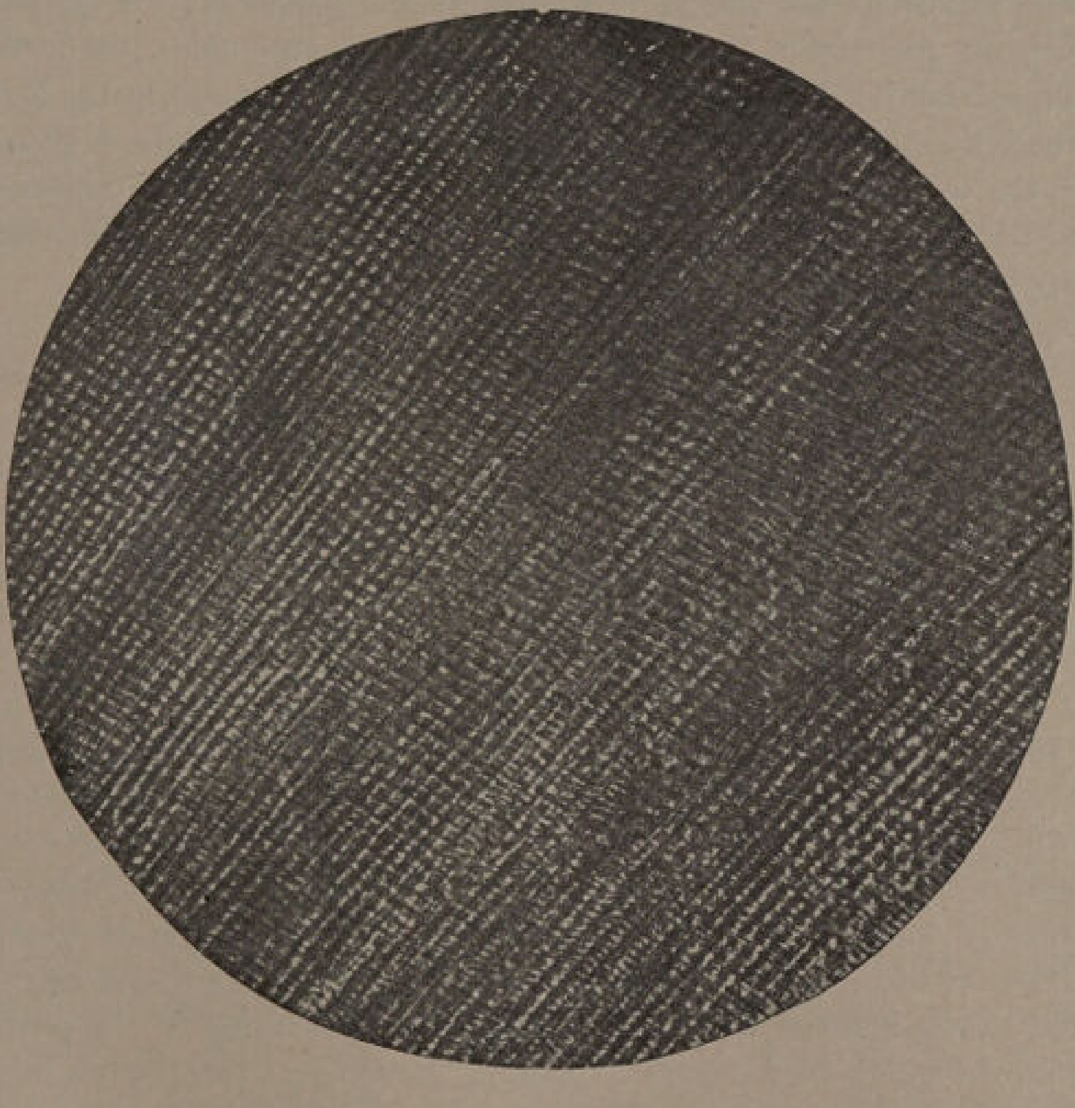


FIG. 216.—Section of enamel from human tooth (specimen by J. Howard Mummery). × 350. (*After Williams.*)

stance, of epithelial origin, containing but little, if any, organic matter as a result of which it is the hardest tissue in the body. The thickness of the enamel cap appears to be strongly influenced by the function of the different parts of the tooth-crown, being thickest over the incisal-edges of the anterior or simple teeth, while in the posterior or complex teeth, the entire occlusal surface is provided with the thickest enamel layer. It more or less evenly distributed over the lateral walls of the crowns, but as the cervical line is approached, its thickness is gradually diminished until it is finished off to a thin knife-like edge. Chemically, enamel is chiefly composed of the salts of lime, calcium phosphate predominating. Calcium carbonate, magnesium phosphate, and calcium fluorid are present in smaller quantities. The proportionate quantity of lime-salts in enamel is not fixed, as a result of which a slight variation in density occurs in the enamel of different subjects. These variations are chiefly regulated by the proportionate quantity of calcium phosphate and carbonate—a greater amount of the former being productive of additional hardness, while an increase in the latter beyond the minimum amount decreases this quality. As a general rule, the teeth of males contain a greater amount of calcium phosphate than the teeth of females, as shown by the following analysis furnished many years ago by von Bibra:

	Man	Woman
Calcium phosphate and fluorid	89.82	81.63
Calcium carbonate	4.37	8.88
Magnesium phosphate	1.34	3.55
Other salts	.88	.97
Cartilage	3.39	5.97
Fat	.20	a trace.
Total organic	3.59	5.97
Total inorganic	96.41	94.03

In general the structure enamel is composed of numerous hexagonal prisms, with a common arrangement favoring protection to the tooth crown. These prisms are known as *enamel prisms*, *enamel fibers*, or *enamel rods*. The enamel prisms may be said to sit on end against the surface of the dentin, minute depressions in the latter receiving the extremities of the rods. The direction of the enamel prisms, as compared to the body of the tooth-crown, varies according to the part of the crown which they occupy. Taking the entire crown of the tooth, they radiate in such a manner from the surface of the dentin that at the incisal-edge or occlusal surface of the tooth they are more or less vertical, while over the lateral surfaces they tend to the horizontal direction. In addition to the calcified enamel prism there exists between the prisms a calcified cementing substance the so-called *interprismatic substance.* A microscopic examination of properly prepared specimens of enamel exhibits numerous evenly distributed varicosities, producing a transversely striated appearance to the rods. The enamel rods are regularly disposed in that portion of the enamel most closely associated with the dentin. On the cusps of the teeth they are twisted, curved and more or less interlaced, while on the lateral walls of the crowns, they are straight and uniformly parallel with each other. In general, the enamel rods, which begin on the surface of the dentin, are continuous through the entire thickness of the enamel. In passing from the dentin to the surface, the individual rod, to occupy a proportionate space in all parts, would have to increase in diameter; but this it does not do. In place of this there

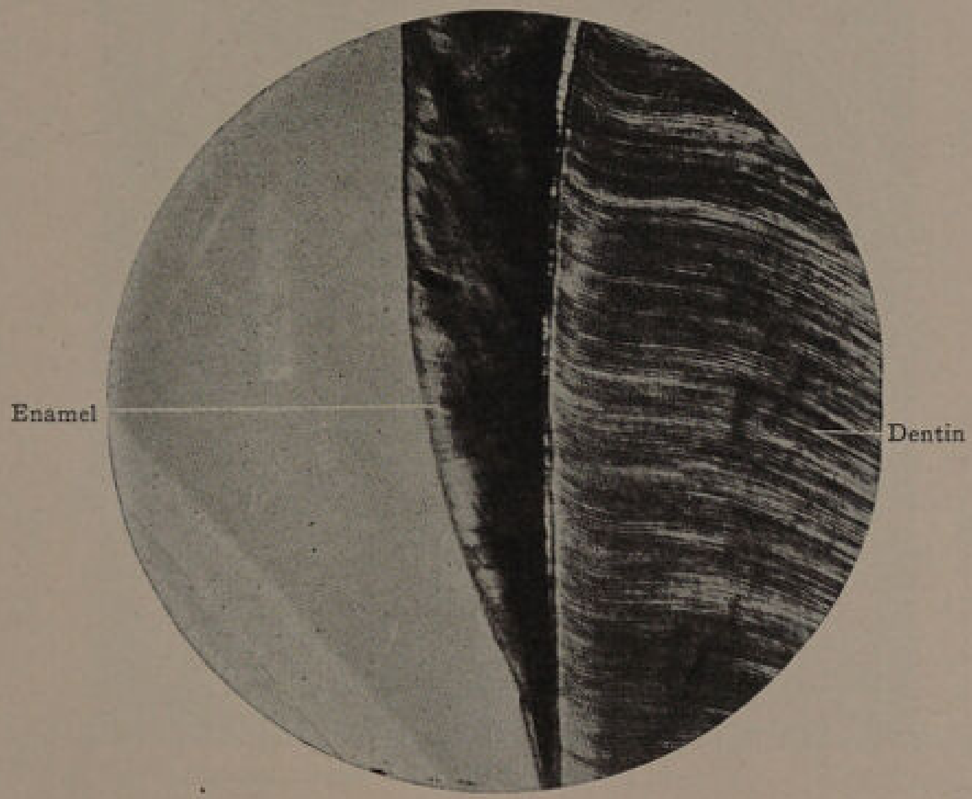


Fig. 217.—Enamel and dentin from human tooth, showing gradual reduction in the thickness of the former as the cervix is approached. × 20.

are present numerous supplemental or peripheral rods, which extend but a short distance from the surface, filling in the interspaces formed by the longer rods. With the exception of the faint transverse striations above referred to the enamel prisms appear to be structureless. A variety of opinions have been expressed in regard to the cause for the striated appearance of the enamel rods. One theory attributes the striated appearance to be due to a temporary arrest of calcification, but more recent investigation has shown the cause to be the presence of varicosities in the individual rods similar in many respects to the varicosities in voluntary muscle fibers, and which produce the striated appearance in that tissue. Some authorities have asserted that normal enamel is non-striated, claiming that they are due to the preparation of the specimen, which usually being mounted in Canada balsam is influenced sufficiently from the slight acid reaction to produce the striated appearance. These statements Leon Williams emphatically denies, saying that, while in some specimens the varicosities are scarcely apparent in some parts, they are decided in others. If this be accepted, it would seem to entirely overthrow the theory in regard to the action of

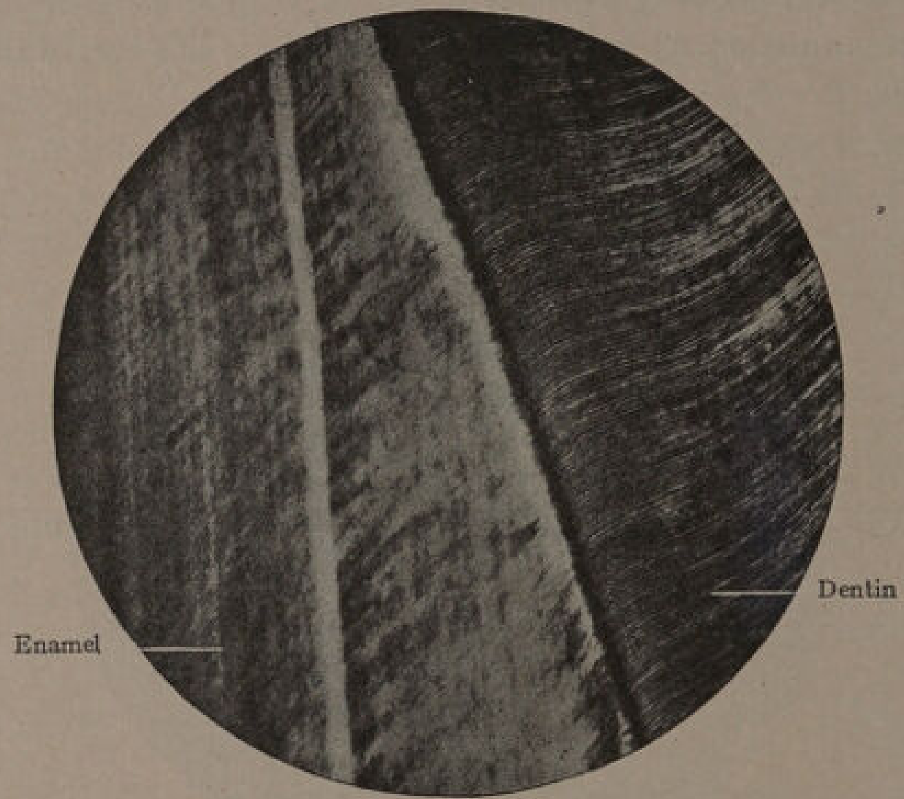


FIG. 218.—Comparison in the appearance of the enamel and dentin under low power of the microscope. × 40.

the acid, which would be distributed to all parts alike. In addition to this the varicosities may be seen when specimens are mounted in media other than Canada balsam.

It is now generally conceded that the striated appearance in enamel is due to the presence of actual varicosities which exist in the individual rods or prisms, this resulting from the globular like deposit of lime during the process of formation.

According to Williams, the varicosities of one enamel prism, are opposite those of the adjoining prisms and by the coming together of the varicosities the prisms become united by means of processes which they send out. In like manner the varicosities upon the same rod are connected by processes running parallel with the prism. According to Von Ebner, enamel is traversed by numerous minute canals, and Heitzmann claimed to have found organic fibers in its substance. Williams, while admitting the enamel structure to be far more complex than past research has shown, appears to have fully demonstrated that neither canals nor organic fibers are present—in fact, he denies the presence of the least trace of organic matter in this structure. The interprismatic substance at one time considered by some authorities to be an organic structure, is now known to be a transparent, inorganic substance.

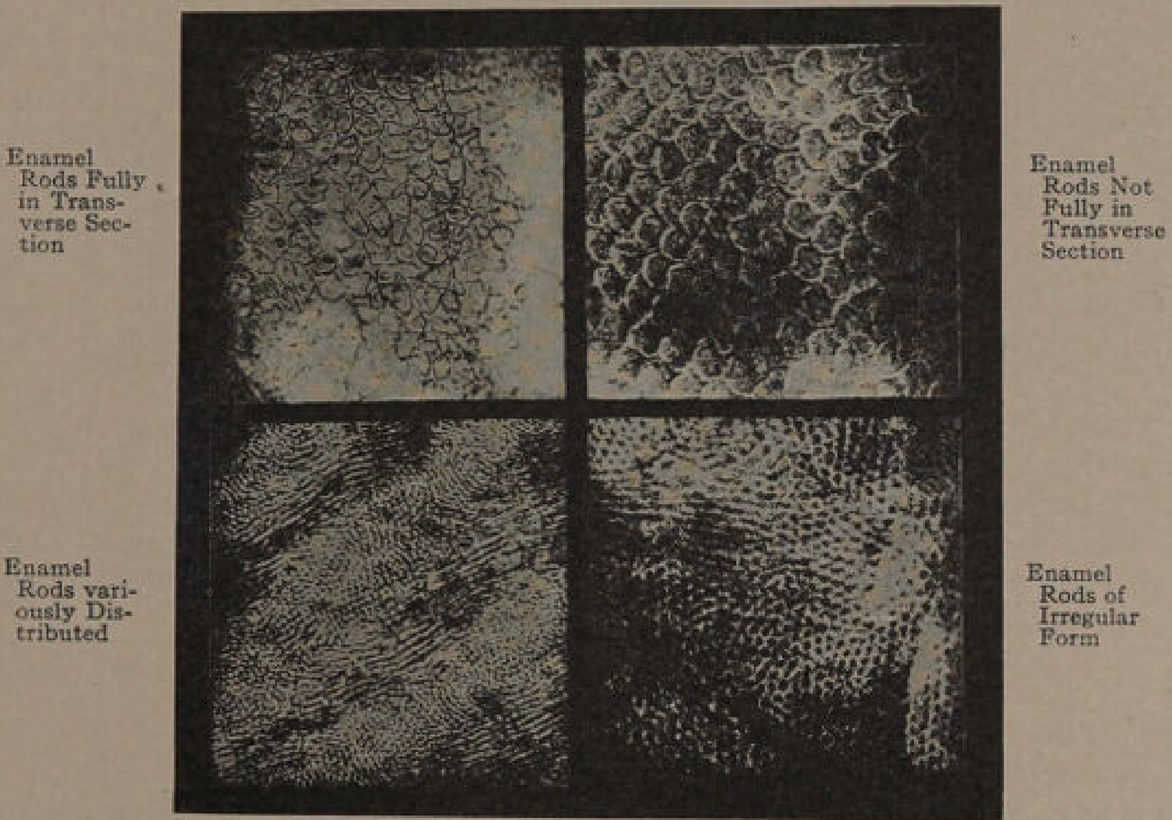


FIG. 219.—Human enamel. Transverse ground sections. (*After Gysi.*)

Williams by numerous experiments was enabled to secure a specimen in which the interprismatic spaces of one layer were not backed up by the rods of another layer. In some instances the specimen showed the rods well separated and the interspace closed by a perfectly transparent substance, in the interior of which might be seen connecting processes passing from one rod to another. That the enamel is entirely made up of inorganic material, and therefore not capable of transmitting or receiving sensations, may be demonstrated by the simple experiment of immersing a thin section of this tissue in a weak solution of chromic acid, the result of which will be a speedy separation of the enamel prisms which have been liberated by the destruction of the interprismatic substance. Chromic acid is one of the best preservatives of organic tissue known, and if the cementing substances in enamel were organic or even partly so, the prisms by this test would not be freed, but instead would become more firmly cemented together. Therefore we infer from this that the interprismatic substance is even less highly organic than the prisms themselves, these not being acted upon until after the material which holds them together. In addition to the striated appearance formed by the varicosities of the individual prisms of fully developed enamel, other markings of a different character, and upon a

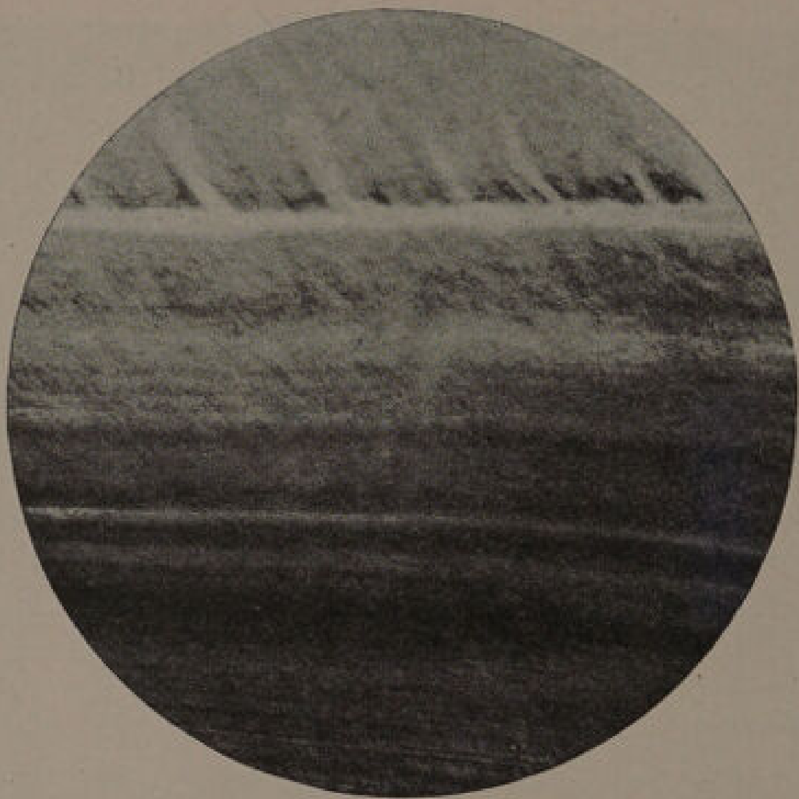


FIG. 220.—Thick section of enamel of human tooth, showing brown striæ of Retzius. × 40.

much larger scale, are present and known as the "*brown striæ of Retzius*" (Fig. 220 and 221). These markings, readily seen with a low power, are of a brownish color, and run nearly parallel with the surface of the dentin or enamel. Those striæ nearest the surface of the dentin are inclined to follow the contour of that structure, extending in many instances the entire length of the crown. The lines nearest the surface are the longest in the region of the incisal-edge, or occlusal surface of the crown, becoming shorter as the neck of the tooth is approached, being directed at an acute angle to the surface of the dentin at that point. A number of theories are advanced to account for the presence of the "brown striæ of Retzius." Tomes suggests that, coinciding as they do with the outer surface of what was at one time the primitive enamel cap, they might be considered as in a measure outlining the stratifications of the primary deposit. Another theory, but one seemingly without foundation, is to the effect that the striæ are produced by an arrest in the calcifying process. In accordance with the now generally accepted belief the lines of Retzius are in reality lines of growth or incremental lines, pigmentation in sufficient amount being deposited with the inorganic salts during the process of enamel formation.

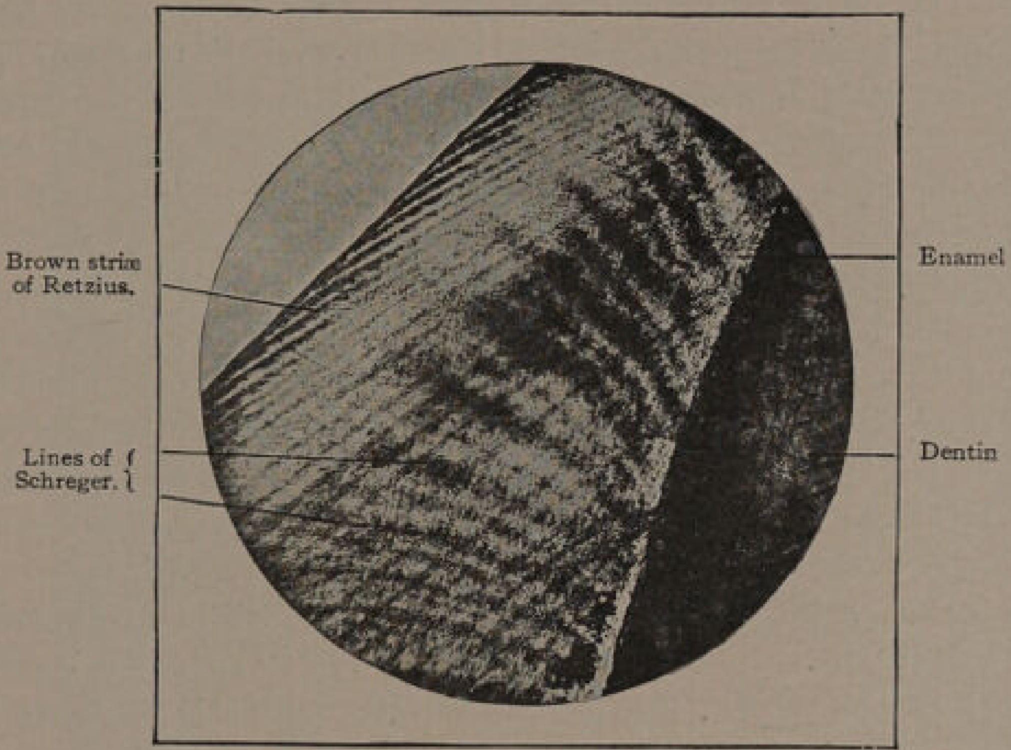


FIG. 221.—Enamel and dentin, human tooth. (*After Gysi.*)

Still another set of lines or markings are to observed in the substance of sections of enamel, these being known as the "*lines of Schreger.*" Figure 221 shows these lines as they appear in the enamel by reflected light, the same being quite invisible by transmitted light. The presence of these lines is due to the various directions assumed by the contiguous groups of enamel rods. Beginning at the dento-enamel junction they are well defined, but gradually become less marked as the surface of the enamel is approached. In that part of the enamel most closely associated with the dentin there can occasionally be seen what appears to be processes from the dentinal fibers penetrating the enamel. Such a state of affairs could hardly be considered normal when it is taken into consideration that the dentin and enamel calcify in opposite directions, and that the outer wall of the former is completed before enamel calcification begins.

Nasmyth's Membrane.—The enamel cuticle, Nasmyth's membrane, or persistent dentinal capsule, is an exceedingly thin and peculiarly indestructible structure, entirely covering the enamel or newly erupted teeth. As to the presence of this membrane, which can be demonstrated only by chemical detachment, there appears no doubt, but in regard to its origin and definite structure much difference of opinion has been expressed. By some writers (Tomes and Magitot) it is maintained that it is continuous with, and similar in structure to, the cementum covering the root, being an extension of the outermost layer in the region of the neck of the tooth; and, in view of the fact that lacunæ are found in its substance, this theory would appear to be correct. On the other hand, it is considered to be a product of the epithelium (Huxley and Kölliker) and in no manner connected with the cementum. In the opinion of the author, it would, be difficult to understand how the theory advanced by Tomes could be accepted. During the entire period of saccular development the crown of the tooth is in close relationship to the enamel organ, this structure intervening between the forming enamel and the wall of the tooth-sac, from which the cementum is developed. It would, therefore, appear that this membrane is generated from the external epithelial layer of the enamel organ by a change in the character and form of these cells and its formation may be attributed to a metamorphosis of the ameloblastic layer, the prismatic cells assuming a horizontal direction. Many years ago Mrs. Emily Whitman at one time devoted much time to the study of the development of mammalian teeth, and appears to be of the opinion that the cuticula dentis is the result of a change in the form and character of the enamel cells, this metamorphosis taking place either before or after calcification of the underlying tooth-tissues. Nasmyth's membrane shows many characteristics which differ from those of the body of enamel subjacent to it, serving as an indestructible, highly polished surface-capping to the enamel prisms. The indestructible nature of this membrane by reagents would appear to indicate that in structure it is closely akin to the structure lining the dentinal tubules, the lacunæ, etc. Another argument against the theory that the enamel cuticle is connective tissue lies in the fact in no other part of the body do we find connective tissue exposed to the surface, or in contact with the air.

It must be understood that this membrane is present only for a comparatively brief period, and is most pronounced on the crowns of the deciduous teeth, and from these as well as from the crowns of the permanent teeth it rapidly disappears through normal abrasion forces.

Development of Enamel.—Preparations for the development of the enamel begin toward the close of the second fetal month, appearing first as a multiplication and specialization of the primitive epithelial cells in the form of a continuous linear projection upon the surface of the future alveolar ridge. From this crest, or *epithelial ridge* the future enamel organs are indirectly given off. Soon after the establishment of the epithelial ridge sometimes called the *dental ridge*, the cells

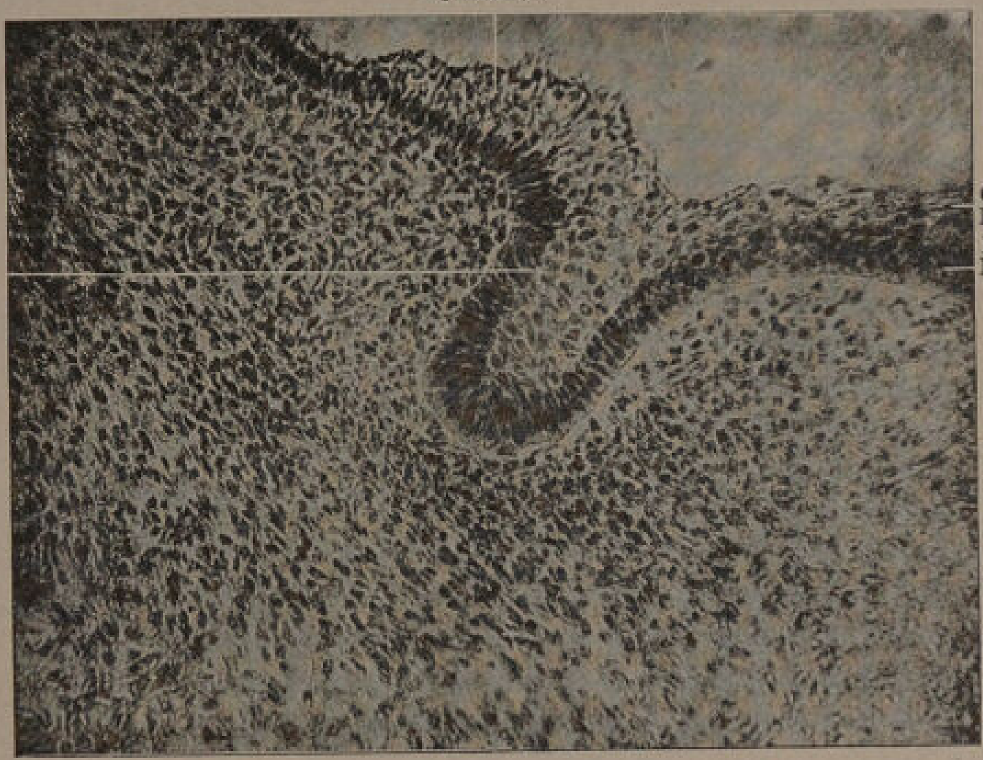


FIG. 222.—Vertical section, tooth-band, human embryo. Tenth week. × 300.

begin to dig down into the subjacent structure forming a decided groove or furrow which expands uninterruptedly from our extremity of the future alveolar ridge to the other. This bow-shaped depression being the *dental furrow* or *groove*. The epithelial cells responsible for the formation of the dental groove are the infant or malpighian layer, and soon force their way more deeply into the mesodermic cells forming a continuous band extending in bow-shaped fashion from one end to the other of the future maxillæ or mandible, this being the *tooth-band*. Given off from the lingual side of the tooth band is a projecting body of epithelial cells the *tooth lamina*. It must be noted that up to this time there has been no provision for individual tooth development, all cellular activity being distributed equally to all parts of the future maxillary arch. Soon after the establishment of the tooth laming its free border gives place to ten little bud-like projections the *tooth-bulbs*. These gradually enlarge, push their way into the mesoderm and become invaginated forming the primitive enamel organ, Fig. 224. These primary dental bulbs, number one for each tooth to be generated, and coincidently with their appearance an aggregation of closely associated mesodermic cells make their appearance in close association with them and form the primitive dentin germ, or *dentin papilla*. It will thus be observed that the enamel is a product of the surface epithelium, *ectodermic*, while the dentin is generated from the connective tissues, *mesodermic*. The dentin

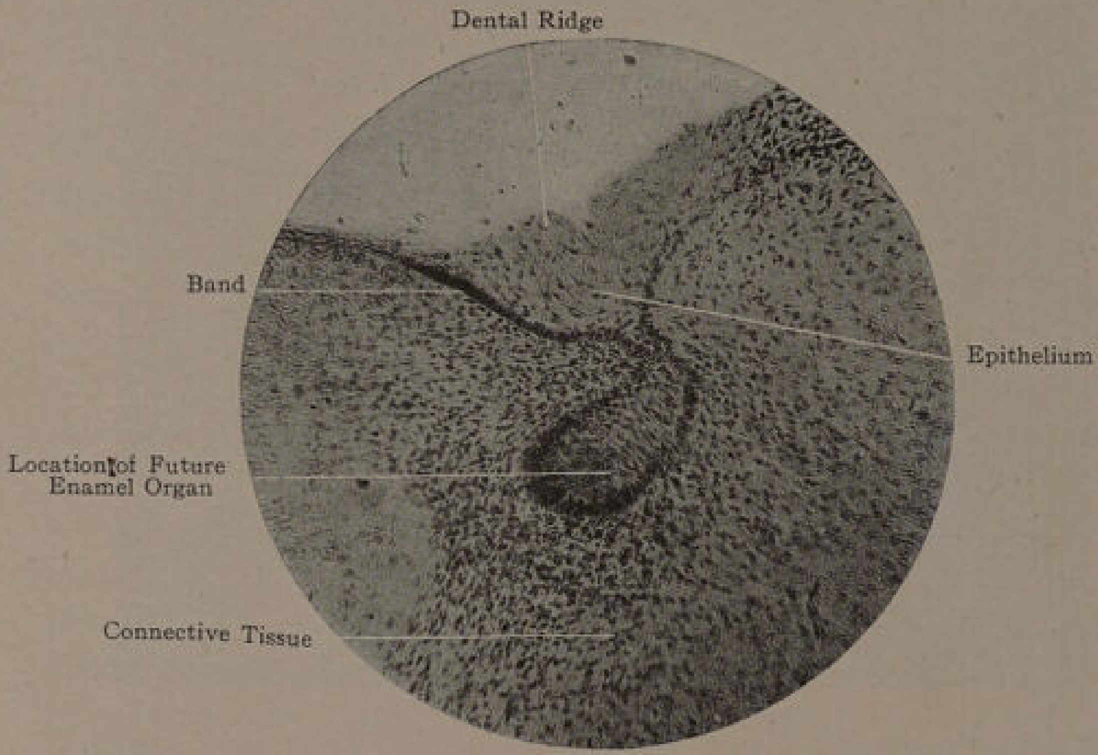


Fig. 223.—Tooth band in vertical section. About twelfth week. × 200.

papilla gradually pushes into the concavity of the forming enamel organ, and at a latter period the odontoblastic cells are generated about the periphery of the papilla, closely followed by a surface calcification of the dentin. Soon after the forming of the external layers of dentin the ameloblasts or enamel-forming cells become active, and a deposition of enamel takes place in contact with the dentin cap. With this relationship existing between the enamel organ and the dentin germ, collectively called the *tooth germs*, the first function of the enamel organ becomes one of moulding the form of the tooth-crown, by controlling the location or position of the mesodermic cells in the dentin germ.

Before taking up the subject of enamel calcification, brief reference will be made to the further development of the enamel organ. As the growth of this organ proceeds there is, as the result of a rapid proliferation of the cellular structure, a marked tendency for the organ to become separated from the tooth-band. The peripheral cells or *external epithelium* are columnar or prismatic, and remain so, while those in the center, primarily polygonal, soon become transformed into a radiating network or *stellate reticulum*. The appearance of a stellate reticulum is first observed to take place in the cells occupying the central portion of the

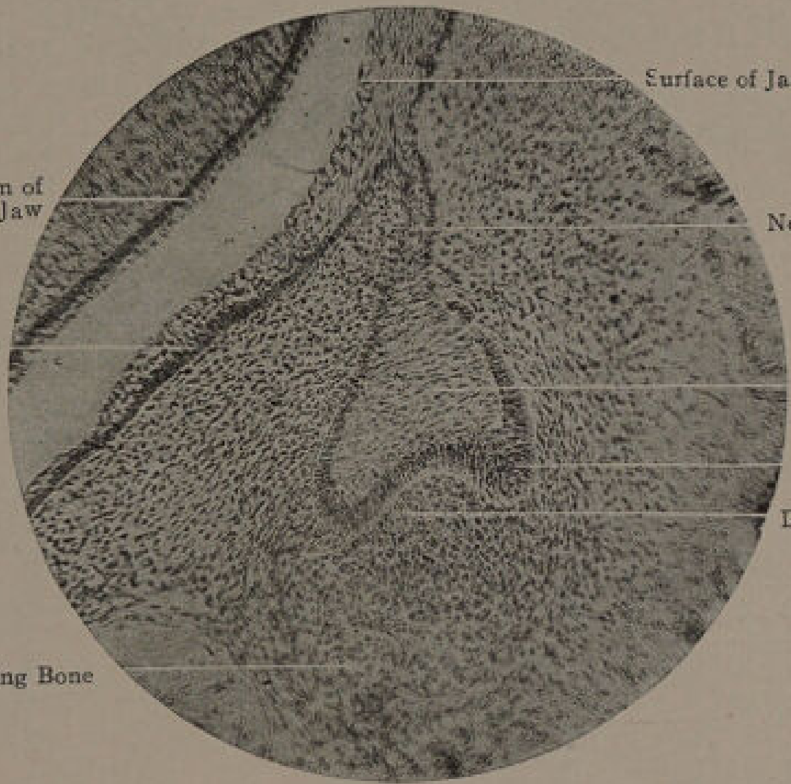


FIG. 224.—Vertical section through tooth-band, cord, dentin papilla, and enamel organ, about fifteenth week. × 150.

enamel-organ, this cellular transformation progressing from the center outward, but ceasing before reaching the columnar surface cells contiguous to the dentin papilla. Between the enamel cells and the stellate reticulum is a layer of unaltered cells—the *stratum intermedium*. In the earlier stages of the development of the enamel organ the peripheral cells are alike, being columnar or prismatic but almost coincident with the appearance of the dentin papilla, the cells most closely related to it are observed to become elongated, and form the *internal epithelium* of the organ. As the cells forming this internal epithelium become differentiated or elongated, their nuclei, instead of occupying the center of the protoplasmic body, are carried to their extremities. It will thus be seen that the completed enamel organ consists of four divisions or layer of cells. Beginning with its convex surface is an external epithelium or outer tunic, successively followed, in passing toward the dentin papilla, by a stellate reticulum, stratum intermedium, and an internal epithelium or inner tunic. As the growth of the enamel organ proceeds, the tooth-band becomes smaller and smaller in size, until

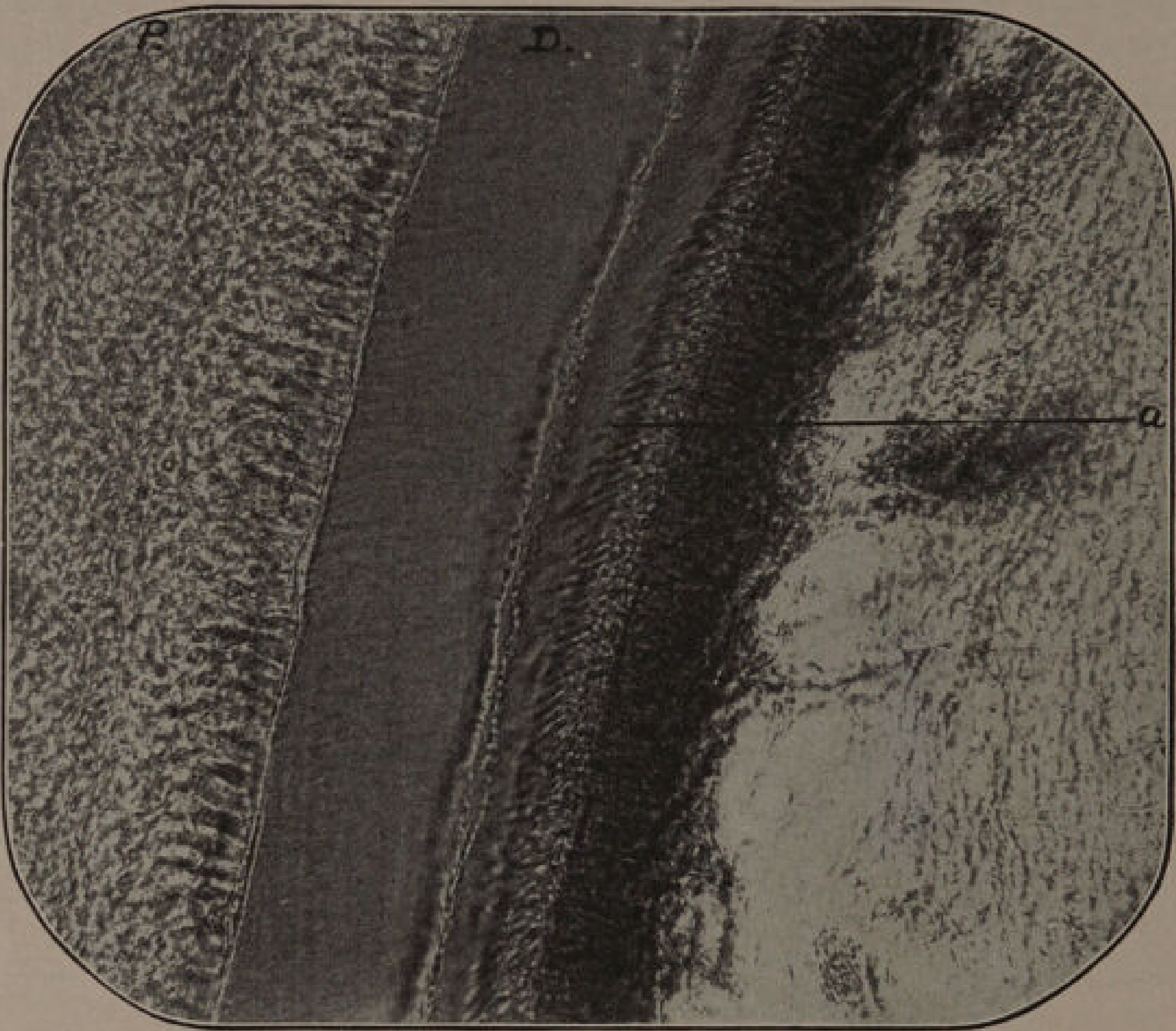


Fig. 225.—Section of a developing tooth of lamb. × 600. *a*, Ameloblasts; *D*, dentin, *P*, dental pulp.

finally a complete rupture takes place. This rupture however, does not occur until the enamel organ has about or fully completed its development, and, after remaining so long under the influence of the oral epithelium, it must be considered, as before stated, an epithelial structure. It is through the agency of the internal epithelial cells of the enamel organ, the *enamel cells* or *ameloblasts*, that calcification of the enamel takes pace, which subject will next be considered.

The Calcification of Enamel. Amelification (Fig. 225 and 226).—Two general theories have been advanced in regard to the calcification of enamel. In one it is claimed that the *ameloblasts* or enamel cells became directly calcified or converted into enamel; in the other the ameloblasts are simply considered as controlling agents, by secreting or depositing the calcium salts which form the enamel prisms and interprismatic substance. In the latter theory it is generally believed that the enamel is secreted or shed out from the extremities of the ameloblasts, thus being productive of enamel rods corresponding in size and

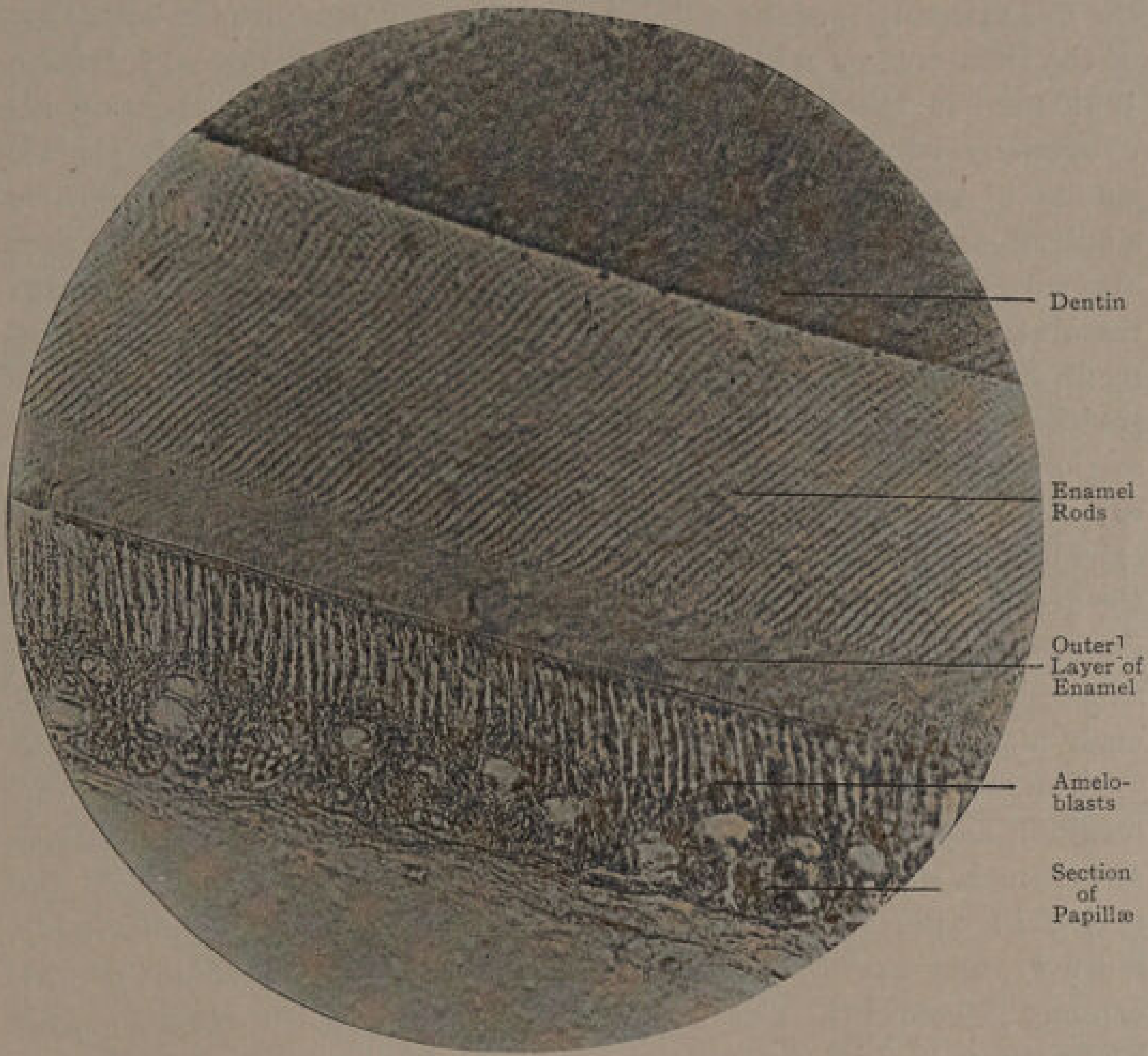


FIG. 226.—Section of incisor of rat. × 200. (*After Williams.*)

position to the secreting cells. By the direct calcification of the ameloblasts, it would be natural to expect the process to begin on the exterior of the cell and gradually pass into its interior the central portion being the last to calcify. This would result in an enamel prism corresponding in size and form to the generating cell, and in a measure this similarity between the calcified and uncalcified structure does exist and is one of the potent factors in the recognition of this theory, but it is hardly sufficiently convincing of itself to warrant a general acceptance of the belief.

By examining figure 225 the importance of the secretory theory is favored. Here we note that the early formed enamel at *A* records what appears to be the definite action of the ameloblasts by prolongations of partly calcified tissue extending from the cells, these markings corresponding in number and location to the cells themselves. Between these prolongations and the ameloblasts are many highly refractive granular bodies which seem to be the actual lime deposit shed out from the free extremities of the cells, from which they pass into the substance of the then organic matrix beyond at *A* and form the *enamel prisms*. Williams has taken exception to this latter view, substantiating his opinion by stating that while the ameloblasts of many animals are similar in shape and arrangement, the enamel produced from these similarly arranged cells varies greatly in structure. The same writer also states that, when such a similarity of arrangement exists between the ameloblasts and the enamel prisms, it occurs near the commencement of enamel calcification, and that at a later period the relative position of the ameloblasts and the prisms is always in longitudinal section. He calls attention to the fact of the enamel prisms or rods not extending through the entire distance between the enamel cells and the calcified dentin (Fig. 225). That part of the structure lying between the ameloblasts and the extremities of the enamel rods is made up of a double set of fibers, some of which are almost at right angles with long axis of the ameloblasts. In figure 226, A, the two sets of fibers previously mentioned are found to join and become closely interwoven.

The ameloblasts are connected with the cells of the stratum intermedium, and more recent investigation goes to prove that this latter structure is directly interested in furnishing to the ameloblasts the material for the calcifying process. The stratum intermedium cannot, however, take part in the primary enamel calcification, as this process commence before the stratum intermedium is fully developed. This being the case, it is generally supposed that the stellate reticulum in addition to supplying bulk to the enamel organ, is in some way instrumental in furnishing the material for the upbuilding of the early enamel prisms.

Lying between the free extremities of the ameloblasts and the enamel in the course of formation is what has been generally considered as a structureless basement membrane or *membrana præformativa*. The existence, exact location and structure of this membrane has been and still remains a matter of conjecture. The generally accepted theory appears to be that given above, but some authorities refer to it as a layer of newly formed enamel, and do not consider it as a structureless membrane, figure 226, A.

As to the formation of the *enamel rods*, Andrews, in 1894, referring to the presence of calcoglobulin in the enamel cells considered these refractive bodies as calcospherites, which, after being taken up by the ameloblasts, were excreted by them, and after coalescing formed

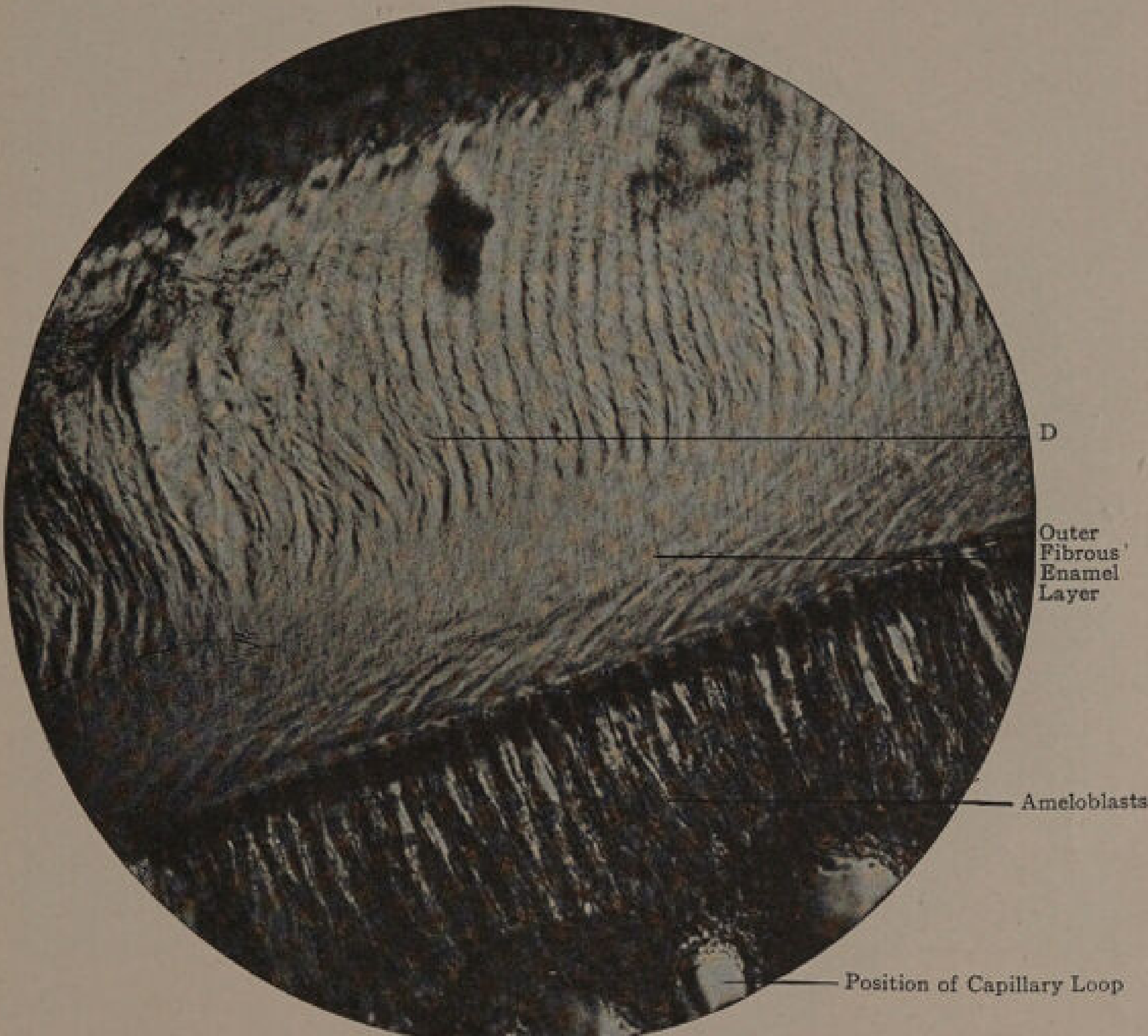


FIG. 226, A.—Section of incisor of rat, showing partial decalcification of enamel. × 600. (*After Williams.*)

globules of larger size, from which the rods were built up. Williams partly agrees with this statement, but he is of the opinion that the calcospherites coalesce while in the ameloblasts, forming large, spheric bodies, but that the deposit of this substance is in no way productive of building the enamel rods. The theory of Tomes in regard to the forming of the enamel rods was that the walls of the ameloblasts themselves became calcified, while the contents of the cells also became solidified, the first forming the interprismatic substance, while the second became the enamel rod. Whatever theory be accepted as to the formation of the enamel rods or prisms, there appears to be no question in regard to the general process of enamel calcification. In the first place, an organic matrix is formed, into which the first-formed layer of enamel is deposited. Gradually the organic matter disappears, leaving behind the

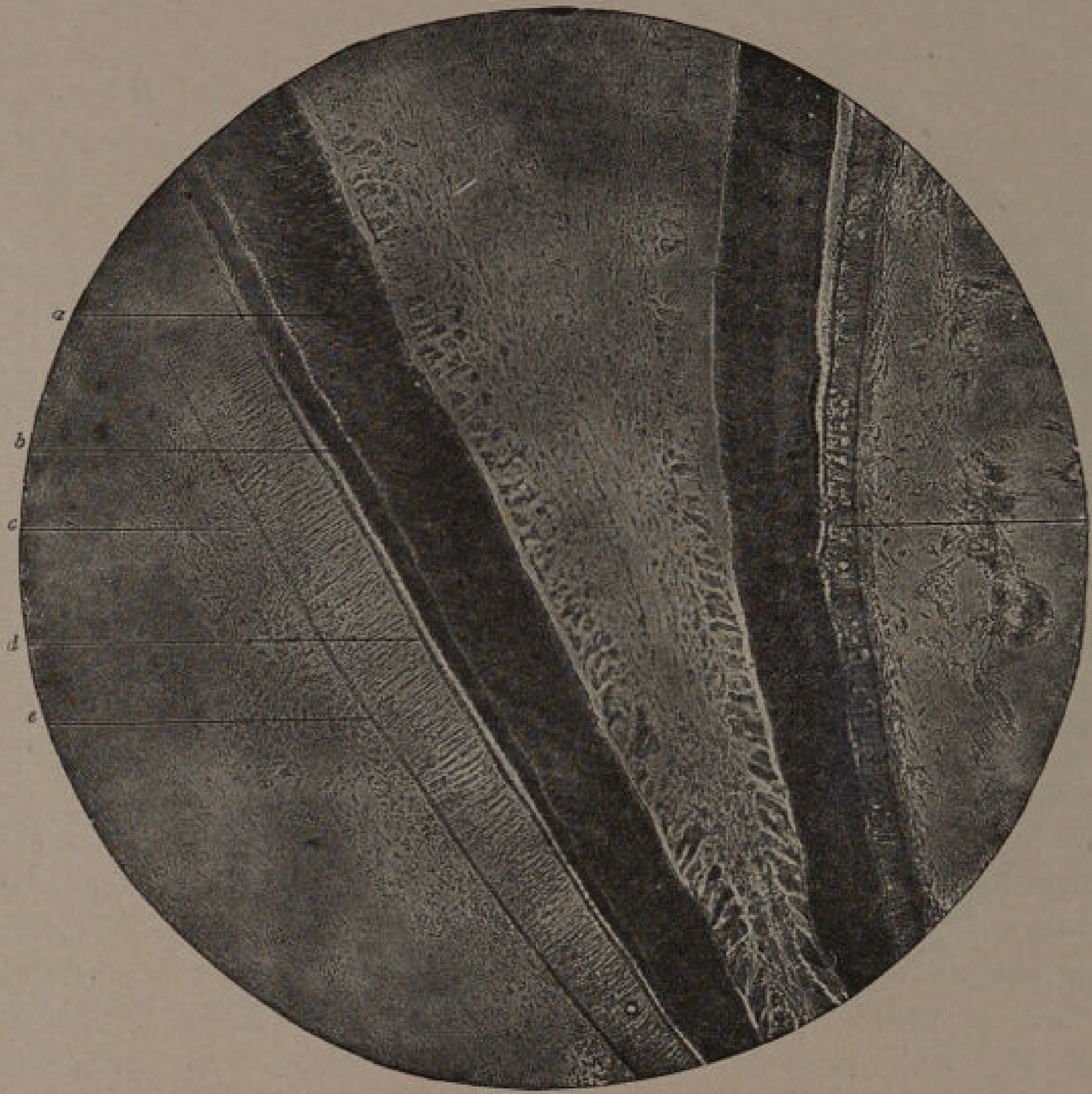


FIG. 227.—Section of developing tooth of embryo lamb. × 150. (*After Williams.*) *a*, Forming dentin; *b*, forming enamel; *c*, stratum intermedium; *d*, inner ameloblastic membrane; *e*, outer ameloblastic membrane; *f*, ameloblasts.

inorganic elements closely resembling in appearance the organic matrix, which it has by atomic change supplanted. The true nature of the interprismatic substance is also one upon which various writers disagree. Some authorities believe that the interprismatic is partly organic, basing their opinion upon the fact that the ameloblastic cells, in common with all epithelial cells, are separated from one another by a homogeneous intercellular substance, and that a certain proportion of this organic substance must remain between the enamel prisms after calcification. Sudduth, by a series of experiments made some years ago, appeared at that time to have furnished conclusive proof that an organic, interprismatic cement-substance does not exist between the enamel prisms of fully developed enamel. By the use of a dilute solution of

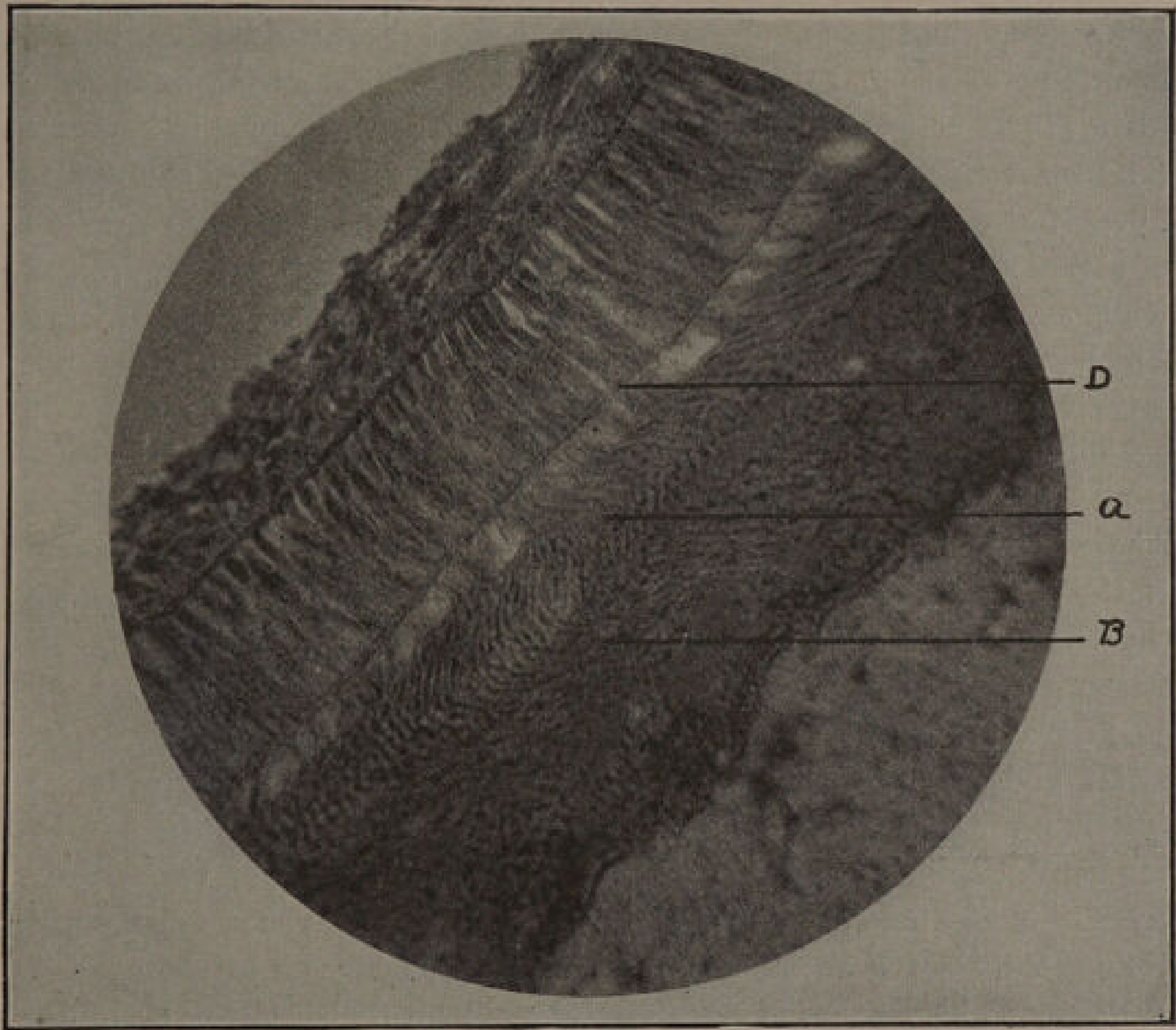


FIG. 228.—Partly decalcified enamel.

chromic acid, the action of which is the preservation of organic substance, the prisms were liberated, which would not have been the result had they been cemented by an organic cement-substance. By substituting dilute muriatic acid, the action of which is the destruction of organized tissue, the prisms were not liberated, the acid acting evenly upon the whole mass of enamel, and finally resulting in its complete destruction, not leaving the slightest trace of an organic matrix behind. Williams claims that this transparent cement-substance is formed by the distribution of a translucent liquid substance about the previously formed pattern for the enamel rods. This pattern, generated through the activity of the enamel cells, is composed of a translucent material somewhat more solid than that substance which surrounds it. These two substances calcify together, the latter forming the enamel prisms, while the former creates the cement or interprismatic substance. There is no better method by which to study the character or mode of development of a growing or matured tissue than by an artificial disassociation of its component parts. In enamel it matters but little in what part of the tissue or at what period of its growth the examination be made to learn of the action of the decalcifying agent; it will never be found to take place in a manner corresponding to the direction of the enamel fibers, but decalcification takes place in older enamel more in the form of a general breaking up of the structure, as shown at *A* in figure 228, while at *B*, which represents the newly formed tissue, the action is one which appears to indicate a breaking up of the interprismatic substance, favoring the secretion theory.

This distinction between the enamel cells and their product possesses none of the characteristics to properly classify it as structureless. There is but little doubt as to its character, being the primary product of the ameloblasts, while the corresponding zone at the distal end of the enamel-forming cells results from the functional activity of the stratum intermedium.

Figure 229 shows a section near the point of the cusp of a developing molar and exhibits a portion of the enamel organ at a time immediately prior to the beginning of enamel calcification. *A* is the uncalcified dentin, *B* the ameloblasts, now closely associated, and a very regular layer of elongated cells, and behind these another layer of cells, which undoubtedly serve as feeders to the ameloblasts, the stratum intermedium. This section is especially valuable in that it shows a number of *capillaries* distributed through the body of the stellate reticulum and actually penetrating the stratum intermedium, as seen at *B*.

When viewed with a low power, these minute *blood-vessels* appear to form a complete network, and in the district between the cusps pervade the entire structure, from the stratum intermedium on one side to the same cells on the other. The appearance of this animated vascular supply to the enamel organ is coincident with the process of calcification, for during the early life of the tooth-germ it is non-vascular. The growth of enamel, from within outward is therefore by the direct calcification of the enamel cells or ameloblasts, and while this is going on, and as long as the crown of the tooth is incased in its epithelial cap, the enamel organ, the growth of the tissue is stimulated through the blood-vessels everywhere present in the stellate reticulum. The presence of this specialized blood supply to the central portion of the enamel organ is no longer a question of doubt (Fig. 229). As soon, however, as the tooth passes through the surface tissue, carrying with it the

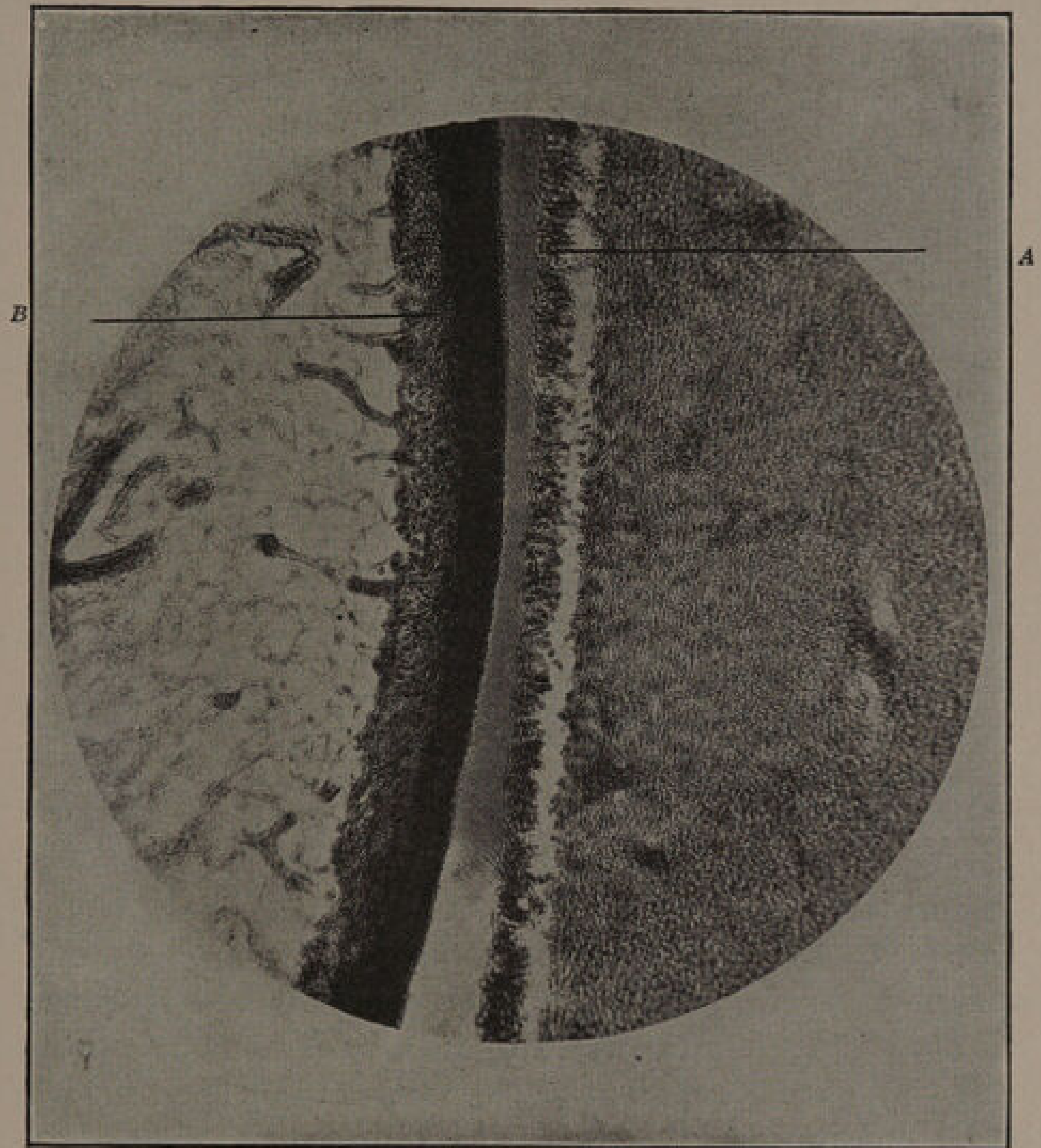


FIG. 229.—Section through developing tooth: Showing capillaries in stellate reticulum.

external epithelium of the enamel organ as the enamel cuticle, all possibility of nourishment has been cut off, and after a little time it becomes a petrified dental epithelium, no longer nourished and absolutely non-vital.

Dentin.—This tissue, developed from the mesoderm and therefore belongs to the connective-tissue group, constitutes the principal bulk of the hard tooth, substance, and forms a complete cap-like investment over the pulp, from which it is generated. It is white or slightly yellowish-white in color, somewhat elastic, and a trifle harder than bone, which it resembles in many of its characteristics. In a perfectly developed tooth no part of the dentin appears upon the surface, that part within the crown being covered by the enamel, while that of the root is inclosed by the cementum. While the thickness of

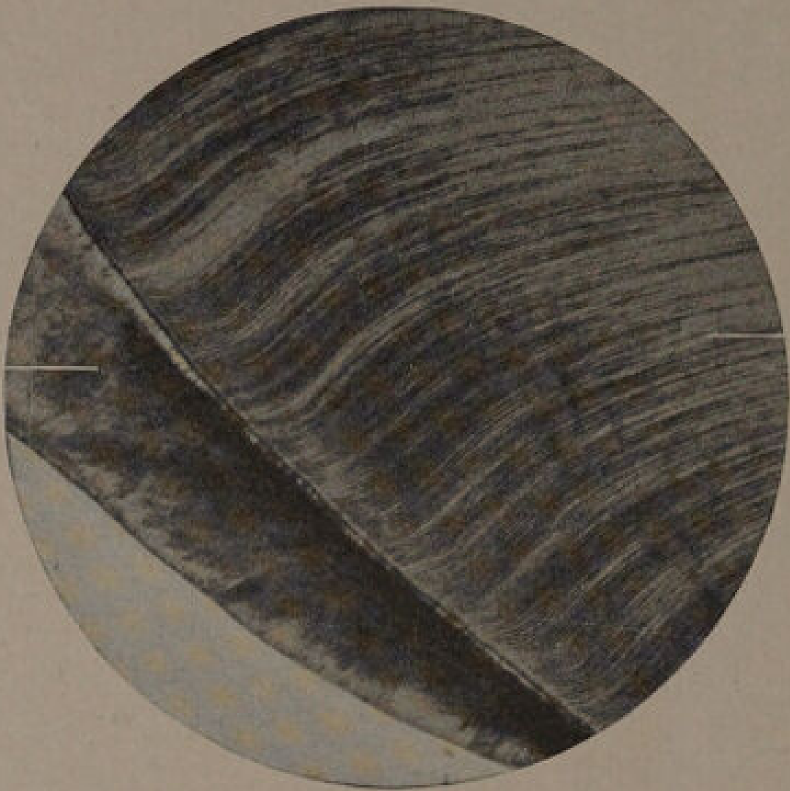


FIG. 230.—Section through crown of human cuspid. × 30.

the dentin varies somewhat over the different parts of the tooth, there is a decided disposition to an equal distribution in every direction. *Dentin*, unlike enamel, consists of an organic matrix—a reticular tissue of fine fibrils richly impregnated with the salts of calcium, in this resembling the matrix of bone. Traversing the matrix are long, fine canals or tubes—the *dentinal tubules*—which beginning at the walls of the pulp cavity reach out and penetrate the entire substance of the dentin. Immediately surrounding the dentinal tubules the matrix is especially dense, forming a lining or sheath to the tubes, known as the *dentinal sheaths*. Occupying the lumen of the dentinal tubules are solid elastic fibers—the *dentinal fibers*. Dentin, therefore, presents for examina. tion, first, the matrix; second, the dentinal tubules; third, the dentinal sheaths; and fourth, the dentinal fibers.

The Matrix.—As previously stated, the matrix is composed of organic and inorganic substances, but the proportionate quantity of organic and inorganic constituents is somewhat variable so that it is impossible to furnish a very definite chemic analysis. The relative quantity of organic and inorganic matter is not only variable in the teeth of different individuals, but is continually changing in the teeth of the same individual, the former being present in larger quantities during youth and gradually diminishing as age advances. From an

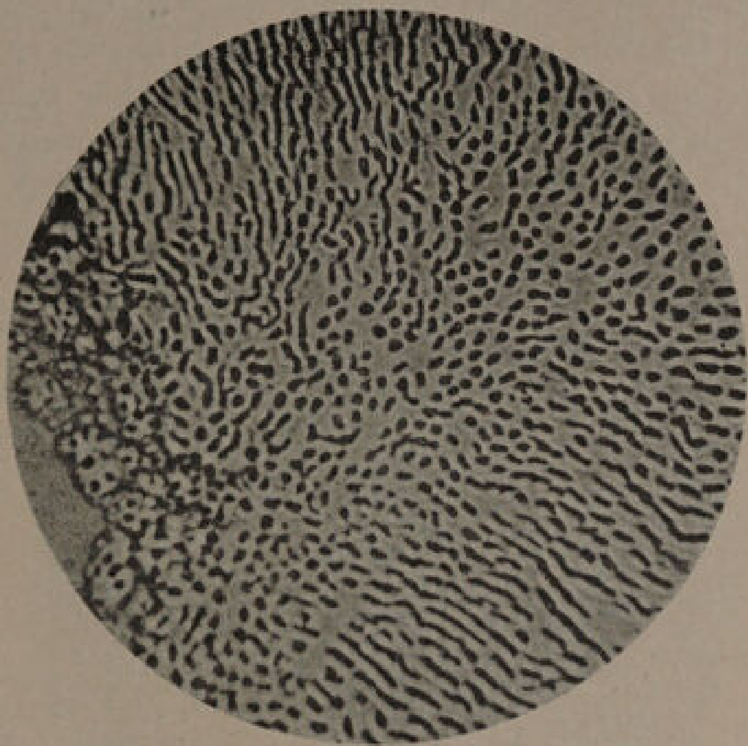


FIG. 231.—Section through root of human incisor, showing many dentin tubules in transverse section. × 200.

examination of perfectly dried dentin, the following approximate analysis has been obtained:

Organic matter (tooth-cartilage)	27.61
Fat	0.40
Calcium phosphate and fluorid	66.72
Calcium carbonate	3.36
Magnesium phosphate	1.08
Other salts	0.83

The organic basis of the matrix appears to be structureless and transparent, and, although closely resembling the matrix of bone, is not identical with it. While the matrix is usually structureless, there are instances in which the presence at one time of connective-tissue fibers are indicated.

The Dentinal Tubules (Figs. 231).—Beginning by a free opening about the walls of the pulp-cavity, the dentinal tubules permeate the matrix in all directions. The tubules are generally disposed in a direction perpendicular to the surface, so that in different parts of the tooth they radiate in various directions. Beginning upon the surface of the pulp-cavity, at which point they are of greatest diameter, they pass more or less in a spiral manner toward the surface (Fig. 234), before reaching which they become gradually reduced in size, as a result of the numerous branches which they give off (Fig. 232). The branches given off from the main tubes are quite variable in size, and anastomose with one another or with the branches from other tubules. In the region of the pulp the tubules are so closely associated that but little

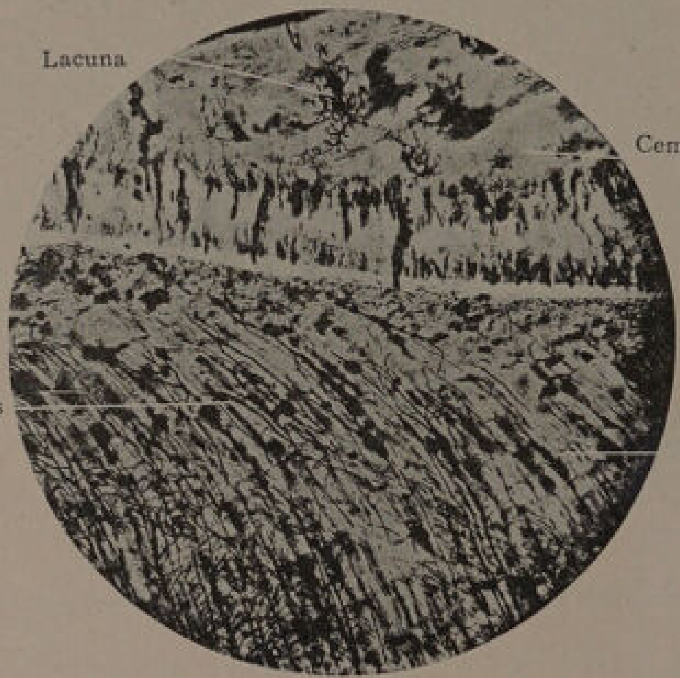


FIG. 232.—Dentin and cementum from root of human molar. (*After Gysi.*)

space is provided for the intertubular substance or matrix; but as the surface is approached they become widely separated, and, in consequence, the matrix substance is present in greater abundance. While the general direction of the tubes is perpendicular, they do not pursue a direct course, but are more or less curved as they pass within outward. The curvature of the tubuli may be divided into two classes—long curves and short curves—usually referred to as the primary and secondary curvatures of the dentinal tubules. The primary curvatures are few in number and are most prominent in the crown, while the secondary curvatures, principally found in the roots, are smaller and more numerous. The branches from the main tubes terminate in various ways, either by anastomosis, by gradually fading out into hair-like terminals, or by ending in hooks and loops. In rare instances they are said to enter the substance of the enamel or cementum, but it is doubtful if they actually do this. The branches from a main tube are usually two in number, the latter being almost equal in diameter to the former, and from this first set of branches a number of minute branches are given off almost at right angles. In the crown this latter class of tubules are seldom observed, excepting near the dento-enamel junction, but in the root they are everywhere noticed. Small varicosities are frequently present, but not in sufficient numbers to produce a striated appearance on the surface of the dentin.

The Dentinal Sheaths.—While the dentinal tubules ramify through the matrix in the form of well-defined channels, the walls of the channels

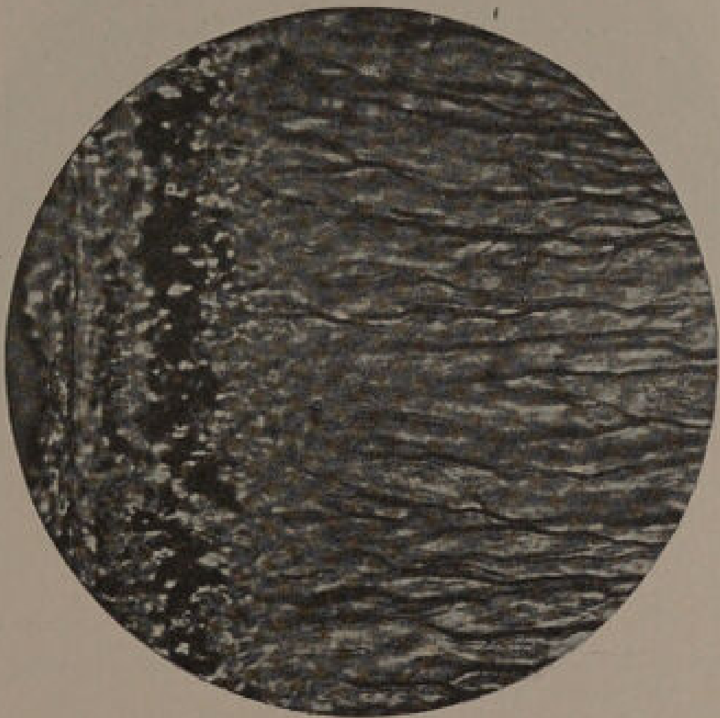


FIG. 233.—Longitudinal section through root of human molar. Branching of the dentinal tubules. × 200.

are not formed by the matrix, but by an indestructible substance the exact character of which is not fully understood. The walls of the tubes, or the dentinal sheaths, as they are termed, are believed by some histologists to be calcified, while others, though acknowledging their apparent indestructibility, are doubtful as to the correctness of this theory. Neumann being the first to accurately describe the walls of the tubules, they have become known as "Neumann's sheaths." The existence of the dentinal sheaths may best be demonstrated by subjecting a section of dentin the action of strong acid for a sufficient time to destroy the intervening matrix, which process usually requires several days. The fibrous mass remaining will be found to contain a collection of tubes, which, however, by careful examination, are found not to be the dentinal tubules themselves, but the walls of these canals. Tomes, while inclined to the belief that the tubes are provided with definite walls, suggests that they may have been produced artificially during the preparation of the specimen, and that they are only brought into existence by the action of the agent used for this purpose. In conclusion, the same writer adds that that part of the matrix immediately surround-

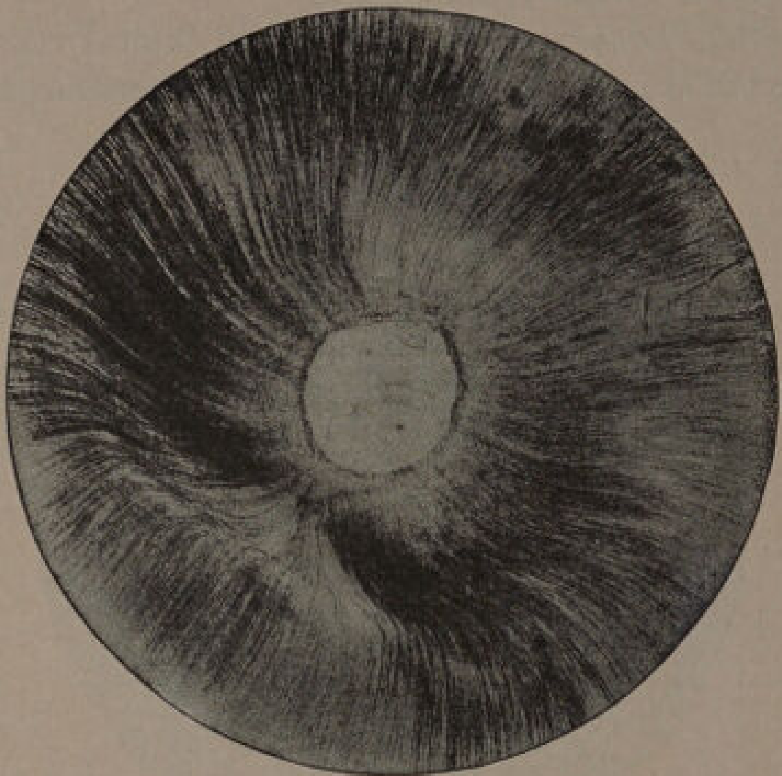


FIG. 234.—Transverse section through root of human molar, showing the curvature of the dentin tubules about the pulp-canal. × 40.

ing the fibril differs in its chemic constituents from the body of the matrix.

The Dentinal Fibers.—Occupying the lumen of each dentin tubule is a soft, elastic fiber, which is continuous with and has its origin from the odontoblastic cells upon the periphery of the pulp. The existence of these elongated processes of the odontoblasts having first been demonstrated by Tomes, they are otherwise known as Tomes' fibers. By means of these fibers, which not only fill the lumen of the larger tubes, but the minute branches as well, the substance of the dentin is both nourished and rendered slightly sensitive. There is still some doubt as to the real nature of the fibrils, but, if they are processes from the odontoblasts, it would appear that the substance would be identical with that of the cell-protoplasm. Bodecker claimed that they are not round but inclined to angularity, but Tomes infers that this form has been produced by the action of some reagent. Klein advanced the theory that the odontoblasts are active in the generation of the matrix for the dentin only, and that the dentinal fibrils are not processes from them, but originate from cells intervening between the odontoblasts and connecting with the dentin tubules. It has never been fully demonstrated that true nerve-fibers enter the dentin along with or in the substance of the

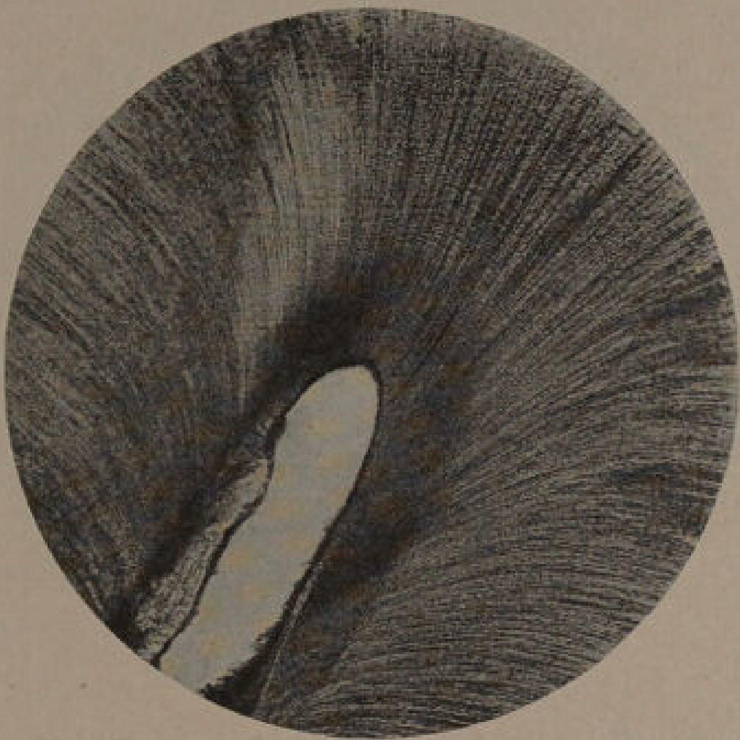


FIG. 235.—Longitudinal section through root of human tooth, showing primary curvature of dentin tubules. × 40.

dentinal fiber, but, while the evidence is not at present forthcoming, there is but little doubt that the sensitiveness of the dentin is produced by the presence of organized tissue in the tubuli. Some contend that the contents of the tubules are made of, first, a creative portion, that given off directly from the odontoblasts; second, a circulatory portion, a minute vessel traversing each tubule, entering either by the side of the cell-bodies or passing through them, and that the nerve terminals are distributed in the same manner. Others say that minute nerve-filaments from the pulp pass directly through the odontoblasts and are continued in the center of the tubule surrounded by a simple connective tissue, the cell process, and that in this way sensations are conveyed. It is now generally conceded that dentin is a highly organized connective tissue; that it has a circulatory system and is endowed with sensation to a slight degree; that these conditions are brought about not by actual entrance into the tubules of separate vessels and nerve-filaments, but more in the way of the tubules being occupied by a general connective-tissue substance resembling in all essential features the pulp itself, being the semi-fluid interfibrillar ground-substance of the pulp; that dentrites of sensory neurons everywhere present in the pulp, after losing their medullary sheaths divide into fine varicose fibers and become closely associated with the peripheral cells, pass between these,

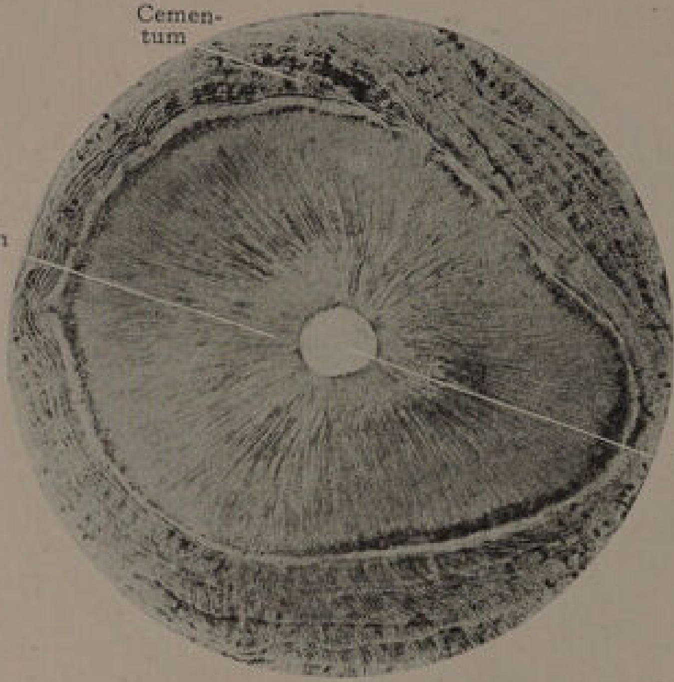


FIG. 236.—Transverse section through the root of a human incisor, showing primary and secondary curvature of dentin tubules. × 30.

and enter the cone-shaped openings of the tubules and terminate soon after doing so.

While the microscope reveals in some instances what appear to be prolongations from the dentinal fibers penetrating the enamel, or between its prisms, such a condition is improbable if not impossible. If this arrangement is present at all, it is so slight as to have no influence whatever over the enamel either as to nourishment or sensation. No conclusions can be drawn with positive certainty from sections, since the slightest deviation from parallelism in the surfaces may easily produce deceptive appearances. It is just as common, and even more so, to find hair-like lines interwoven and running parallel with the surface of the dentin immediately between this tissue and the enamel, as it is to see slight fibers crossing beyond their boundary-line to penetrate the enamel. The most likely place of all to find such a condition would be in the beginning of calcification, and here it is never observed. The peripheral pulp-cells, the odontoblasts, are never found outside their own territory, the dentinal papilla; but their location in the beginning on the very surface of the papilla, almost in direct contact with the inner tunic of the enamel organ, would make it possible for their processes, when appearing, to penetrate between the cells of the enamel organ if they were grown out from the body of the cells from which they spring.

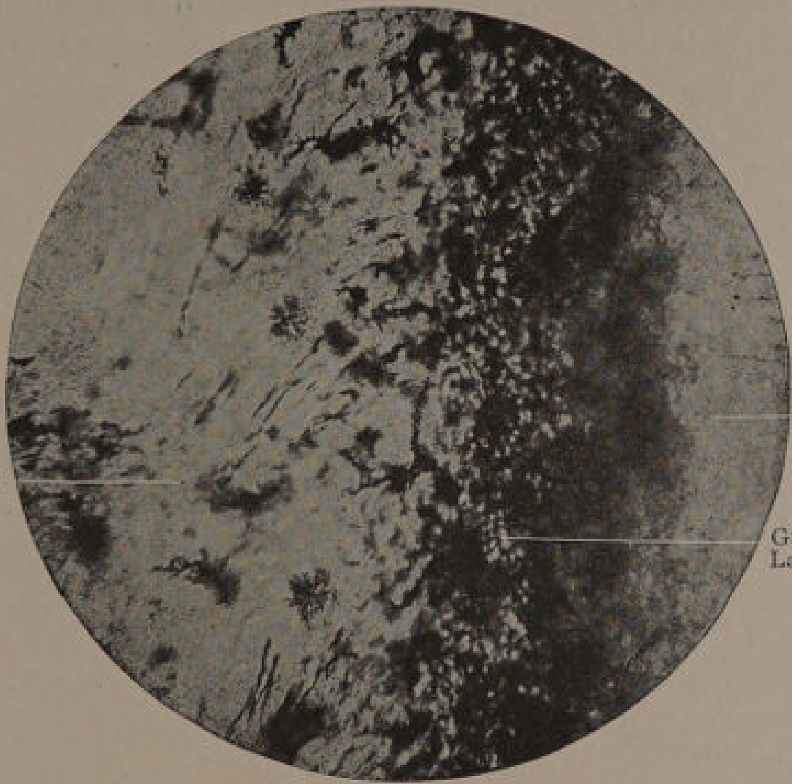


FIG. 237.—Tomes' granular layer. × 40.

This, however, they do not do. They do not grow out from the cell-body, so to speak, but the cell recedes, toward the center of the pulp spinning out its process or processes when so doing Fig. 239. By this arrangement the terminals of the future fibers become definitely established, all increase in length taking place in the opposite direction, toward the pulp. While the active enamel-forming cells are present some little time prior to the odontoblasts, calcification of the enamel does not take place until after a definite cap of dentin has been formed, encapsulated in which are the terminal branches of the fibers. Therefore the fact that this cap of dentin is formed first, and this is not a question in dispute, with the fibers or cell processes securely encapsulated within it, would seem to be sufficient evidence to qualify the statement that the dentinal fibers do not penetrate the enamel. The examination of very many sections of young growing teeth exhibits the fact that the early formed dentin and enamel will separate bodily as the dento-enamel function leaving a positive clear line of separation and a surface absolutely devoid of anything resembling the prolongation of the fibers extending from the surface of the dentin.

Interglobular Spaces.—In that part of the dentin which immediately underlies the cementum numerous intercommunicating, irregularly branched so-called spaces are found. These are known as the interglobular spaces (Fig. 238). On account of the granular appearance which these so-called spaces collectively exhibits under low magnifying power, Tomes has designated this as the "*granular layer.*" A somewhat similar granular layer is also found upon that portion of the dentin which underlies the enamel, but in this region it is far less marked.

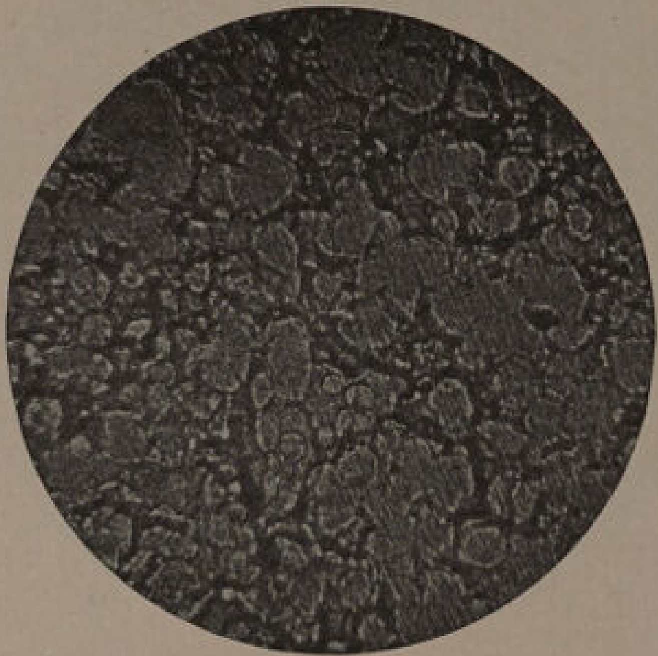


FIG. 238.—So-called interglobular spaces in dried section of dentin. × 100.

Many of the dentin tubules have their endings in these spaces. While the interglobular spaces are most numerous near the peripheral portion of the dentin, they are by no means confined to these parts. They are present in all parts of the dentin, but not so closely associated, and may be observed, when a dried section of dentin is examined, as spaces with irregular outlines and sharp-pointed processes extending in various directions (Fig. 238). The term "interglobular spaces" becomes partly a misnomer when the so-called "spaces" are more carefully examined. In normal dentin the "spaces" are filled with a soft, living plasma, having a structural arrangement similar to the general matrix of the dentin, and it is only in a dried specimen that a true space is found by the shrinking or shriveling of the organic contents. The interglobular spaces forming the granular layer, which are much more numerous, but of smaller size, and much more closely associated than those found in the body of the dentin, are also filled with a soft living plasma, and communicate, with the dentinal fibers. According to some authorities, the interglobular spaces (so-called) are occupied by masses of calcoglobulin which have not become fully calcified.

Calcification of Dentin. Dentinification.—The dentin bulb, or *papilla* from which the dentin is forced, having been previously described in Chapter VIII, the process of calcification will at once be taken up. It

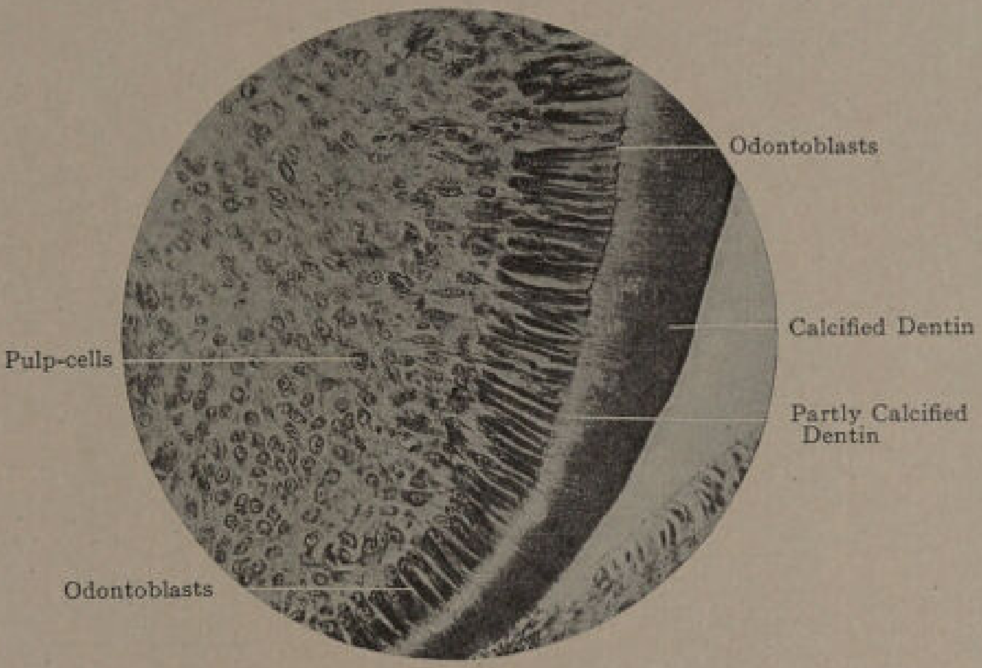


FIG. 239.—Pulp and forming dentin from an incisor. (*After Gysi.*)

must be understood that calcification of the dentin does not begin until the *dentin papilla* has developed to the form and size of the dentin of the future tooth-crown. When this has taken place, there is generated upon the surface of the papilla a modified form of connective-tissue cells called *odontoblasts* (Fig. 239). These cells, which are arranged in a single row upon the periphery of the papilla, vary in form according to their activity but usually assume a club-shaped outline. When most active, they are broadest at the extremity directed toward the interior of the papilla. Proceeding from a single odontoblast there may be one or more processes, which eventually occupy the tubes of the dentin, as the dentinal fibers. These cells each contain an oblong nucleus, which occupies the extremity of the cell most distant from the dentin, but during the period of greatest activity becomes elongated or pointed in the direction of the process or processes. The odontoblastic cells, while actively engaged in performing their function, are closely associated or crowded together, but previous to this time there is more or less space between them, which is filled with an indif-fent substance. The first layer of dentin being formed upon the surface of the papilla, it will be observed that all additions to its bulk take place from within the tissue therefore growing from without inward (the reverse being true of enamel).

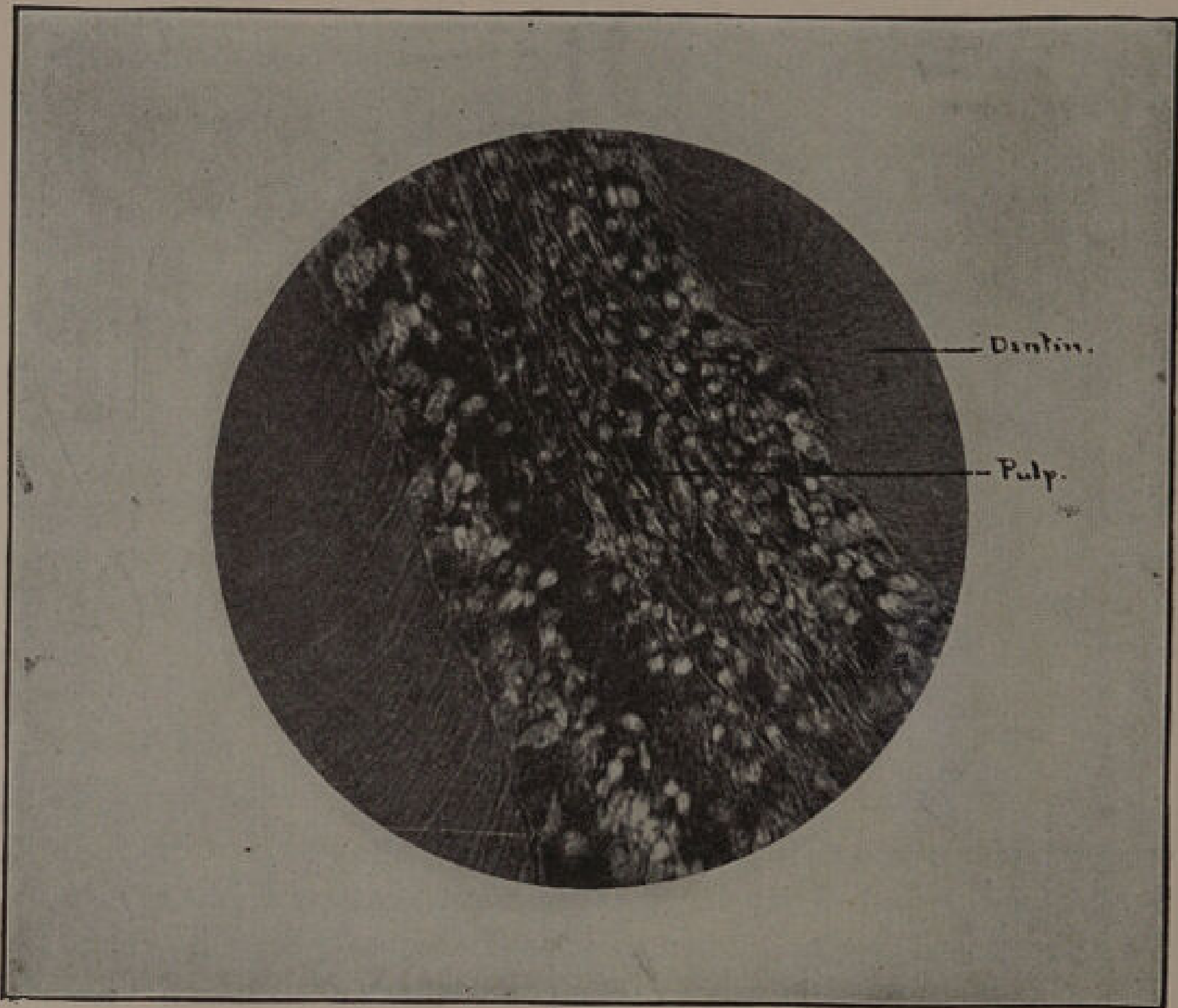


FIG. 240.—Section through pulp and forming dentin.

As stated elsewhere, calcification of the dentin begins upon the coronal extremities of the crowns, the incisal-edges of the incisors and cuspids, and the summits of the cusps in the cuspidate teeth first receiving their lime-salts. While the odontoblasts are directly concerned in depositing the lime-salts to form the dentin by a secretary process, this does not take place around the cells, and in that way completely encapsule them, but around their fibrils. While this is taking place the odontoblasts remain free upon the surface of the pulp, and the fibrils assume their places as the organic *dentinal fibrils*. As the body of dentin beomes thicker, the odontoblasts are forced to recede, and in so doing the fibers lengthen. The dentinal tubules are, of course, formed in a like manner, the walls of the tube being first calcified from the secretion of lime-salts by the fibrils; and as the fibrils lengthen by the increasing thickness of dentin and the receding of the odontoblasts, the tubules also increase in length.

The general character of the *pulp cells* at a time immediately prior to the appearance of the ameloblasts is vastly different from the same cells at maturity or after calcification of the dentin has taken place. The reason for this is obvious, the connective-tissue mass, the future tooth pulp not assuming its principal function until the odontoblasts are generated about its periphery. While at a later period the cells of the pulp are oblong in outline, with slender tail-like processes given off from each end, we find the same cells in the early embryo (sixteenth to twentieth week) spheroidal in outline and distributed as they continue to be, at irregular intervals about the semi-gelatinous matrix. (See Fig. 240.) When the periphery of the pulp is reached, a definite layer of cells is present, corresponding in every particular to those of the interior, and it is from these spheric bodies that the *dentin-forming cells* the odontoblasts, are derived. While the odontoblasts are usually characterized as spindle- or club-shaped cells, this can only apply more fully to the cells of later life. Figure 241 (twentieth to twenty-fourth week) shows the first formed odontoblasts actively engaged in their function of dentinification. It will be observed that the cells, instead of being individualized as they appear at a later period, now present a racemose arrangement, such a cluster appearing about the entrance to each dentinal tubule, which at this period are widely separated and apparently without anastomosing branches. The nearer the summit of the cown is approached, the less apparent is this grape-like association of the cells, showing conclusively that it is a primary condition.

After a definite thickness of calcified dentin appears about the surface of the tooth-pulp, the character of the odontoblastic cells becomes materially changed (twenty-fourth week), but even yet they do not answer to the description generally accorded them. The elongated, spindle-shaped or club-shaped *odontoblasts* are without question found in connection with the tissue only after calcification has progressed to a considerable extent; and while it does not appear possible to detect the minute processes which penetrate the calcifying structure before this stage has been reached, they have nevertheless existed from the earliest inception of this specialized layer of cells.

In this connection the query presents itself in regard to the manner in which the intercommunication between the dentinal fibers is established, and the probable cause for the so-called interglobular spaces about the periphery of the dentin. The former can probably be explained by an examination of the peripheral cells of the pulp at a time immediately prior to the beginning of calcification, when it will be

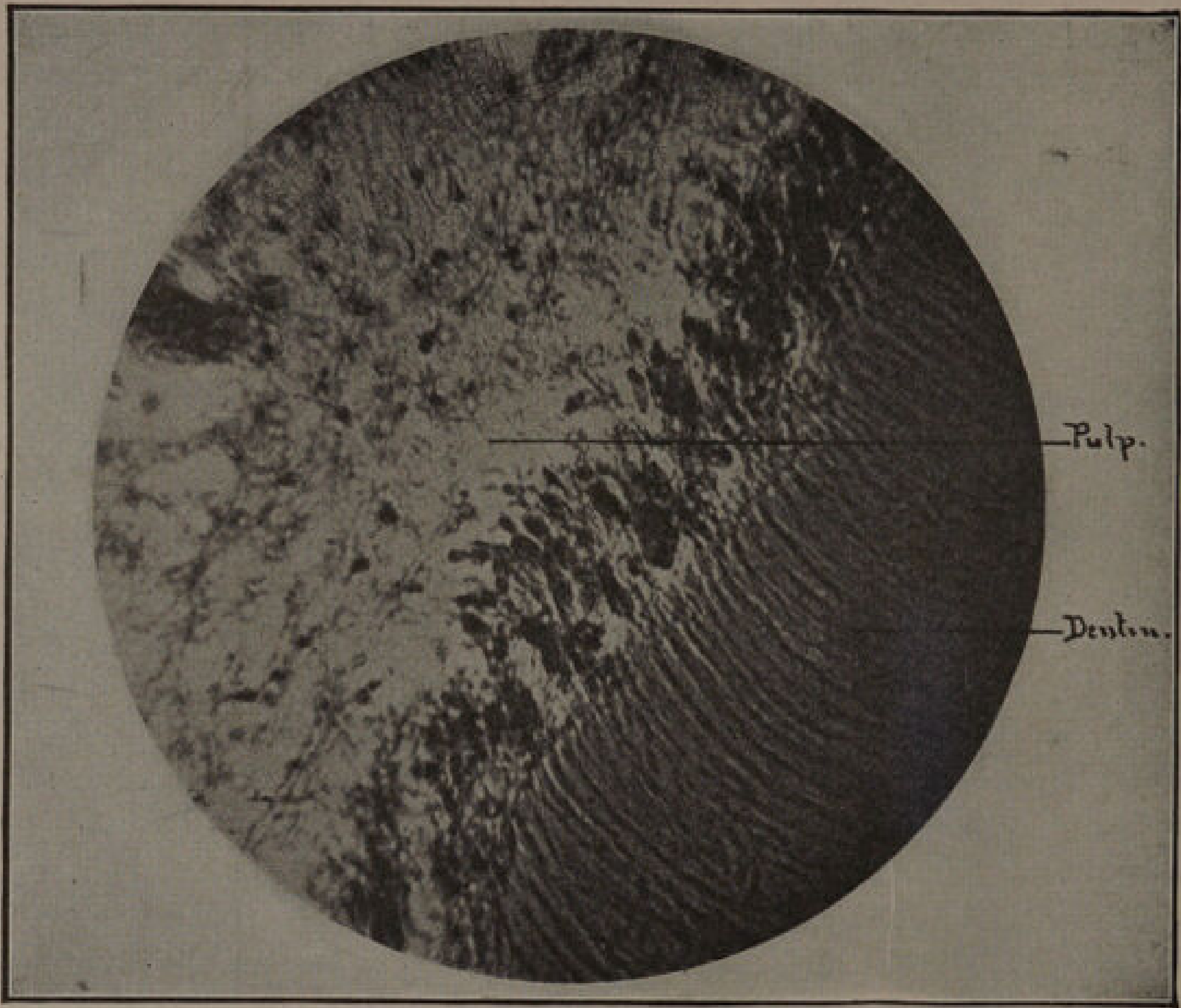


FIG. 241.—Young odontoblasts attached to forming dentin.

found that these primitive odontoblasts communicate with one another in a manner quite similar to the canaliculi between the lacunæ of the true bone, the connecting processes later becoming encapsuled within the substance of the calcifying tissue.

Figure 242 is taken from a very thin section of a growing tooth at a time in which we would most naturally look for the appearance of the interglobular spaces, and many such imperfections, if they be so classified, are observed within the substance of the newly formed tissue.

Exceptions might be taken to the statement concerning the racemose appearance of the early odontoblasts previously referred to, by claiming the section to be one not directly through the long axis of the cells, or perhaps transversely through them. The examination of a number of sections, one of which is shown in figure 243, shows the cells cut transversely; the forming dentin at *a* appears with the tubuli squarely cut off, showing the dentinal fibers confined, or rather appearing as

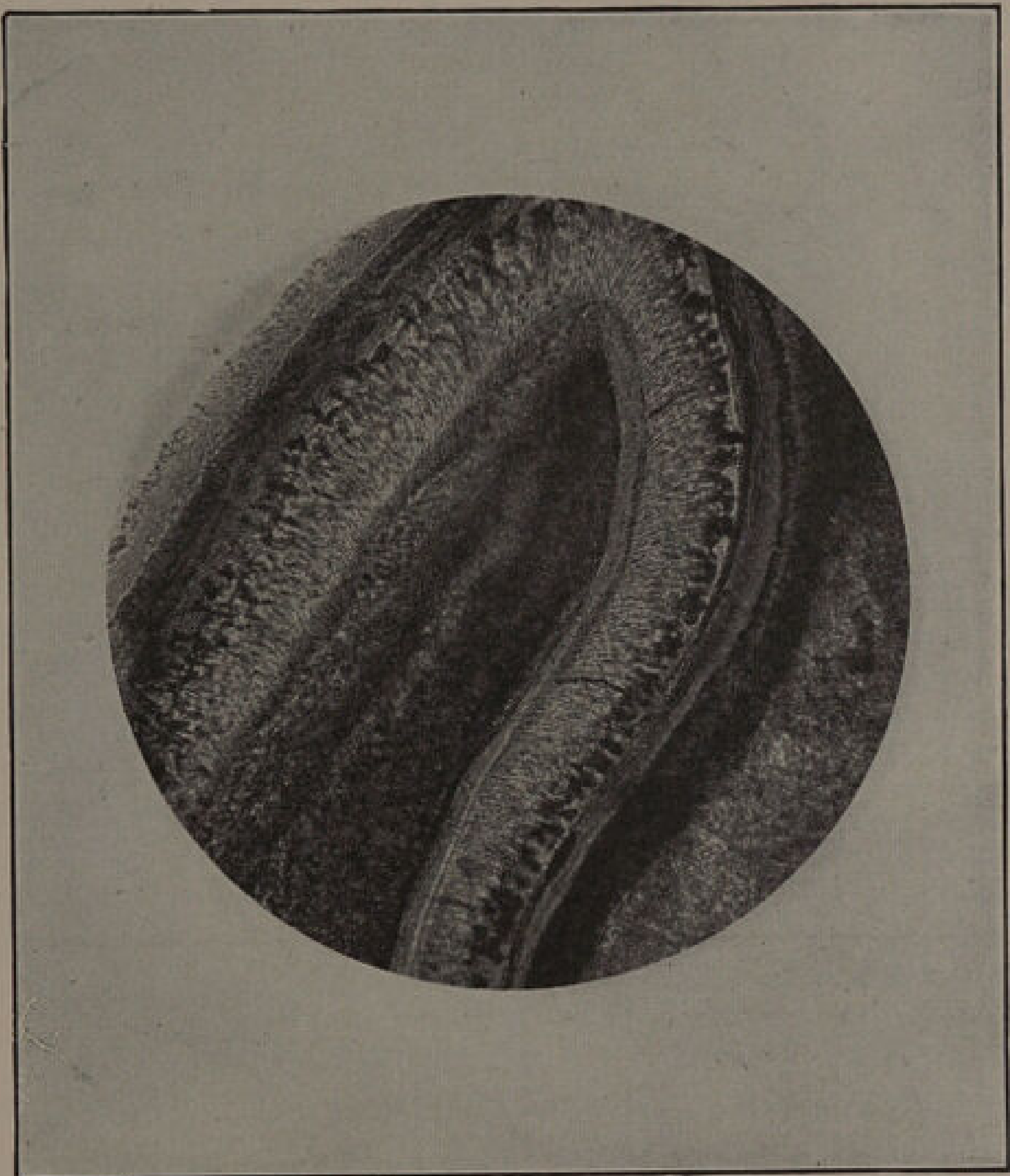


FIG. 242.—Section through crown of growing tooth of lamb.

though projecting from the lumen of the tubules. It will also be noted that the odontoblasts are irregular in outline, some of them being almost hexagonal, and as the calcified tissue is approached, they gradually become reduced in size and much modified in contour.

After a dentin cap or matrix of considerable thickness has made its appearance and the enamel cells are about to assume their functional activity, the odontoblasts for the first time begin to resolve themselves into the elongated flask-shaped cells, thus answering the description usually accorded them, as illustrated in figure 239. In fact it would appear that they assume this shape only after the actual deposit of lime-salts has begun. If we examine the line of union between the

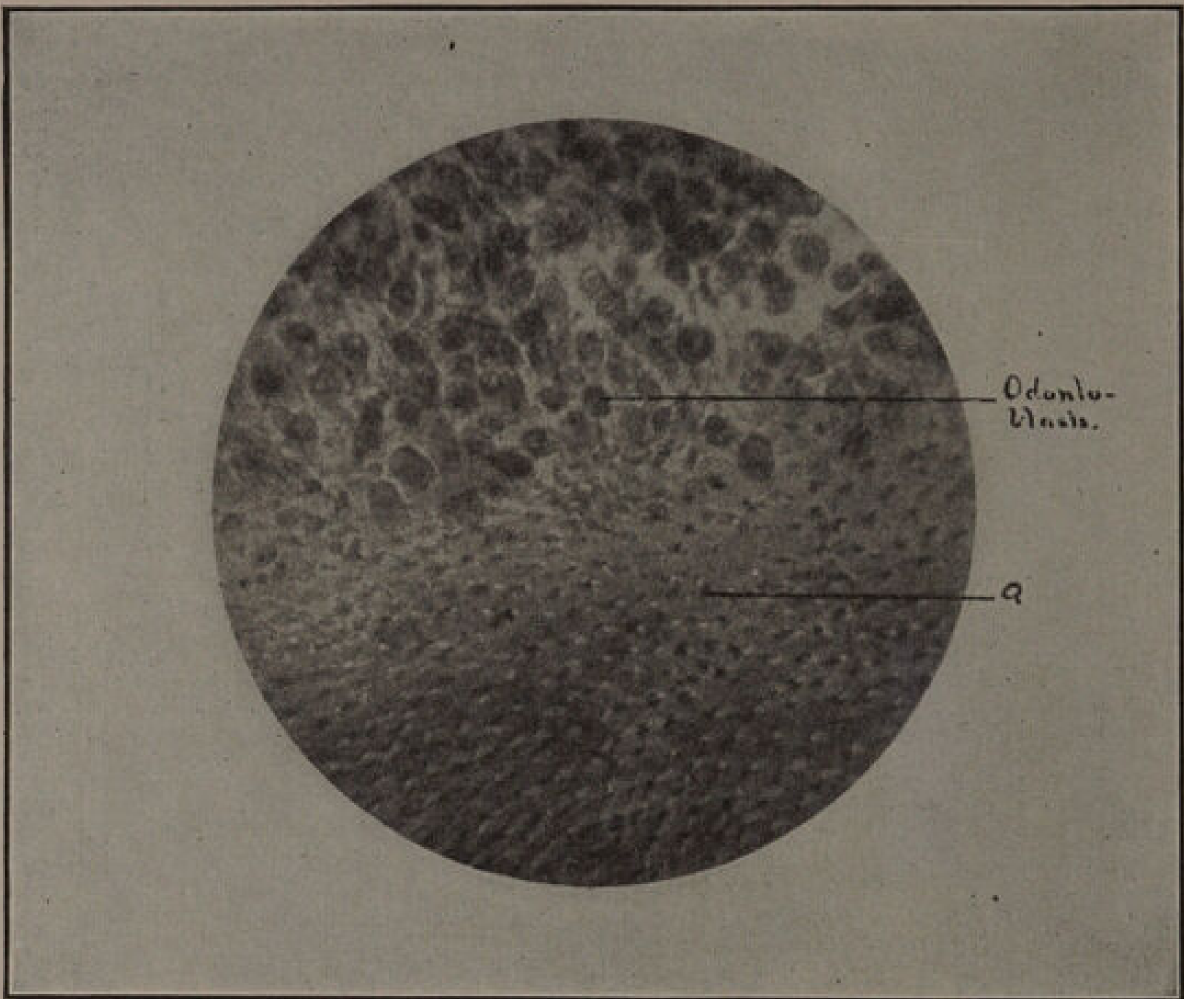


FIG. 243.—Odontoblasts in transverse section.

dentin and enamel during the early growth of these tissues, it will be ascertained that, notwithstanding the dissimilarity of the two structures at maturity, there appears at this line of junction a matrix which may be differentiated only by the free extremities of the ameloblasts, as shown in figure 244. When the enamel matrix begins to form, a faint line of demarcation between the two may be observed, the difference in the appearance of the groundwork of the two structures being one brought out by differential staining, that of the enamel staining the darkest.

It will be observed, therefore, that after the dentin germ has assumed the exact size of the dentin of the future tooth, certain cells appear upon its periphery, and under their superintendence a definite layer of dentin soon results. This first formed layer of dentin is definite and unchangeable in location, and it has within its substance the minute processes from the dentin-forming cells which are destined to become and really

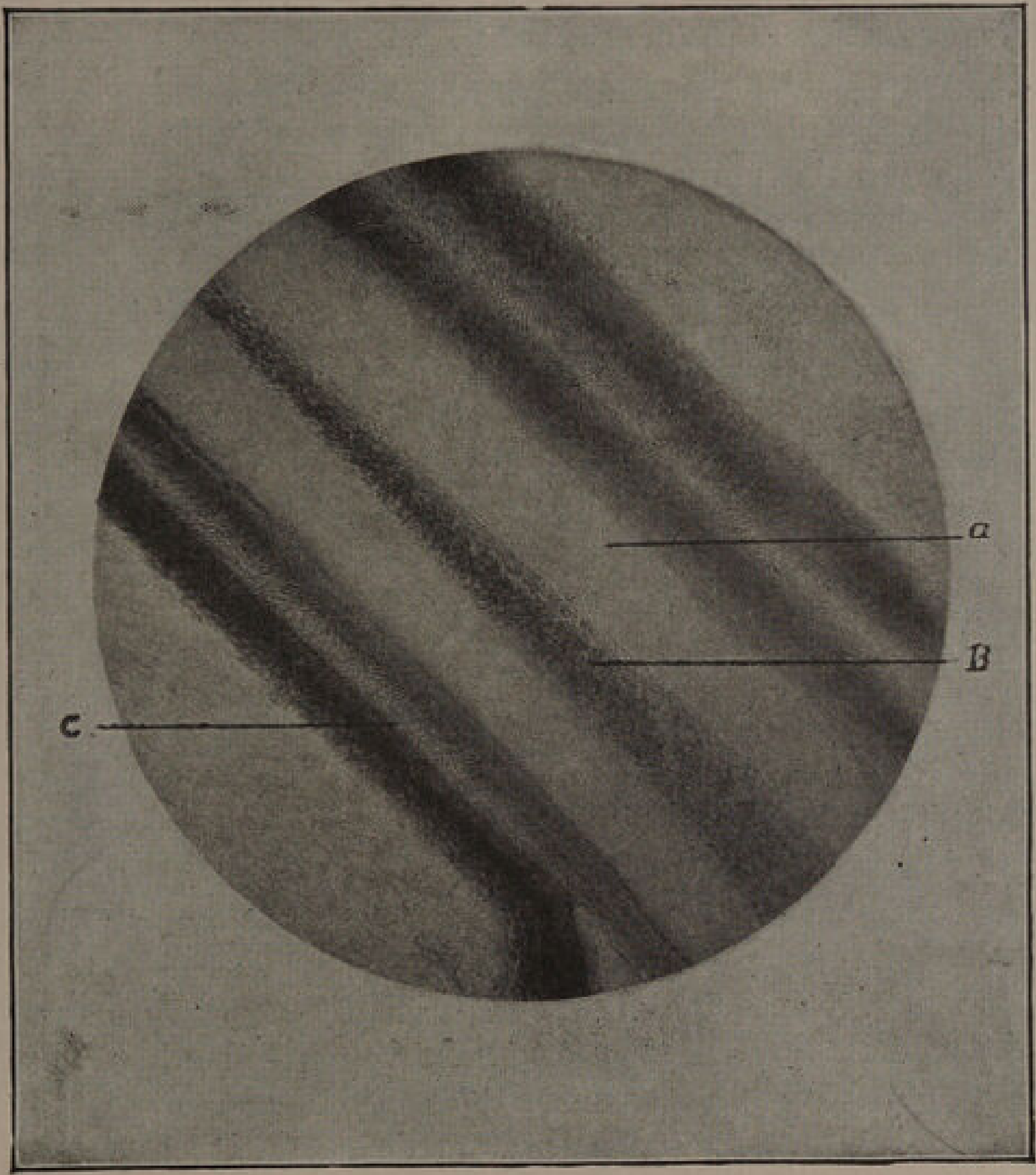


FIG. 244.—Section through pulp, dentin, and forming enamel. *A*, Calcified dentin; *B*, pulp; *C*, ameloblasts.

are the terminals of the dentinal tubules. All who have given the subject of dentin calcification careful consideration are practically agreed as to the part which the peripheral pulp-cells play in the process. This is to the effect that not about the body of the cells themselves, but around their processes the lime salts are deposited. After a distinct layer of specialized cells has become fully established upon the very periphery of the papilla, the first change which takes place is a slight withdrawal of these cells from this point, leaving behind slender hair-like processes which occupy a portion of the space previously taken up by them, and about the extremities of the cells and their processes which are directed toward the enamel organ calcified material is generated. Zone upon zone of calcified dentin appears in this way, the body of the cell receding, leaving in its wake its processes encapsuled within the calcified structure as the dentinal fibers.

In connection with the primitive layer of dentin-forming cells, there are usually described lateral processes passing from cell to cell, apparently serving the purpose of inter-communication beween the cells. But these have recently been shown to be simply a network of connective-tissue fibers supporting the body of the cells. The theory of Andrews, brought out some years ago in regard to the specialized layer of pear-shaped cell—*dentin corpuscles*, as he termed them—may be accepted, and these should be considered as having something to do with the process of dentinification. The presence of these pear-shaped cells at the beginning of calcification and during the continuance of this process can be easily demonstrated, and if we accept them as being concerned in the process of dentin formation, they might in a measure modify the function now accorded the elongated club-shaped cells, the odontoblasts. It is questionable whether the odontoblasts alone are responsible for the growth of dentin; they undoubtedly control the actual process of lime deposit, but additional cells, no doubt, contribute to the structural make-up of the tissue. It may be that by modifying certain parts of the matrix, the result in the general structure is the dentinal sheaths; this part of the tissue being so markedly different from the bulk of the inter-cellular substance would lead us to believe that it was developed from specialized cells. Further, it is said that while the dentinal tubules are filled with a living substance, this substance is not solely the product of the processes of the odontoblasts. That there is a special distribution of non-medullated nerve terminals as well as a rich plexus of blood-vessels about the periphery of the pulp is unquestionable, and this supply is just as plentiful, or perhaps more so, at maturity as it is at the beginning of calcification when the dentin cells are most active. From this we might be led to believe that this special blood and nerve supply to the periphery of the pulp is not solely for the upbuilding of the dentin and therefore distributed to the peripheral cells, but also for the permanent welfare of the resultant tissue, this being brought about by some circulatory system throughout the tubules of the dentin. The process of dentinification is a continuous one, proceeding more or less continuously throughout the life of the tooth.

Cementum (Fig. 245).—Investing the roots of the teeth is a connective tissue substance which, both chemically and physically, is closely allied to bone, and is known as *cementum*.

Generally speaking, the cementum begins by a thin margin at the neck of the tooth or cervical line. It may commence at the free enamel margin of the crown, or it may slightly overlap this structure. It is thinnest at the neck of the tooth, and gradually increases in thickness as

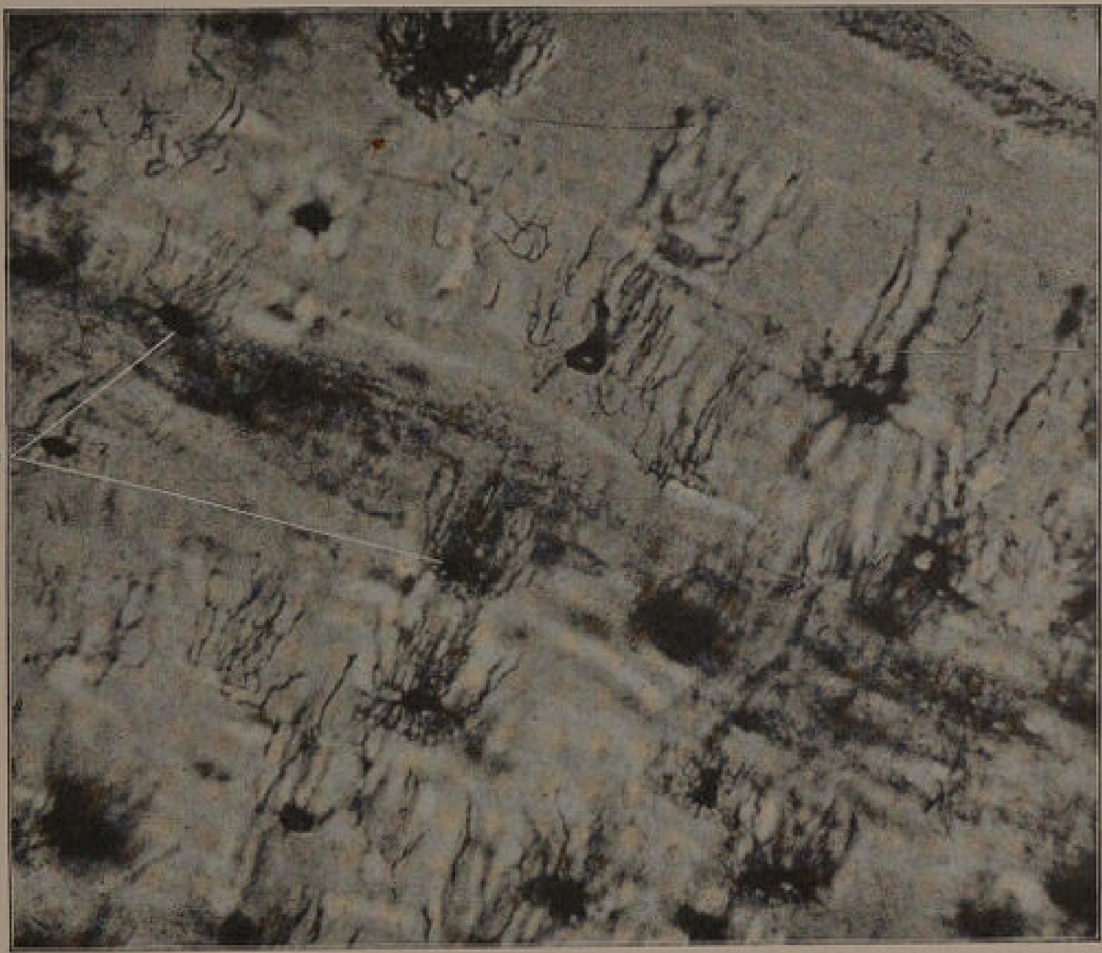


FIG. 245.—Cementum from root of molar. × 200.

the apex of the root is approached. In teeth with closely associated roots the cementum frequently extends from one root to the other, resulting in a firm, union between the roots. Histologically considered, the structure of cementum, like ordinary bone, consists of a gelatinous, basic substance, combined with the salts of lime, and of numerous little hollow spaces—*lacunæ*. Branching in every direction from the lacunæ are many minute processes—*canaliculi*. These combine to form the cement corpuscles, and represent the encapsuled remains of the cells from which the tissue is developed.

The Matrix.—The matrix is so nearly identical with that of bone that it is with difficulty that they can be distinguished. By decalcification it retains its form and structure, and by the intimate blending of organic and inorganic substances it is provided with hardness, solidity, and elasticity. Calcium salts and collagenous fibrils, united by a small amount of cement-substance, in finer or coarser bundles, compose the ground-substance, or matrix, of cementum.

Let us first take up the study of this tissue at different periods of its existence, and in this manner learn of its character, its mode of

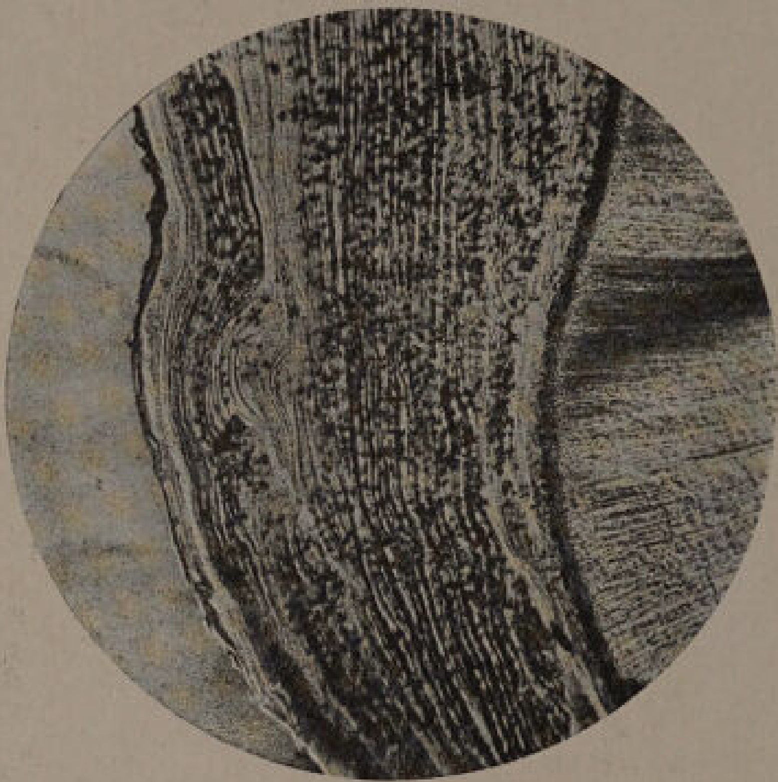


Fig. 246.—Longitudinal section through root of human molar. Incremental lines of cementum. × 30.

development, and the changes which take place as its growth proceeds. The striated markings of the tissue have led to the belief that there are, during the process of formation, periods of activity and periods of rest or little activity. An examination of the structure under low power (Fig. 246, shows the *incremental lines* or lines of growth placed, with more or less regularity, one beyond the other, and when thus studied adds much to the strength of the theory of interrupted development.

Figure 247 is prepared from a developing deciduous incisor three months after birth. At this period the developing organ is made up of enamel and dentin alone, the development of cementum not yet being under way. The establishment of the dentinal periphery, which surface is unchangeable, provides a basis for the first layer of cementum generated by the cementoblasts, which at this period are forming upon the inner wall of the tooth-sacculus. In close proximity to the surface the interglobular spaces are observed somewhat widely distributed, and proportionately large in size, resulting in a surface poorly calcified and forming a ready attachment for the cemental tissue. Figure 248 shows the process of cementification under way, the section being prepared from a six-month-old tooth. In an examination of the ground-substance of this developing tissue there is an unbroken granular appear-

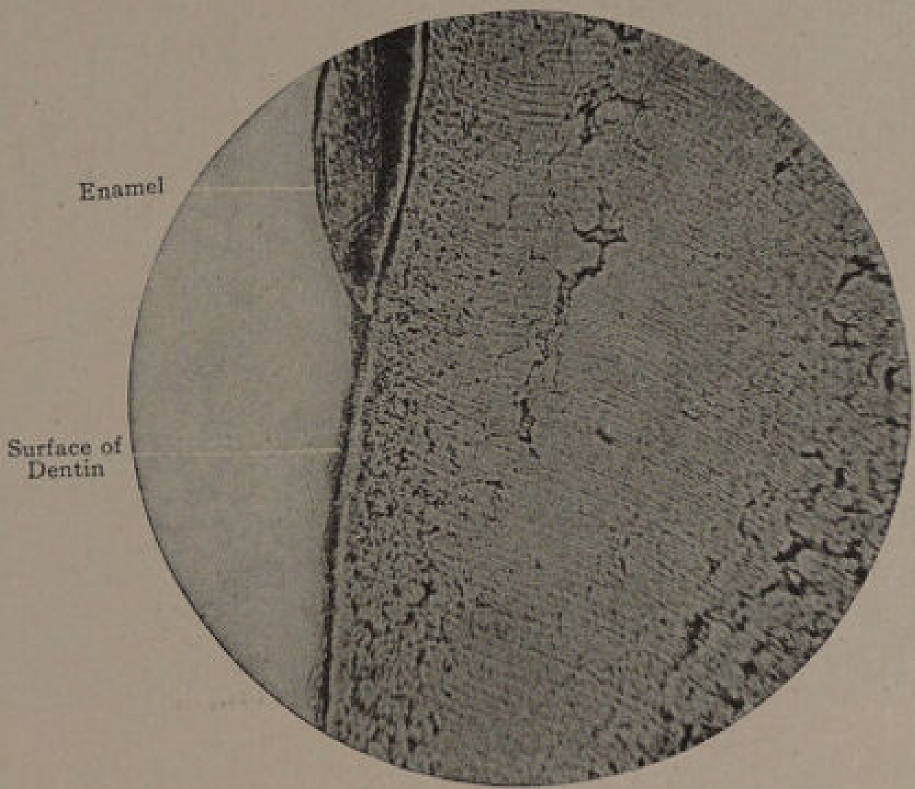


FIG. 247.—Section through developing incisor, three months after birth. × 30.

ance, possessing neither striations, fibers, nor cement-corpuscles. This appearance is one which persists in the oldest or first-formed layer, and is again noticeable in the outermost or youngest layer. While the oldest stratum or strata retain this primary character, this cannot be said of those subsequently laid upon it, for they successively develop in their matrix by inclusion the partially calcified cells and fibers associated with the formation process.

Figure 249, taken from a one-year-old tooth, shows a further advance in the process of dentin formation. Many of the transverse fibers of the alveolodental membrane are observed penetrating the developing tissue, and will, at a later period, by their partial calcification, become a part of its substance. Already there has been established an intimate blending of the cemental tissues with the dentinal tissues through the medium of the granular layer, and by the further calcification of the latter this union gradually becomes more firmly established. Figure 255 illustrates three distinct zones of developing cementum; the older unbroken granular zone at A, now cemented to the granular layer; a second or intermediate zone, B, having encapsuled within its ground-

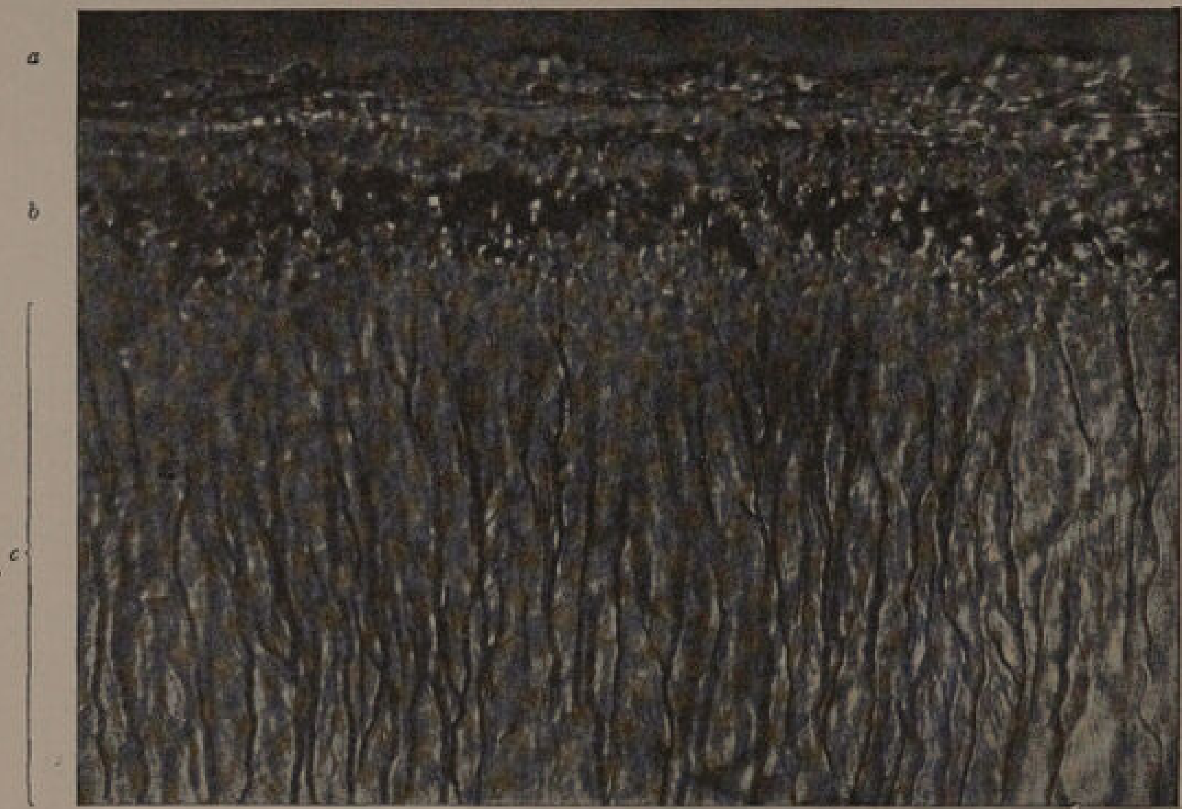


FIG. 248.—Developing cementum, from six-month-old tooth. × 200. *a*, Developing cementum; *b*, granular layer; *c*, terminals of the dentinal tubuli.

substance many of its formative cells; and an outer zone, C, but recently laid down, showing numerous, longitudinal, wave-like striations, emblematic of cementoblastic activity. In this outer zone the minute laminations disappear as the tissue becomes more thoroughly calcified and the matrix gradually partakes of the nature of the older tissue.

The position occupied by the cementum on the root has much to do with its character. In the region of the cervix the cement-corpuscles are few in number, and when present possess extremely short and irregular processes. In the region of the apex the structure is much more complex in character, longitudinal striæ, transverse fibers, cement-corpuscles, and zones of apparently unbroken granular matrix all serving to this end.

To continue the study of this tissue let us examine in detail the lamellæ, the cement-corpuscles, and the cement-fibers.

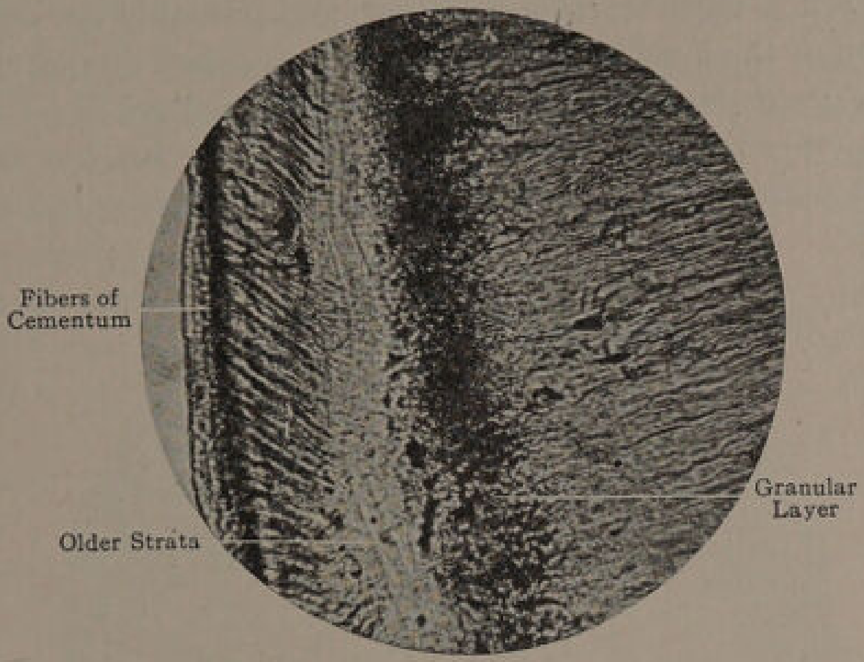


FIG. 249.—Section through one-year-old tooth. × 60.

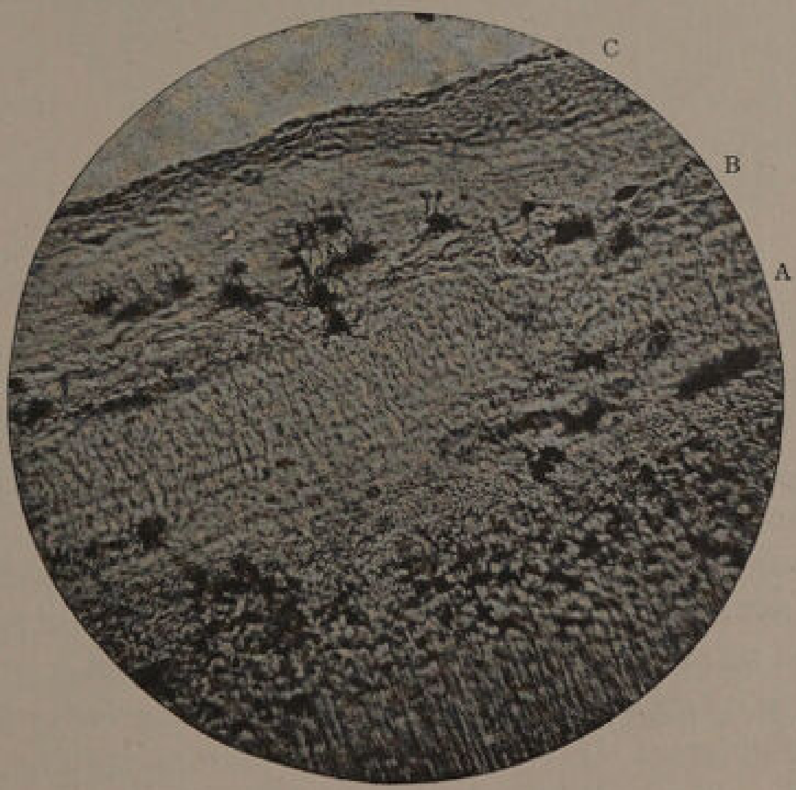


FIG. 250.—Developing cementum, from transverse section of bicuspid. × 100.

The Lamellæ.—We are told that the lamellæ are about the same in number over all parts of the tooth-root, but that they are much thinner at the neck than at the apex. In addition to this they are usually considered as running parallel, or nearly parallel, to the surface of the dentin. While these statements might, and probably do, describe the disposition of the lamellæ in young cementum, they do not apply with so much certainty to the conditions after the adult period. The lamellæ in the region of the apex are not only of greater width, but are usually greater in number than those occupying the cervix of the same root.

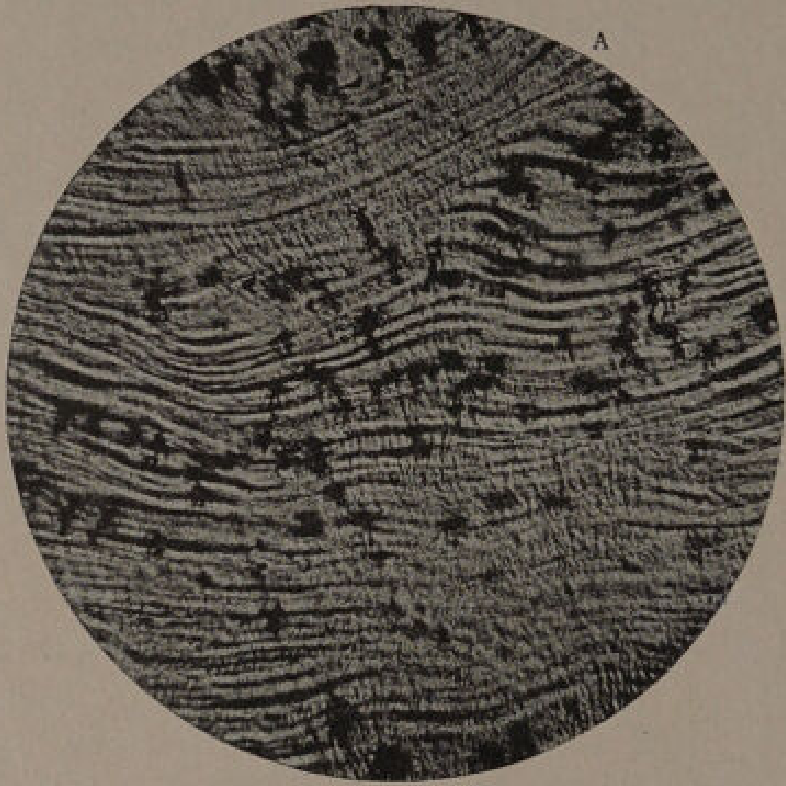


FIG. 251.—Transverse section from root of bicuspid, showing variation in the disposition of the lameliæ. × 40.

Figure 251 is prepared from the transverse section of an adult bicuspid in the region of the apex, and shows how the disposition of the lamellæ may vary in thin, normal cementum. At A, which represents the granular union of the cementum with the dentin, the incremental lines are observed to follow the surface of the dentin. As the center of the area is approached this regularity is much interfered with, some of the lamellæ being discontinued, others greatly thickened, while the field, taken in its entirety, exhibits anything but regularity in the laying down of the different strata. This same condition may be observed in longitudinal section. While the lamellæ are usually characteristic of the cemental tissue in general, they are seldom found in interdentinal cementum, or that growth which takes place between the roots, resulting in their fusion (Fig. 252). This, of course, refers to the tissue as formed between closely associated roots of an individual tooth, and not to that union which sometimes takes place between the roots of different teeth. The interdentinal tissue previously referred to appears to have many characteristics common to itself; thus, the cement-corpuscles are peculiar in form, fibers are few in number, and, as before stated, the lamellæ are not decided. The functional activity of the tooth and the nature of this activity has much to do with the arrangment of the lamina in mature cementum.

Cement-corpuscles.—Many of the cementoblasts or the cells responsible for the development of the cementum, like the osteoblasts in bone formation, become encapsuled within the developing tissue, and persist

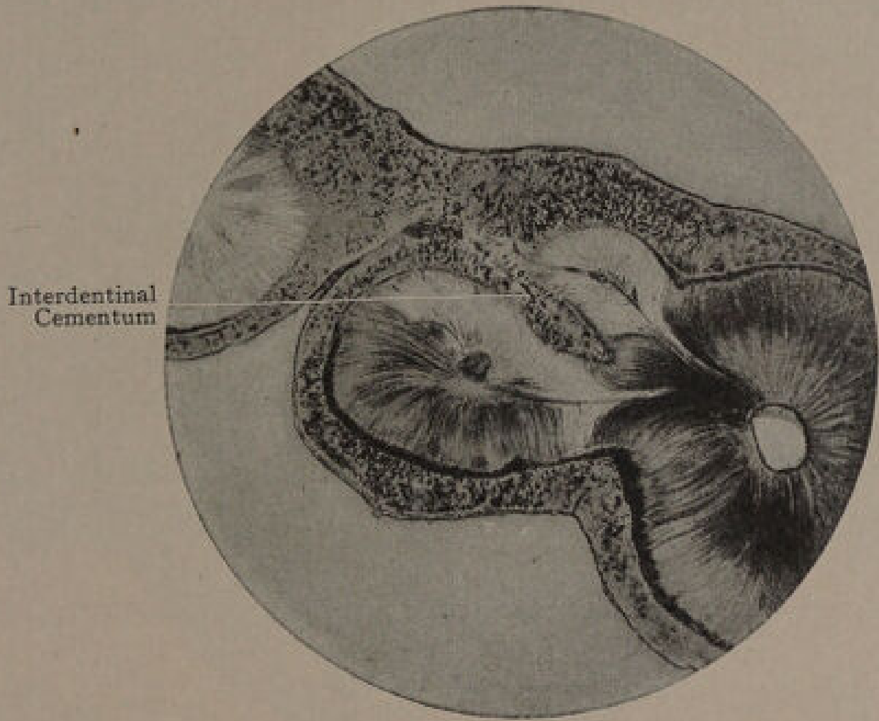


FIG. 252.—Transverse section through fused roots of molar, showing interdentinal cementum. × 30.

as irregularly shaped spaces, filled with a protoplasmic mass, and are known as *cement-corpuscles*. These correspond to the *lacunæ of bone*, but, unlike these, are very variable in size, in form, and in the number and direction of their processes which processes fail to inter communicate, present in this bone. Figure 245 shows a number of cemental leaving thes tructure devoid of a complete Hewassian system, such as is lacunæ and canaliculi. In the majority of instances the body of the corpuscle will be found to be oval or slightly oblong, with its long axis parallel to the surface; but it is by no means uncommon to find them very irregular in outline, with the greatest diameter in the opposite direction. The processes are quite variable in length and irregular in their course, and, while there is a general disposition for them to extend toward the surface, they in many instances radiate in various directions. All of these features are in contradistinction to the lacunæ and canaliculi of bone, which are placed with much more regularity in the osseous matrix, the corpuscles being oblong or cylindric in outline, with their processes about equally distributed in every direction, and uniting directly and positively with the canaliculi of neighboring lacunæ. As previously stated, the cement-corpuscles are very variable in outline, this difference in form appearing to be much influenced by the part of the tooth examined. The younger corpuscles (Fig. 253), or those associated with the outer strata, are usually distinctly outlined and provided with delicate processes, the majority of which are directed

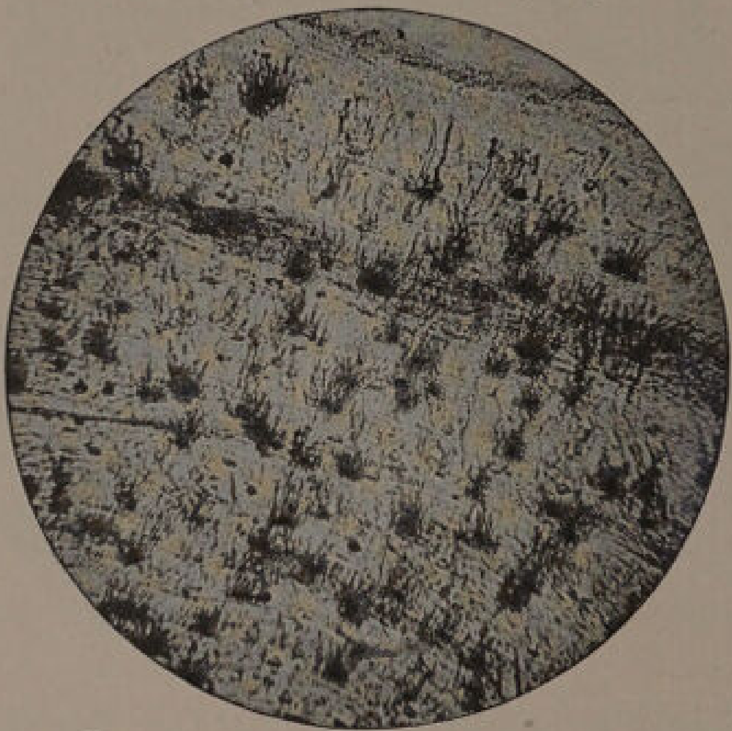


FIG. 253.—Cement-corpuscles of outer or younger strata. × 40.

toward the surface. In the older strata the outlines of the corpuscles are much more irregular, the processes short and extremely clumsy.

The proportionate distribution of the corpuscles to the various parts of the tooth-root is as follows: The innermost or oldest zone and the outermost or youngest zones contain but few; in the intervening strata they are most abundant, especially in the region of the apex, becoming less numerous in passing crownward. In interdentinal cementum the corpuscles are somewhat regularly distributed throughout the ground-substance adjacent to the granular layer, but near the center of this confused mass of imperfectly calcified tissue they are seldom present. When the interdentinal space is slight, peculiarly formed corpuscles are often observed (Fig. 254), provided with a long, rod-like, central portion or trunk, from which are given off numerous tree-like branches, the terminals of which are frequently lost in the granular layer upon either side.

Cement-fibers.—In a manner similar to that in which the cementoblasts become encapsuled within the developing cemental tissue forming the cement-corpuscles, many of the fibers of the peridental membrane undergo a like transformation, and are found in the tissue as more or less

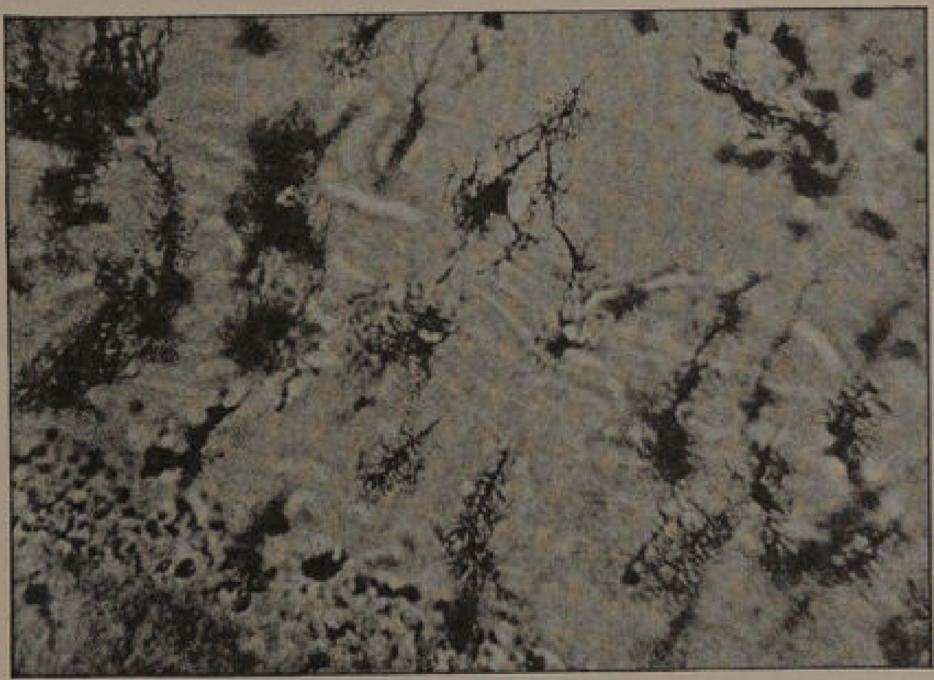


FIG. 254.—Cement-corpuscles common to interdentinal cementum. × 100.

imperfectly calcified fibers transversely disposed. By many writers these filamentary, thread-like structures have been compared to the delicate, net-like processes which pass through the concentric lamellæ of bone, serving to hold them together and designated as *Sharpey's fibers;* In figure 260 the fibers are shown under high power; A represents the primary or older stratum of the tissue, and it is from the outer margin of this zone that the fibers first make their appearance, passing more or less directly in the direction of the surface until the next incremental line is reached, at which point they gradually disappear, but recur in the succeeding lamellæ. There is a marked disposition for the fibers of each concentric lamella to keep within its borders, or, in other words, to become individualized; but in many instances they pass through from one lamella to another, and occasionally extend unbroken through the entire thickness of the tissue. It occasionally happens that the fibers are plentifully distributed to a region comprising three or four lamellæ, followed by a zone of similar proportions in which they are entirely absent. The cement-fibers, considered as the partially calcified residue of the principal fibers of the alveolo-dental membrane, would naturally assume a general direction relative to their manner of distribution before this change had taken place, and in most instances they are thus disposed. In figure 256, taken from the center of a long axis of a growing bicuspid, the disposition of the fibers, which are alone observed in the second lamella, is slightly crownward. The inclination for the

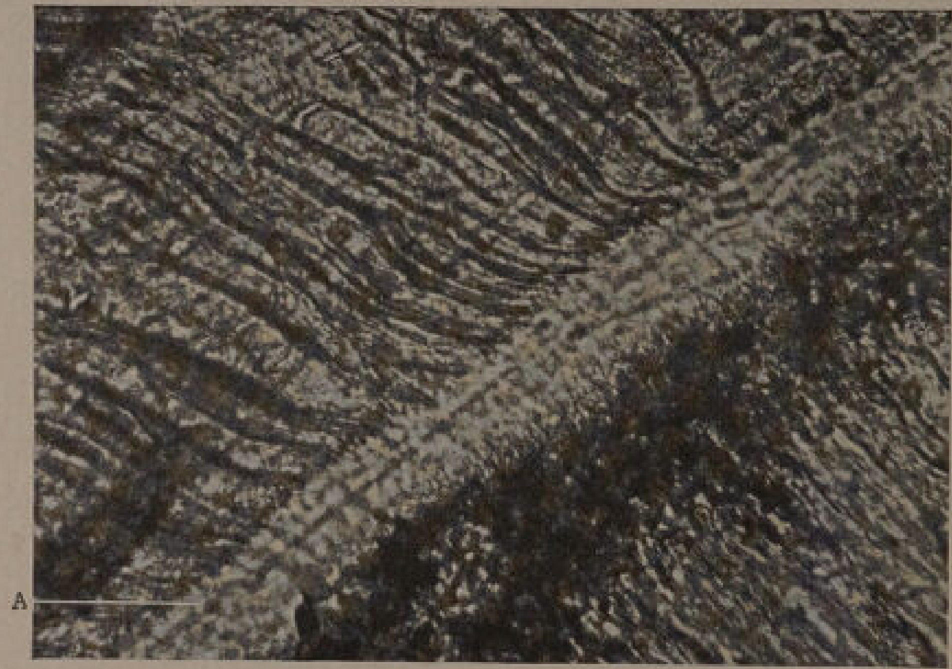


FIG. 255.—Transverse section through root of molar, showing cemental fibers. × 300.

fibers to be thus disposed is most pronounced in young cementum, but after middle life, or at a period when the tissue has greatly increased in thickness, the course of the fibers, even in the same locality, is greatly at variance.

In figure 256, also from a young tooth, the fibers are shown springing directly from the alveolo-dental membrane, with their free extremities penetrating this structure. This illustration is prepared from a transverse section in the cervical region, and the inclination of the fibers is such as to warrant the belief that they were some of those belonging to the dental ligament whose function it has been to return the tooth to its normal position when slightly rotated upon itself. Another class of fibers common to the cement-tissue are those which appear to be grouped in bundles, springing more or less regularly, at intervals, from the granular layer and penetrating the basement layer of the cementum as though serving to tie this tissue to the periphery of the dentin. In figure 257 a number of these bundles are shown at A, B, and C. While the field is but a small proportion of the circumference of the root, they are observed, under low power, to be distributed in a like manner to all parts. These circumferential fibers, as they may be called, are also observed in longitudinal section, being distributed with considerable regularity throughout the whole extent of the root. They

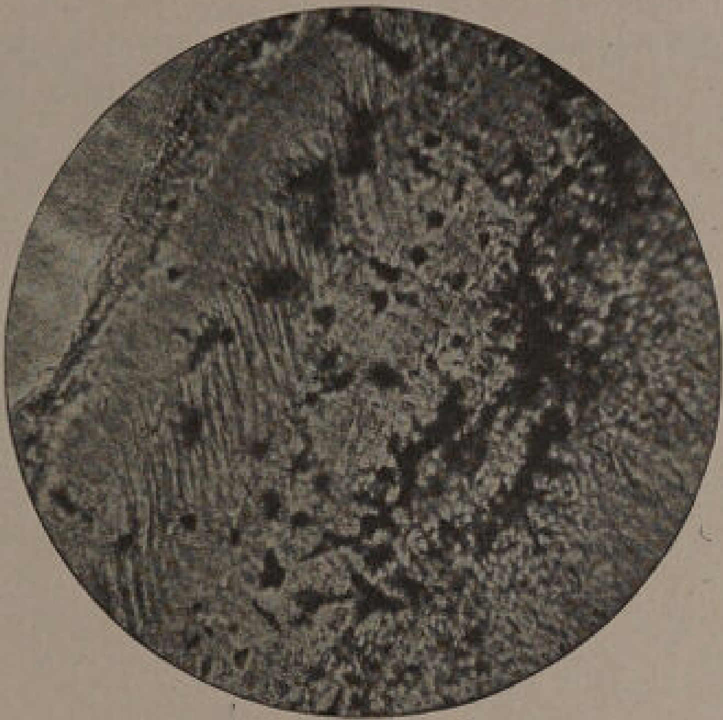


FIG. 256.

are also present in the tissue at the earliest period at which it may be studied, the individual bundles at this time being proportionately larger. These might be, and probably are, considered as prolongations from the dentinal fibers, but it is doubtful if the true fibers of the dentin are ever found penetrating the cementum.

Calcification of Cementum, Cementification.—We shall see in the study of the development of the teeth, that the tooth-generating organs were confined in a closed sac—the *dental sacculus*, and while the walls of this sac are not directly interested in the calcification of the dentin or enamel, this cannot be said of the cementum. Attention has also been directed to the fact that at the time of the eruption of the crown of the tooth a portion of the root only is calcified. As the growth of the root continues, the saccular wall becomes closely adherent to it. Upon the inner face of this vascular membrane cementoblasts make their appearance and from the activity of these the cementum is calcified. It will thus be seen that the process of cementification is but a slightly modified form of subperiosteal bone development. At the beginning of cementum calcification the diameter of the dentin of the root is as great as it will ever be, all additions to its bulk taking place from within. But while the diameter of the dentin is thus fixed, the diameter of the root is increased by the additional layers of cementum as they are deposited upon its surface. As previously stated, a single layer of cementoblasts is first formed in the membrane surrounding the root, these soon becoming inclosed in a

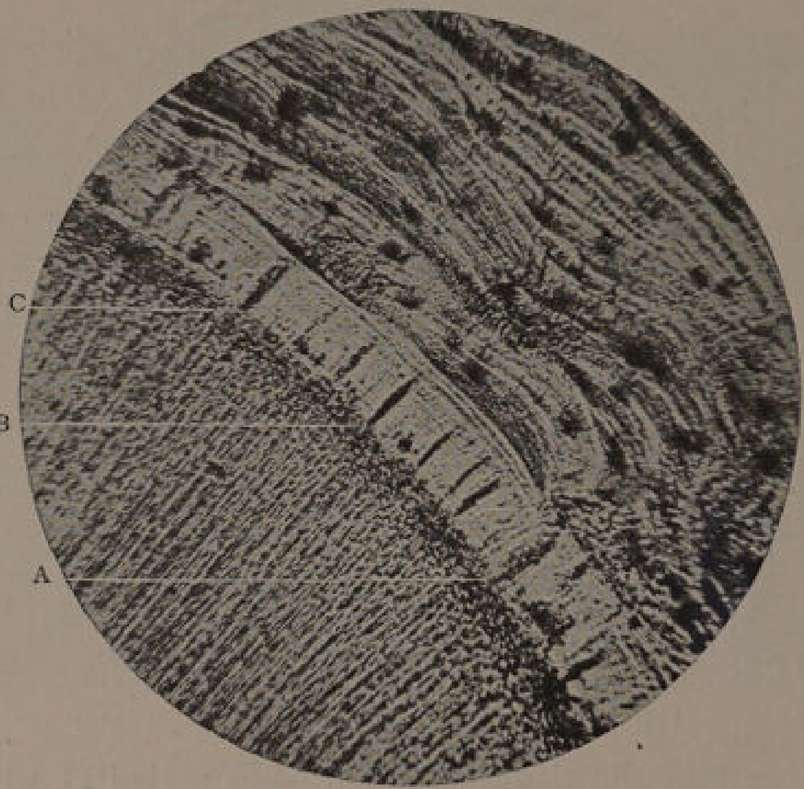


FIG. 257.

spherule of lime. By the time this has taken place another layer makes its appearance, assuming all the characteristics of the first formed layer, and so the process continues with little interruption throughout the life of the tooth. It is to be noted that the process of cementification like that of dentinification is a continuous one, and therefore generally speaking the older the tooth the thicker the cementum.

The Dental Pulp (Fig. 258).—The dentin papilla previously referred to as the formation organ of the dentin, finally becomes encapsulated in the fully developed tooth and is then known as the dental pulp. Occupying as it does the pulp-cavity, it assumes an outline closely corresponding to the external contour of the tooth. The process of dentin formation being a continuous one, and at the expense of the pulp substance, results in a gradual induction in the size of the pulp, being largest in youth and smallest in advanced age. Along with its primary function of generating the dentin, it becomes the medium through which this structure receives its vascular and nervous supply.

Histologically considered, the pulp may be described as a *mucous-like*, protoplasmic mass of connective tissue, containing delicate fibers not formed into bundles and numerous nucleated cells, *pulp cells*, the

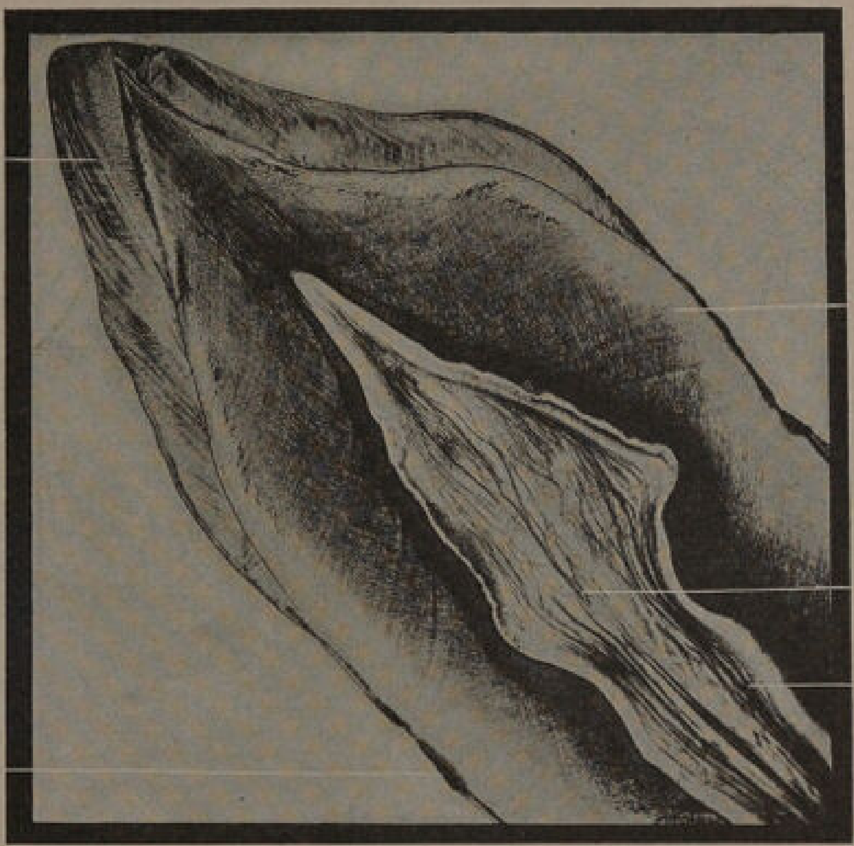


FIG. 258.—Longitudinal section through human cuspid, showing tooth-pulp. (*After Gysi.*) × 10.

latter being especially numerous on the periphery of the pulp, or that portion which comes in contact with the dentin. The cells are not closely enough associated to form a complete tissue in themselves, but are found embedded in a mucoid matrix, with always a definite space between them. In general the cells are elongated or spindle-shaped, with a delicate, hair-like process attached to either extremity. In the pulp-chamber the cells vary somewhat in outline, in some instances being spheroid, in others appearing as slender filaments, so that the cell proper can scarcely be distinguished from its processes. A third class of cells may be met with, from which three or more filaments are given off. As stated, the distribution of cells varies considerably in different parts of the pulp, this being true not only as regards numbers, but also as to the relations existing between the cells. In the coronal portion of the pulp the position assumed by each individual cell appears to be without regard to the position of neighboring cells, while in that portion of the pulp occupying the root-canals the cells are arranged parallel

FIG. 259.—Transverse section through pulp. Blood-vessels and nerves in cross section.

with the root. The cells are least in number in the interior of the pulp, but gradually become more plentiful as the periphery is approached. (See Cells of Dentin Papilla, page 400.)

The Odontoblasts (Fig. 260).—The most active cells of the pulp are those directly on its periphery, in contact with the dentin, responsible for its growth, and known as the odontoblasts. The *odontoblastic layer*, otherwise known as the *membrana eboris*, is composed of a single row of cells, each of which contains, near the extremity most distant from the dentin, a well-defined nucleus. They are large, elongated club-shaped cells, each furnished with three sets of fibers or processes—the *pulpal process*, the *lateral process*, and the *dentinal process*. The pulpal process or processes—there may be more than one present—communicate with the deeper-lying cells of the pulp, while by means of the lateral processes the cells are brought into communication with neighboring cells. The processes given off in the direction of the dentin, or the dentinal processes, may be one for each cell, in which case they are of considerable size, and are inclined to taper as they enter the substance of the dentin. Again, a single cell may give off a number of smaller processes in this direction. The odontoblasts vary much in form according to their functional activity. Before the period of dentinification they are spheroid or pyriform, during the period of

FIG. 260.—Pulp and dentin in longitudinal section.

calcification the dentin extremity becomes somewhat flattened and square, while in advanced years they again return to their primitive, rounded form. Covering the entire surface of the pulp, the odontoblasts are especially closely associated at the end nearest the dentin, forming an unbroken layer, while the pulpal extremities are inclined to assert their individuality by disassociation.

Blood-vessels of the Pulp.—The pulp is richly supplied with blood-vessels, forming networks extending principally in a direction parallel to the long axis of the tooth, and finally terminate in a capillary plexus closely associated with the odontoblastic layer. The veins of the pulp are ordinarily somewhat larger than the arteries, and form numerous anastomoses. This organ appears to be destitute of lymphatics—at least, none are known to occur in its substance. The blood-vessels of the pulp are provided with a longitudinal layer of thinly distributed muscular fiber, but otherwise the walls of the vessels are noted for their delicacy.

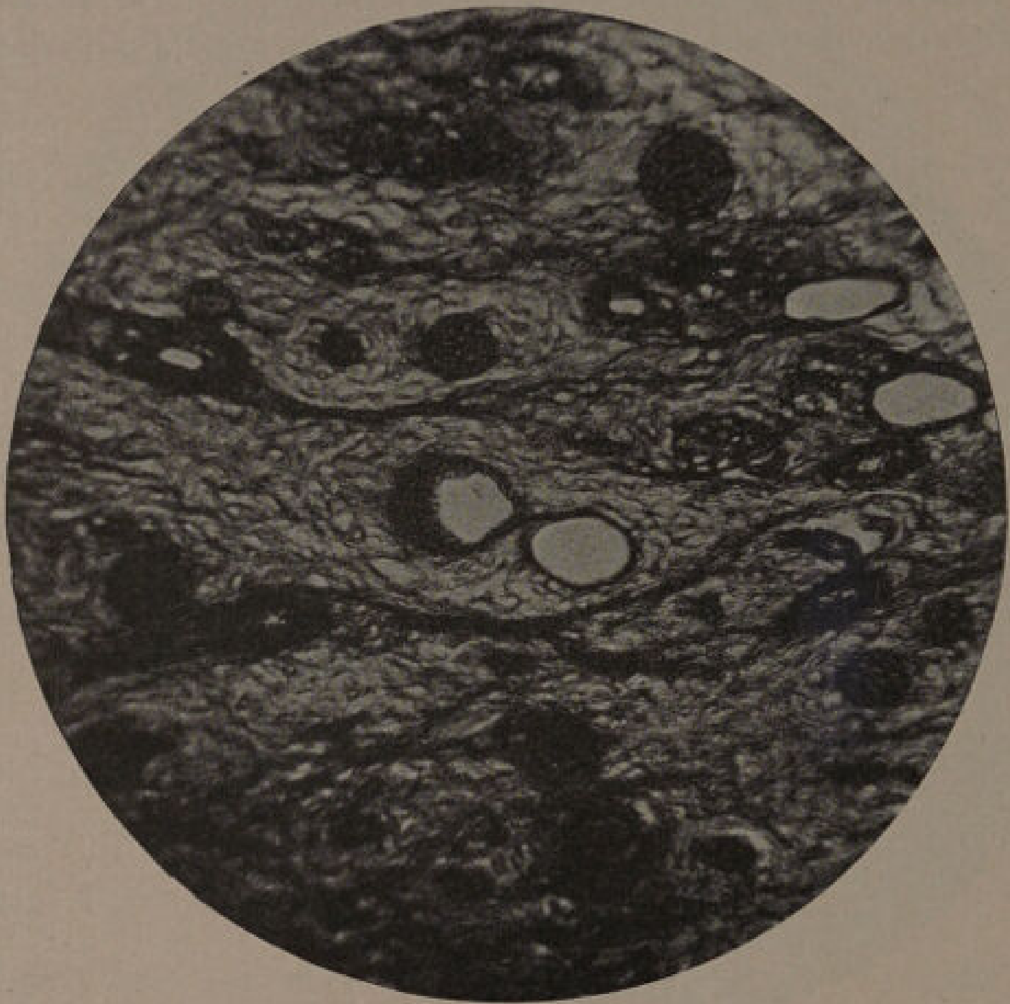


FIG. 261.—Section through pulp. Fig. 260 in transverse section.

Nerves of the Pulp.—After entering the apical foramen either by one large trunk or by two or more minute ones, the fibers pursue a parallel course, breaking up but little or giving off but few fibers in that portion of the pulp confined to the canal. When the expanded to coronal portion of the pulp is reached, numerous subdivisions occur which are distributed in every direction, and ending in a rich plexus beneath the odontoblastic layer, or membrana eboris. In the body of the pulp the fibers are medullated, but those occupying the periphery are non-medullated and supposed to pass into the dentinal tubules. While this latter hypothesis is in all probability correct, such a distribution of nerve fibers has never been definitely demonstrated. Two investigators (Ball and Magitot) claim to have partially satisfied themselves in regard to the final distribution of the non-medullated fibers. The former states that he had traced these fibers into continuity with the larger medullated fibers in the deeper pulp-tissue, and claims to have found them passing through the membrana eboris, beyond which point they assumed a direction parallel to the dentinal tubules. This theory is controverted by Magitot, who claims that the dentinal fibers are, in a

FIG. 262.—Distribution of blood-vessels and nerves to the pulp of human molar. (*After Gysi.*) × 20.

measure, themselves prolongations of the nerves, being so constituted through the medium of the branched stellate cells which lie immediately beneath the membrana eboris, and by which the nerves are made continuous.

Alveolodental Membrane (Figs. 263 and 264).—As a general description of this membrane has already been given in Chapter V, it alone remains to treat of its histologic character, which may best be accomplished by first referring to its various functions. These may be divided into three classes—generative, physical, and sensory. The generative function is accomplished through its cellular elements—the osteoblasts and cementoblasts; the physical function is performed by the fibrous

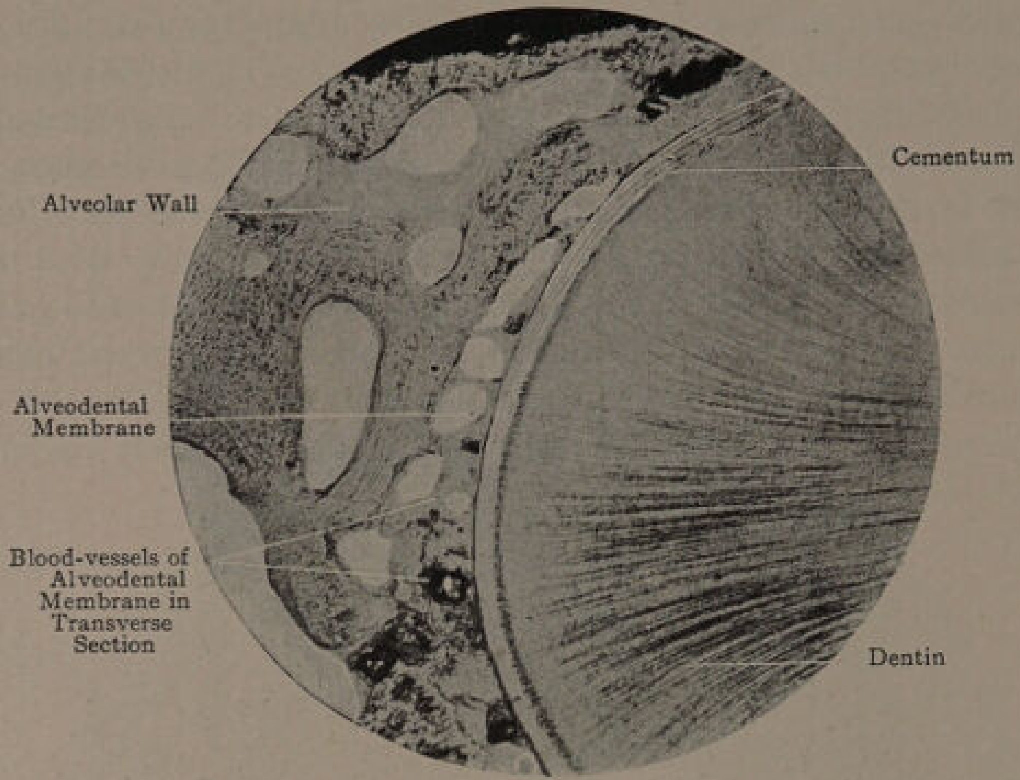


FIG. 263.—Transverse section through root of human incisor and surrounding alveolar wall, with alveolodental membrane intervening. × 40.

FIG. 264.—Section through root of tooth, alveolodental membrane, and alveolus. *a*, Alveolus; *b*, blood-vessel; *c*, alveolar portion; *d*, dental portion; *e*, cementum.

elements, through which the tooth is fixed in its position; and the sensory, through the abundance of nerves, which are richly distributed to all parts of the membrane; in addition both the cementum and alveolar wall receive nourishment through its generous blood-supply. We, therefore, find this membrane to be a characteristic connective tissue, richly supplied with all the elements which serve to make up such a structure. The principal cells, as already stated, are the osteoblasts and cementoblasts, but there are also present fibroblasts.

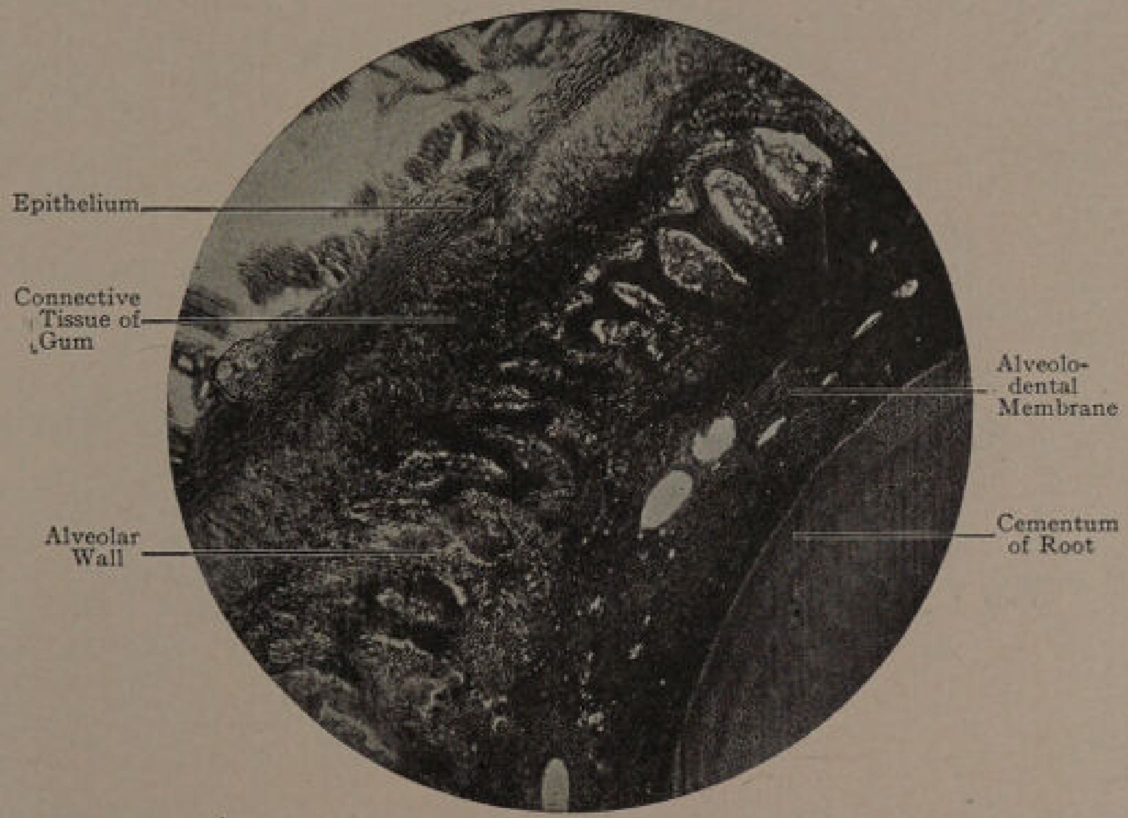


FIG. 265.—Transverse section through root of tooth, alveolodental membrane, thin wall of alveolus, and gingival tissue.

The osteoblasts, which are instrumental in the upbuilding of a portion of the alveolar walls, are found lying against the bone, between the principal fibers. These cells do not appear to be evenly distributed, being numerous and crowded together in some parts, while other will appear to be almost destitute of them. They are most plentiful in the young subject, and seldom present in old age. In youth the alveolodental membrane is thickest, and, as the building of bone occurs on the inner wall of the alveolus, it can only progress as the membrane becomes reduced in thickness. The osteoblasts are polygonal cells, inclining to the oval form and vary greatly in size, with their longest diameter at right angles with the surface of the forming bone. During the period of development of the young alveolar wall they are inclined to be crowded together, and are frequently much distorted from pressure upon one another. As age advances this condition becomes less pronounced, and the cells separate into groups.

The Cementoblasts.—Stationed upon the opposite side of the membrane, or that in contact with the root of the tooth, are another class of cells—the cementoblasts—or those cells which are concerned in the formation of the cementum. Like the osteoblasts, these cells are found lying between the principal fibers of the root-membrane. They differ

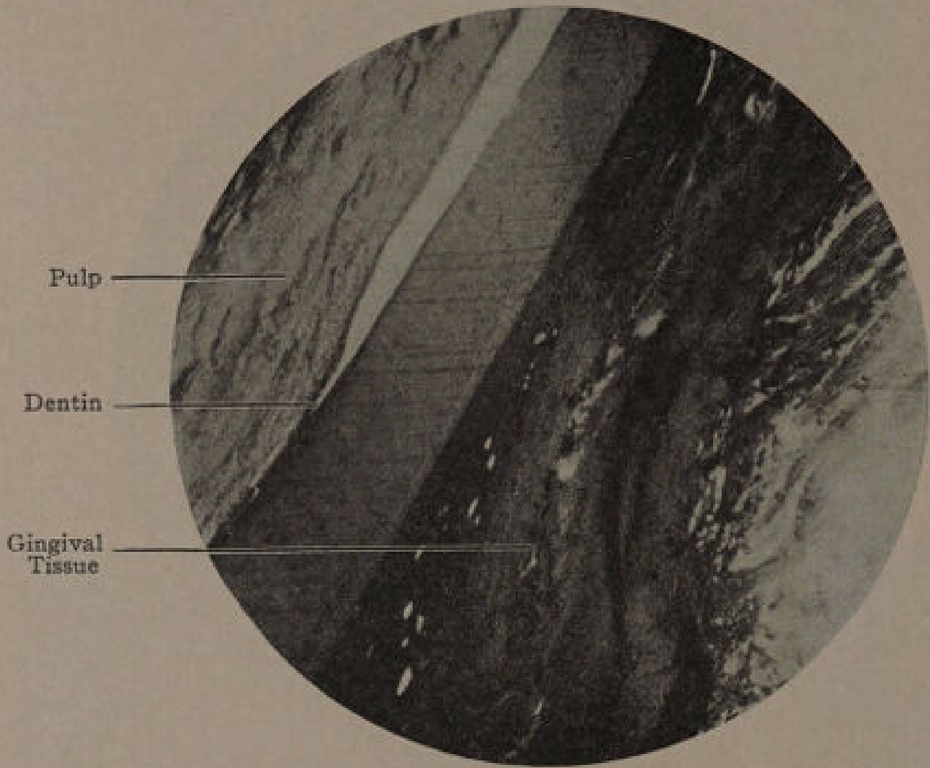


FIG. 266.—Longidutinal section through root of growing tooth near the cervix.

in form from the osteoblasts, although having a similar function. Instead of the polygonal form common to the osteoblasts, we find these cells to be more or less flattened, with outlines somewhat irregular. Extending from the body of the cell, which contains a well-defined nucleus, are a number of irregular processes, which penetrate the neighboring fibers or the interfibrous substance. Unlike the osteoblasts, the cementoblasts appear at all times to be evenly distributed over the surface of the cementum, occupying all the space except that taken up by the fibers as they leave the cementum. As to the development of the osteoblasts and cementoblasts, they appear to be carried to the fibrous meshes of the membrane by the blood as leukocytes or ameboid cells, after which, by differentiation, they become fitted for the development of bone or cementum, assuming their respective places against the surface of one or the other of these structures.

Fibroblasts and Osteoclasts.—Fibroblasts and at times osteoclasts are present in the alveolodental membrane, the former for the purpose of the increase or renewal of the fibrous tissue, the latter being functionally concerned in the removal of a part of the alveolar walls to accommodate the ever-varying position of the teeth, or occasionally acting in a similar manner upon the cementum in which case they are known as cemento-

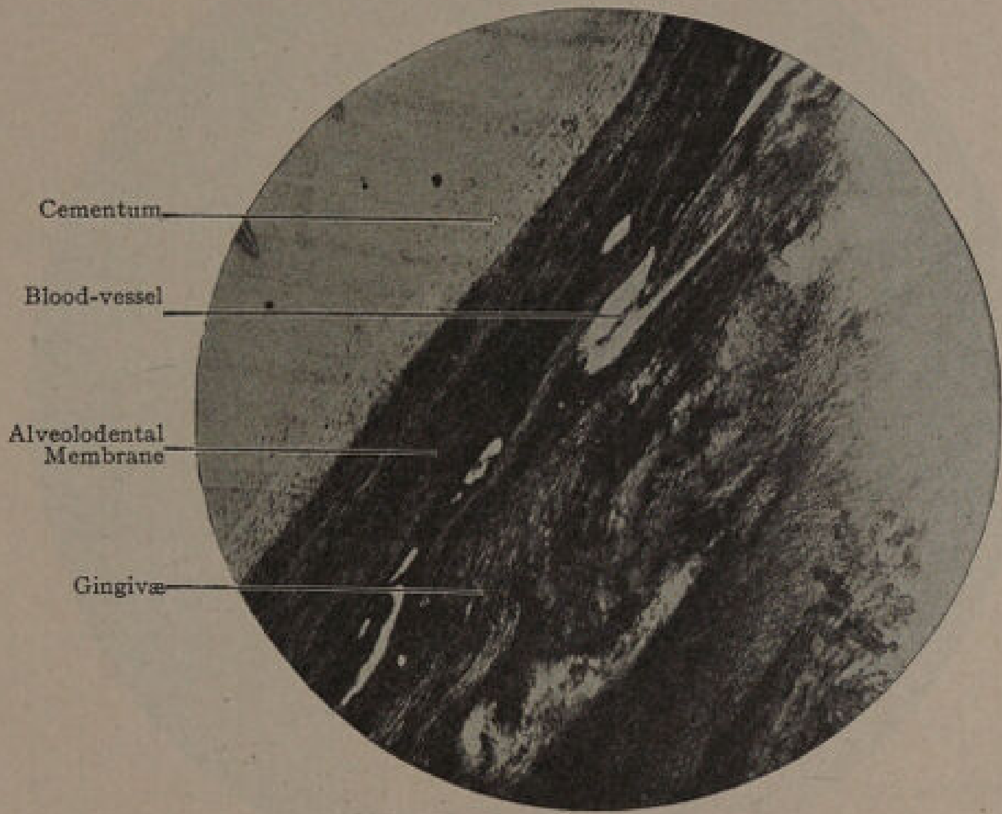


FIG. 267.—Longitudinal section through alveolodental membrane, gingival tissue, and root of tooth. Cervical district.

clasts. The osteoclasts, or giant-cells, are generally inclined to the round or oblong form, and usually contain a number of nucleoli. They vary much in size, and are seldom branched or provided with processes.

The Fibers of the Alveolodental Membrane.—The principal fibers of the alveolodental membrane are those which extend from the cementum on one side to the alveolar wall on the other, and become firmly fixed at either extremity by penetrating the calcified structures. The fibers are all of the white, or inelastic variety. It is by means of these connective-tissue fibers that the actual attachment of the membrane both to the bone and to the cementum takes place, the fibers passing directly into the hard tissues, which they traverse for some distance, being here known as *Sharpey's* or *Cemental fibers.*

The arrangement of the fibers is somewhat different over the various parts of the socket. Beginning at the neck of the tooth they pass out and are attached to the rim of the alveolar socket, and are so arranged that they serve the special function of a ligament, righting the tooth in its socket when slightly twisted upon its axes during mastication, or assisting to lift it when depressed in its socket from the same forces.

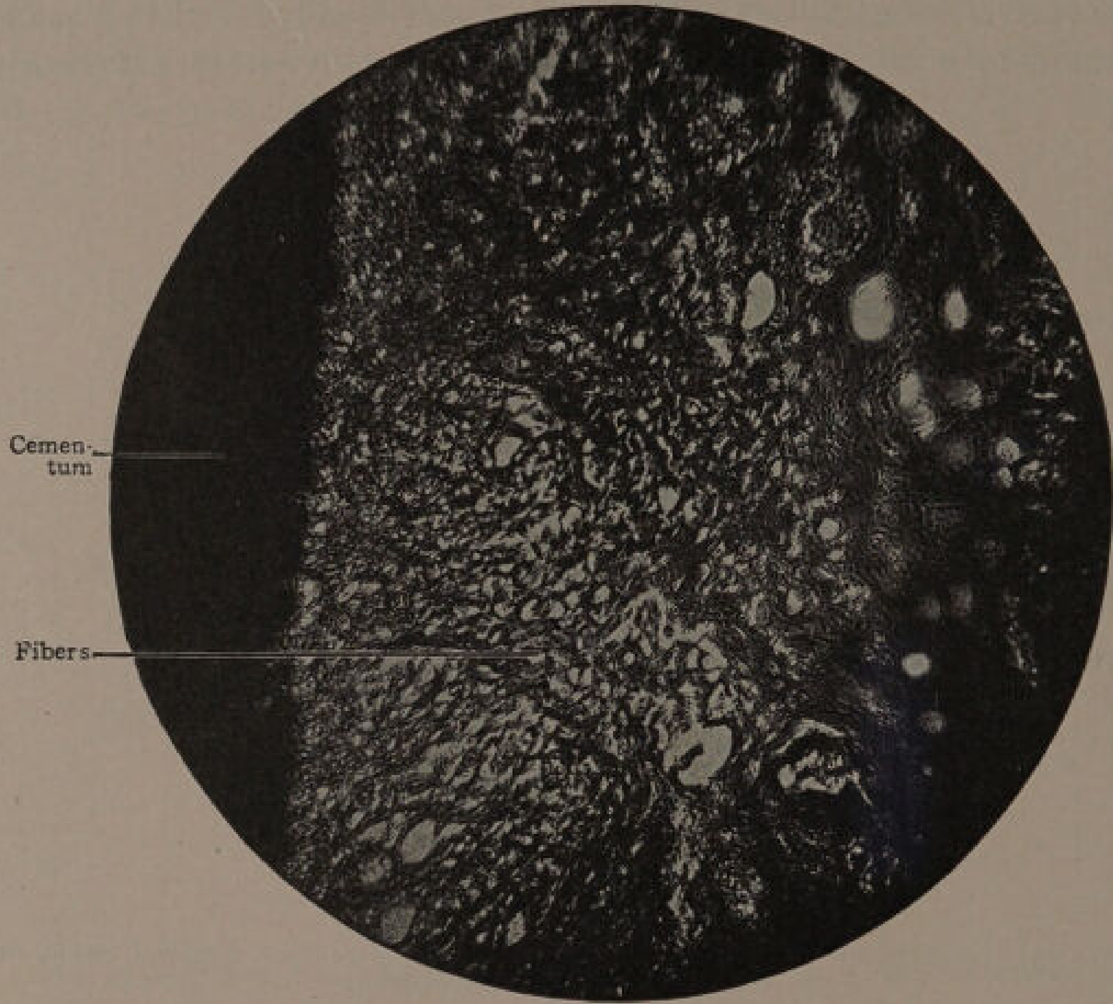


FIG. 268.—Section showing fibers of alveolodental membrane, attached to and passing out from the cementum.

These special fibers collectively are known as the *dental ligament*. There is some variation in the distribution of the fibers about the different gingival surfaces. Upon the labial and lingual surfaces they pass out directly into the fibrous tissue of the gum, and soon become lost in this tissue. On the mesial and distal surface the fibers passing the lower margin of the alveolar wall join the fibers of the neighboring tooth. This disposition for the fibers to bend toward the adjacent tooth is first observed at the various angles of the gingival margin. All about the free border of the gum the fibers from the alveolodental membrane assist in forming this tissue, which is covered by a dense epithelial coating of moderate thickness, surrounded or surmounted by the peridental fibers. As the border of the alveolar wall is approached, the fibers are observed to pass under the proper tissues of the gum, and unite with the outer periosteal layer overlying the outer alveolar wall. The fibers immediately within the alveolus are slightly inclined in an apical direction, while those occupying the central portion of the membrane, or that midway between the apex and the gingiva, pass nearly straight across

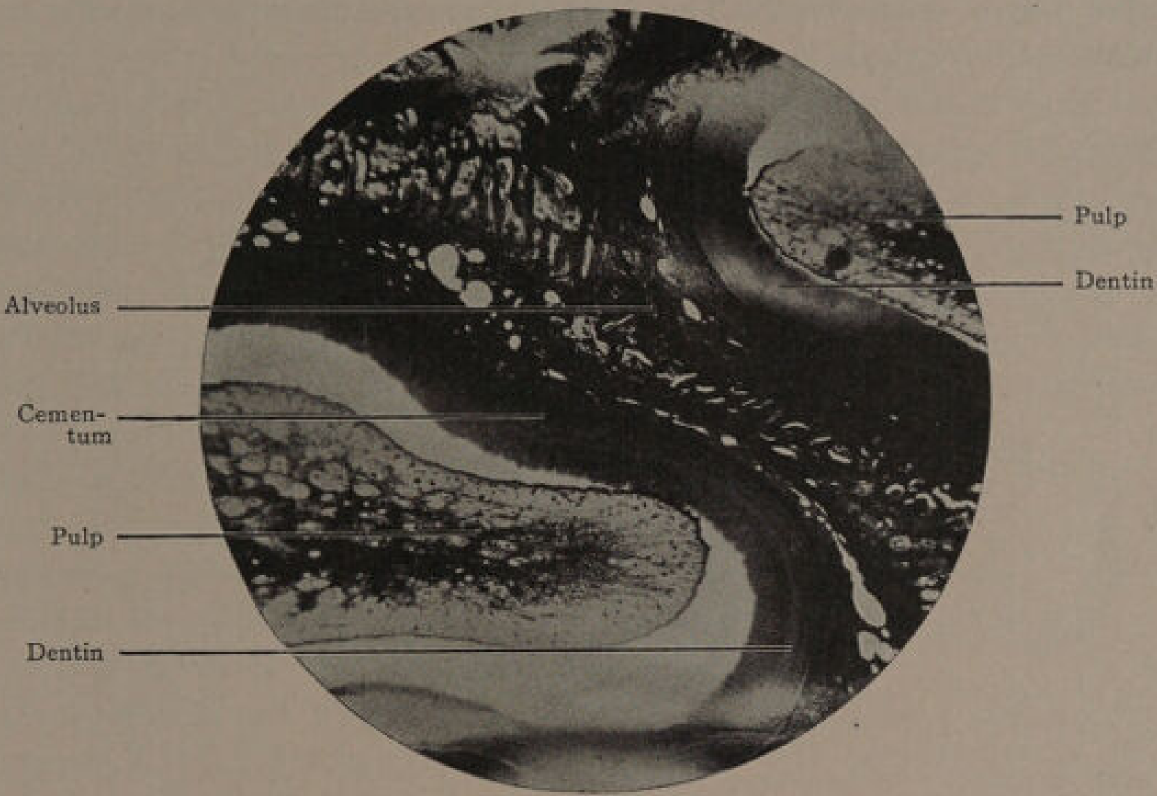


FIG. 269.—Transverse section through growing roots and alveolus.

from the cementum to the bone and are known as the *principal fibers*. It is in this locality that the largest and strongest fibers are found. As the apex of the root is approached the inclination of the fibers is crownward from the cementum to the alveolar wall. Immediately surrounding the apex of the root and occupying the apical space, the fibers are disposed in a regular or fan-like fashion. While in most respects the fibers of this membrane closely resemble the corresponding fibers of attached periosteum, they possess some peculiarities. It might be supposed that the fibers passing out from the cementum would in some way differ from those springing from the alveolar wall, but, with the exception of being somewhat less in size, they are otherwise of the same character.

Interfibrous Elements.—Besides the various forms of cells, blood-vessels, and nerves, there is present in the alveolodental membrane an interfibrous substance. This substance is principally composed of the fibroblasts belonging to the principal fibers, and other fibroblasts accompanied by delicate fibers which appear to be independently distributed. This interfibrous substance, which is thus seen to be ordinary fibrous connective tissue, appears to pervade the entire membrane wherever sufficient space is found to permit of its presence. In some parts of the membrane this tissue appears to be more plentiful than the principal fibers themselves. The interfibrous substance also forms an investment for the blood-vessels and nerves.

CHAPTER VII

Embryology of the Mouth and Teeth

The nourishment required for the growth of the embryo and its maintenance during the earliest part of its development, and in higher animals during the whole of this period, is supplied either from the mother by means of a placenta, or it is drawn from the supply of concentrated food-material, stored up for that purpose in the form of yolk in the egg. The formation of the future digestive organs of the mature organism begins, however, at a very early stage of the development of the embryo. The essential apithelial parts of the digestive canal are derived from the *entoderm*, while the more auxillary parts, such as muscles, connective tissue, blood-vessels, etc., which are not present in the lower animals, but become more and more conspicuous as we advance in the scale of animal organization, are derived from the *visceral* layer of the *mesoderm*. At first, the primitive gut presents a shallow, wide groove, but it becomes gradually deeper by a folding up of the sides; the edges approximate more and more, and when finally a union has taken place, there is a tube formed—the so-called *primitive digestive tract*. While the latter still has for a time an outlet in the form of the vitelline or umbilical duct, the tube is closed anteriorly, as well as posteriorly. As development proceeds, there becomes noticeable a depression of the ectoderm at the anterior end of the tube, opposite the ventral side of the latter, and here *ectoderm* and *entoderm* lay closely attached to each other, forming a thin *membrane*. This point of contact of the two layers is known as the *oral plate*. Soon the plate ruptures, and thus an anterior aperture of the gut, the *oral sinus* or *primitive mouth*, is formed.

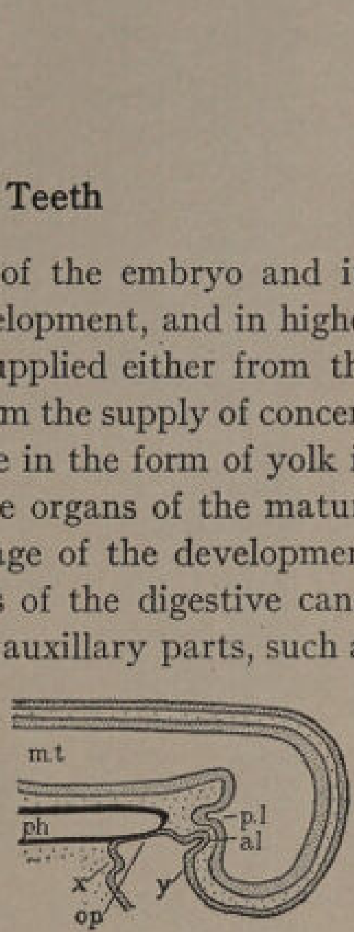


FIG. 270.—Diagram showing the relation between Ectoderm and Entoderm in the mouth of a mammalian embryo.

a.l. and *p.l.*, Anterior and posterior lobes of the hyphysis *m. t.*, medullary tube; *ph.*, pharynx; *o.p.*, oral plate; *x* and *y*, ectoderm which produces the lip and teeth of the lower and the upper jaw, respectively. (*Stöhr.*)

The gradual transformation of the primitive aperture into the permanent mouth and face is brought about mainly by the development and transformations of its boundaries, and are, in brief, the following:

FIG. 271.—Evolution of the face. (*After Haeckel.*)

About the end of the third week, a series of conspicuous elevations or *processes* are developed around the opening, from the front and the sides. The one coming down from the head is called *fronto-nasal process;* those coming from the sides are arranged in form of parallel bars and are known as *arches*. There are five pairs of arches; in fishes they give rise to the formation of the gills, and the individual pairs separated from one another by slits. In human embryos there is no

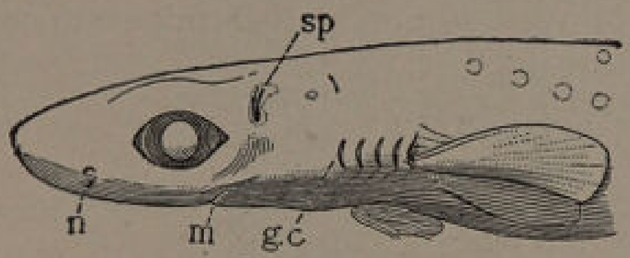


FIG. 272.

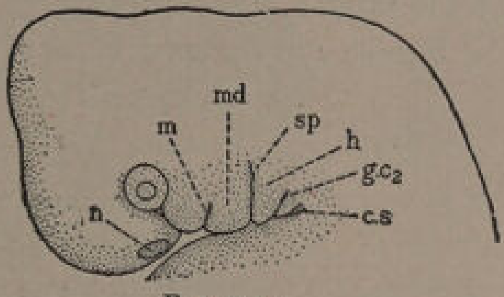


FIG. 273.

FIG. 272.—Head of a young dogfish. (*Stöhr.*)
FIG. 273.—Head of human embryo of 10 mm. It illustrates the phylogenetic relation of the visceral arches. (*Stöhr.*)

g.c., Gill cleft; *m*, mouth; *n*, nasal pit; *c.s.*, cervical sinus; *g.c*$_2$, second gill cleft; *h*, hyoid arch; *md*, mandibular arch; *sp.*, (spiracle) auditory groove.

communication between the inside and outside of the arches, but there are distinct furrows which serve as lines of demarcation between the individual bars. On account of these formations having connection genetically with air-absorbing viscera, the following names are given: *Visceral* or *branchial arches, inner visceral furrows* or *pouches, external furrows* or *clefts*. From the accompanying illustrations it can be clearly seen that only the frontal process and the first visceral arch participate

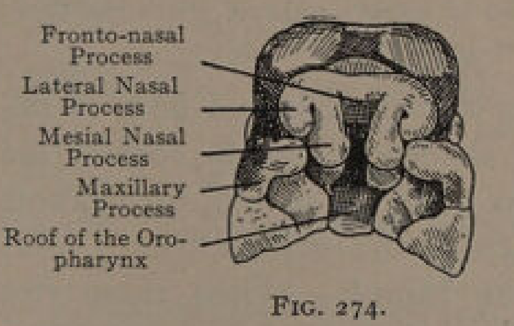


FIG. 274.

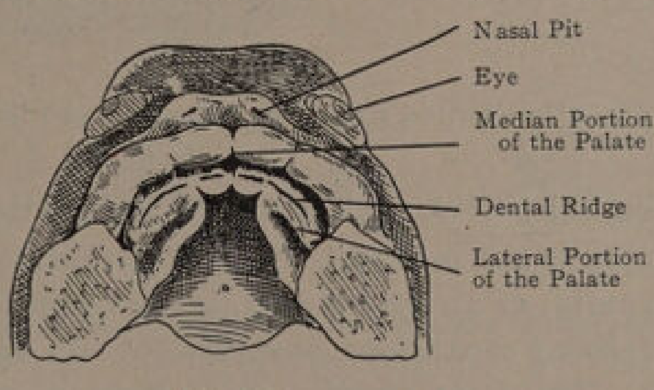


FIG. 275.

FIGS. 274 and 275.—Present development of the various parts of the palate. (*After His.*)

in the formation of the permanent mouth and face; the other four arches give rise to parts, the consideration of which is beyond the scope of this book. In regard to the details of the formation of the individual parts, the following statements may be made:

The Buccal Cavity.—The early appearance of the entrance to the alimentary canal is found by the formation of an open cavity bounded by the primitive maxillary processes above and mandibular arch below.

The cavity thus formed is the common buccal space, the upper portion being the respiratory or nasal section, while below is the true mouth. The cavity of the mouth, as such, does not exist until these two are completely separated by the palatal plates forming the future roof of the mouth.

Figure 276 shows a vertical transverse section through this common

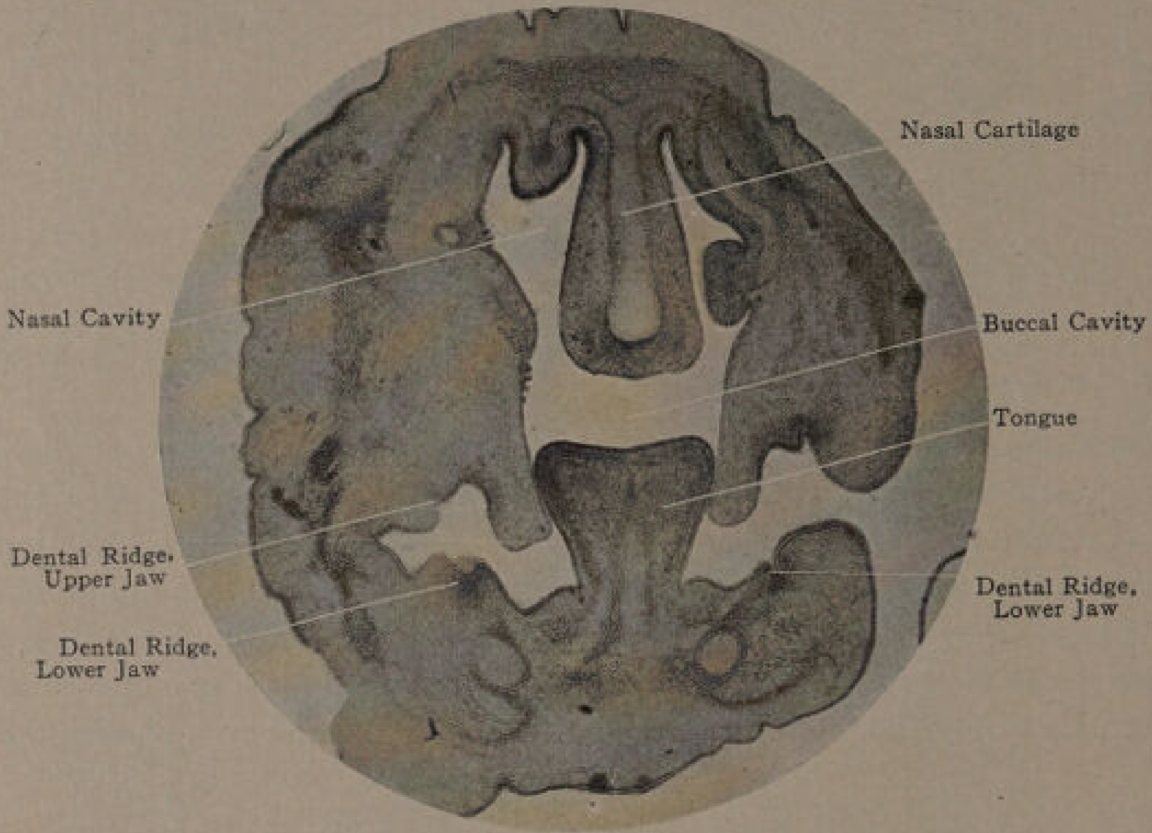


FIG. 276.—Vertical transverse section through head of human embryo, about the tenth week. × 30.

buccal cavity. At this early period the lateral walls and floor of the mouth are manifest by certain cellular elements, but the roof of the cavity, as already stated, is not complete until the palatal plates, now existing separately, grow inward and unite at the median line.

The Oral Cavity. The Roof of the Mouth.—When these two processes which arise from the mesoblast unite at the median line, they establish a permanent horizontal septum, dividing this part of the stomodeum into a respiratory or nasal section and an oral section, the mouth. The cells entering into this part of the fetal head at this time (eighth to tenth week) are of three varieties, being connective-tissue cells, cartilage cells, and epithelial cells, the latter being distributed in a layer of varying thickness over those parts destined to become a part of the lining membrane of the mouth.

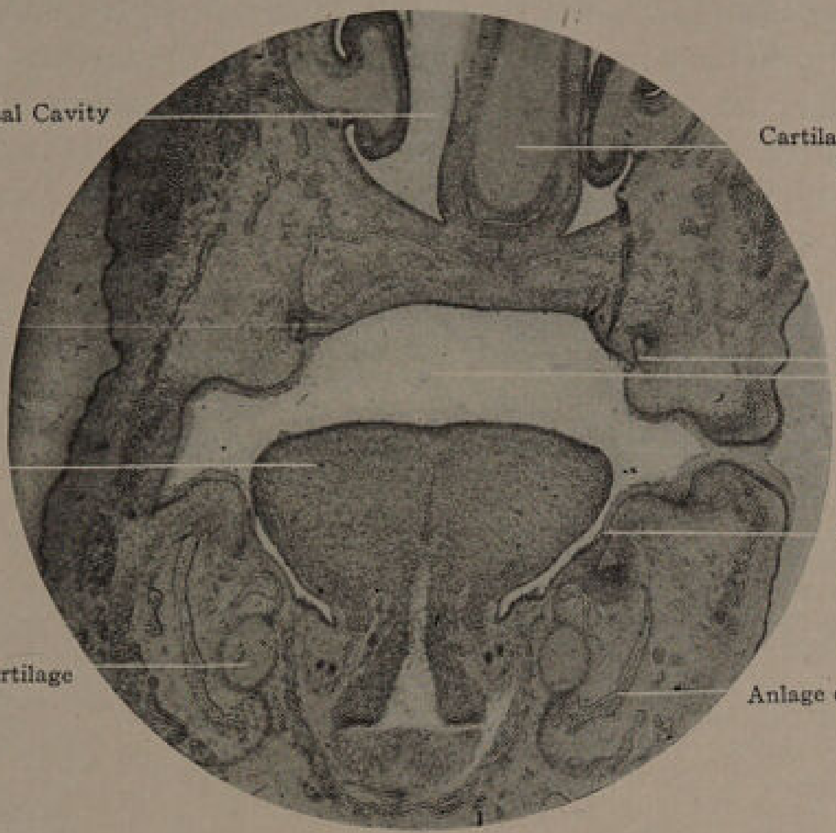


FIG. 277.—Vertical transverse section through head of human embryo, about the twelfth week, showing the single buccal cavity transformed into the oral and nasal cavities. × 30.

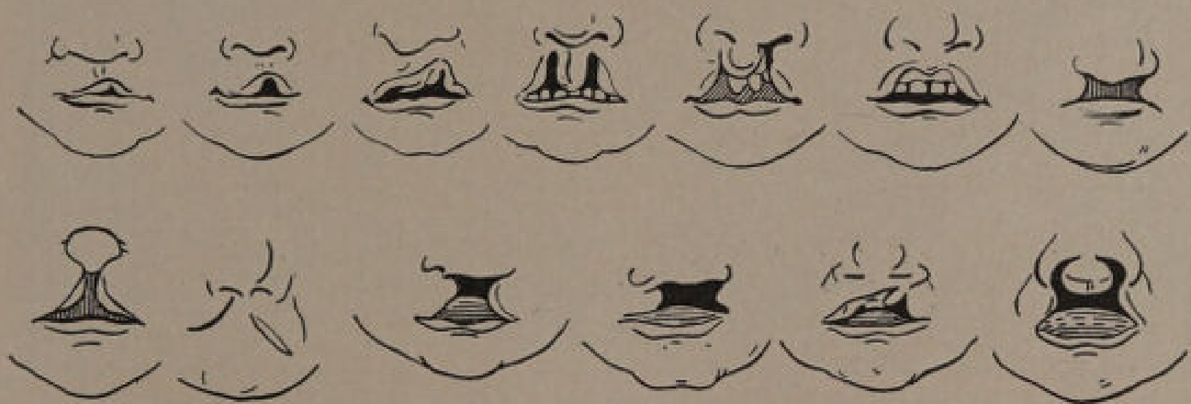


FIG. 278.—Diagram of various forms of hare-lip following the lack of union of various processes participating in the formation of the mouth.

In figure 277 (twelfth week) the superior maxillary processes are shown united and the permanent separation between the mouth and nasal cavity established. This embryonal bridge is for the most part made up of connective-tissue cells, about isolated bundles of which osteoblasts arrange themselves, resulting in the production of two intermembranous bony plates.

By the fourteenth week a further advance in the generation of the hard palate is noted, the septum now being largely composed of calcified tissue. The disposition for these primitive bony plates to exist as separate and distinct processes is exemplified at the median line by a definite separation formed by the connective-tissue sheath from which they are derived. Covering the surface of the hard palate there now appears a thin layer of mucous membrane, the line of union being recorded in the median raphe.

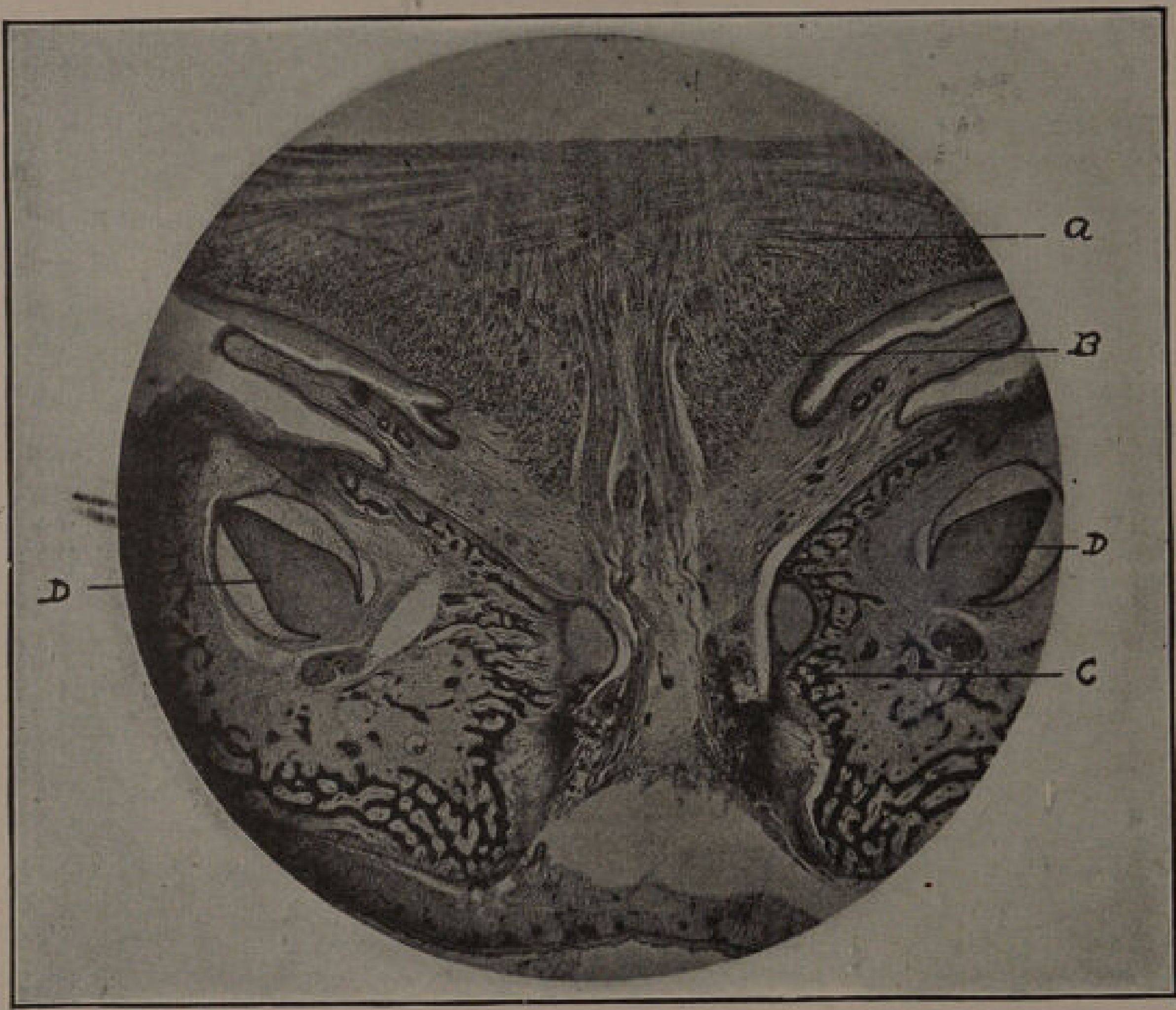


FIG. 278 A.—Section through base of tongue and lower jaw. × 40.

The Floor of the Mouth.—Having thus briefly noted the evolution of the roof of the mouth, let us next consider the floor of the cavity, the tongue and its attached muscles, together with considerable glandular tissue making up the bulk of this district. Figure 278 A is a vertical transverse section through the floor of the mouth of a human embryo about the tenth week, or at a period somewhat earlier than that shown in the previous illustration. An examination of the parts in general at a time prior to this is of little value, save the early preparation for the development of the teeth, which will be referred to later. The tissues and organs here shown will be recognized as the tongue (*A*), the glandular tissues (*B*), the forming mandible (*C*), with developing tooth-germs at *DD*.

The tongue appears on the floor of the mouth between the thirtieth and thirty-sixth days as a bud from the mesoblast covered by a layer of

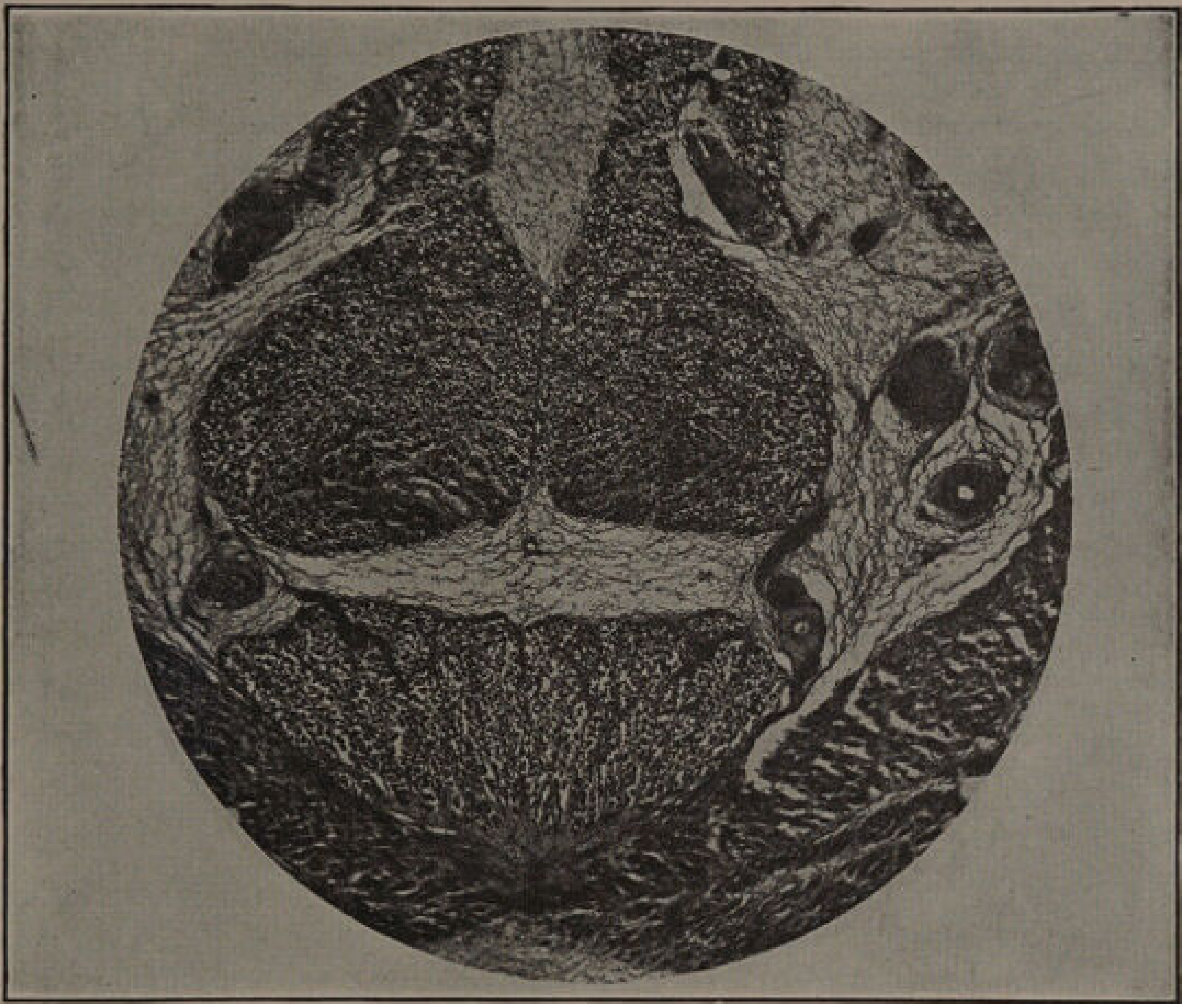


FIG. 279.—Section of sublingual district. × 100.

epiblastic origin. The muscle-fibers, be they intrinsic or extrinsic, are all of the striated variety. In a very short time, and at a comparatively early period, the tongue becomes an independent organ, presenting most of the characteristics common to it after birth. Not a small portion of the floor of the mouth is made up of another class of cell elements which, although eventually a distinct organism, is composed almost entirely of epithelium. These cells, together with the connective-tissue cells, and eventually blood-vessels, unite in the production of a mixed salivary gland, the sublingual, figure 279. The section is one from the region of the premolars, and is bounded above by the tongue, laterally by the borders of the mandible, and below by fibers of the mylohyoid and digastric muscles. Three distinct lobes or sections of the gland are observed, the two largest being separated by a reticular network of connective tissue.

The general character of these developing glands even at this early period (about the twelfth week) appears to be very similar to the ma-

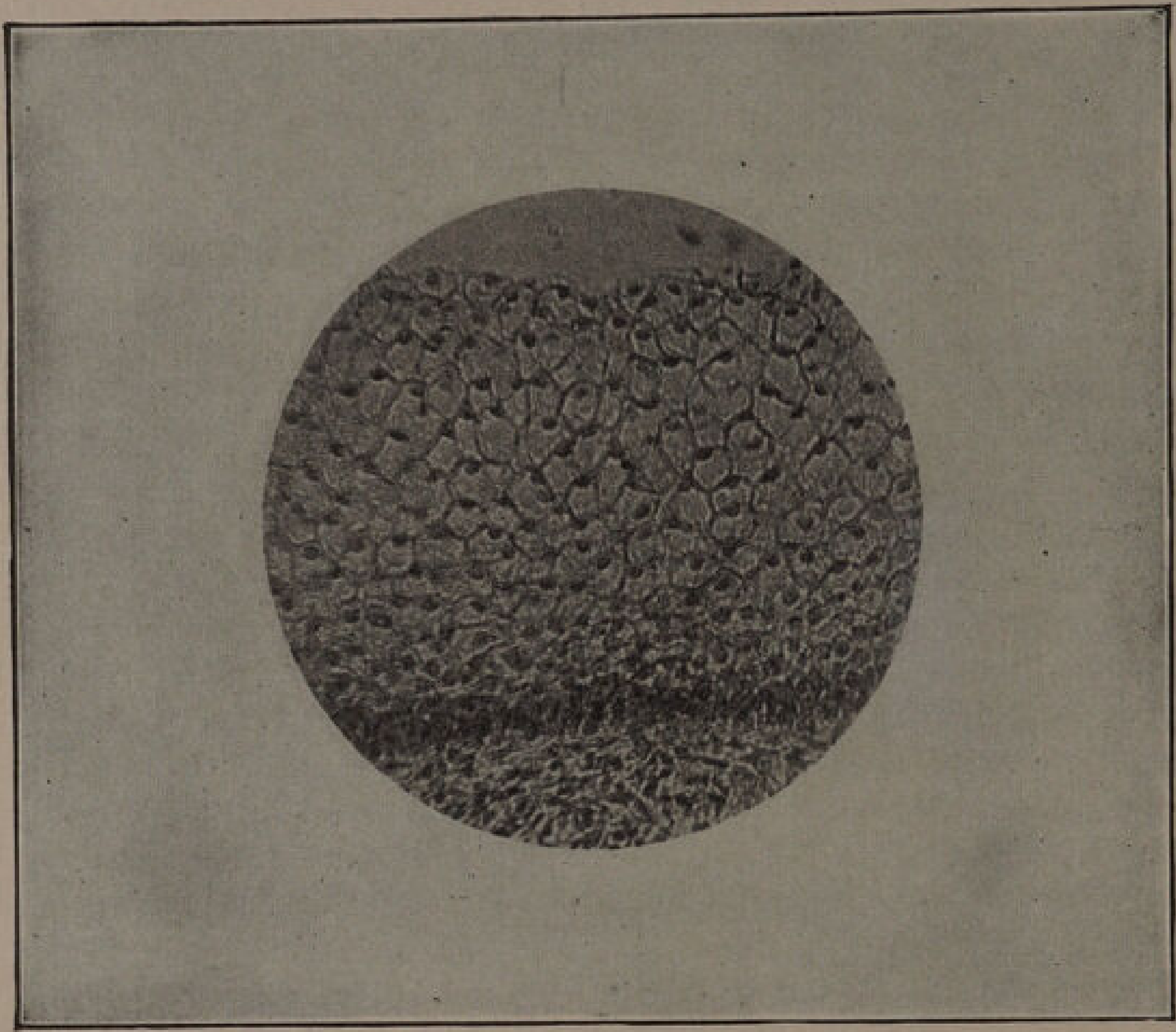


FIG. 280.—Embryonal labial mucous membrane.

tured organ, being composed of a number of small tubes emptying into a single duct, constituting a gland of the compound tubular variety.

Let us next give some consideration to the embryology of the mouth in its entirety; and to do this, it is necessary to make sections of the parts in various directions.

The growth of the cavity is usually studied, and probably to the best advantage, by vertical transverse sections, and attention will first be called to a number of sections made in this way, beginning at the lips and passing backward through the incisor region, and finally through the districts occupied respectively by the cuspids and molars. The period at which such an investigation is made has much to do with the histologic character of the parts involved, but the time best suited to the purpose is included between the fortieth and sixtieth days. At this time nearly all the structures making up the organs and parts which enter into the construction of the cavity have advanced to such a

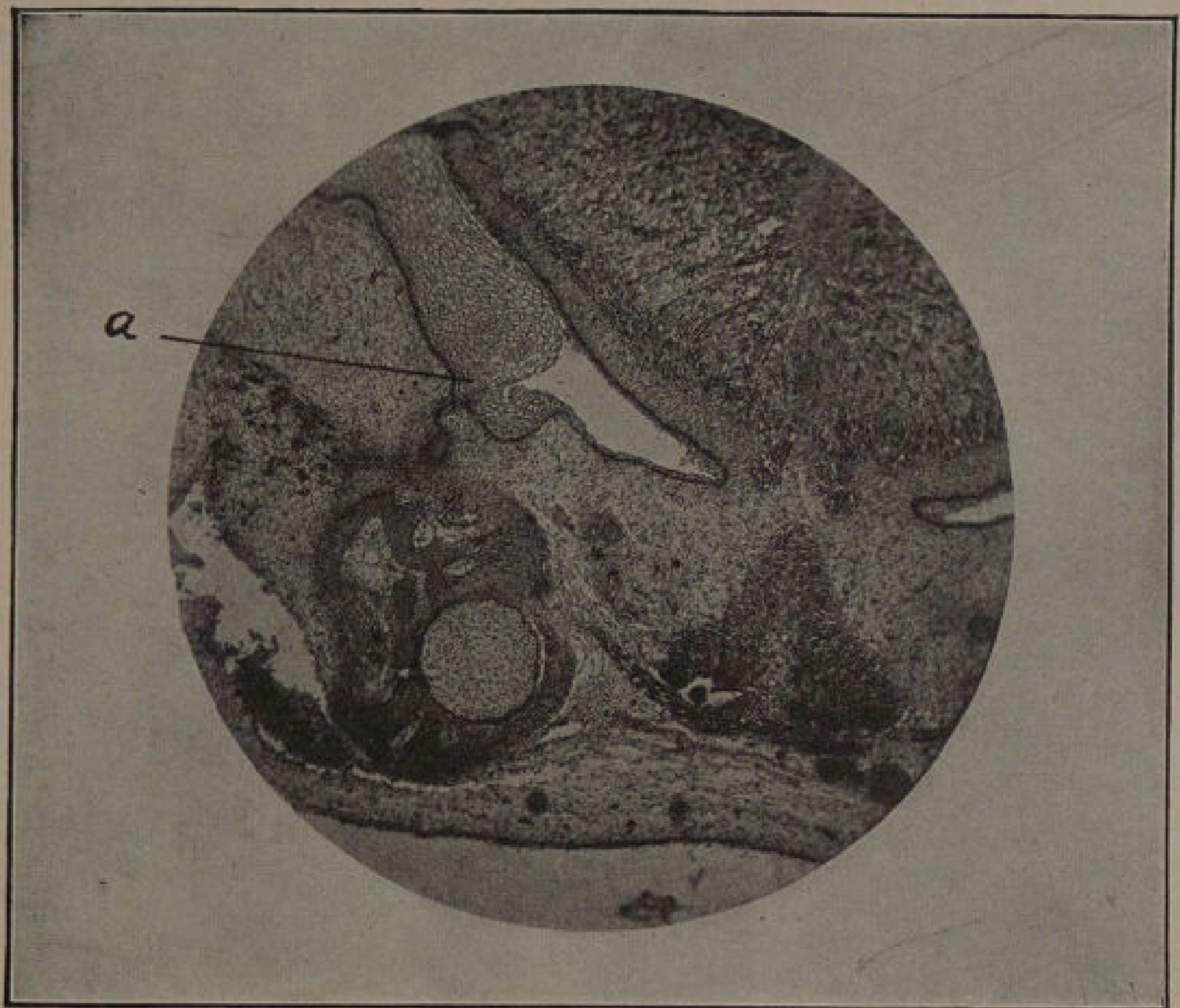


FIG. 281.—Section through base of mandible.

degree of perfection that the investigation may proceed with considerable satisfaction.

Figure 280 shows a cross-section through one of the primitive labial folds about the period named. Little is to be observed in this district at this early period except the simple cells of three varieties which serve to make up the parts, but attention is at once attracted to the abundant thickness of the epithelium given to the lip.

If a section be made somewhat to the distal of that previously shown, a marked change in the relationship existing between the various cells is observed in a body of cells of another character, those which are destined to become the cartilage of Meckel, and about which the younger layer of cells of mucous membrane are observed outlining a new district.

If a section be made through this same location, say about the forty-eighth day, a vast change in the appearance of the parts is noticed

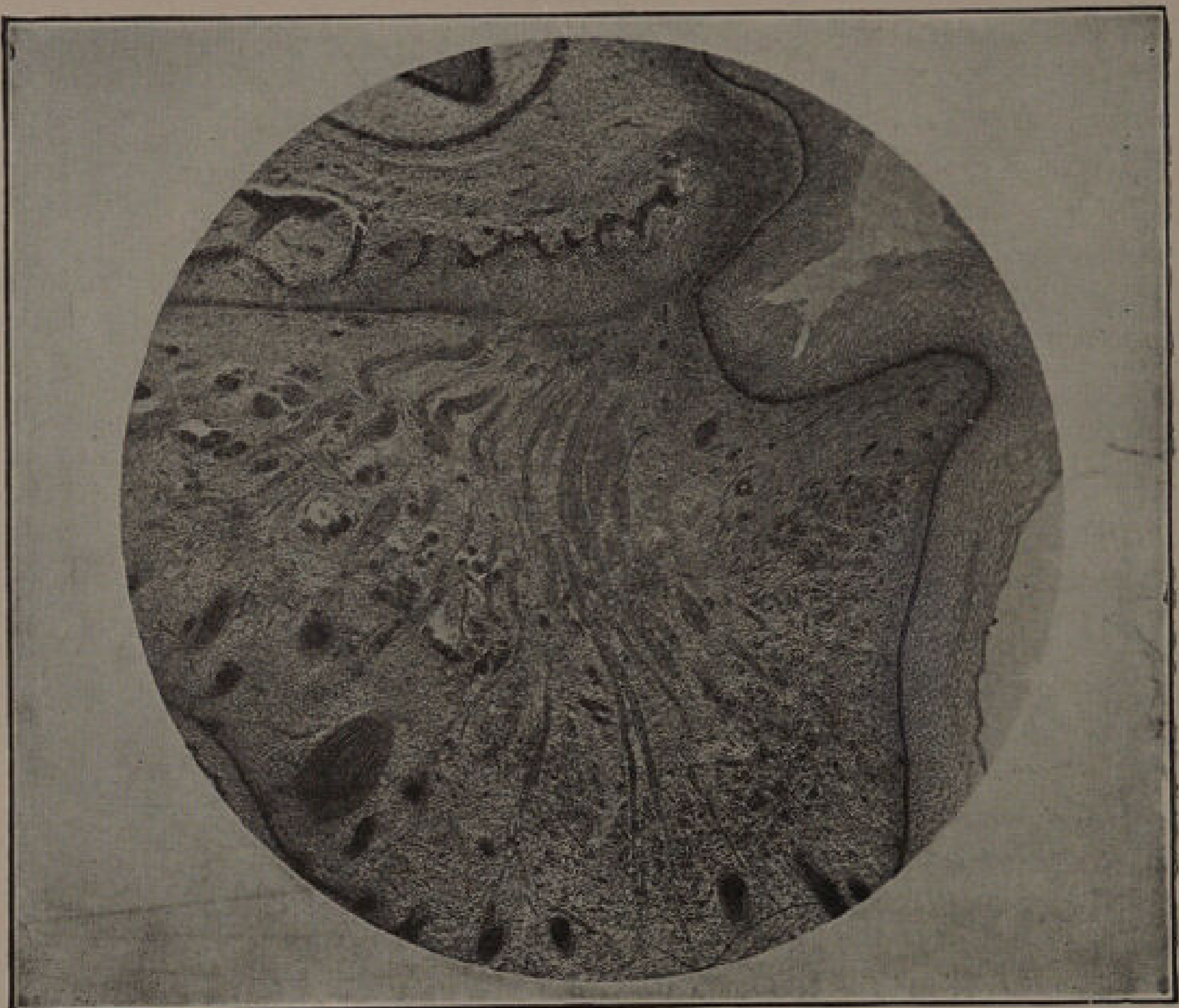


FIG. 282.—Section through the wall of the mouth of an embryo, sixtieth day.

(Fig. 281). The buccal walls of the mouth have in a measure become complete by a union of the upper and lower sections, the union at this time being accomplished through the agency of the embryonal epithelium. A cartilaginous nasal septum has made its appearance, and active preparation for the ossification of the maxillæ is apparent. In the center of the section is a distinct body of cells forming Meckel's cartilage, and early preparations for the growth of the teeth may be seen at *a* by a dipping down of the surface epithelium.

A transverse section through the same district about the sixtieth day (Fig. 282) shows all the part strongly differentiated. Ossification has taken place to a considerable extent in the lower jaw, the two halves being at this period, and for some months afterward, separate and distinct. Many muscle bundles are observed beneath the jaw, and

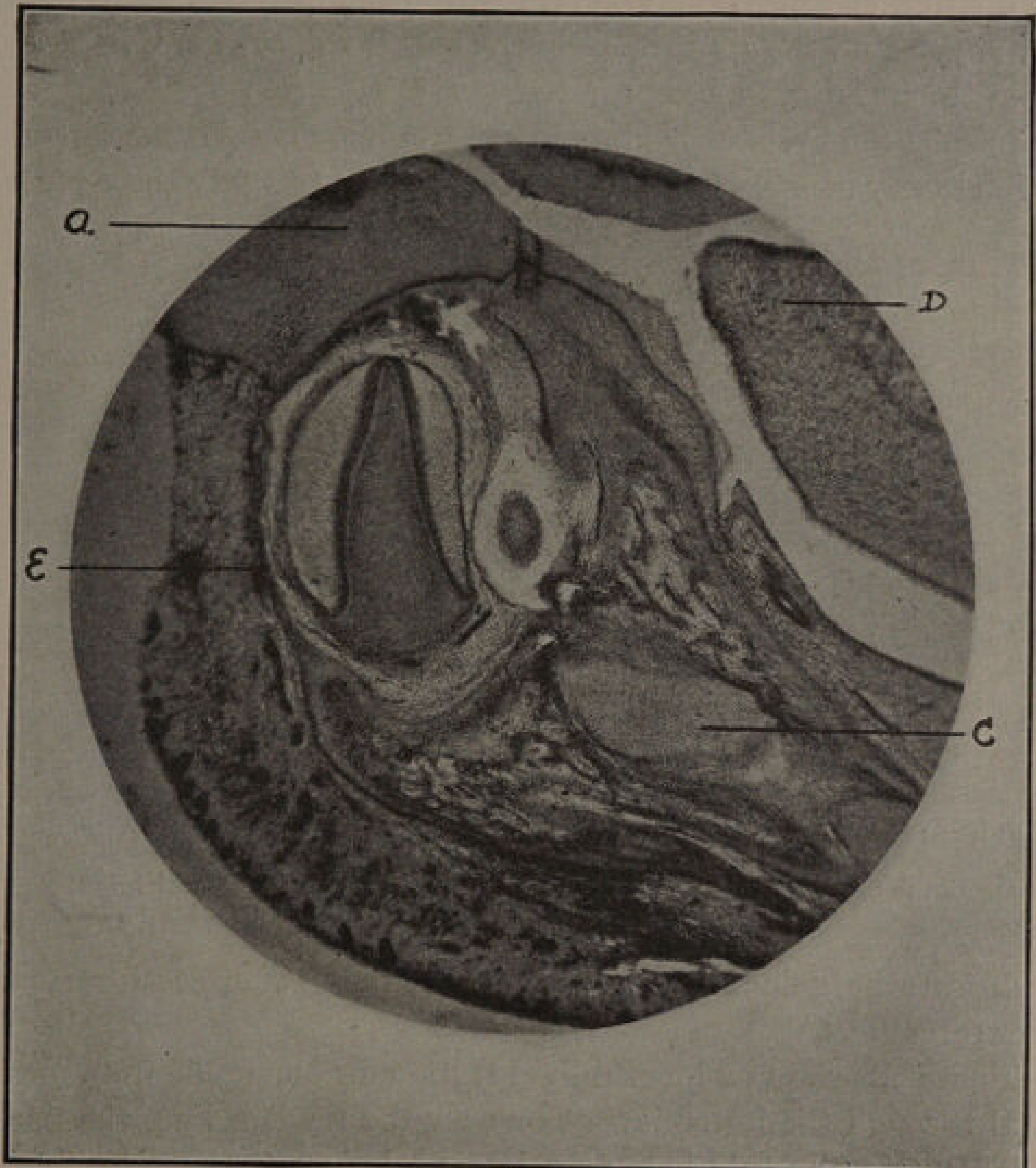


FIG. 283.—Longitudinal section through chin of embryo lamb.

beyond these the integument with its numerous blood-vessels and nerves most of which are seen in transverse section. A longitudinal-section upon the same specimen about the sixtieth day in the region of the cuspids finds the tissues and organs advanced to a certain degree of perfection. (See Fig. 283.) The tooth-germs of the cuspids have their crowns outlined by the cells composing them; the tongue with its complex muscular arrangement has become a specialized and independent organ, while beneath it we see that product of the epiblast, the glandular structure, so plentifully supplied to the floor of the mouth in this locality.

Passing further back into the region of the molars, the appearance of the parts does not differ to any marked degree from that in the cuspid district, except in the general distribution of the muscular fibers of the tongue, and the appearance of the submaxillary gland, here appearing in three distinct lobes or parts.

It has been previously stated that sections made in the direction of those already considered are usually employed to study these parts, but

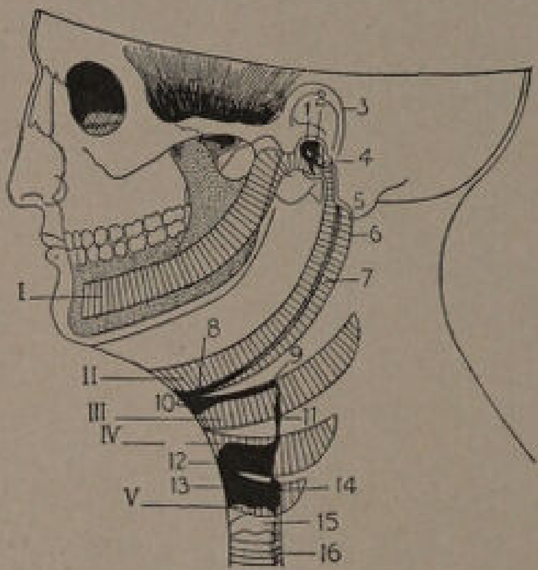


FIG. 284.—Diagram to illustrate the metamorphosis of the visceral arches during development.
I, Presents the first visceral arch, it gives rise to Meckel's cartilage, which becomes transformed into the mandible. (*After Wiedersheim.*)

much is to be gained by supplementing these with sections made in other directions.

Figure 283 shows a longitudinal section, or one made from mesial to distal through the lower jaw at or near the median line, the parts included within the field being the labial folds at *A*, the mandible at *C*, the tongue at *D*, and a tooth-germ at *E*. An examination of the lips shows them to be covered with a varying thickness of embryonal epithelial cells which are continued backward over the future alveolar ridge and thence to the hard palate above, or over the floor of the mouth and the surface of the tongue below.

Meckel's Cartilage.—One of the earliest products of the mesoblast is that which results in the production of Meckel's cartilage, which is closely associated with the growth and early support of the mandible. In the beginning, as already pointed out, the mandibular and hyoid arches resemble one another, but soon after they become fully established they take on different functions, and with this become dissimilar. The first appearance of this cartilage as a distinct body of cells is found about the middle of the second month, and when a transverse

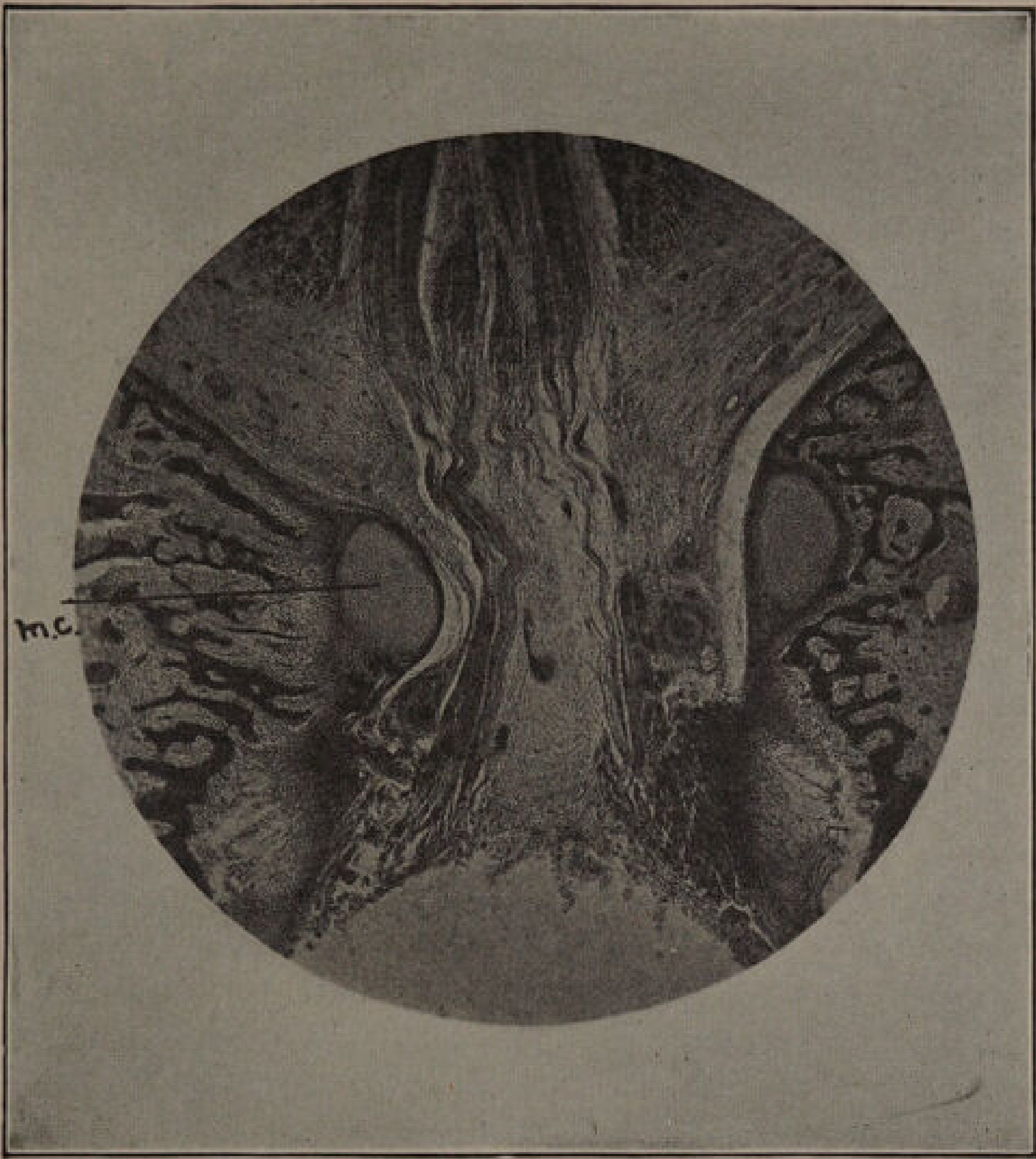


FIG. 285.—Section through base of mandible, showing Meckel's cartilage.

section of the jaw is made for the purpose of studying its location and environments (see Fig. 285), it is found near the base of the fetal head, considerably below and to the outside of the base of the tongue. At mid-jaw it appears as a circular body of cells separated from the surrounding parts by a distinct layer of elongated cells. Even at this early period a portion of the bony structure of the jaw is outlined by an aggregation of connective-tissue cells, and the forming cartilage appears to subserve the purpose of controlling the outline of the future jaw.

The bow-shape of the cartilage is manifest as we pass toward the symphysis by the lateral halves approaching each other (Fig. 286), but the circular character of the cartilage in cross-section is still retained.

Figure 287 represents a section through the symphysis about the eighteenth week, and shows the two halves of the cartilage closely associated, but not united, the separation being by a layer of connective-tissue cells passing between the two. It will be noted also that the

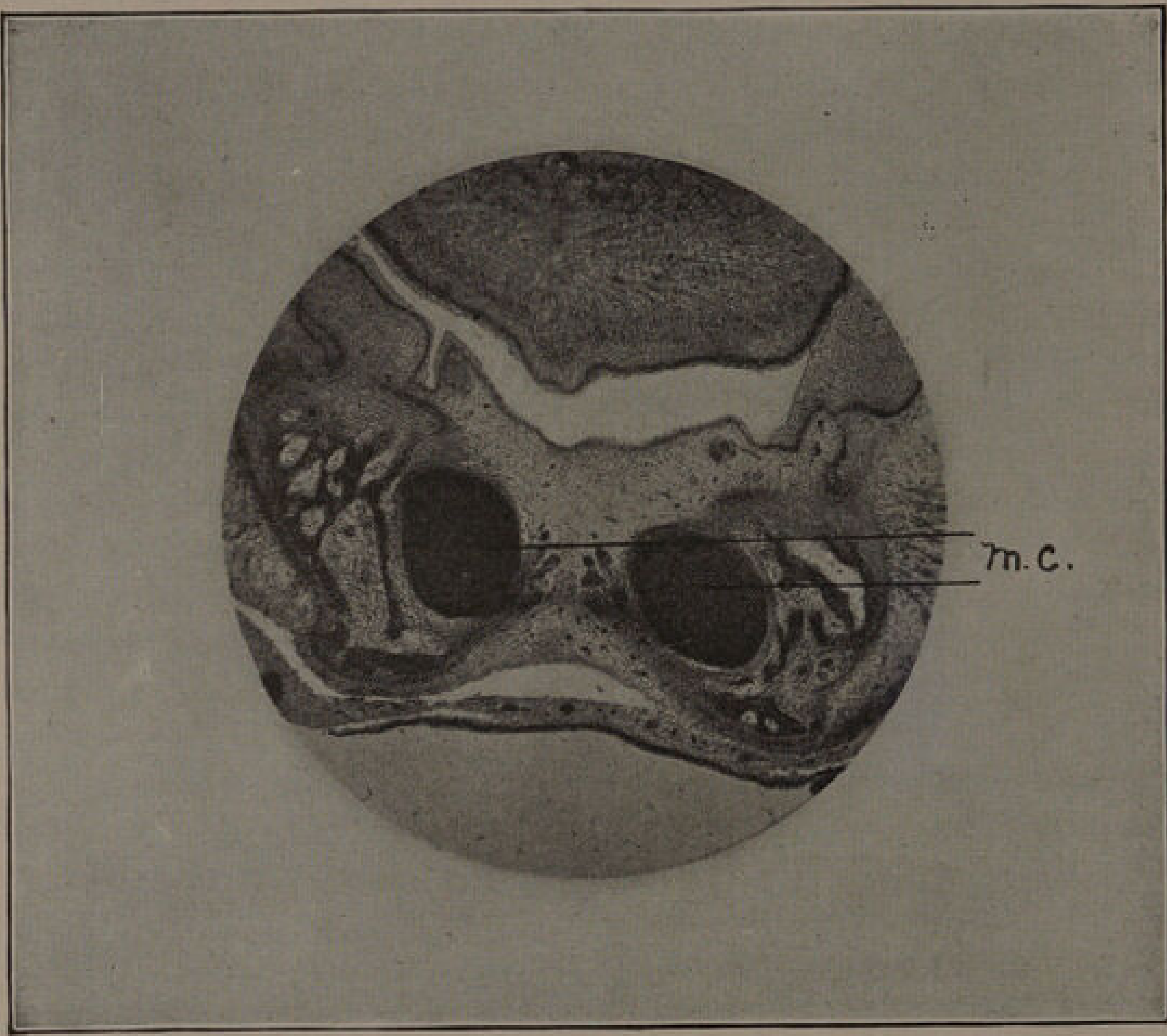


Fig. 286.—Section through lower jaw. *M. C.*, Meckel's cartilage.

cartilage, instead of being near the base of the jaw as in figure 292, here appears near the floor of the mouth.

Figure 288 shows the relations existing between the two halves of Meckel's cartilage and the growing mandible at the median line (*a*). It also illustrates how little the development of the bone is dependent upon the cartilage, the growth of the former being in this district far below and apparently distinct from the latter. Here, as in the upper jaw, the periosteal cells from either side are observed to unite at the

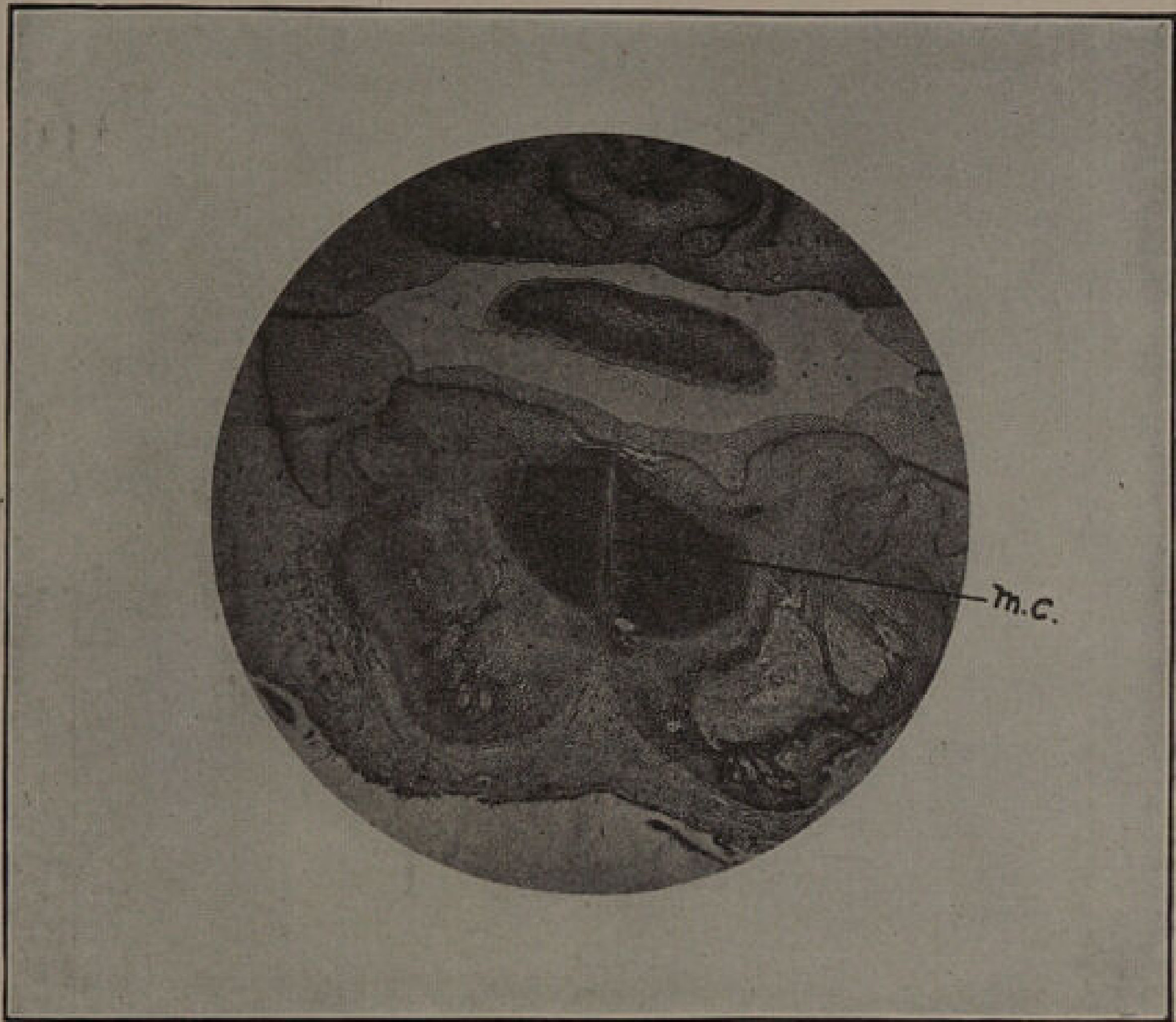


FIG. 287.—Meckel's cartilage (*M. C.*) at the symphysis.

symphysis and pass as a somewhat thickened layer between the two bones, the only difference in the final change which takes place between the two being that in the maxillæ a suture results, while in the mandible a layer of solid bone is formed. The character of this cartilaginous framework as well as the cells which divide the two halves is shown in

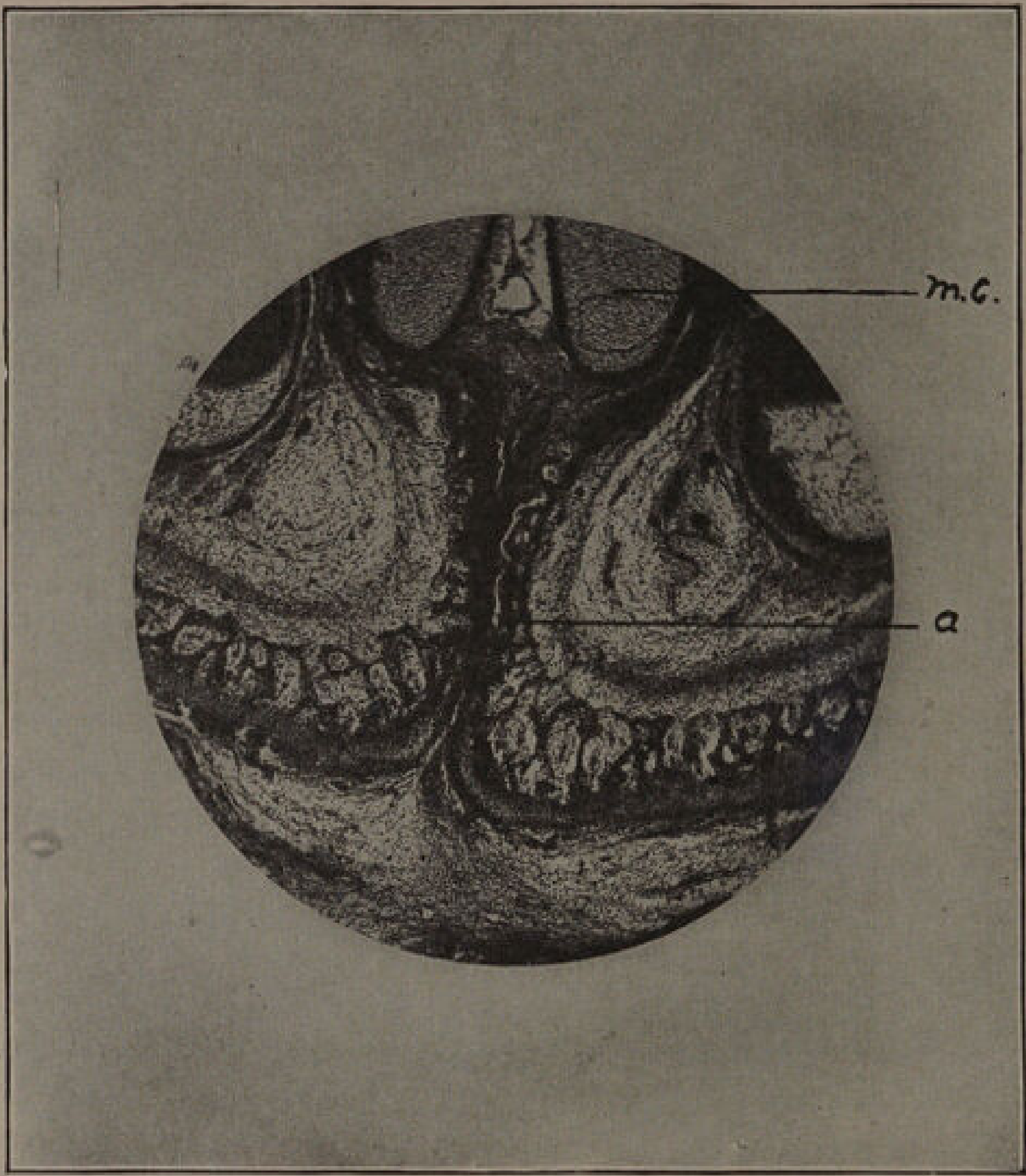


FIG. 288.—Ossification of the mandible at the median line.

figure 288, the cartilage cells being oblong or cylindrical, with a bountiful supply of intercellular substance, while the connective-tissue cells are oblong or spindle-shaped.

As soon as ossification takes place to any extent on the mandible, the cartilage begins to atrophy, that portion lying next to the jaw degenerating first, so that by the tenth or twelfth week it has entirely disappeared, but before this takes place we find it surrounded by the periosteum, and finally completely inclosed within the bone.

Figures 289 and 290 show the character of the cartilage cells about the time that they are beginning to atrophy. It will be observed that

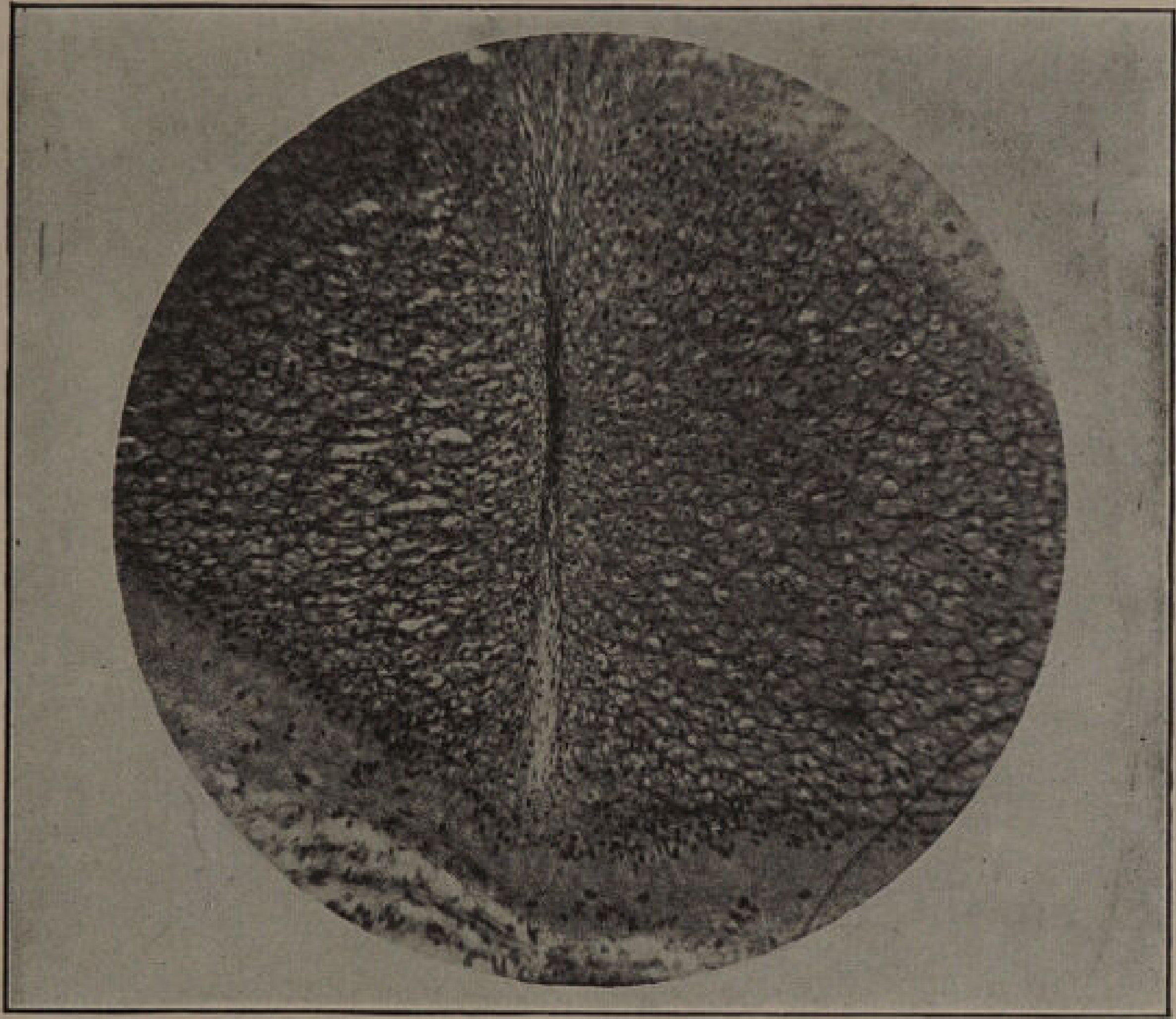


Fig. 289.—Section of Meckel's cartilage at median line.

the cells are inclined to a change in form, and that they are proportionately larger with larger nuclei, A represents the part nearest the jaw, and the cells in this region have already lost their characteristic outline.

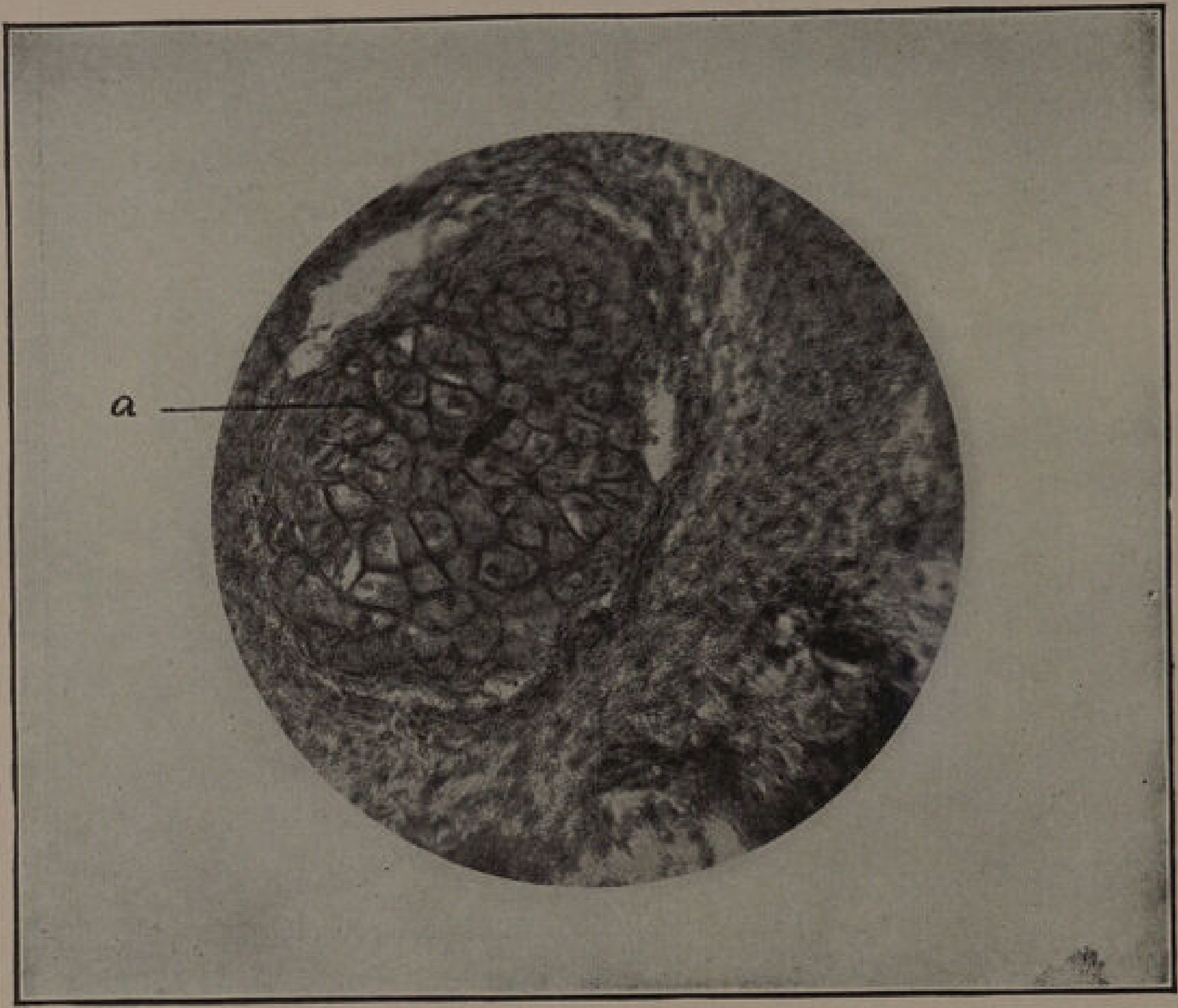


FIG. 290.—Cartilage cells in the beginning of atrophy.

CHAPTER VIII

Development of the Teeth—The Dental Germs, Enamel Organ, and Dentin Organ; the Dental Follicle; Calcification and Eruption

DEVELOPMENT OF THE TEETH

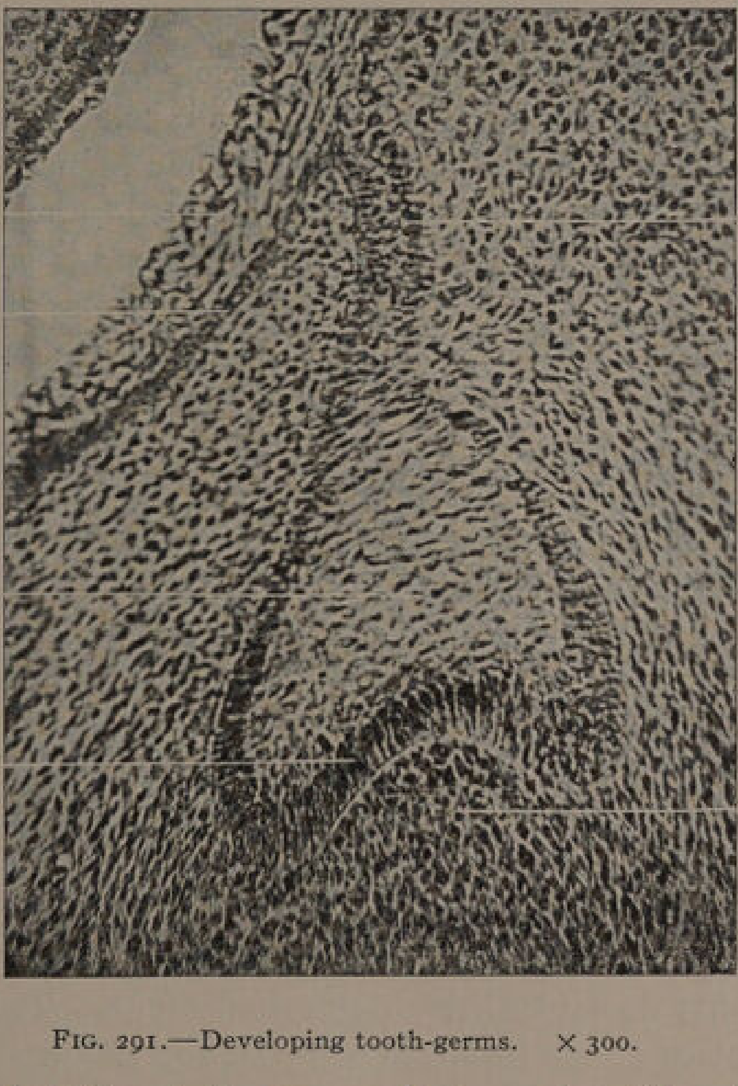


Fig. 291.—Developing tooth-germs. × 300.

In order that the student may obtain a clear idea of the cellular changes which take place at a very early period, and which eventually result in the formation of the teeth, the genesis of the subject will be first considered. Preparation for the development of the teeth takes place as early as the middle of the second fetal month, prior to the formation of the bony structures which finally surround and give support to the organs. At this early period there will be found following the line of the future alveolar ridge a slight heaping up of the surface epithelium (*epithelial ridge*), while immediately beneath this proliferation of cells there appears a dipping in of the deep or infant epithelial layer (early called the *dental groove*), in the direction of the future alveolar walls. This epithelial reflection is later known as the epithelial band or *tooth-band*. This so-called tooth-band is not, as might be supposed, a special inflection for each tooth-germ, but is continuous from one distal end of the future jaw to the other. It must be remembered that at this time the outline of the jaws has not been established, and the tooth-band, is principally instrumental in directing the location of the forming dental organs. The position and form of this epithelial band may best be studied in vertical transverse section. When first making its appearance it is somewhat broad and shallow (dental groove) but as it passes more deeply into the embryonic tissue it partakes of the shape of the letter **V** with its open end directed toward the surface. As it grows in length the free extremity of the band is inclined to the lingual, its external surface is slightly convex, and its internal surface correspondingly concave. After the tooth-band has assumed certain proportions, there appears on its inner or lingual surface a thin membranous plate, *tooth lamina* which is likewise a continuous structure, extending the full length of the epithelial band.

This lamina does not spring from the free margin of the tooth-band, but is given off at a point about midway between this border and the base of the band. The character of this secondary band is so similar to that of the primary one that it should be considered as an inflexion from it rather than a new structure. We find then between the seventh and eighth week, the maxillary regions giving place to two bow-shaped bands (one for each jaw), each of which is preparing to throw out from its secondary lamina ten little buds, *tooth buds* which soon develop into the germs for the twenty deciduous teeth. When these buds make their appearance they are simple, rounded bodies, placed somewhat closely together, but they do not long retain this simple form. The first change which takes place is one in which they appear to lengthen out into slender cords, the extremities of which soon begin to extend laterally, and a pear-shaped enlargement of the epithelial cells appears, which by invagination later assumes a bell-shaped outline, which phenomenon is rapidly increased by a proliferation of connective-tissue cells forcing into the concavity.

This bell-shaped proliferation of cells, given off directly from the tooth-lamina, to which it continues for a time attached, together with the specialized connective-tissue cells crowding into its concavity, constitute the tooth-germs, the former being the *enamel organ,* and the latter the *dentin organ.* It will, therefore, be seen that the enamel is dependent upon the oral epithelium for its development (ecdermic), while the dentin springs from an entirely different source—the connective tissue of the jaw (endermic). The enamel organ rapidly under-

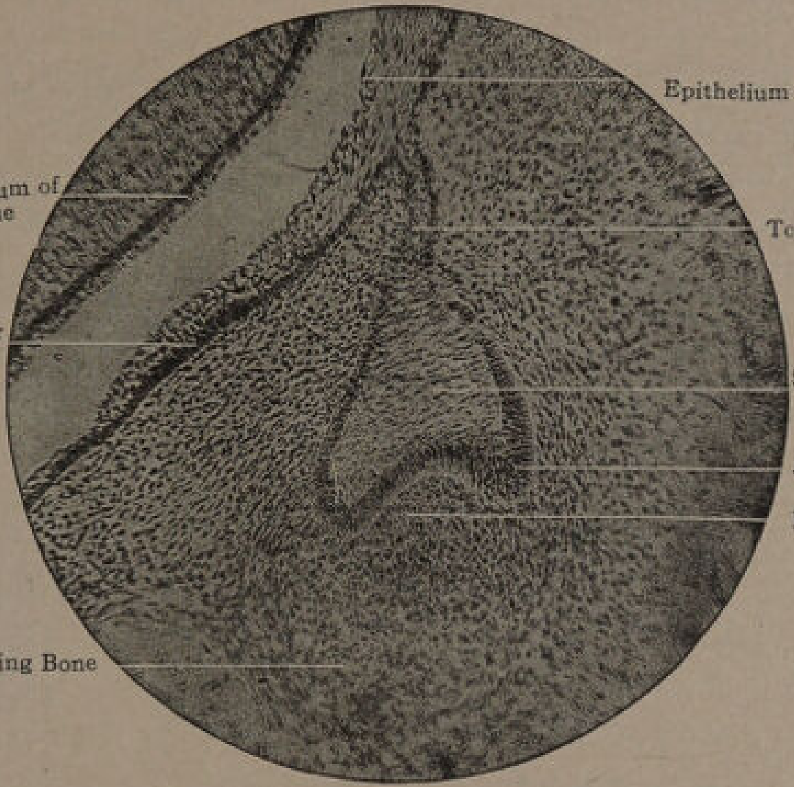


FIG. 292.—Developing tooth-germs, twelfth week. × 40.

goes a cellular transformation: its concavity is increased, and the bell-shaped outline more strongly defined. Accompanying this change in form it gradually recedes from the surface, and its connection with the tooth-band becomes less secure. The connective-tissue cells, which have been rapidly filling in the concavity of the enamel organ, are also preparing to take upon themselves a special function, that of the formation of the dentin. Up to this period (tenth week) the enamel and dentin germs are not definitely separated from the surrounding cellular structure, but now a gradual transformation takes place, whereby the tooth-germs become enveloped in a sac-like covering—*tooth-sac,* this together with its contents the tooth germs forming the *tooth-follicle.*

Enamel Organ (Figs. 291, 292, 293 and 294).—This portion of the tooth germ, as previously stated, is derived from the concave or lingual surface of the tooth-band, the tooth lamina. From the free extremity of its slendor cord-like attachment it spreads out and forms a hood-like covering to the dentin germ. The surface of the enamel organ contiguous to the dentin germ, or dentin papilla, as it is frequently called, is concave in the direction of the oral surface, being thickest over the center of its concavity, thinning down as its periphery is approached. Externally, the enamel organ is covered by an epithelial layer, which is reflected upon its inner surface or that in contact with the dentin papilla. These two layers are named according to their location, the *external* and *internal epithelium* of the enamel organ. Placed between these two layers, and constituting the bulk of the organ, are numerous stellate bodies which penetrate a layer of rounded cells, the *stratum intermedium.* It is from this internal layer of epithelial cells that the enamel is calcified, and they are, therefore, the essential cells of the enamel organ. In the fully developed enamel organ, there are to be found, therefore, four distinct layers of cells, the *external epithelium, stellate reticulum, stratum intermedium,* and *internal epithelium,* the latter after a time becoming the *ameloblasts* or enamel forming cells. As its name implies, the function of the enamel organ is principally that of enamel calcification, but in the opinion of many writers its primary activity is that of molding the tooth-form as represented by the dentin papilla, and it is not until this latter organ has assumed the form and extent of the dentin of the future tooth-crown that calcification begins.

The life of the enamel organ may properly be considered as beginning when the bulbous extremity of the specialized cells given off from the lingual face of the tooth-band become invaginated, and from this by a rapid proliferation of its cells it assumes by successive stages on its internal or concave surface the outline of the crown of the future tooth. This proliferation and differentiation of cells continues up to the time of beginning of calcification, but with the advent of this phenomenon certain parts of the organ begin to degenerate. This degeneration may or may not be classed as an atrophy of the cells interested, but the fact that a new tissue is generating, and gradually occupying the space previously taken up by the formative cells, calls forth a demand for the removal of the latter by the former. The cells which first undergo this change are those of the internal epithelium and stratum intermedium, the individuality of these two layers evidently being kept up by migratory cells from the stellate reticulum. It is argued by some writers that the external epithelium begins to atrophy at this period; by others this change is not recorded until the enamel cuticle has been deposited to effectually seal the young tissue and protect it until well desiccated. While there appears to be a decided disposition upon the part of this outer layer of cells to change, they do not disappear, and the alteration is not one which affects the shape of the cells, for they remain flattened or prismatic with their long axis parallel with the anlage of the crown and most likely become the enamel cuticle. The stellate cells making up the bulk of the organ are, in common with those which

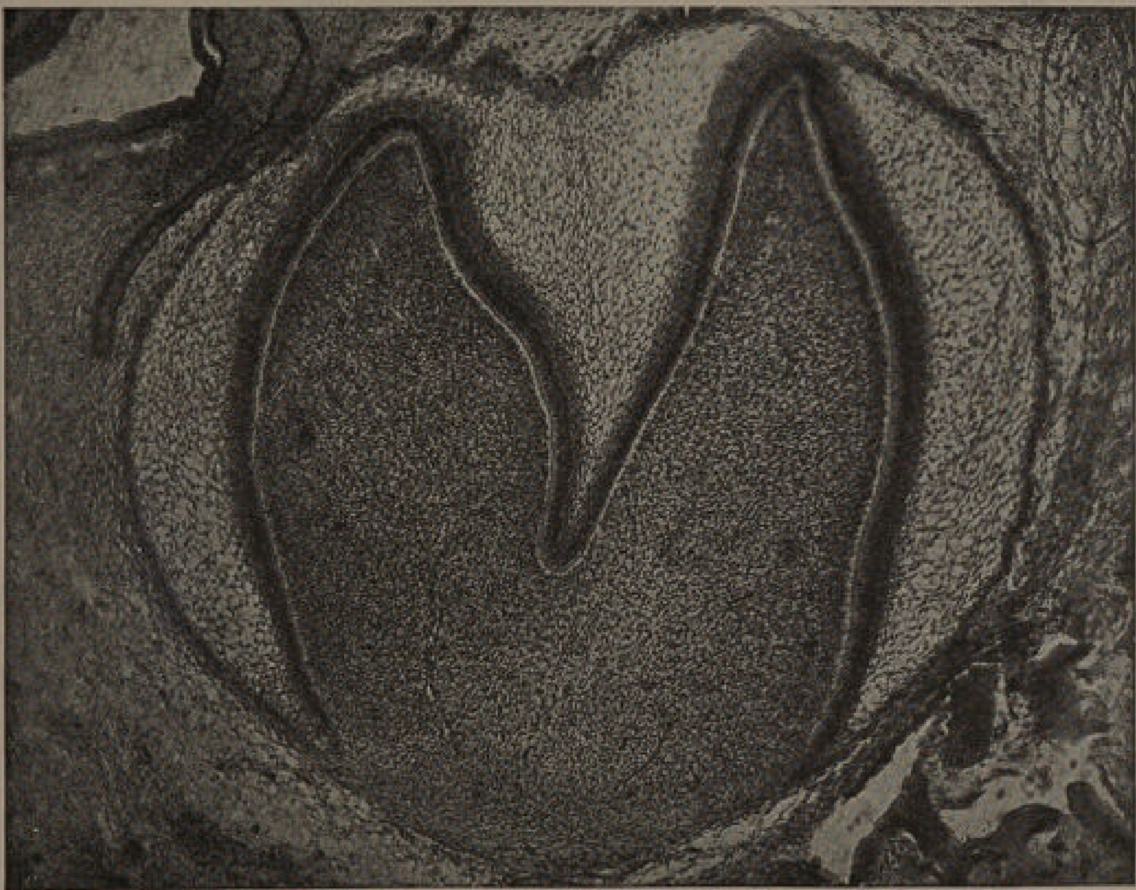


FIG. 293.—Developing tooth-germs, enamel organ, and dentin papilla.

inclose them, continually undergoing a degenerative change, at least this is true of those cells closely associated with the stratum intermedium, for in this location they rapidly proliferate, shed their many processes, and gradually take on the characteristics common to this layer of which they eventually become a part. A careful examination of no less than one hundred enamel organs in all stages of development, and by section cut transversely, obliquely, and longitudinally, fully justifies the statement that the real life of the enamel organ begins as previously stated, and continues until the structural arrangement of the enamel is completed.

The question of form in the enamel organ—that is, its external epithelium—is one which may be advantageously used in the consideration of the life and function of its different cell layers. It has been said that the apparently extravagant area taken up by the enamel organ subserves the purpose of reserving space for the growing tooth-crown, but there are many reasons why this theory cannot be accepted. In

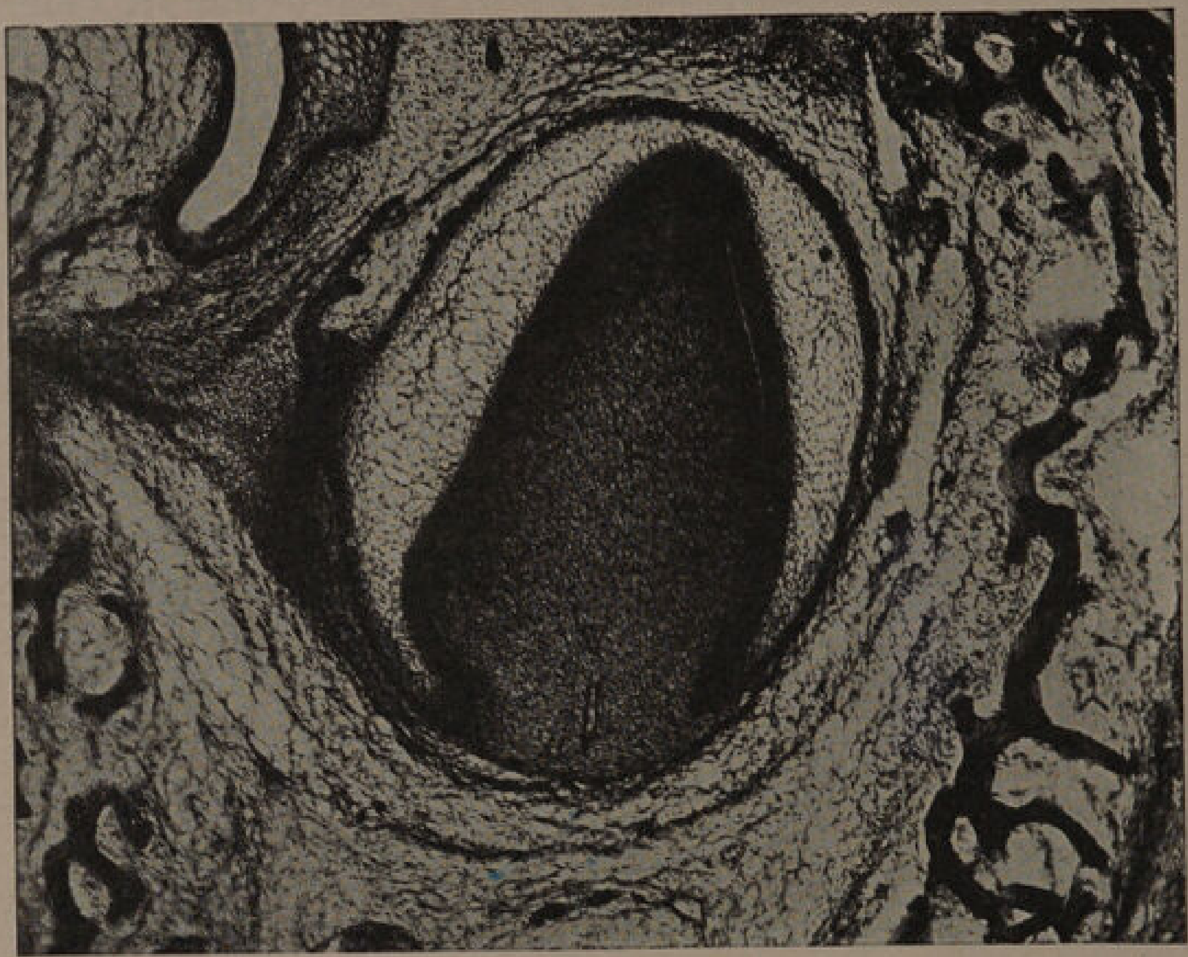


Fig. 294.—Developing tooth-germs. Longitudinal sections from buccal to lingual.

the first place, the extent of the organ or the space existing between the dentin papilla and the outer enamel epithelium does not in very many instances correspond to the bulb of enamel when this tissue is completed at a given point. In the developed tooth we find the enamel thickest over the incisal-edges of the anterior teeth and about the summits of the cusps of the cuspidate teeth, while these same parts are represented during the cellular stage of development by the external layer of cells closely associated with the surface of the papilla.

Again, the outline of the tooth is definitely represented by the cells making up the dentin papilla (Figs. 293 and 294), but the surrounding epithelial cells are characterized by an unbroken semicircular margin describing the extent and form of the enamel organ. Exception may be taken to this hypothesis from the standpoint of generative changes and these in a great measure have much to do with the relative outlines assumed by the two organs, but by studying very many sections representing nearly every stage of the process, and all of them in a measure

FIG. 295.—Developing tooth-germs. Longitudinal section from mesial to distal.

showing the same characteristics, nothing but a definite opinion can result.

Of the many changes in general form which the enamel organ undergoes, none are so pronounced and positive in character as those described by the inner tunic, and first recorded when the bulbous end of the enamel organ becomes invaginated by the mesodermic connective-tissue cells forcing themselves into it. This is an alteration which is gradual and continuous up to the time of beginning of calcification, and while the cells forming the dentin papilla are generally accorded the power of "pushing" or "forcing" their way into those derived from the epiblast, the latter has always been recognized as having a controlling influence over the former. In this connection a reasonable doubt presents itself covering the theory so long accepted that the early function of the enamel organ is one which in a measure superintends the contouring of the tooth-crown as first represented in the dentin papilla. When the character of the two embryonal tissues making up the two germs is

Fig. 296.—Developing tooth-germs in transverse section.
A, Stellate reticulum. B, Papilla. C, Cartilage cells.

compared, we find the dentin germ possessing all the characteristics favorable to a rapid proliferation of its cells resulting in a highly vascular, compact tissue. On the other hand, the bulk of the enamel organ is a gelatinous-like mass, one that would readily succumb to the pressure exerted by the active connective-tissue cells within its borders. When thus considered, the evidence is almost sufficiently convincing to reverse the generally accepted theory, placing the general form of the enamel organ as subservient to the dentin papilla.

Figures 293, 294 and 295 illustrate some of the variations common to the general form of the enamel organ, and afford a good idea of the relationship existing between the enamel organ and the dentin papilla, in teeth both of the simple and complex class. These were taken from sections which represent a period just prior to the generation of the ameloblasts and odontoblasts, at which time the external and internal epithelial layers of the enamel organ most closely resemble one another in general outline. It is from this aspect and from sections cut longi-

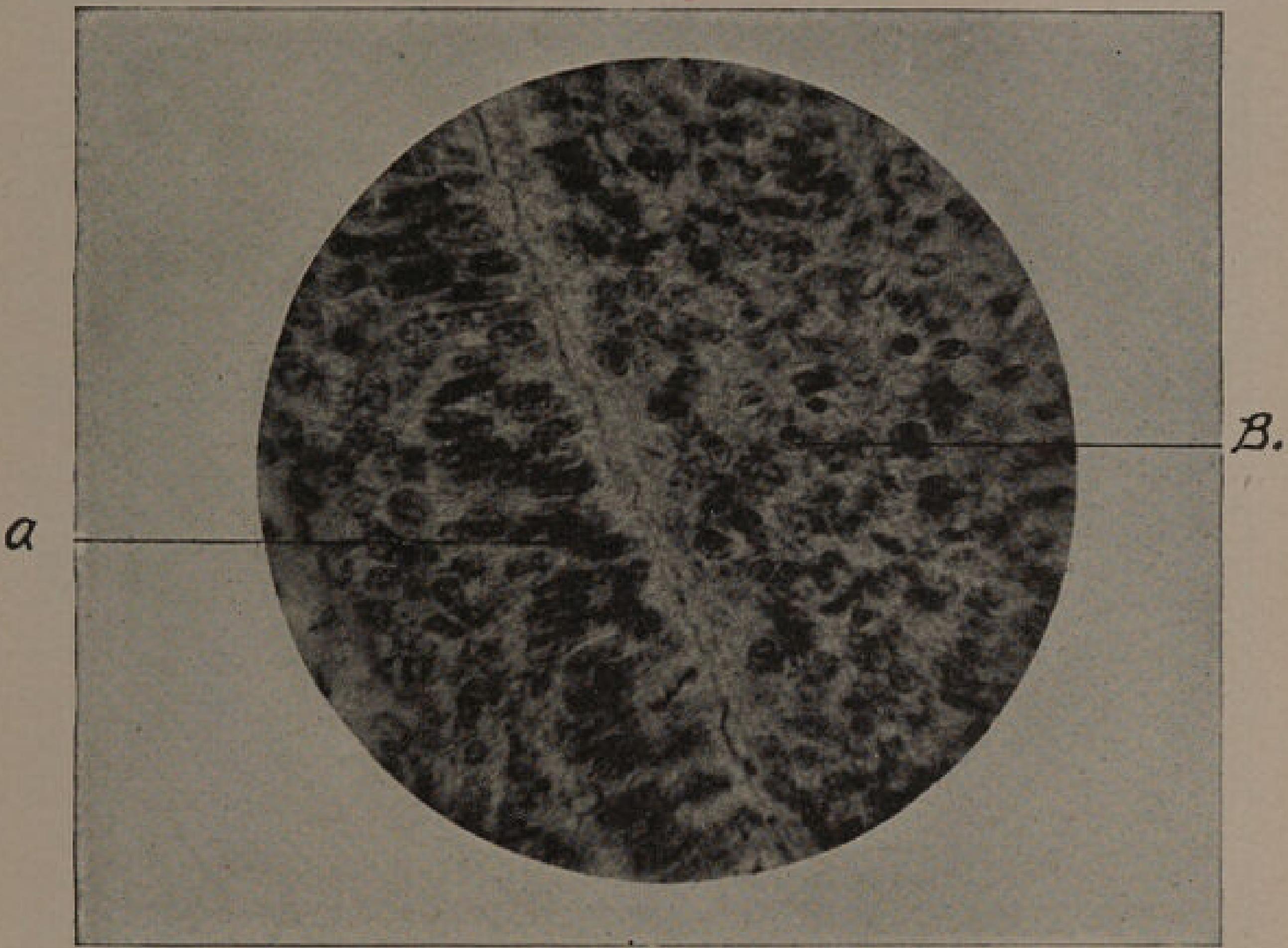


FIG. 297.
A, Inner tunic of enamel organ.
B, Cells of dentin papilla.

tudinally that most of the information given by the older writers has been derived. Few attempts have been made to show this organ in sections transverse to the long axis of the tooth. In figure 295 the germs of two teeth are shown by a section made in this direction. One striking feature here illustrated is the relationship existing between the inner and the outer tunic of the enamel organ, and attention is called to the apparent coalescence of these two layers at those points which represent the mesial and distal surfaces of the developing crowns. This condition is apparently brought about by the cartilage cells forcing the peripheral cells of the enamel organ into direct contact with the inner tunic completely obliterating the stellate reticulum in these localities. As a result of this lateral pressure the outer epithelial cells representing the labial and lingual surfaces have become widely separated, but with no perceptible alteration in the character of the cells composing the stellate reticulum. The relationship existing between the tooth-germs and the surrounding parts is one that will continue throughout the generation of the organs, and makes questionable the

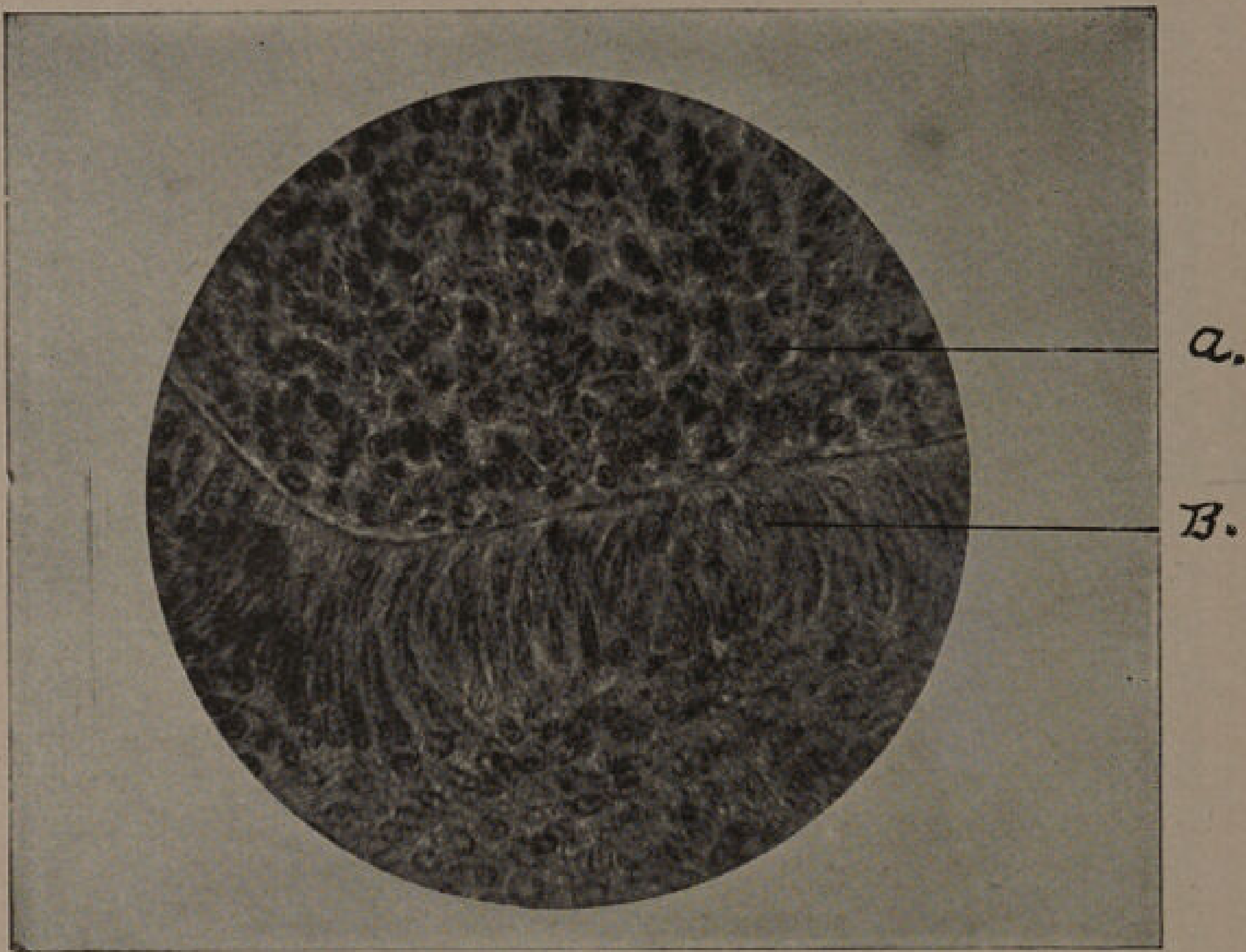


FIG. 298.
A, Cells of dentin papilla. B, Elongated cells of inner tunic.

theory that the stellate reticulum performs the function of reinforcing or providing the ameloblasts with nutrient or calcific material. If these same germs were examined, as they usually are, in longitudinal section (see Figs. 293, 294 and 295), the investigator would at once arrive at the conclusion that there was an equal distribution of the stellate cells about all sides of the dentin papilla. In their very early life they apparently establish an equal bulk about all sides of the dentin germ, but with the preparation for the growth of the alveolar walls they may assume the proportions shown in figure 302. At a period corresponding to the complete envelopment of the dental germs by the dental sacculus the development of the buccal and lingual walls is well under way, but as yet no provision has been made for the septa between the teeth, and it is undoubtedly to this latter phenomenon that a definite lateral pressure is brought to bear upon the tooth germs.

Now let us pass to a consideration of some of the characteristics of the various cell layers composing the enamel organ. These are designated according to their location, so far as three of the four layers are concerned; in fact, the remaining cells, or those which receive their name from their form, the stellate reticulum can scarcely be classified as a distinct layer, these cells not being of uniform thickness in all parts of the organ. The first layer of cells, or those making up the inner tunic, will be traced from their primary spherical condition to their final generation into ameloblasts. Figure 302 shows the character of these cells at a very early period, corresponding to the sixteenth week in the human embryo. They are for the most part spherical or slightly oblong multinucleated cells, and are more or less closely associated. They partake very much of the nature of the connective-tissue cells surrounding them, being differentiated from these principally by a transparent zone not unlike the specialized matrix immediately surrounding cartilage cells. About the first change recorded in these cells (see Fig. 298) is one in which they become markedly elongated or cylindrical, but during this process of differentiation some of the cells apparently recede, while others advance in the direction of the papilla, lining up in a single layer to become the early enamel cells, the cells which have been thus forced to the rear subsequently developing into ameloblasts as the older cells disappear. At this period the stratum intermedium also asserts itself in the form of a distinct layer of rounded cells, to be described later on. When first observed, these cylindrical cells are devoid of processes, but are provided with rounded extremities, with little or no variation between the end directed toward the papilla and that looking in the opposite direction. This form is one which persists in all of the cells included in this layer until a definite body of cells is formed contiguous to the dentin papilla, these latter cells becoming more markedly elongated and further differentiated by the addition of processes, while the remaining cells, or those nearest the stratum intermedium, continue for a time unchanged. The next alteration in the character of the inner tunic is one well illustrated in figure 297, in which the body of the generating ameloblastic cells rapidly recede from the surface of the papilla, while the elongating processes reach out to this latter point, all of this occurring before the appearance of the odontoblasts. Soon after this latter change in the cells of this layer the odontoblasts are developed and form the periphery of the dentin germs. All of these changes are of course first recorded about the free extremity of the tooth-crown, becoming less noticeable as the union of the outer and inner tunics is approached.

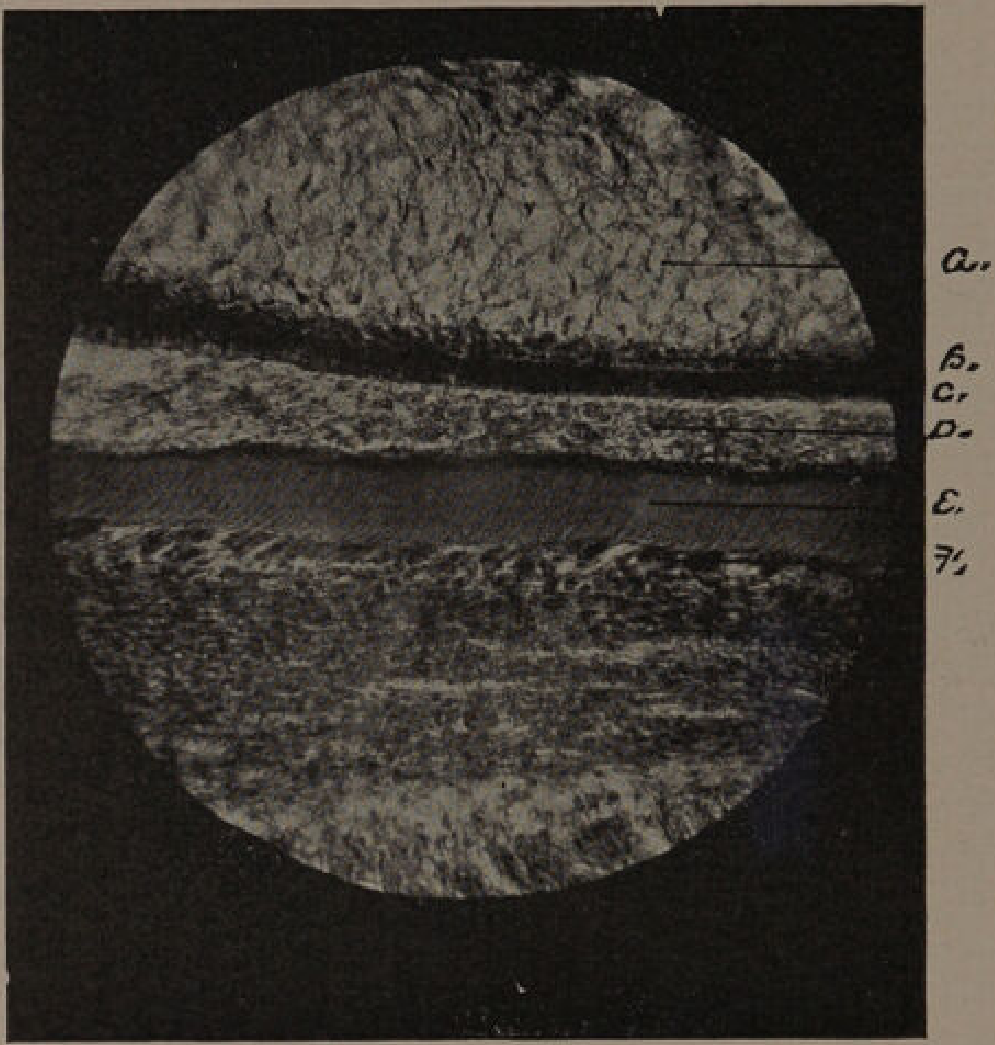


FIG. 299.
A, Stellate reticulum. B, stratum intermedium. C, Ameloblasts. D, Forming enamel. E, Calcified dentin. F, Odontoblasts.

A study into the special characteristics of the fully developed ameloblasts shows that these active cells are the result of a gradual change in the character of the columnar epithelia common to both the external and internal epithelial layers in the primitive enamel organ.

Next in importance to the internal epithelial layer are those closely associated cells making up the stratum intermedium (Fig. 300). Primarily oval or spheroidal in form, we find these cells gradually assuming a columnar outline and occupying a position parallel to the long axis of the crown. It may be said that the general character of these cells is intermediate between those destined to become the proper enamel cells and those stellate cells making up the bulk of the organ. There appears to be much confusion, at least considerable doubt in regard to the office or the cells of the stratum intermedium. It is most likely that these cells are not only intermediate in character, but are also intermediate in function to those cells upon either side of them, recruiting

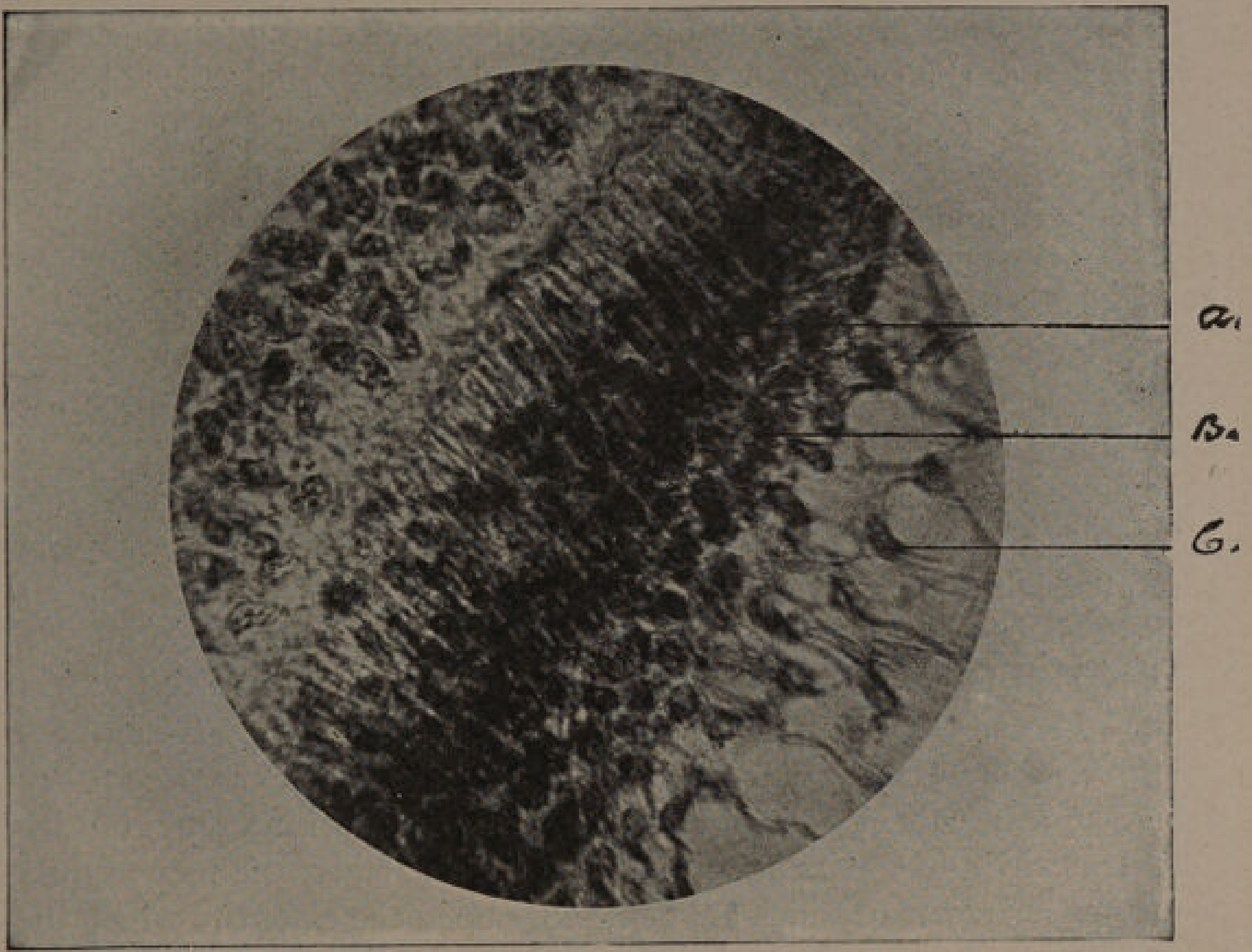


FIG. 300.
A, Generating ameloblasts. B, Rounded cells of stratum intermedium. C, Stellate reticulum.

the ameloblasts as they fall, while in turn they themselves are supplied with nutriment from the enamel pulp or stellate reticulum. No stronger proof that these cells are secondary in importance to the ameloblasts need be mentioned than reference to the fact that they are always more generously supplied to those parts about to undergo calcification. Nor is their increase in numbers the only reason for believing that they are thus employed, for at the same time those cells most closely associated with the developing ameloblasts take upon themselves a decided change in outline. This alteration may be brought about by the conditions which influence the shapes of all cells, *i.e.*, by the pressure of surrounding cells or by their preparation for functional activity, or both. Some of the earlier writers speak of the cells of this layer as being branched, and in this way closely resembling those of the stellate reticulum. By strong amplification it is somewhat difficult to distinguish between the two layers, but most certainly if there are branched cells present they are confined to the intermediate zone, and should properly be classed with those of the stellate reticulum.

The cells of this layer do not remain long columnar with a general direction at right angles to the forming ameloblasts, but they become spheroidal and extremely closely associated in the deeper portion of the layer; in fact, cells corresponding to these in general appearance may be found in connection with the fully developed ameloblasts, being observed to best advantage by the aid of a high power objective and a full flood of light from a powerful sub-stage condenser. The cells thus found appear to be distributed at regular intervals about the ameloblastic layer, and are so closely allied to the cells of the stratum intermedium that they may be considered as migratory cells from this layer. In the earlier stages there appears to be no definite line of demarcation between the cells of the inner tunic, and those composing the stratum intermedium, but soon after the establishment of the ameloblasts the two layers are strongly differentiated by the interposition of a highly transparent membrane covering the outer extremities of the ameloblasts. After they are thus definitely separated from the enamel-forming cells, a most radical change takes place in their character, they become markedly elongated, and by anastomosing form a series of continuous chain-like belts about the ameloblastic layer, the number and further character of which are dependent upon the extent to which the ameloblasts have performed their function. If at any time there is a similarity between the cells of the stratum intermedium and the stellate reticulum it is at this period, because the former cells begin to lose their individuality, although under low power they still appear as a distinct layer (Fig. 298).

There is probably no body of cells directly interested in the development of the tooth tissues so widely discussed as those making up the so-called stellate reticulum, and while the chief basis for argument has been with reference to their function, the general character and form of the cells have received but little consideration. Ever since the first description of this portion of the enamel organ, the cells therein have been characterized as "star-shaped," and while this stellate form is the most common, it is by no means a universal condition. The form of the cells in common with the other cells composing the organ appears to be much influenced by the position which they occupy, and by the age of the organ, those cells in the region of the inner tunic partaking of the globular form characteristic of this layer (see C, Fig. 305), while those closely associated with the outer tunic are inclined to be columnar or somewhat elongated. While the cells in these respective locations are more or less influenced by their environments, they still retain to a certain extent the stellate feature by their many processes. But it is in the center of this myoxomatous epithelial product that the most perfect stellate cells are located. We find, therefore, where this part of the organ is of the greatest width, that the true stellate cells are the most numerous, while at the summit of the crown and at the base of the organ, at both of which points the outer and inner epithelial layers are closely associated, the star-shaped cells are little in evidence. In the study of this layer very much depends upon the thinness of the section, only the thinnest possible sections affording an opportunity for a correct conception. This is, of course, true of all parts of the organ, but the peculiar character of the stellate reticulum makes it especially necessary that great care be bestowed upon the preparation of the section. In transverse section the cells present no characteristic differences from those shown when the section is made longitudinally. One very pronounced feature about the cells of the stellate reticulum is the granular appearance of their protoplasm, resembling very closely the flattened squamous cells from the epithelium of the mouth, and it is no doubt this special feature which furnishes the ground for the opinion of many writers that it is a peculiarly modified epithelium. One peculiarity in connection with this tissue which is contrary to the generally accepted character of epithelial cells is the abundance of intercellular substance; but when the many minute spines or processes are considered as a part of the individual cells, the proportionate quantity of cellular and intercellular substance is somewhat decreased. The connecting processes are quite similar to those described by Stohr as connecting bridges of protoplasm, while the cells themselves may be otherwise described as prickle-cells. The change in the form of the cells of this layer is not due to the presence of neighboring cells, as in the case with most epithelial cells, but, being soft and extremely plastic, it is more than likely that their form is strongly influenced by the tension of their connecting filaments. One of the most marked alterations in the general character of this part of the enamel organ is that which takes place at a time corresponding to the beginning of amelification, and is no doubt attributable to this phenomena. The cells which up to this period have remained widely separated now become more closely associated, not so much by a change of position as by what appears to be an increase in the size of the cell body with a corresponding decrease in the length of the anastomosing processes.

It is a fact admitted by most histologists that the peculiar star-like nature of the cells of the stellate reticulum is one principally brought about by postmortem changes, and that in reality they are polygonal cells filling up a greater part of the tissue with but little intercellular substance. That some shrinkage and distortion does take place may be proved by the examination of a section which has accidentally or otherwise become for a moment dry during its preparation, in which case little can be seen but the connecting processes, and even these are much shrunken. All the cells contained within the organ are more or less affected by this procedure, but none of them exhibit such a marked change in the outline as those of the stellate reticulum.

The layer of cells which is usually considered of least importance is that which makes up the outer tunic. In the young enamel organ the cells partake very much of the nature of these forming the inner tunic, but the older the organ becomes, the more dissimilar are the two layers. Primarily this layer is constructed of a single row of elongated cells with remarkable regularity, upon the inner side of which are a number of similarly formed cells variously disposed, but with a common direction at right angles to those previously referred to. Like the internal epithelial layer, the cells of the outer tunic partake more or less of the nature of the stellate cells in passing from the single row of well-defined cells toward the stellate reticulum. While in the beginning the external epithelial layer is strongly differentiated from the surrounding cells, this is of but short duration. The atrophy of this layer begins with the appearance of the fully developed ameloblasts, by which the regular arrangement of the cells is greatly disturbed by an apparent breaking up of the entire layer. Many reputable writers claim that the external epithelial layer is of little or no interest, save, as Tomes puts it, "as a matter of controversy." This admission upon the part of so eminent an authority practically opens up a new field for research, especially so when we consider that various other writers (Waldeyer, Kolliger, and Magitot) have expressed conflicting opinions in regard to it. After carefully following the changes which occur in this layer from its earliest inception up to an advanced stage of calcification, it would appear that while marked changes occur in the character of the individual cells as well as in the general appearance of the layer, it is nevertheless persistive, and in some way is essential to the process of amelification even to a more marked degree than are the cells of the stellate reticulum. One important reason for this belief is based upon the fact that in the cuspidate teeth there appears at a time corresponding to the beginning of amelification, a decided disposition in the cells of this layer to dip down and completely divide the stellate reticulum between the forming cusps. That this alteration is one instrumental or essential to the calcifying process receives additional proof by referring to figure 299, which shows the fully developed enamel organ with the

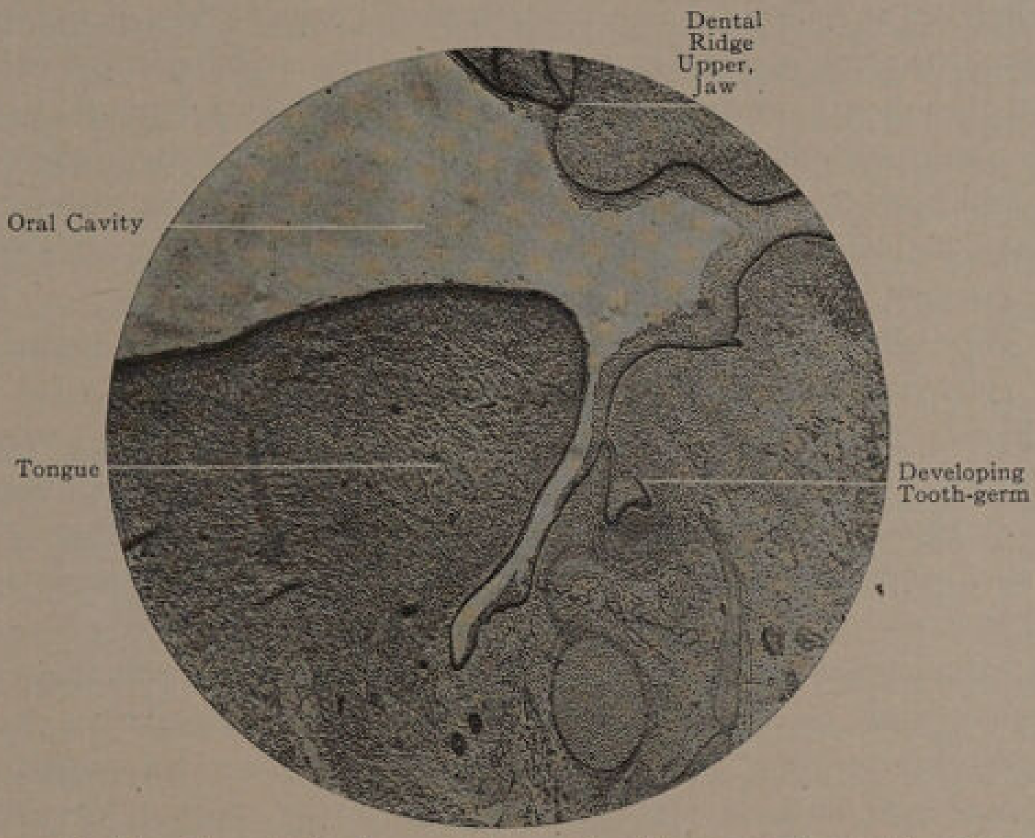


FIG. 301.—Section through the floor of the mouth of human embryo. Twelfth week. × 30.

exception of the actual appearance of the ameloblasts, and the lack of any attempt upon the part of the external epithelial to penetrate between the cusps. As previously stated it is the belief of the author that the external layer is directly intrusted in forming the enamel cuticle.

Dentin Organ (Fig. 292).—This part of the tooth-germ, formed from the mesoderm, occupies the concavity of the enamel organ, and at an early period begins to assume the form of the future tooth-crown. Thus, primarily, the papillæ for the incisors will have their incisal-edges outlined by three small lobes, each of which represents a separate point of calcification, while the papillæ for the molars will be molded according to the number of cusps of the future tooth, a small tubercle making its appearance for each cusp. In its inception the dentin papilla is composed of cellular elements identical with that of the surrounding parts. The growth of the papilla is in the direction of the surface; at the same time the enamel organ forces itself more deeply into the substance of the parts, not only overhanging the coronal extremity of the papilla, but extending about the inclosing its lateral walls. Accompanying the growth of the papilla is a rapid change in its structure, becoming more vascular throughout, and its peripheral cells, differentiating, form the essential dentin-forming cells—*the odontoblasts*. This layer of cells is in close relation to the enamel cells of the enamel organ, the combined activity of the two finally resulting in the calcification of the tooth-crown. The dentin papilla, which eventually becomes the tooth-pulp, decreases in size as calcification proceeds in the dentin, all additions to the calcifying surface taking place from within; while the enamel organ may be said to increase in size, the calcific action in the enamel progressing from within outward.

The Cells of the Dentin Papilla.—In the early life of the dentin germ, the cells are all simple embryonal connective-tissue cells. After differentiation takes place they are widely scattered and are of four varieties; spindle-shaped, round, stellate, and the elongated or club-shaped odontoblasts. None of these are constant in location except the layer of odontoblasts, which, as has been said, are arranged in a single row on the surface or the periphery of the organ, this zone being classed by the older writers as the *membrana eboris*. Like the ameloblasts of the enamel organ, the odontoblasts do not make their appearance until the papilla has assumed certain proportions, this about corresponding to the size and form of the dentin of the future tooth. Immediately beneath the layer of odontoblasts appears a zone almost devoid of cells. This is followed by a district in which the cells are quite numerous, and finally when the central portion of the papilla is reached the cells are again few in number and widely scattered. For the most part the cells in the interior of the papilla are spindle-shaped or stellate, having rounded nuclei about which there is a small amount of protoplasm which penetrates the intercellular substance by numerous hair-like processes.

The Odontoblasts.—These are club-shaped or flash-shaped cells, each provided with a large nucleus which usually assumes the outline of the enlarged end of the cell which is directed toward the interior of the papilla. From the opposite end of the cell, or that directed toward the enamel organ, and in close proximity to its concave surface, one or more protoplasmic processes are given off. These persist and are finally encapsuled within the calcified dentin, forming the dentinal fibers. These cells are very closely associated, so much so, in fact, that their enlarged extremities are almost or quite in actual contact, more or less space existing between the constricted portion of the cells as they pass toward the surface.

Germs for Permanent Molars.—Reference has been made to the fact that the enamel organs for the deciduous teeth are given off from the tooth-band at a point somewhat distant from its free margin, so that the tooth-band is continued beyond the primitive enamel germ, this free margin of the band afterward generating the enamel organ for the succedaneous tooth. As the twelve permanent molars are not succedaneous teeth, some other means must be provided for their development.

Opinions of various writers upon this subject are somewhat conflicting. The theory is advanced by some that as the jaw increases in length the tooth-band and lamina primarily provided for the deciduous teeth are extended backward, first giving off a bud for the first permanent molar; at a somewhat later period, and with the increase in the growth of the jaw, an additional bud is generated for the second molar, the third molar being provided for in a like manner. Another theory, and one generally accepted as correct, is that the cords for the permanent molars spring individually and directly from the subepithelium. There may be found an exception to this in the case of the first permanent molar, which sometimes appears to have its origin from the enamel organ of the second deciduous molar. Whatever theory be accepted in regard to the genesis of these permanent teeth, the process of development after the appearance of the primary bulb or enamel germ is identical with that of the deciduous teeth.

The Dental Follicle, or Tooth-sac.—During the early life of the tooth-germ, both the enamel organ and the dentin papilla are differentiated from the surrounding parts by dissimilarity of structure only, but as development proceeds, a more definite separation appears between the tooth-generating organs and the general tissues of the primitive jaw, this separating medium being the dental sacculus. The term "follicle" is only one of a number applied to these parts, "dental sacculus," "tooth-sac," and other appellations being employed with equal significance. By some writers it is customary to apply the term "follicle" up to the period of complete closure, the term "sac" or "sacculus" being employed after that time. There appears, however, to be little foundation for such a distinction, the terms being synonymous. The follicle is properly referred to as meaning the sac and its contents. As to the development of the tooth-follicle, it appears to be a generally accepted theory that at a very early period there is developed from the base of the papilla, cells which, differentiating, form the walls of the follicle. By this growth of cells the periphery of the papilla is first surrounded, and this step is soon followed by an extension of the cellular structure in the direction of the surface epithelium, to the deep layer of which the cells become firmly attached, and in so doing inclose the enamel organ, which hangs like a hood over the extremity of the

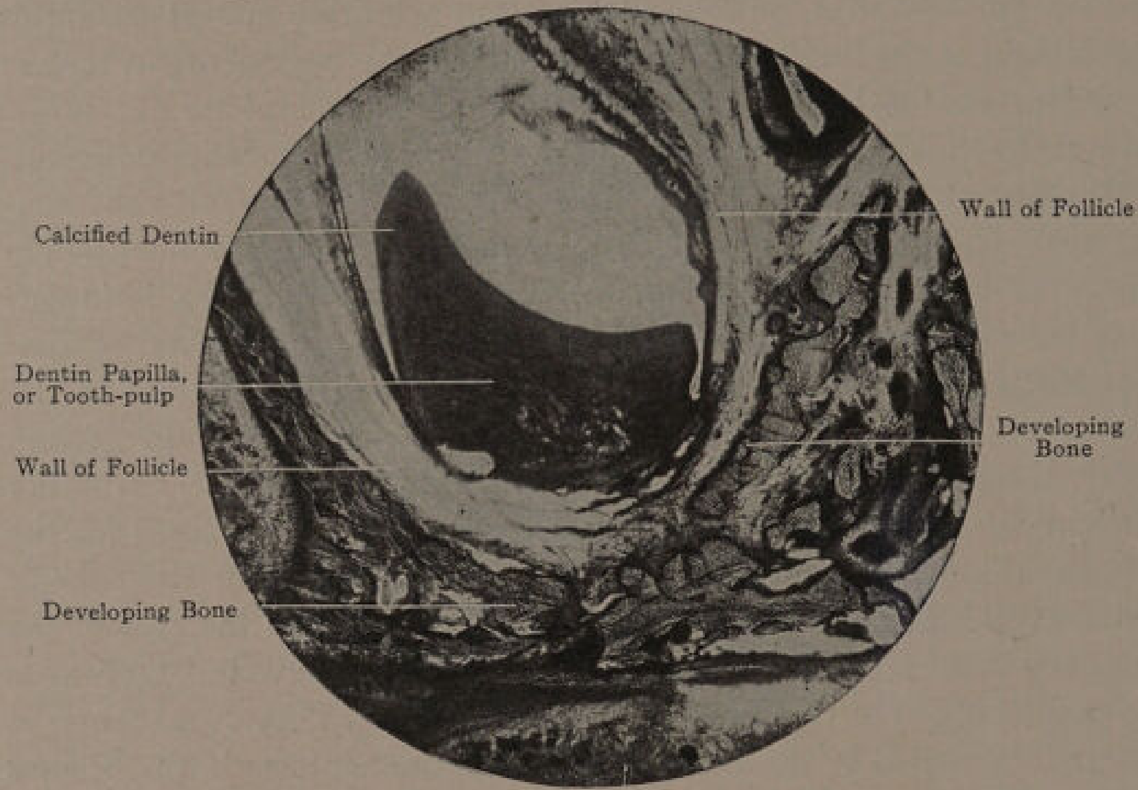


FIG. 302.—Developing tooth about the fourth fetal month. Appearance of the tooth-follicle.

papilla. The tissue thus formed from the base of the dentin germ is continuous with and similar in its origin to the pulp-substance. The primitive tooth-germ, during the formation of the follicular wall, is found swinging in a membranous pocket, being supported by the epithelial band, which, in turn, is attached to the oral epithelium; but as the walls increase and completely inclose the germs, which is accomplished about the fourth fetal month, the epithelial band is broken and the second or saccular stage of tooth-development is reached. The walls of the follicles are made up of two layers; the outer layer is dense and firm, and finally becomes the dental periosteum; the inner layer is thin, frail, and in the recent state somewhat transparent, and at an advanced period assists in the formation of the cementum, the two layers finally evolving into the alviolo-dental membrane.

SECONDARY OR SACCULAR STAGE OF TOOTH DEVELOPMENT

Having thus briefly described the primary or cellular stage of tooth-development, the careful study of which can only be pursued with the aid of the microscope, we will now pass to the secondary or saccular stage. By the introduction of a number of illustrations, prepared from original dissections by the author, this phase of the subject will be readily comprehended.

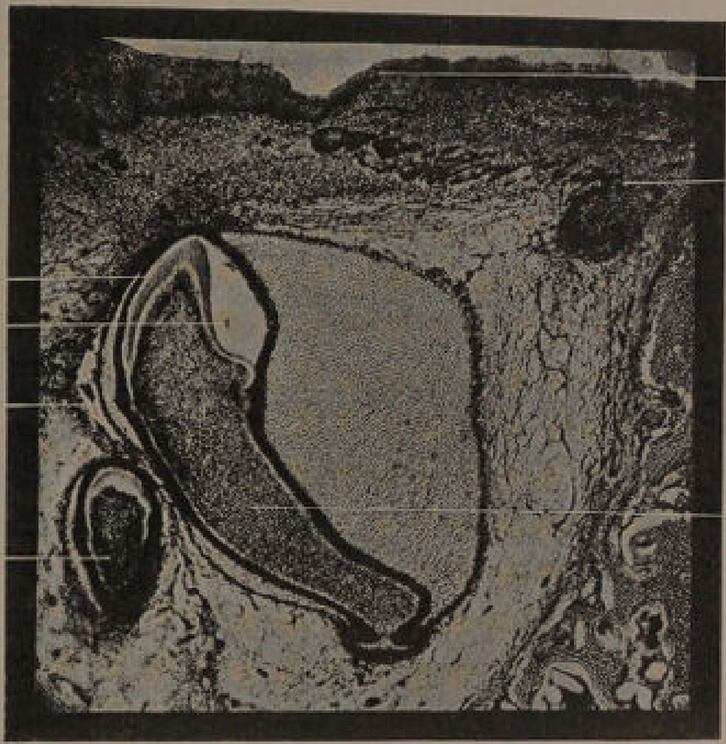


FIG. 303.—Development of deciduous incisor, from human fetus. (*After Gysi.*)

The development of the maxillary bones is so closely associated with the development of the teeth that it will first be necessary to briefly describe this process. At a very early period of fetal life we find preparations are being made for the development of the maxillary bones. That these are about the first bones to be called into functional activity accounts in a measure for their very early development. The development of the mandible begins about the middle of the second month of fetal life, while at a somewhat later period similar action takes place in the region of the maxillæ. A detailed description of the body of these bones having been given on another page, it will not be repeated here, but attention will be given to that portion which gives lodgment to the tooth-germs, and which in a measure is controlled by their presence, and for this purpose the mandible will principally be used.

Figure 304 represents the lingual face of the mandible after removal from a three months' fetus. Attached to it is the remaining portion of Meckel's cartilage, which by this time is much wasted. It will be recalled that this cartilaginous band appears in the mandibular processes before the beginning of the second fetal month, being formed in two distinct halves, the free ends of which finally unite at the median line, forming a continuous support or framework, about which ossification takes place. At a corresponding period, and in a similar manner, two like processes are thrown out for the maxillæ, but unlike Meckel's cartilage, these do not unite at the median line, but stop short of this, thus providing for two additional processes, which shoot down from

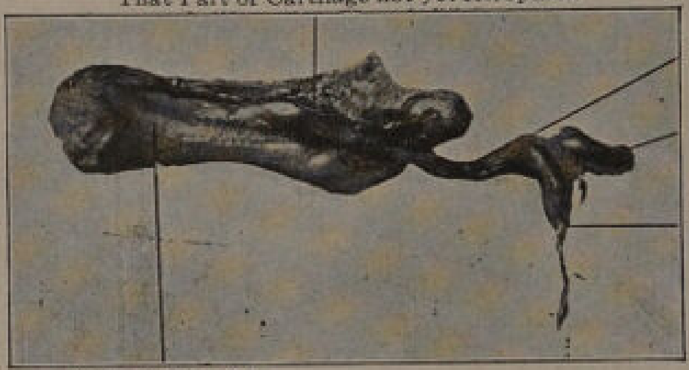


Fig. 304.—Developing mandible, three-month fetus.

the region of the forehead and provide for the development of the intermaxillary bones. About the middle of the second month a center of ossification appears in the neighborhood of the future mental foramen, quickly followed by others at the symphysis and at the angle of the mandible. These secondary centers soon unite with the primary one, and by the end of the second fetal month the osseous contour of the primitive jaw is established. While ossification takes place in the membrane surrounding Meckel's cartilage, the cartilage itself does not appear to be directly concerned in the process, and by the sixth or seventh embryonic month the madibular portion completely disappears, while that portion near the tympanum is ossified into the malleus. That portion of the bone which forms above Meckel's cartilage and the inferior dental nerve is that which finally gives support to the tooth-germs.

Figure 305 represents the evolution of the mandible from the middle of the third fetal month to the time of birth. It will be observed that during this interval there is a gradual increase in the size of the bone, but little alteration in its contour. By a constant and gradual osseous deposit about the distal extremity of the bone its length is increased to accommodate additional teeth as they make their appearance. While the external form of the bone shows but slight variation during this period, the internal structure, or that wherein the tooth-germs lie, is undergoing a complete transformation.

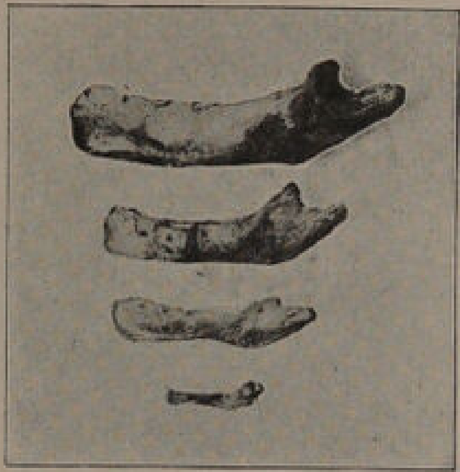


FIG. 305.—Evolution of the mandible from the third fetal month to birth, two-thirds actual size.

Figure 306 is illustrative of these changes; beginning with a simple groove, or gutter, into which the tooth-follicles hang, and exerting a controlling influence over its contour. Next comes the appearance of septa between the interior follicles, which at this period are somewhat irregularly placed in the arch, followed in a few weeks by a well-defined partition between the cuspids and molars, until finally, at birth, each follicle is inclosed in its individual crypt, with the single exception of the second molar, in which the distal septum, or that which is to separate it from the permanent first molar, has not yet made its appearance. As the tooth-follicles increase in size, by the development of the teeth within, they become more perfectly inclosed in the bony vaults, the sides of the alveolar walls arching over and almost completely inclosing the developing teeth. Figure 307 shows the mandible of a seven-months-old child embodying the condition above referred to. Soon after the crypts have grown to this extent, a destructive action produced by, or provided for, the advancing crowns speedily results in

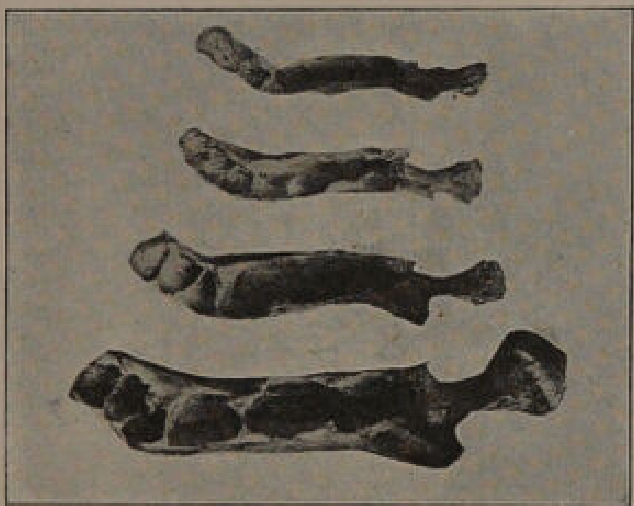


FIG. 306.—Evolution of the mandible from third fetal month to third month after birth.

their downfall, to be again built up with the evolution of the permanent teeth.

About the first visible sign of preparation for the development of the teeth, other than that made apparent by dissection, may be observed as early as the beginning of the third fetal month, when, looking upon the alveolar ridge of the future hard palate, a well-defined infolding of the

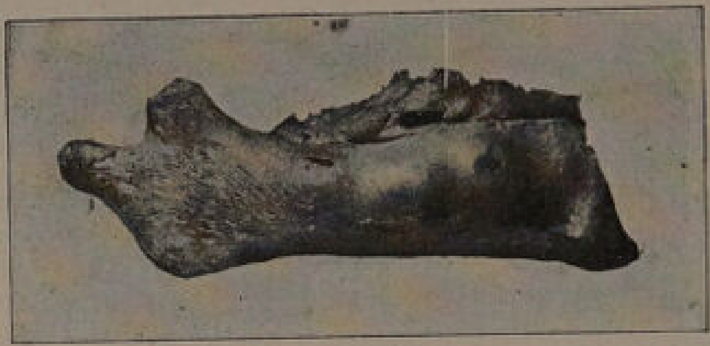


FIG. 307.—Inferior maxilla of seven-months-old child.

epithelial eminence will be seen. In figure 308 is shown a dissection through the oral cavity of a four months' fetus, the outer fold being that of the cheeks and lips, while within are the hard palate and primitive alveolar ridge. The mouth at this period has passed the rudimentary state, the transverse plates which contribute to the formation of the

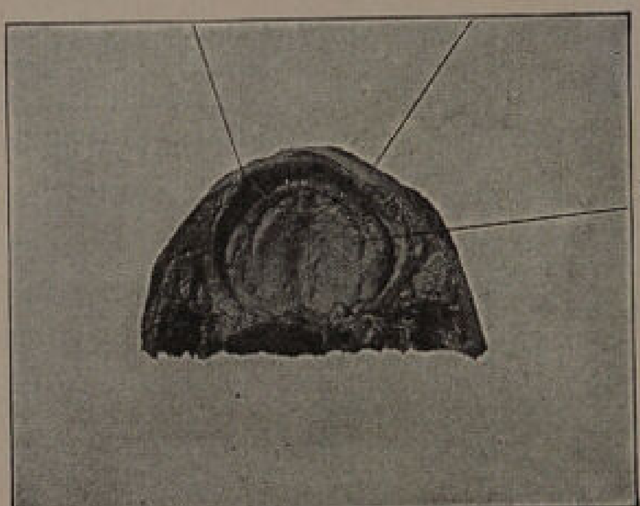


FIG. 308.—Section through the mouth of four-month fetus.

hard palate having approached each other until the oral and nasal cavities, heretofore existing as a single buccal cavity, have become separate and distinct. The infolding of the oral epithelium, as outlined on the summit of the primitive alveolar ridge—the primitive dental furrow or groove—marks the position of the tooth-band from which are given off the incipient tooth-buds. For the purpose of further investigation, a dissection of these parts was made and the maxillary bones removed, after which they were divested of their fibrous covering, including the periosteum. That portion which overlies the palatal processes was readily lifted in one sheet, while that upon the facial surface was separated at the median line and stripped independently of the other (Fig. 309). The removal of these tissues is readily accomplished until the margins of the partly formed alveoli are reached. Here the periosteum dips down into the various crypts, and serves as a lining membrane for them, and probably contributes fibers to the outer layer of the follicular walls. After advancing thus far, the detached tissues may be grasped, and by careful manipulation the tooth-follicles containing the formative organs removed from their respective vaults and turned over for examination.

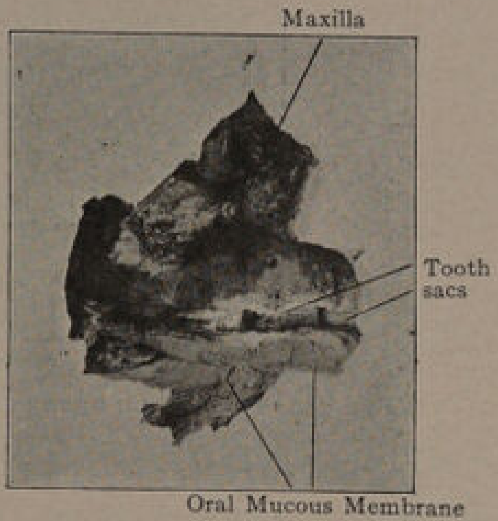


FIG. 309.—Superior fetal maxilla showing manner of dissection to expose tooth-sacs.

Figure 310 shows the result of such a dissection. On the left, the palatal plates and alveolar walls of the divested bones may be observed; on the right, is the fibrous covering, which has been turned completely over after removal from the bones, having firmly attached to it the ten tooth-follicles for the deciduous teeth. If this dissection be made without the precaution of lifting the periosteum, the follicles would not cling to the oral membrane with sufficient tenacity to permit of their ready removal. It may be of some interest to note that at this early period the position of the follicles containing the germs for the lateral incisors is that which the tooth is forced to occupy up to and frequently beyond the eruptive period, being crowded within the tooth-line by the central and cuspid follicles, in consequence of which the lateral crypts are thrown well into the palatal plates.

Figure 311 represents the sacs broken down, exposing to view the dentin papillæ, or those structures destined to become the tooth-pulps. The position which these occupy in the illustration is exactly the reverse from that which they assume when in position in the follicle, being thus reversed that a better idea of their shape may be obtained. Prior to the twelfth or thirteenth week of fetal life this incipient bulb or papilla is without definite form; but by the latter period each papilla begins to assume the contour of the future tooth-crown, as faintly outlined in the illustration, those of the incisors presenting the angular form of the future incisive edge, the cuspids that of the single cone, while the coronal

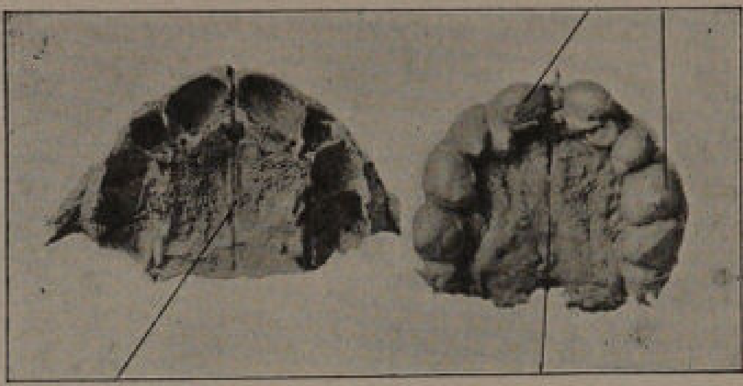


FIG. 310.—Dissection upon superior maxilla, fourth fetal month, exposing tooth-follicles.

extremities of the molars are represented by outlines corresponding to the future cusps and marginal ridges. Besides the dentin papillæ, there is contained within the follicular walls the enamel organ which later on is productive of the enamel, but up to this time has been actively engaged in molding the tooth-form as outlined by the papilla.

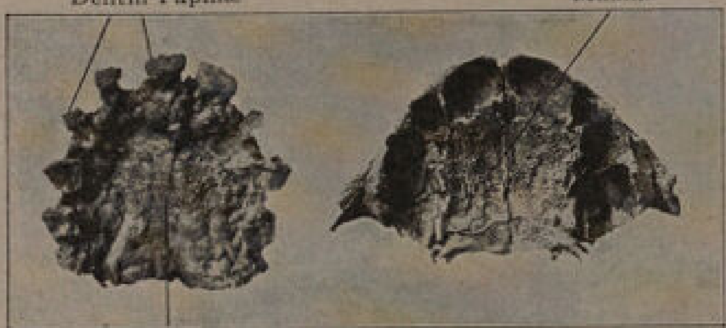
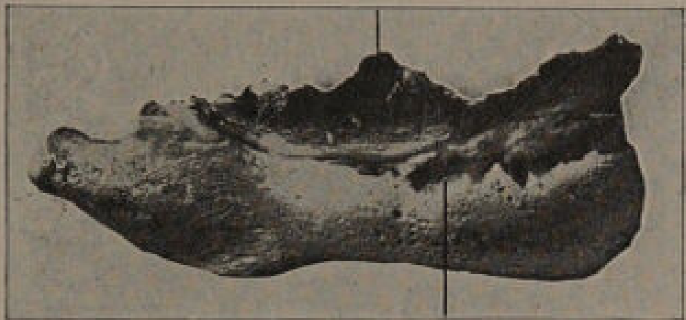


FIG. 311.

Similar dissections were made on the mandible beginning with a four months' fetus. Figure 312 shows the mandible removed and the dissection carried to the point at which the follicles may be lifted from their bony encasements, this being accomplished by an incision along the base of the bone, followed by a stripping of the membrane first from the facial and then from the lingual side of the bone. When these two flaps reach the margin of the crypts, they are firmly grasped and the follicles removed from their sockets, as illustrated in figure 313.

At the beginning of the saccular stage of development the form of the future tooth-crown is well outlined by the dentin papilla, which in figure 314 is brought into view by a dissection of the walls of the follicles shown in figure 313 without breaking the attachment between the

Oral Mucous Membrane and Periosteum Dissected from Mandible

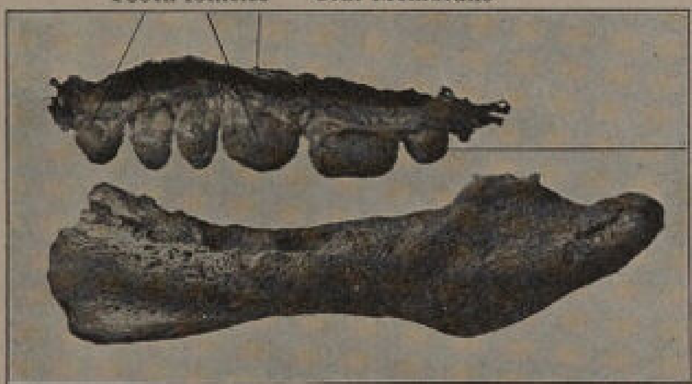


Attachment of Follicle to Oral Membrane (Enlarged One-third).

FIG. 312.—Manner of dissection to expose tooth-sacs.

two. As previously stated, the enamel organ, until this period, has been principally devoting its energies to the molding of the tooth form, and it is not until this model, as represented in the papilla, is complete

Tooth-follicles Oral Membrane



Follicle of Permanent First Molar

FIG. 313.—Tooth-follicles removed from mandible, fourth fetal month.

that the process of calcification begins. About the fourth fetal month preparations for the calcification of the deciduous teeth begins by the appearance of the odontoblastic cells for the dentin, which first made their appearance on the periphery of the dentin papilla, in the region of the summits of the various cusps in the molars and the future incisal-edges of the incisors. This phenomenon is soon followed by the appearance of the ameloblastic cells for the enamel, which establish themselves in the internal epithelial layer of the enamel organ, the line of relationship between the two sets of cells forming the dento-enamel function in the fully developed tooth.

Figure 315 is prepared from a dissection made in a manner similar to that shown in figure 311 but at a period about a month later, being from the maxilla of a five months' fetus. The dissection shows the extent of calcification at this period, which process also defines the position of the odontoblastic cells upon the extremity of the papillæ. In the incisors (one of which was lost in the preparation of the specimen) the dentin may be seen capping the incisive-edges. The cuspids in this specimen have not yet begun to calcify, although it is not unusual to find the cusp of this tooth receiving its lime-salts at this period. In the

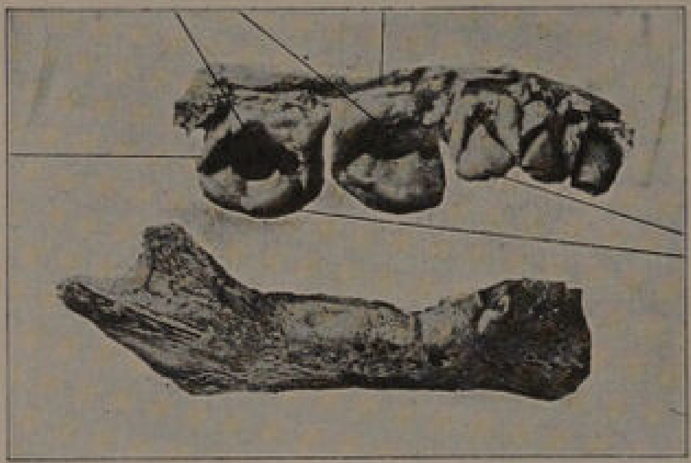


Fig. 314.—Tooth-follicles shown in Fig. 315 opened.

molars the summits of the various cusps, as well as a portion of the various ridges descending therefrom, are undergoing the change produced by the impregnation of the lime-salts. From this time forward the papillæ undergoes a gradual transformation as to size and form, and there is likewise a change in the cellular elements on those parts adjacent to the calcific action. While the outline of the papilla is gradually changing, its original form is permanently recorded upon the periphery of the dentin cap, which, when once formed, is unchangeable, all additions taking place from within.

Figure 316 illustrates the result of a dissection upon the mandible of the same subject, disclosing practically the same conditions, with the exception of the sac containing the developing cuspid, which was found with a slightly calcified cap of dentin. This slight variation between the development of the upper and lower teeth is one that is present in nearly every instance, the latter being somewhat in advance of the former.

In figure 317 the dentin germs, with their primitive cappings of dentin, have been removed from the follicles, affording a better opportunity of studying the relations between the two parts. The next

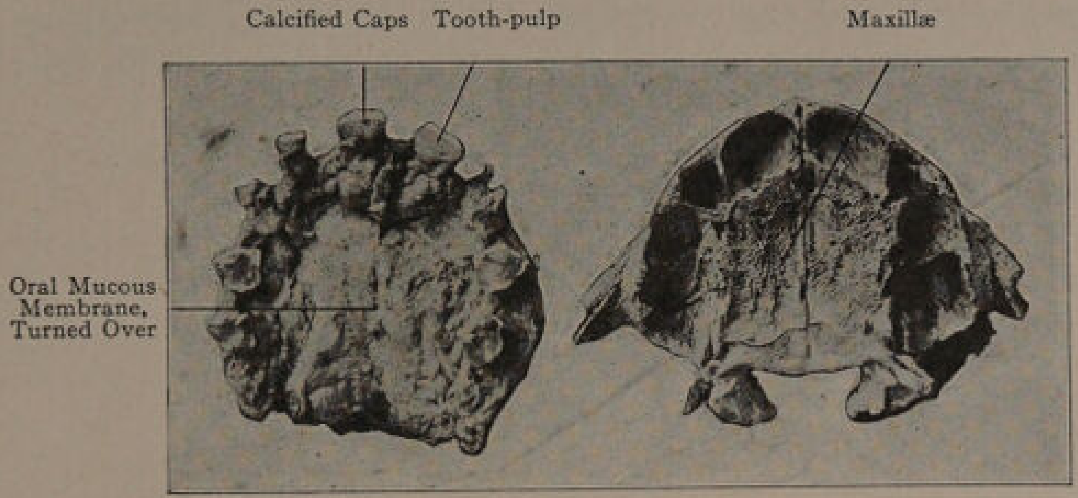


FIG. 315.

dissection was one upon the mandible of a six months' fetus. Figure 318 shows the tooth-follicles removed from the partially formed bony crypts in which they have been incased. At an early period of fetal

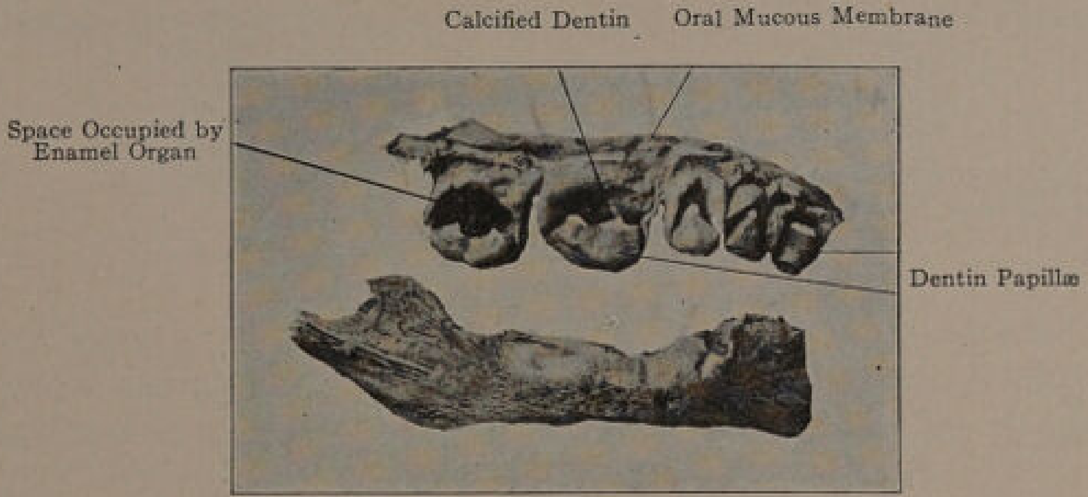


FIG. 316.—Tooth-follicles opened, exposing dentin papillæ and beginning of calcification, fifth fetal month.

life, and at a time prior to the completion of the tooth-follicles, there is deposited beneath the tooth-germs a thin layer of bone, which at once begins to assume the form of the partially developed follicular walls. As the growth of the follicle proceeds, there is a corresponding increase in the osseous deposit, the alveolar walls extending about and accommodating themselves to the membraneous sacs. Thus we find in this portion of the maxillary bones a feature peculiar to itself—that of a continuous transformation from its earliest inception to the adult period, first developing about the temporary tooth-sacs and completely incasing them, which is speedily followed by complete absorption of the walls, again followed by a rebuilding during the evolution of the permanent teeth, and again swept away with the loss of these organs. Figure 319 illustrates the opposite side of the same jaw, with its outer

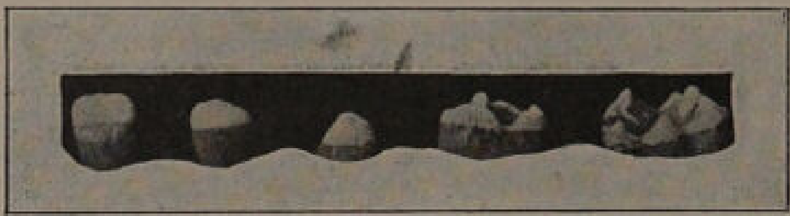
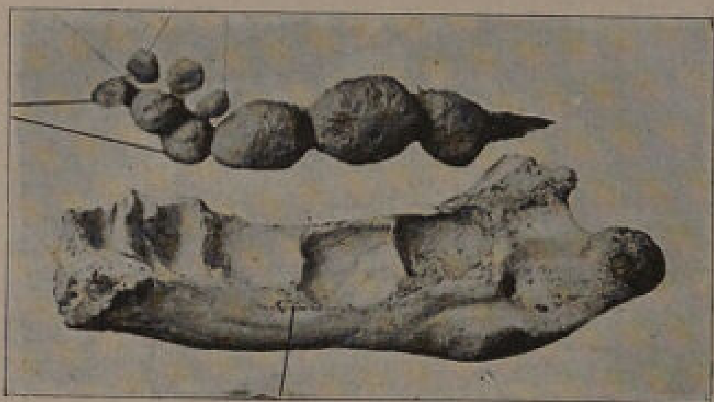


FIG. 317.

or facial plate removed, together with the intervening septa. The follicles are opened, and the extent of calcification at this period (six months) made apparent. The pulps and calcified caps are approximately as found when dissected, save a slight settling of all the parts. The incisors have calcified to about one-third their full coronal length; the contour of the cuspid has been established, as shown by the deposit



Lingual Surface of Mandible

FIG. 318.

of the lime salts upon its summit. The first molar has about completed its occlusal surface, and, while the cusps of the second molar are nearing completion, there is a lack of union in the central and distal fossæ. Immediately posterior to the second deciduous molar, the sac containing the formative organs for the first permanent molar is shown opened, exposing to view the dentin papilla, which at this early period has assumed the form of the future tooth-crown, and calcifications is about to begin. Figure 320 illustrates the extent of calcification in the deciduous teeth at the sixth fetal month. As the growth of the teeth proceeds, it will be observed that the angularity which originally

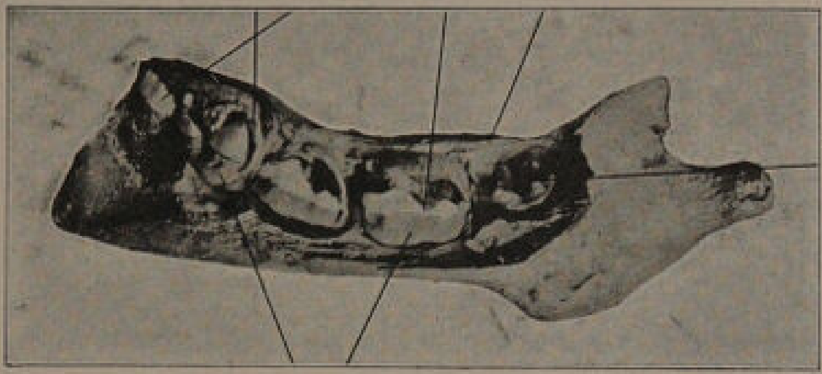


FIG. 319.

accompanied the calcifying caps of the molars is gradually disappearing, as is also the tritubercular form of the incisors and cuspids, this change being brought about by the deposition of enamel.

FIG. 320.

Figures 321 and 322 show the calcified caps removed from the papillæ, and so arranged that both their external and internal anatomy may be studied. Prior to this time there has been but little alteration

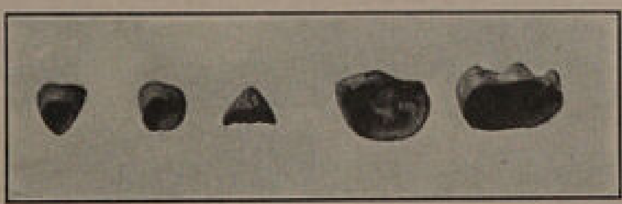


FIG. 321.

in the form of the dentin papilla, only a gradual decrease in its size being noted; but now we find it being divested of many of its angles, particularly those which originally served as a basal form for the coronal extremities of the future tooth. With the disappearance of these the concavity within the cap is slowly assuming the form of the future pulp-chamber.

That a better understanding of the saccular stage of tooth-development might be had, a longitudinal section was made through the molar follicles, as shown in figure 321. In this the attachment of the follicular

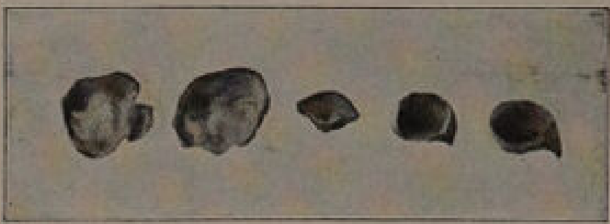


FIG. 322.

walls to the deep epithelial layer is visible, while within the walls is the enamel organ, the calcified dentin, and the tooth-pulp. As previously stated, the enamel organ is seen suspended above and forming a hoodlike investment to the calcifying structure. This organ not only overhangs the occlusal surface of the tooth-crown, but completely envelops the sides of the calcified dentin cap. Previous to the beginning of calcification the enamel organ is in close proximity to the dentin

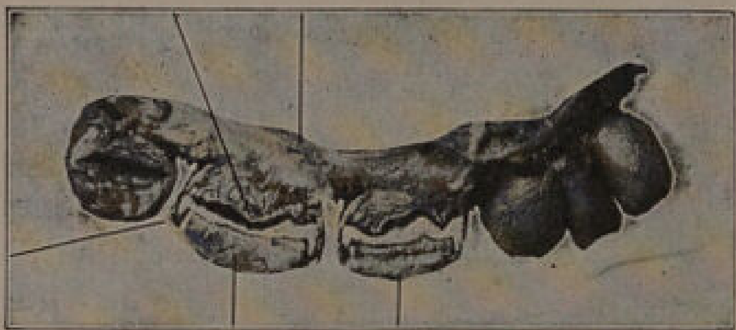


FIG. 323.—Dissection showing pulp, calcified cap, and enamel organ.

papilla, the original form of the latter being represented by the calcified dentin.

We have now arrived at that period of fetal existence when it is possible to study the macroscopic development of the first permanent molar. Figure 324 represents a section of the lower jaw of a six months' fetus, and displays not only the sacs of the deciduous teeth, but also that of the first permanent molar. In most respects the evolution of this tooth is similar to that of the temporary organs, having its origin from the infant epithelium, either directly or by extension of the tooth-band backward. Preparations for its growth are begun as early as the third fetal month, at which time the enamel organ makes its appearance and thereafter the developmental process is identical with that of the deciduous teeth.

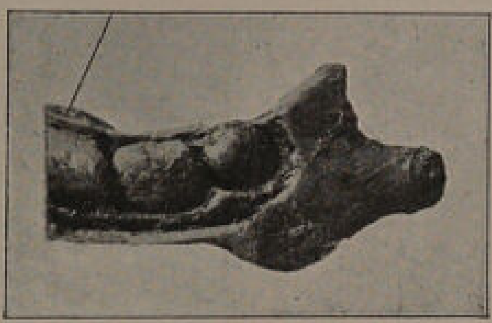


Fig. 324.

There is one structure, however, intimately connected with the development of the permanent teeth not found in connection with the deciduous teeth —the *gubernaculum*, or leading cord. Figure 325 represents another section of a six months' fetal mandible, with the dentin papilla for the permanent first molar turned out from the follicle after being rolled from its bony incasement. Attached to the apex of the tooth-sac (which has been turned back), and leading from it to the epithelium of the jaw, is the gubernaculum. This fibrous structure was at one time thought to be directly concerned in the development of the tooth. Although this is denied at present, little is said in regard to its function, but it undoubt-

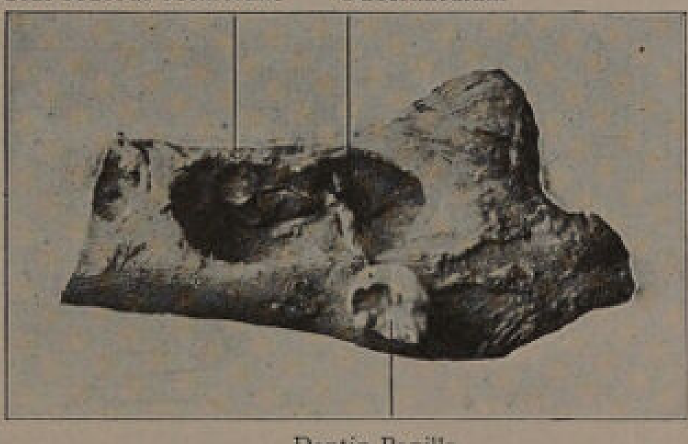


Fig. 325.

edly serves the purpose of directing the tooth to that position which it should occupy in the jaw, and where the least resistance to its eruption is formed by the foramen which the cord has established. Each of the permanent teeth is provided with a similar membranous cord, an illustration and more complete description of which will follow later on.

We have now arrived at a period when the subject under consideration naturally becomes of deeper interest. A time when the being changes from a complex dependent condition to one of self-providing independence. Previous to birth the teeth appear to be but little disturbed by certain morbid conditions which might be present in the parent, and from their earliest inception up to this period their development proceeds with but little interruption and with much regularity. Figure 326 illustrates the condition of the deciduous teeth

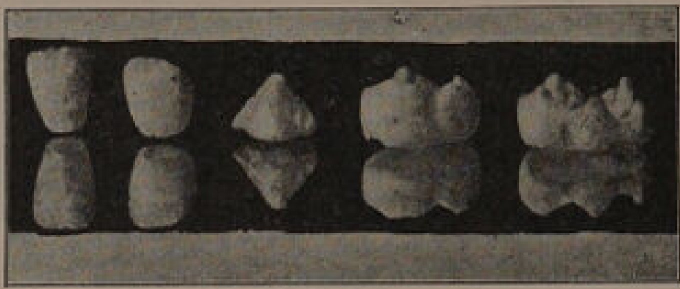


Fig. 326.—Deciduous teeth at birth. (Reflected picture.)

at birth; the central incisors are calcified externally to the cervical line, the lateral incisors to a point somewhat less extensive; the cuspids have advanced somewhat beyond the angles of the crown, while the molars have their crowns calcified to about one-half their completed length. With all this progress as represented by the external contour of the tooth-crowns, the internal form appears to be somewhat slow

Oral Mucous Membrane

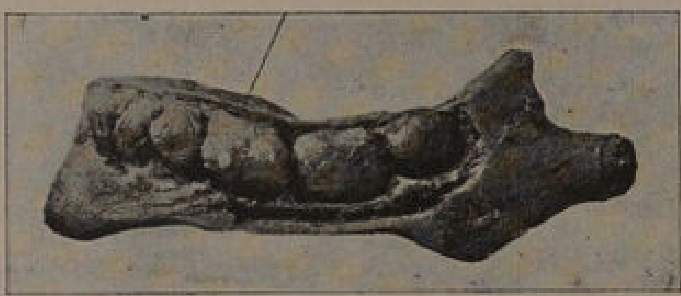


Fig. 327.

in assuming the shape of the future pulp-chamber. From the beginning of the saccular stage of development up to the time of birth there is but little increase in the diameter of the tooth-sac, but there occurs a gradual increase in its length. Figure 327 shows the mandible from a child one week old, with the greater part of the external or facial surface of the bone removed, exposing not only the sacs containing the developing deciduous teeth, but also that of the first permanent molar. The relation of the sacs to the inferior dental canal is apparent, as well as the firm attachment of the follicular walls to the surface oral tissue. In figure 328 the tooth-sacs have been dissected and the pulps removed from the calcified caps, presenting an additional illustration of the amount of dentin deposit at this age. To further illustrate

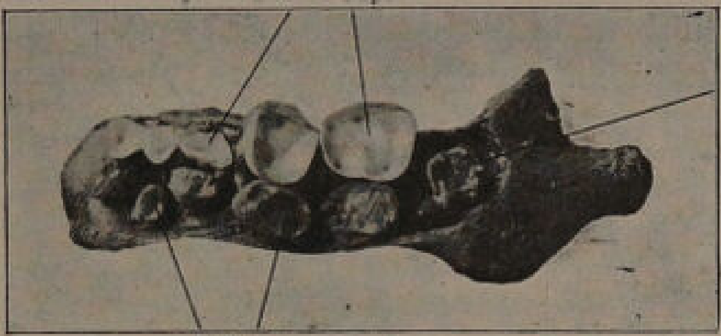


FIG. 328.

the size and form of the pulp as compared with the calcified cap at birth, a transverse incision was made through the left maxilla, at a point corresponding to the base of the pulp, as shown in figure 329. The calcified parts remain in position resting against the remaining

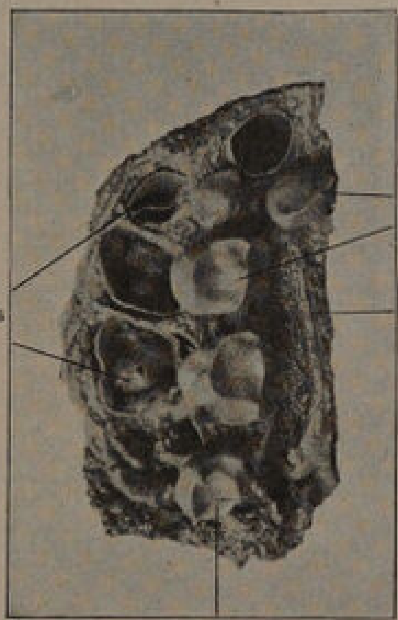


FIG. 329.

portion of the enamel organ, while the pulps are dislodged and may be observed resting upon the incised surface. In this illustration the dentin papilla for the first permanent molar is also seen, being supported by the walls of the follicle, which in turn are attached to the oral epithelium by the gubernaculum. It may also be noted that those parts of the pulp corresponding to the cusps and marginal ridges show a decided convergence of the surface toward the center.

Reference has been made to the formation of the follicular walls by a differentiation of cells, which at an early period are given off from the base of the papillæ and to the continuity of the two structures. Figure 330 was prepared for the purpose of showing these intimate relations.

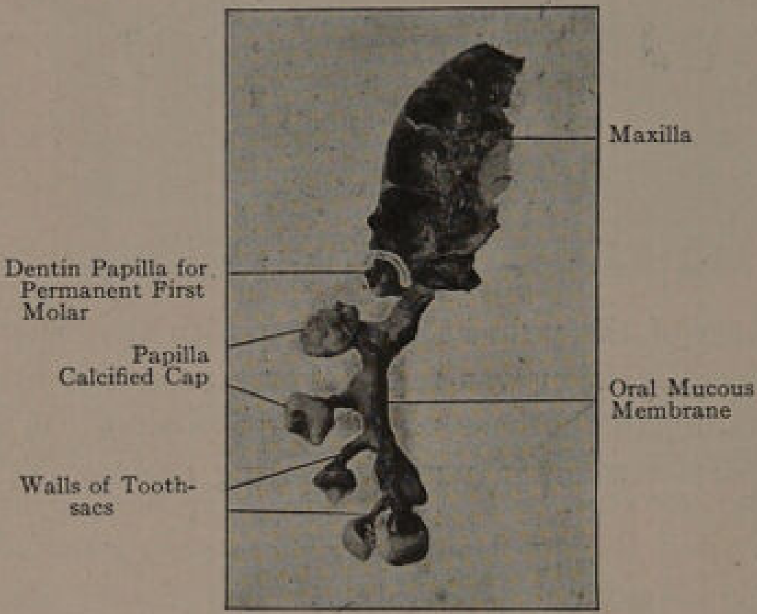


FIG. 330.

The sides of the sacs were opened and turned back, the calcified tooth-caps with pulps in position were grasped and given several revolutions, thus twisting the remaining portion of the walls, the floor of which is seen as a continuous structure given off from the pulp and connecting it with the surface.

PREPARATIONS FOR THE DEVELOPMENT OF THE PERMANENT TEETH

A little before the time of birth sufficient advance has been made in the development of the permanent teeth to permit a study of their relations to the temporary organs. The early preparations for the growth of these teeth was for a long time a subject of much controversy, some writers advancing the theory that the buds for the permanent teeth were produced or given off from the sacs of the temporary teeth; others contending that the cords were derived from the remnants of the primitive cords immediately after their rupture. The theory now generally accepted is that the cord is given off from the primitive cord at a point in close proximity to its attachment to the deciduous enamel organ. This can only apply to those teeth which are succedaneous, and, therefore, does not include the permanent molars, as heretofore stated. Whatever theory be accepted in regard to the genesis of the permanent teeth, there can be no mistake in regard to that part of the process which we are permitted to investigate with the naked eye. Let us, therefore, proceed to describe the position and contents of the permanent tooth-sacs at birth. Figure 331 presents the result of a vertical dissection through the maxillary bones, the inner approximal surface of the right maxilla being exposed to view. Many of the frail processes, particularly those entering into the construction of the nasal cavities, were lost

FIG. 331.—Section through maxillæ, sixth month after birth.

during the preparation of the specimen, the whole purpose of the dissection being to show the sac of the permanent incisor and its relationship to its predecessor. By this time calcification in the deciduous incisor has so far advanced that the contour of the tooth-crown may be plainly outlined through the walls of the sac. Resting against the lingual concavity of the crown of the temporary incisor is the sac containing the formative organs for its permanent successor. This permanent tooth-sac does not long remain in such close proximity to the deciduous tooth-crown, for as the latter advances toward the surface of the gum the former recedes and is soon inclosed in a separate crypt, which, were it not for the gubernaculum, would completely inclose it. Figure 332 represents a section of the left maxilla, introduced at this point for the purpose of showing the position of the foramina for the gubernacula. These may be observed immediately posterior to the incisor and cuspid teeth. At birth these foramina do not exist as such, the partially formed vaults containing the sacs for the permanent teeth appearing as an extension of the temporary crypts in a palatal direction; but as the temporary teeth advance and the permanent teeth recede, the roof of the crypt is completed, and the foramen established by the presence of

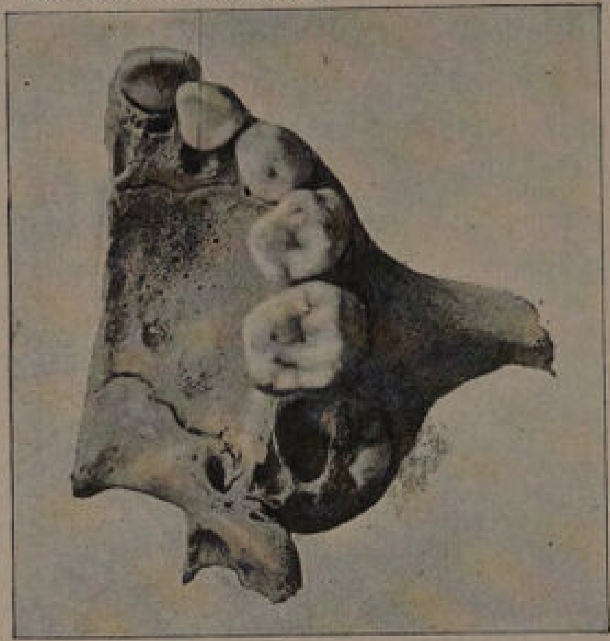


FIG. 332.

the gubernaculum. This extension of the temporary crypts is more clearly demonstrated in figure 333, which represents one side of the lower jaw at birth with the partially calcified deciduous teeth in position in the bone. Suspended above this is the gum, which has been dissected

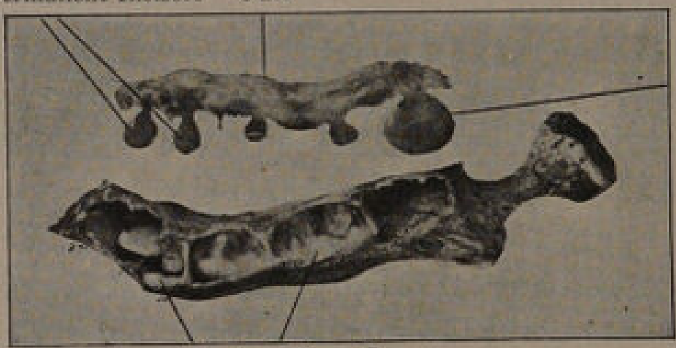


FIG. 333.

from the bone, having attached to its under surface the sacs for the permanent teeth. Those for the incisors are particularly well defined and their place of lodgment in the bone readily noted. In the case of the cuspid, both the deciduous tooth and the permanent tooth-sacs are in position in the crypt. The cords which support the incisors are somewhat lengthened from the weight of the sacs, the gubernacula not assuming this thread-like form until the permanent sacs have further receded.

Figure 334 shows the result of a dissection upon these permanent tooth follicles. The dentin papillæ of the various teeth are seen in a

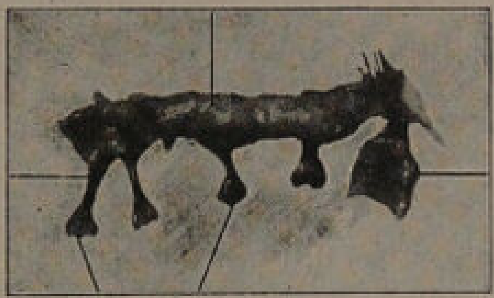


FIG. 334.

reversed position, with the follicular walls attached to their bases. At this period the papillæ for the permanent incisors may be compared to the tail of a fish, being perfectly transparent over its free extremity, which feature is gradually lost as its thickened base is approached. The fishtail appearance is further represented by the division of the free extremity into three distinct parts, each of which provides a separate

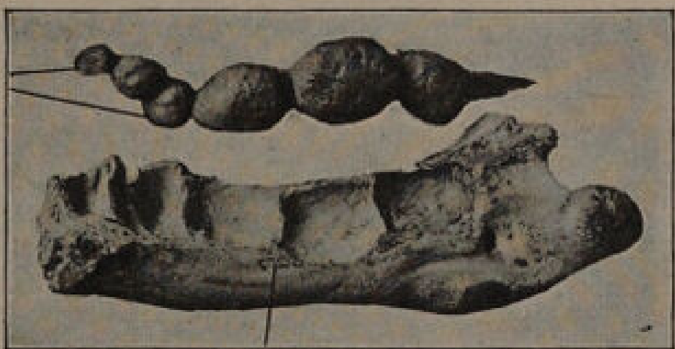


FIG. 335.

point of calcification. The cuspid papilla is missing, and the bicuspids have advanced little beyond the form of the primitive bulb. The first molar is shown with the full diameter of the crown represented by the pulpal mass, and the tips of the cusps are already beginning to take on the calcific action.

A further illustration of the progress of the development of the permanent teeth and their relation to the deciduous organs may be seen in figure 335, the dissection in this instance being upon the lower jaw of a one-month-old child. The membrane has been lifted from the bone with the tooth-sacs attached to it. Immediately posterior to the sacs containing the crowns of the temporary incisors and cuspids are those for their corresponding successors, the papillæ of which have already assumed the tubercular outline of the future cutting-edge. While the permanent tooth-sacs are distinctively independent pouches, there appears, nevertheless, to be a well-established fibrous connection existing between the outer layer of the two follicular walls. This

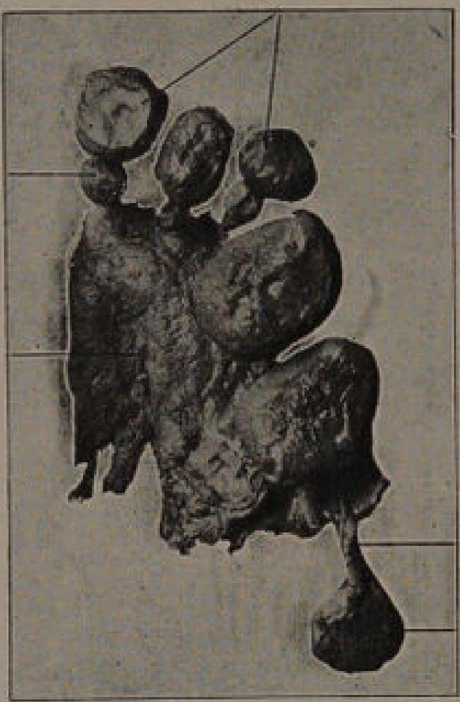


Fig. 336.—Same as Figure 341, except on upper jaw.

fibrous union is gradually broken as the permanent sacs recede and become incased in their own vaults.

While the permanent tooth-sacs are generally referred to as "receding," it is a question if this term is fully justified. While the follicles do not remain in close relation with their predecessors, the change in the relative position of the two is principally brought about by the advance in the deciduous sacs, this forward movement being accompanied by a marked growth of the bone in the direction of the future alveolar ridge, thus leaving the permanent tooth-sacs well buried in the substance of the jaw.

Figure 337 represents the result of a dissection upon the maxillæ of a three month's old child. The mucous membrane covering the hard palate, together with the periosteum, has been dissected from the bones and turned over for examination. The tooth-follicles for all the deciduous teeth, as well as those of the permanent organs, may be observed firmly attached to the fibrous tissue. The permanent incisor sacs at this age are almost equal in size to those of their predecessors, and the dentin papillæ within possess a mesio-distal diameter almost

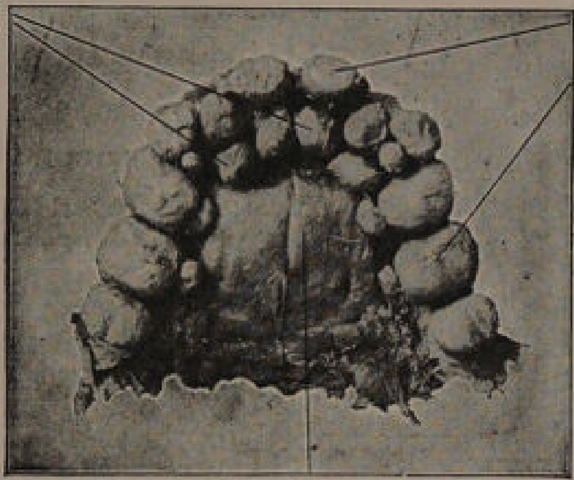


FIG. 337.—Tooth-follicles for deciduous and permanent teeth, three months after birth.

equal to those of the calcified temporary caps. The sacs containing the germs for the permanent cuspids and bicuspids are somewhat diminutive, but the enamel organs within are already molding the contour of the future tooth-crowns upon the dentin papillæ.

By the beginning of the second month after birth calcification in the crowns of all the deciduous teeth is about complete, and preparation for

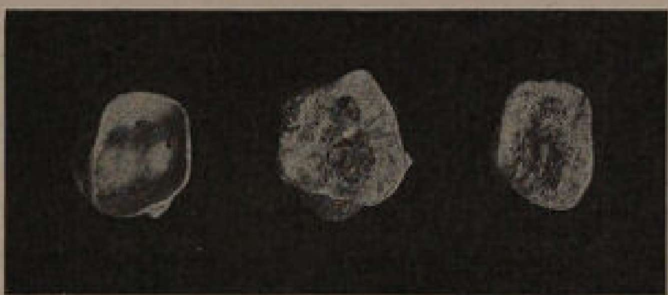


FIG. 338.

growth of the roots is under way. While at this period the tooth-crowns may be said to be almost completely calcified, this does not apply to the interior of the crowns, the deposit of dentin internally being a continuous process, resulting in a gradual reduction in the capacity of the pulp-cavity. It is also true that the enamel organ is somewhat active up to the eruptive period, and the enamel covering of the crown is not complete until this time. As the tooth-crowns gradually approach completion, the time for the formation of the roots has arrived, and it is principally through the activity of the tooth-pulp that they are generated. We have seen that the contour of the tooth-crown was first molded upon the dentin papilla; so it is with the tooth-root; by a gradual elongation of the sac, accommodations are afforded the tooth-pulp for a corresponding growth. As the pulp lengthens out toward the future apex of the root, it is molded to the root-form, and calcification takes place by the generation of odontoblastic cells upon its periphery.

While the process of root-formation in the single-rooted tooth may be readily comprehended, the bifurcation or trifurcation of the molar roots presents a complication which calls for special reference. Figure 338 will assist in explaning this phenomenon. In the illustration three deciduous molar crowns are shown, two of which are incased in their tooth-sacs, the third being stripped of its membrane. The view is directly upon the base of the tooth-sacs, immediately beneath which is the base of the pulp. Up to this period the odontoblastic cells have been generating about the occlusal surface and lateral walls of the crown only, but now an accumulation of these cells is to be found upon the base of the pulp, lining up in the position of the future root-walls. This structual change is faintly outlined in the illustration. By this inward extension of the odontoblastic cells from various points about the margins of the pulp, and their union near the center of the mass, provision is made for the calcification of the various roots, which process is continued separately by an extension and molding of the pulp into two or more divisions.

Calcification of the Cementum Cementification.—While the dentin of the root is derived from the tooth-pulp, the external covering of the root (the cementum) is generated from another source. In every respect cementum is closely allied to bone, and we find its development provided for in a similar manner. As stated in another part of this chapter, the tooth-sac is made up of an outer and an inner layer, both of which are rich in blood-vessels. These membranous walls continue to invest the roots of the teeth during their upbuilding. The outer layer of the sac remains as a permanent structure placed between the root and the alveolar walls, forming the alveolodental membrane, while upon the surface of the inner layer cementoblasts are developed, which in turn calcify cementum. It will therefore be seen that the process of the calcification of cementum in a measure compares with subperiosteal bone development as seen in the ossification of long bones. Like the enamel cap of the tooth-crown, the cementum is deposited upon the surface of the dentin of the root, thus increasing its diameter. The calcification of cementum is more fully considered later on.

ERUPTIVE, OR THIRD STAGE OF TOOTH DEVELOPMENT

Up to this time no reference has been made to that process by which the teeth burst forth from their bony incasements, and, penetrating the mucous membrane, made their appearance in the mouth. Attention has been called to the growth of the bone about the tooth-follicles—first forming beneath them as an open gutter, next surrounding their lateral walls and inclosing each follicle in a separate compartment, or crypt, and finally each tooth becoming more completely enveloped by an arching-over of the mouth of the bony vault. This condition in the maxillary bones is reached between the seventh and eighth month after birth, and, almost simultaneously with the completed incasement of the teeth by the bone, active absorption begins, that portion of the bone which was last in forming being gradually removed. The cause of the absorption of the bone may readily be attributed to the advancement of the tooth, but the forces which are responsible for this latter phenomenon do not appear to be clearly understood. In a general way, the advancement of the crown may be said to result from the elongation of the root by the addition of dentin to its free extremity. But, when it is taken into consideration that the cuspids, both deciduous and permanent, have their roots fully or nearly calcified before they begin to advance toward the surface, an exception may be taken to the generally accepted theory.

The eruptive process takes place first in the anterior teeth,* and the bone overlying the labial surface is first removed. This loss of bony structure is continued until fully one-half of the labial surface is uncovered, and, as the crowns continue to advance toward the surface, they assume a more prominent position in the arch, and thus their incisive-edges become bared. The lingual face of the crypt serves a double purpose, forming not only a covering to the deciduous tooth, but also serving the permanent tooth-sac in the same capacity. This part of the crypt remains unabsorbed, the tooth-crown glides by its margin, and, after penetrating the mucous membrane, makes its appearance in the mouth. Closely following the absorptive process

* See Description of the teeth in Detail.

comes a rebuilding of the parts, until, finally, when the tooth is fully erupted, it is firmly supported by new bone filling in about the base of the root. Accompanying the eruption of the anterior teeth and their establishment in the arch, is an increase in the depth of this portion of the jaw, and, as the molars advance and assume their position, there is a corresponding increase in the depth of the jaw in this locality. At the beginning of the eruptive period the roots of the deciduous teeth are but partially calcified, but as the crowns advance the calcific action at the extremity of the roots is continued, and, in the majority of instances, by the time the crowns are fully erupted the roots are completely formed.

FIG. 339.—Hard palate from a nine-months-old child, actual size.

During the period of eruption the transitory nature of the alveolar portion of the jaw-bone is made manifest, accommodating itself to the growth of the teeth as well as to their change of position. The free margins of the alveolar walls are taking on new structure, which advances with, and becomes adapted to, the base of the tooth-root. Coincident with this the deeper portion of the alveolar process is formed by a rapid filling-in about the root as the tooth travels onward to assume its final position in the jaw. The eruption of the teeth is usually by pairs, with a slight internal between each class. The central incisors first make their appearance, followed by the laterals, after which the first molars are erupted. The cuspids usually follow the first molars, and, finally, the second molars take their place in the arch. While this brief description of the eruption of the teeth refers to the deciduous organs only, the process in the permanent teeth is almost identical with this. Further reference to the eruption of the permanent teeth will be made in connection with the degeneracy of the temporary set.

To return to the subject of tooth-development, attention is called to figure 339, prepared from a dissection upon a nine-months-old child, the illustration representing the hard palate, or roof of the mouth, at this period. The four incisors have made their appearance, the labial surfaces of the crowns being fully exposed, while the lingual surfaces are but slightly uncovered. The approach of the remaining deciduous teeth is plainly indicated by the fullness of the alveolar borders, and the margins of the crypts are now being removed by absorption.

If the mucous membrane should be removed, the crowns of the advancing teeth would be brought to view after the removal of the walls

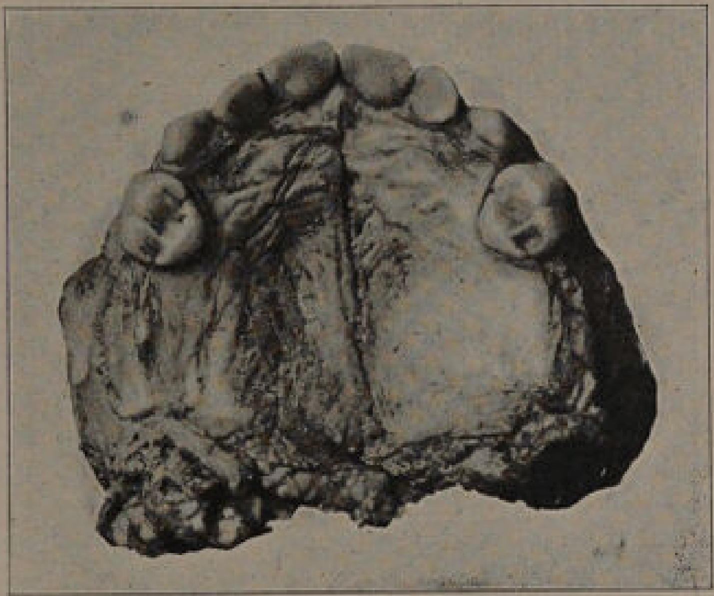


FIG. 340.—Hard palate from a two-year-old child, actual size.

of the tooth-sacs, while the approaching cuspids and second molars yet remain partly covered by an arching over of the walls of the crypts; the process of absorption has also begun in these parts. It would also be observed that, while the walls of the crypts are molded to the outlines of the tooth-crowns, there exists a well-defined interspace between the two. During the growth of the tooth this interspace is filled by the wall of the tooth-sacs, and even after the teeth have passed the saccular stage of development, and assumed their positions in the mouth, there yet remains between the roots and the alveolar walls sufficient space for the accommodation of the alveolo-dental membrane.

The next dissection is one upon the maxillæ of a two-year-old child (Fig. 340), showing the roof of the mouth. In this specimen it will be noticed that all of the deciduous teeth are erupted with the exception of the second molars. The lingual surfaces of the incisors are fully uncovered, while in the cuspids the labial surfaces are much more exposed than the lingual. In figure 341 the mucous membrane and sufficient of the bone have been removed to expose the tooth-sacs of the developing permanent teeth. The dissection furnishes no additional information over that obtained from figure 340, excepting that the primitive follicles for the permanent second molars make their appearance at this time.

At this early period the jaw has not lengthened sufficiently to permit of these follicles occupying their future position; consequently they are found generating immediately over the tooth-sacs of the first permanent molars. As the first molars advance and the jaw lengthens backward, these follicles will be carried to the distal by the extension of the mucous

FIG. 341.—Roof of the mouth of a two-year-old child.

membrane, to which they are firmly adherent. If these follicles were to be dissected at this time, the papillæ would be without definite form, showing that the early function of the enamel organ has not yet begun. The tooth-sacs containing the permanent lateral incisors are found immediately beneath the palatal plates, and frequently during their earlier life they are not even protected by the bone, being in immediate contact with the mucous membrane. On account of the imperfect protection frequently afforded 'these sacs, the germs are sometimes injured and the teeth fail to make their appearance.

In figure 342 the walls of the sacs shown in figure 346 have been opened, and the relations existing between the first and second dentition at the end of the second year become apparent. The crowns of the permanent incisors are deeply set in the substance of the jaw, while the partially calcified crowns of the permanent lateral are in close proximity to the palatal surface. The partially formed crowns of the permanent

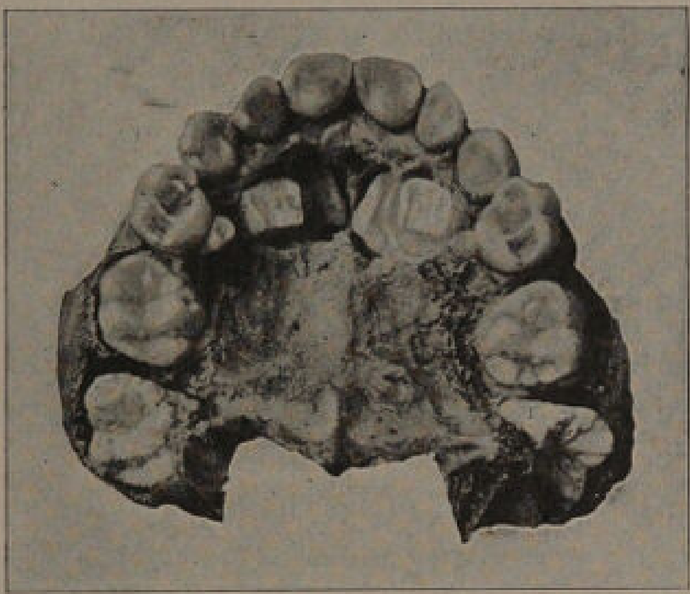


FIG. 342.—Development of the teeth about the second year.

cuspids are still more deeply seated in the substance of the jaw than those of the central incisors, and are not visible in the illustration. In this connection it will be well to again refer to the gubernaculum, and

FIG. 343.—Dissection of lingual face of lower jaw, child nine months old.

to its function—that of directing the tooth to its proper position in the arch. By reference to the illustrations the crowns of the permanent teeth will be observed heading in various directions, and, while in this instance there appears to be a general tendency for them to advance and assume their proper positions in the arch, in many cases they will be found directed at right angles to the point at which they should emerge from the bone. The gubernaculum, which appears to be nothing other than an elongation of the follicular walls, not only directs the tooth by the tension of its fibers, but the foramen which its presence creates stimulates absorption over the tract to be traveled by the tooth. Figure 343 was prepared for the purpose of better showing the gubernacula, and the manner of connecting the tooth-sacs with the oral mucous membrane. This condition is well shown in the anterior teeth, the tooth-crowns having receded well toward the body of the jaw. The follicle for first bicuspid may be observed attached to the lingual face of the deciduous molar sac, and the leading cord is not yet an adjunct to the developmental process, but this structure will make its appearance as the follicle recedes from the surface.

In figure 344 the deciduous molars have been removed from the jaw and the relations existing between these teeth and the developing bicuspids is shown. The tooth-follicles for the succedaneous teeth are found immediately beneath the gingival margin, and apparently attached to the deep layer of the mucous membrane. This relationship between the permanent and temporary organs is present about the eruptive period, but as the deciduous tooth advances and the permanent tooth-sac recedes, the two organs becomes more widely separated, and the permanent follicle is connected to the surface only by the elongated follicular fibers which form the gubernaculum.

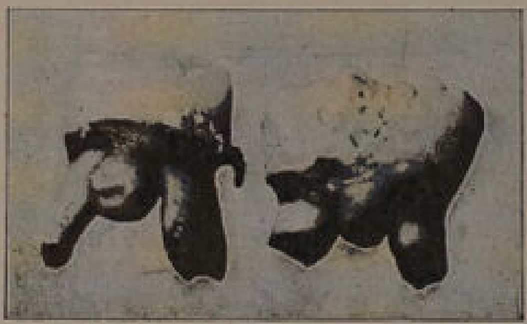


Fig. 344.—Deciduous molars with tooth-sacs for bicuspids attached to the gingival tissue.

Decalcification of the Deciduous Teeth.—By the close of the second year the twenty deciduous teeth have taken their place in the dental arch, their roots have become fully calcified, and the apical foramina established; it is only for a short period, however, that they remain thus perfect, the process of decalcification beginning about the fourth year. This process begins at the apical extremities of the roots and gradually progresses in the direction of the crowns. Commencing about the fourth year with the central incisor, decalcification takes place in the teeth in the order of their eruption, the lateral incisor following the central, the first molar following the lateral, etc. By reference to

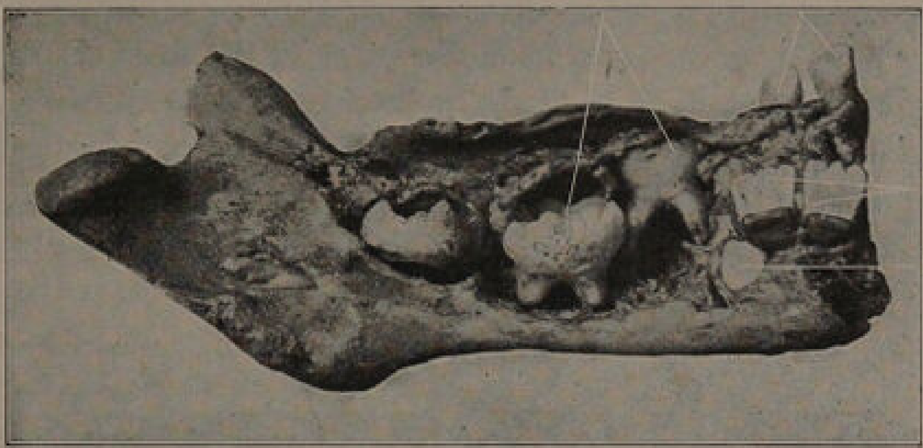


FIG. 345.—Same as Figure 235, with tooth-sacs opened showing developing teeth in the jaw.

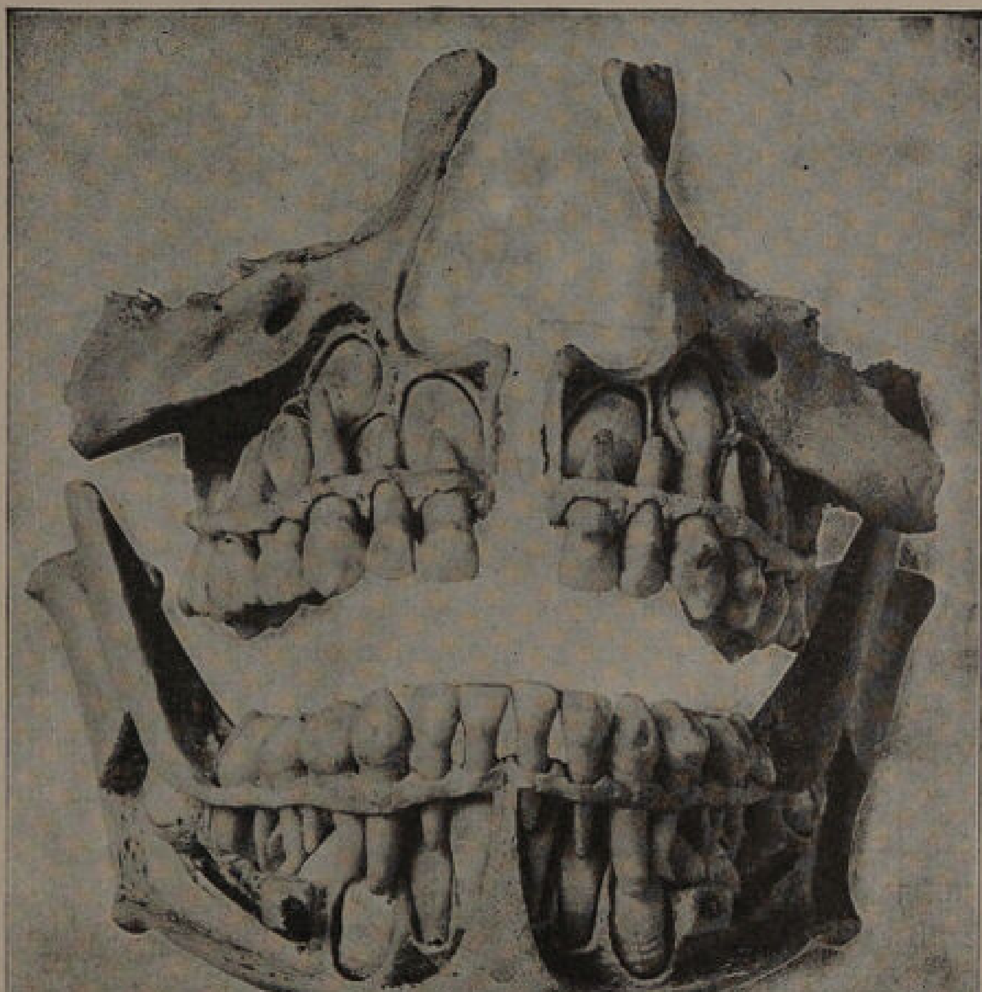


FIG. 346.—Development of the teeth about the sixth year.

figure 346 an approximate idea of the progress of decalcification may be obtained, and it will be observed that about three years elapse from the beginning of this process to its completion, and the final casting-off or shedding of the tooth-crowns. In reference to the causation of this dissolution of the deciduous teeth, but little appears to be known. It has been said to result from the presence and pressure of the advancing permanent teeth, but there is no question but that it occurs absolutely independent of these organs, decalcification frequently taking

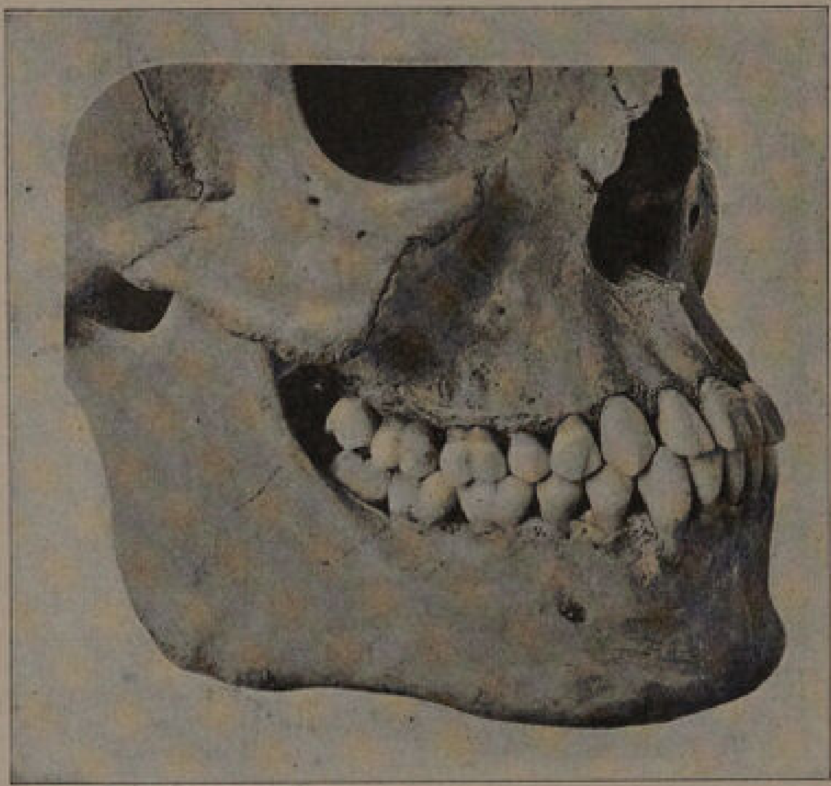


Fig. 347.—The completed dentition.

place when from some obscure reason, one or more of the permanent teeth are absent. During the entire period of root decalcification, the pulp of the tooth, which is also involved in the destruction, retains its vitality, but with the loss of vitality in the pulp absorption of the root ceases, so that the gradual removal of the root-substance must be considered as a purely physiologic action.

Figure 346 shows a dissection upon the jaws of a six-year-old child, by a careful study of which, a fair knowledge of the extent of absorption in the deciduous teeth at this period may be maintained.

Advance of the Permanent Teeth.—By referring to figure 346, the relations existing between the deciduous and the permanent teeth at about the sixth year may be noted. While the crowns of the deciduous teeth remain in position, a part of the space formerly occupied by their roots is taken up by the advancing crowns of the permanent teeth, the latter being calcified but little beyond their cervical lines. Between this seventh and eighth years the crowns of the deciduous incisors are cast off, and gradually the crowns of the permanent incisors force their way through the gum, the arch by this time having sufficiently increased in size to accommodate the additional width possessed by them. Previous to this time, or about the sixth year, by a backward extension of the jaws, the permanent first molars have erupted, assuming a position in the arch immediately posterior to the deciduous second molars. Between the tenth and eleventh years the crowns of the deciduous molars are lost, and the bicuspids advance to take their places. Usually by the twelfth year there has been sufficient increase in the length of the jaws to permit of an additional tooth, and the permanent second molar gradually takes its position immediately posterior to the first. Between the twelfth and thirteenth year the deciduous cuspids are lost by decalcification of their roots, and they are succeeded by the permanent cuspids. We therefore find, by the fifteenth year, fourteen fully developed teeth occupying the dental arch of each jaw, the full number, thirty-two, or sixteen in each jaw, not being present until the eruption of the third molar which, like the other teeth of this class, is compelled to await accommodations by a further increase in the length of the maxillary bones. This tooth usually takes its place between the eighteenth and twenty-first years, and thus completes the dentition (Fig. 347).

FURTHER CONSIDERATION OF TOOTH DEVELOPMENT

One phase of the subject to which special attention will be given in this chapter is that which denotes the period at which the various events take place. This is a part of the study which is very difficult to determine, and it would appear, for this reason, if for no other, that investigators of recent years have been perfectly satisfied to accept the results arrived at by their predecessors without any apparent effort to qualify the deductions. It has for a long time been conceded that the primitive changes which ultimately result in the formation of a tooth-germ are first noted in a heaping up of the epithelial cells over the district representing the surface of the future jaw. While in many instances this is true, there are reasons why it cannot be considered an essential feature.

In the first place, such a condition is not always present, as shown in figure 348, a transverse section through the primitive jaw of a human embryo about the fortieth day. The tooth bands at *A* and *B* have penetrated the submucous tissue for a considerable depth, but the surface epithelium does not show a greater thickness at these points than it does over the general surface.

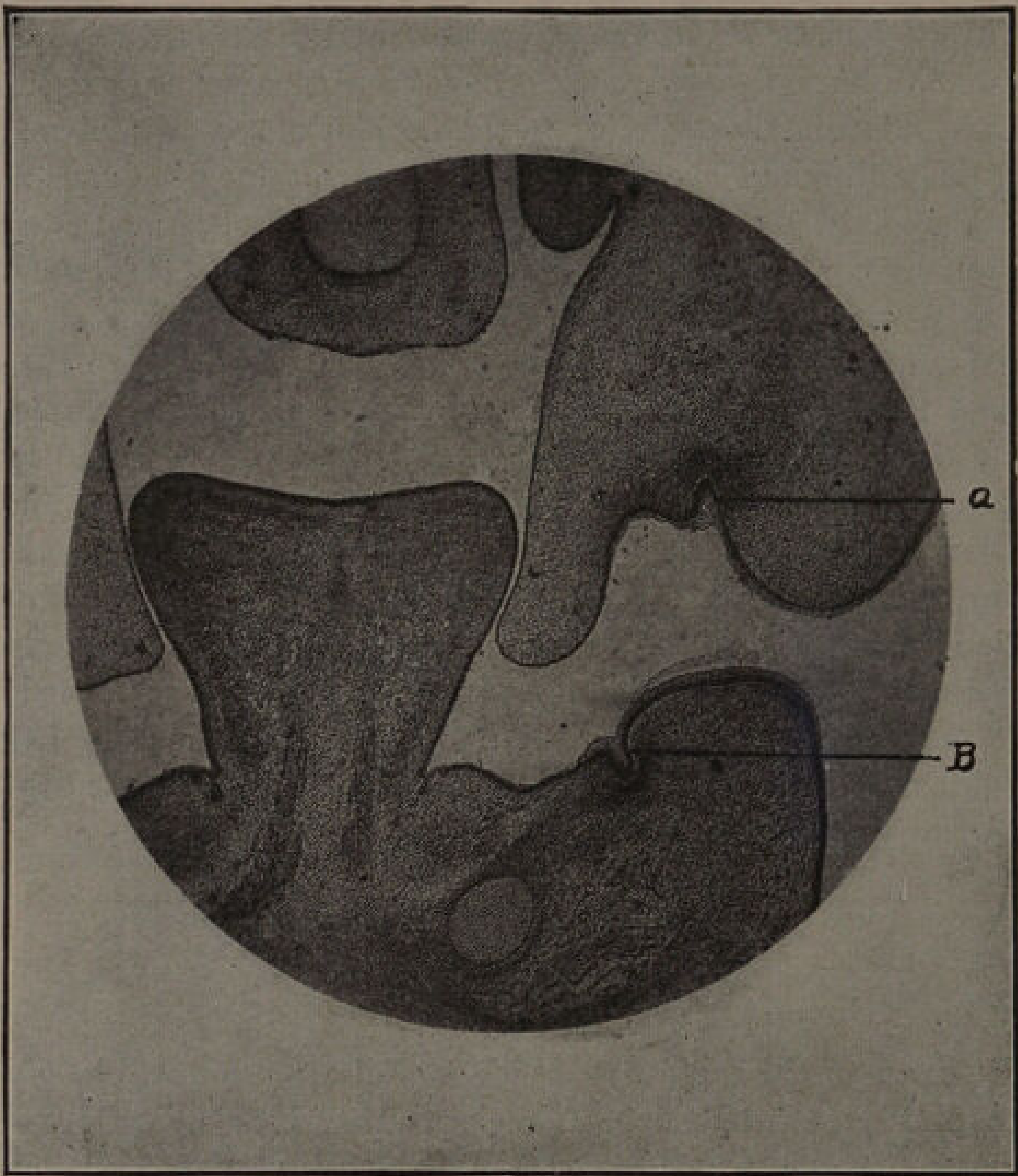


Fig. 348.—Transverse section through primitive jaws of human fetus.

Figure 349 shows a section made in the same direction upon a human embryo about the sixtieth day, and while the tooth-band (*A*) has penetrated the embryonal connective tissue to a greater depth, there is yet no increase in the thickness of the epithelium, but rather a disposition for the parts to become depressed. Another reason why the heaping up of the superficial layer of cells forming the embryonal mucous membrane should not be considered the first sign of the preparation for tooth development lies in the fact that these cells are not directly interested in the process, but that the inflection of cells which results in the formation of the tooth band results from the deep or infant layer of cells known as Malpighi's layer, as shown at *B* (Fig. 348).

There is no question but that the location from which the section is taken has much to do with the character and thickness of the older layer

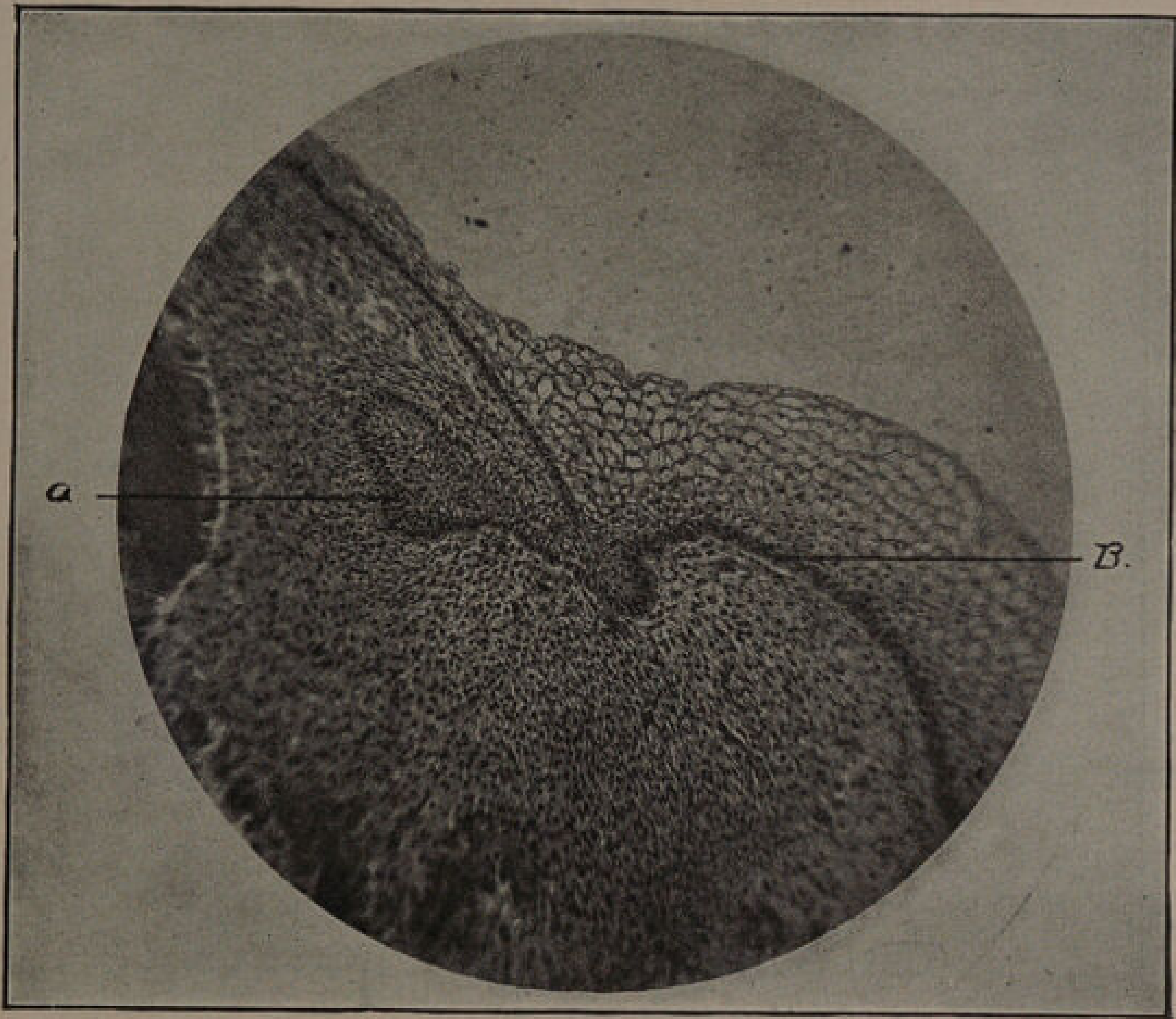


FIG. 349.—Transverse section through lower jaw, human embryo, sixtieth day.

of epithelial cells, and that they do at certain points constitute an epithelium exceeding in thickness that of other parts of the cavity, but this condition most frequently occurs after the enamel organ has assumed definite proportions.

After the formation of the tooth band, which, it must be remembered, encircles the entire jaw in the form of a well-defined body of oval epithelial cells from the infant layer (shown at *A* in cross-section, Fig. 350), the next step in the process is one which concerns the location of the individual buds for the enamel organs of the various teeth, and the approximate time at which these appear.

In the human subject we find ten such spots appearing upon the lamina given off from the lingual face of the tooth band. These do not appear, however, at the free extremity of the band, but at some little distance toward the surface from this point. In this section the tooth-germ is severed from the surface epithelium, but

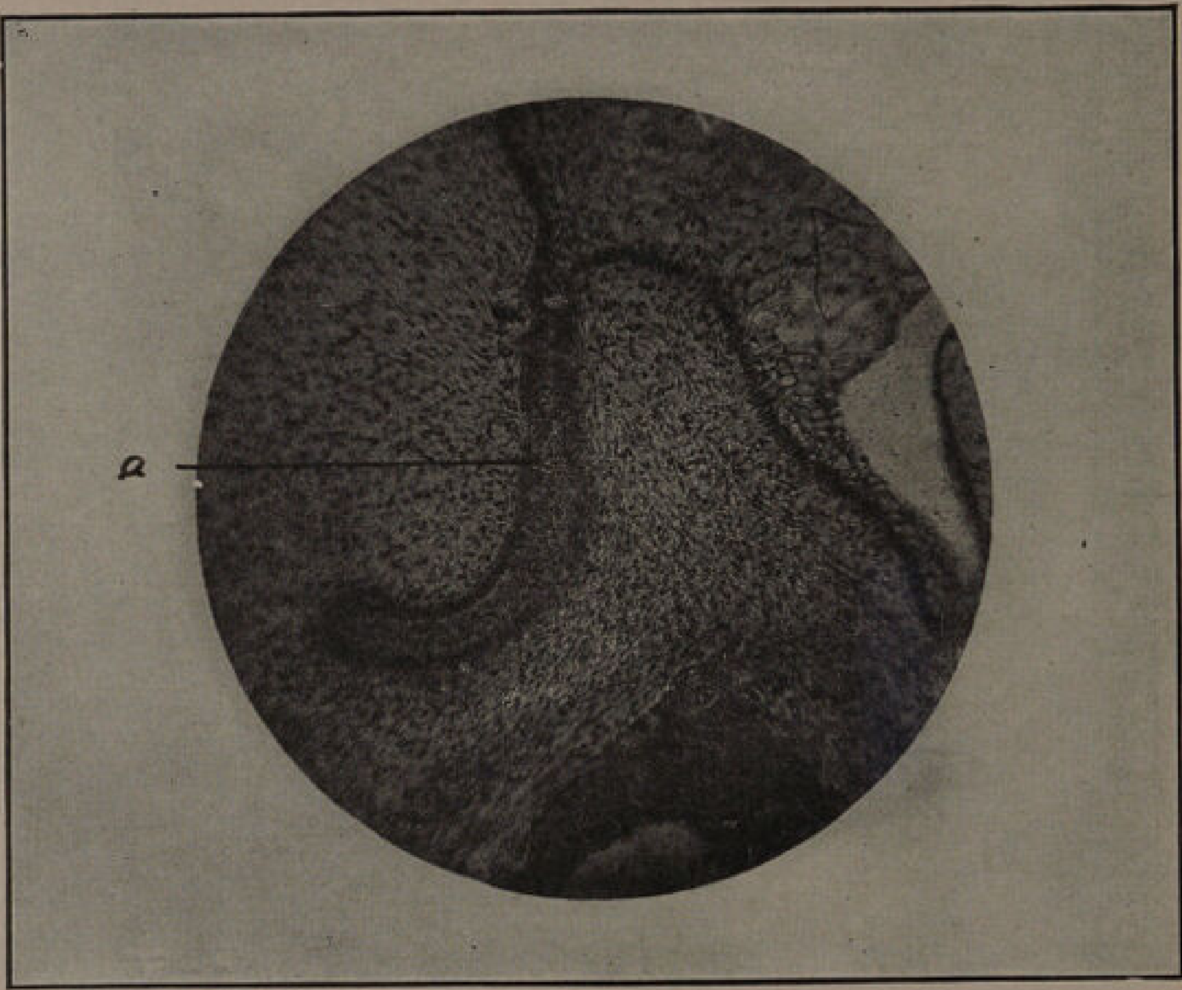


FIG. 350.—Section through tooth band of human embryo.

this is not a true condition at this period, as it still retains its connection with the surface by a narrow band of cells, the neck of the enamel organ. Two distinct classes of cells are now (sixtieth day) concerned in the process of tooth development, those at *A* being of epithelial origin and forming the future enamel organ, while at *B* an aggregation of cells from the mesoblast provides for the generation of the pulp and dentin. At *C* the narrow band of cells which should continue to the surface is shown, while the free extremity of the same body of cells at *D* will persist and eventually become the germ for the succeeding tooth. In regard to the time at which the buds for the various teeth appear, it might be expected that the same variation which follows the development and eruption of the teeth throughout would obtain, but such is not the case, the buds for the deciduous incisors appearing about the sixtieth day, while the germs for their permanent successors are but little later in forming.

The next stage in the development of a tooth to which attention will be called is that in which the entire tooth-crown is outlined by the den-

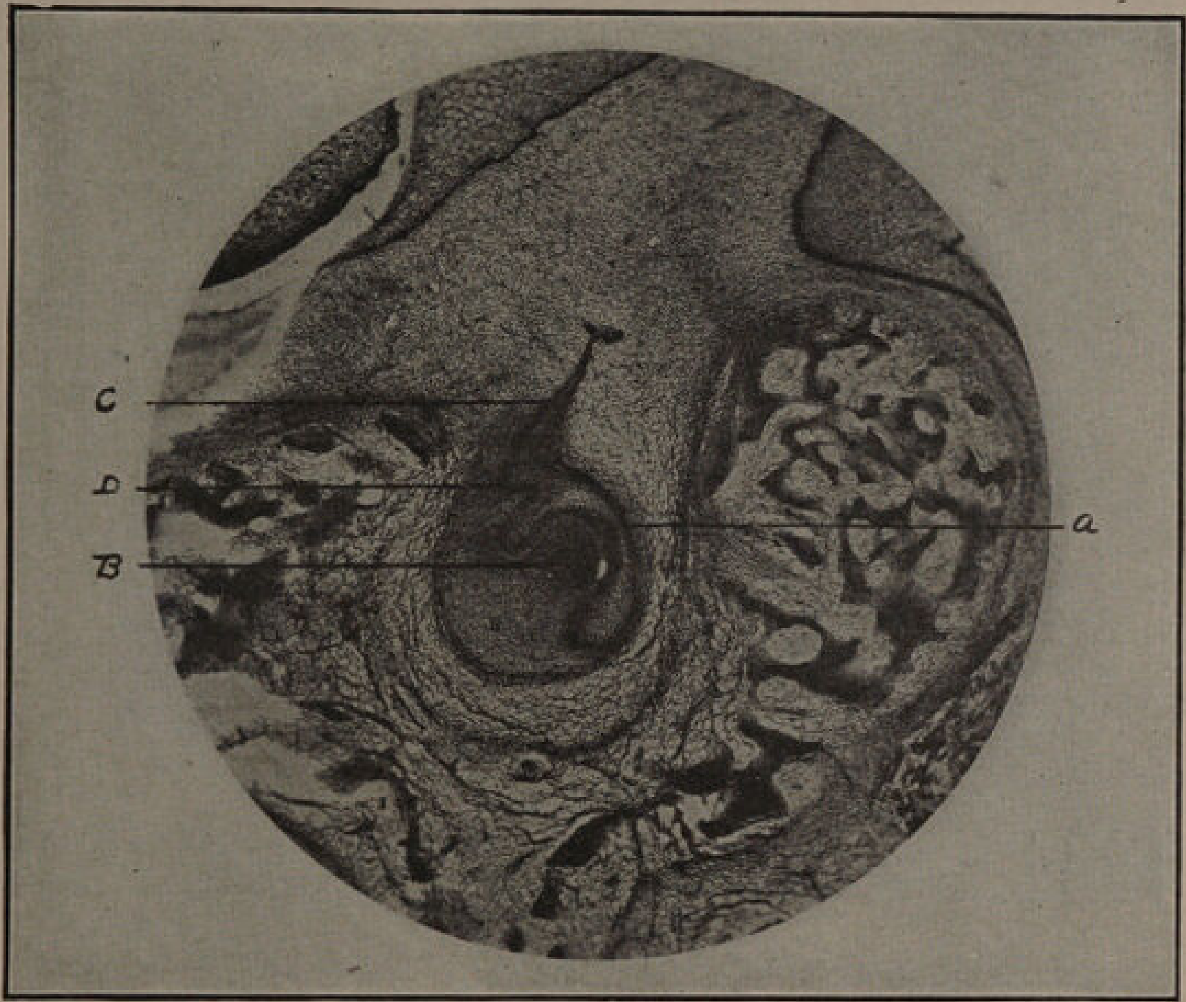


FIG. 351.—Tooth-germ, embryo lamb, corresponding to sixtieth day (human). × 40.

tin papilla and surrounded by its epithelial cap, the enamel organ. Such an advance in the process is shown in figure 351, together with the surrounding structure. When this stage is reached, the individual cells of the tooth-germ are strongly differentiated, and the odontoblasts are making their appearance about the summits of the cusps.

Up to this time the cells present are those which result in the formation of but two of the calcified tooth tissues, but now there is a marked disposition upon the part of the forming connective tissue of the jaw to pass down by the side of the enamel organ (*A*), this being the first indication of the formation of the tooth follicle, the alveolodental membrane, and cementum. At this period it will be observed that there appears in this, the molar region, a "heaping up" not only of the surface epithelium, but also of the connective tissue as well.

Fig. 352.—Tooth-germ, premolar, embryo lamb. × 40.

Figure 353 shows a section through the growing mandible taken from a portion not occupied by a tooth-germ. This is of interest, first, as giving a view of the detached tooth band in cross-section, at *A*; second, by showing the distribution of the periosteum to the interior of the jaw to serve the double function of the future tooth-sac and alveolodental membrane; and, third, the thickened epithelium with the underlying tissue pushing into it.

Although the germ for the second tooth may be observed at a period somewhat prior to this, a study of some of its characteristics is best made at this time. The fact has already been referred to that this interesting phenomenon occurs soon after or even simultaneously with that for the first tooth, a portion of the primitive cord for the latter persisting as the germ for the former.

In figure 354 the cells forming the primitive germ for the enamel organ of one of the permanent teeth are shown highly magnified. It

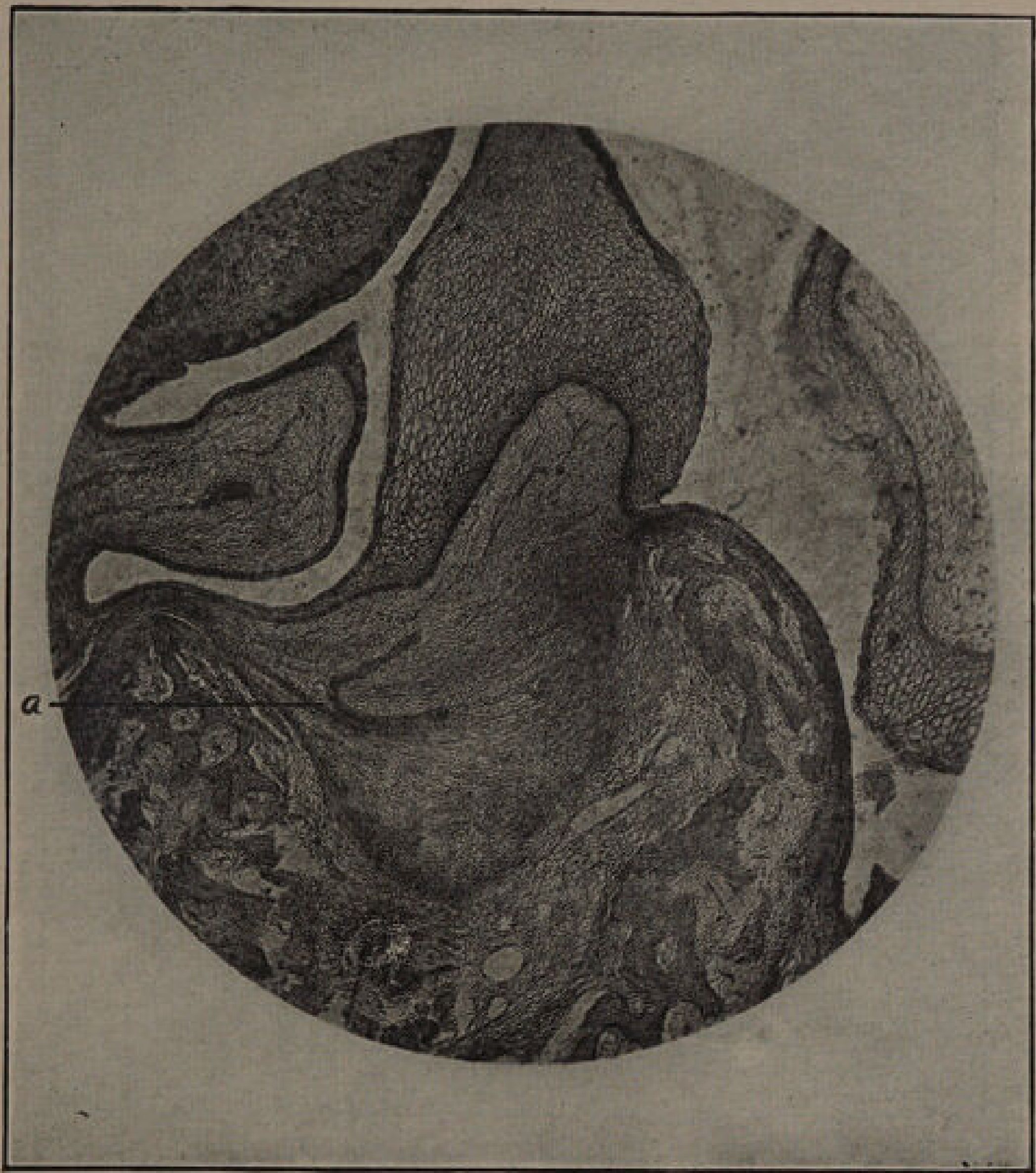


FIG. 353.—Section through jaw of embryo lamb, in a district not occupied by a tooth-germ. × 40.

will be observed that they are of the simplest epithelial character, and that they are derived directly from the enamel organ of the pre-existing tooth, on the one hand, while on the other, they communicate with the surface by a narrow band of cells. In this way it is for a time dependent upon both of these parts for continuance and growth, but after a time it, too, like its predecessor, severs its connection with the surface, but remains intact with the epithelial cells of the former enamel organ until these cells begin to atrophy.

The cells which made up this primitive germ are of three varieties: the inner layer, or those derived from the epithelium of the enamel organ

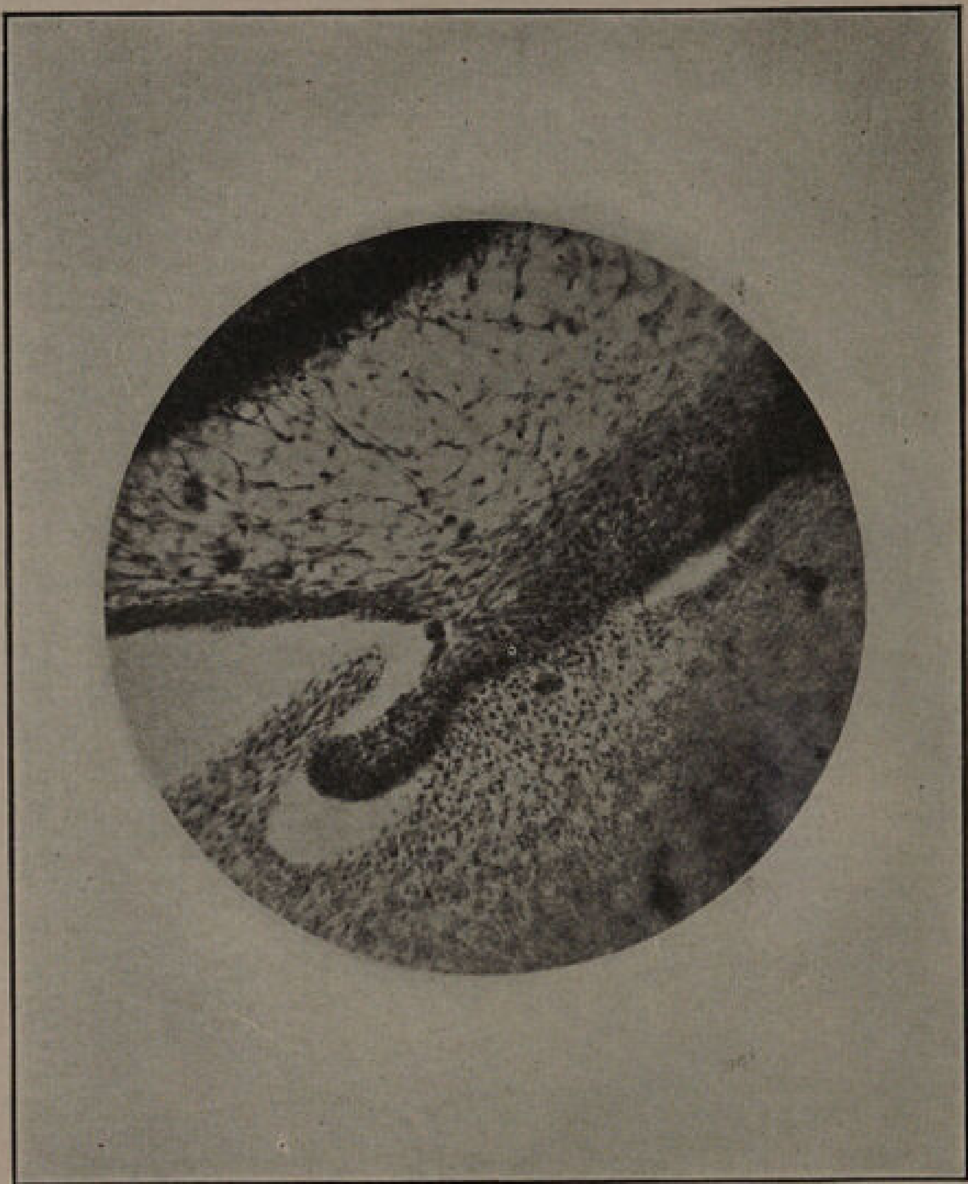


FIG. 354.—Primitive bud for enamel organ of permanent tooth, human embryo. × 300.

of the first tooth, being small and spheroidal; those of the outer layer, which spring from the surface epithelium, being proportionately larger and cylindrical or oblong; while those which intervene are markedly irregular in outline. In this respect—that is, in the character of the early cell layers—the tooth-germs for the permanent teeth differ from those of the deciduous.

The question of the origin of those teeth which have no predecessors is one upon which there has always been more or less discussion, some writers contending that they are derived directly from the oral epithelium by a special generation of cells for each tooth, while others are of the opinion that as the jaw grows backward certain changes take place which result in the establishment of an epithelial fold or lamina, in every particular corresponding to the tooth band of the deciduous teeth. With these two conflicting opinions in mind, a number of sections were made through the extreme distal end of the jaw. The result favored the latter theory, for here the tooth band is seen similar in form and location to that observed in the jaw in those locations from which succedaneous teeth result.

CHAPTER IX

Anomalies of the Teeth

It has always been conceded that the dental organs of man are susceptible of much variation in form and structural arrangement, and that frequently this variation is so positive that the organ is pronounced anomalous in character. Just where the line of distinction between the normal and abnormal should be drawn is a subject worthy of some consideration. Some authorities define the word anomaly as a marked deviation from the normal, while, in the opinion of others, a much broader meaning is accorded it; and we find all those conditions which are in themselves an irregularity from the typical structure or occurrence

FIG. 355.—Anomalous teeth.

included in this category. Under the first definition a given structure or organ is accorded a wide field for its normal existence, while under the latter but slight deviation is necessary to classify it among the abnormal.

Upon first thought it would appear that the ability or inability of a tissue or an organ to perform its special function should, in a measure, decide the question of the nature of its being, and no doubt to a certain extent this is true; but while the action of an organ or a part of the body may, by observation, appear entirely satisfactory, it is only so at the expense of other organs or tissues, and these in the course of time, by this extra exertion, become hypertrophied or in other ways pathologic.

While this is especially applicable to those organs or tissues which have a wide range of function, it may with a good deal of force be applied to the dental organs and their immediate environments. Anomalous conditions in the teeth may originate in, or be confined to, one or more of the tooth tissues, in any of which the structural disarrangement may eventually result in the death of degeneracy of the part. Enamel malformation is of such a character that it may be observed upon the surface either in the form of a multiplication of cusps, or by an extra development of the various ridges formed by pronounced folds of this tissue. But probably the most disastrous anomaly of the enamel, and one frequently responsible for the downfall of this tissue, is found in some defect of its structural arrangement other than those just referred to. In some instances the enamel rods of a given district, instead of being normally distributed by assuming a direction principally at right angles to the long axis of the tooth crown, are arranged without regard to the base or periphery of the tissue, and we have as a result an anomaly of structure. The question of normal and abnormal rod distribution now presents itself, because in certain locations—*i.e.*, the summits of the cusps—an arrangement of the rods similar to that referred to is so common that it may be considered a normal condition, while, if a like distribution were found in other locations, the tissues should properly be considered abnormal.

Malformed teeth, in respect to the number and forms of the cusps present, are not alone confined to the enamel, but also to the dentin which first records the tooth form on its periphery.

Anomalies in the general contour of the tooth crown are usually confined to the incisors and third molars, both the dentin and the enamel contributing to the deformity. Here the defect is usually so pronounced that but little difficulty is experienced in properly classifying the organ. One of the most frequent variations in form met with in these locations is found in the peg-shaped or cone-shaped crown. If it were possible it would be interesting to trace the development of such a malformation; but with our present knowledge of this process in general, there is little doubt as to its origin, the enamel organ failing to fulfill its early and primary function of moulding the tooth crown in the dentin papilla, the responsibility for this resting in the special cells composing it, as well as the so-called stellate reticulum, which, it is believed, exerts a controlling influence over the form of the enamel cap.

While the organic defects of tooth crowns are numerous and varied, those which are confined to the roots are most frequent, in many instances interfering to some extent with the function of the organ. When a given peculiarity is confined to this portion of the tooth, it is frequently difficult to discriminate between the normal and the abnormal. Certain teeth are recognized as normal when either a single root or two roots are present, and the acceptance of this fact increases the difficulty of a proper classification of its peculiarities.

In very rare instances do we find the roots of the cuspidate teeth more or less crooked; yet, at the same time, many decidedly crooked roots are considered within the natural law; while, on the other hand, roots with but little more deflection are classed as anomalous.

Marked flexions of roots or crowns, cases of fusion or concresence, are usually so positive in character than anomalous condition is at once acknowledged. While tooth anomalies are usually referred to as external, or as belonging to the hard tissues of the organ, they are not infrequently found in the pulp or pulp cavity. This cavity, normally following the external contour of the tooth, is subject to much variation in outline and capacity, regardless of those changes which are incident to the continuous process of dentinification.

Among these are a complete division of the pulp chamber; horn-like processes penetrating the dentin in the direction of the occlusal surface in locations where they would be least expected, and unusual number, or a peculiar distribution of the canals, etc.

Lack of Dentition.—Cases in which there is a total absence of teeth have been reported. Guilford reports the case of a man fifty years of age who never had teeth, the jaws not differing in appearance or form from those of a person whose teeth have been extracted. The mother of the subject had the usual number of teeth, but the grandmother and an uncle were both edentulous and hairless from birth. J. Tomes mentions two cases having been reported to him, and Linderer mentions one.

On the other hand, instances of a third dentition have been reported, but there is great possibility of such observation being erroneous. Teeth belonging to the permanent set which may have remained unerupted for years could readily be mistaken as the beginning of a third set, when in after years they made their appearance.

Supernumerary Teeth.—All teeth appearing in the mouth in addition to the normal number are designated as supernumerary teeth. These are divided into two classes, those normal in size and form and those abnormal in size and form. The first-named are most likely to be of the simple class, incisors and cuspids, and they may occupy a regular position in the arch or may be found inside the arch closely associated with teeth of the same type. Supernumerary bicuspids and molars are sometimes present either in regular position in the arch or inside of it. When the jaws are long enough to accommodate them, an additional molar may appear back of the third molar, making four molars instead of three, and cases in which two extra molars were thus placed have occasionally been met with.

Supernumerary teeth of the second class or those which are abnormal in size and form are usually inclined to be cone-shaped and small in size, this in respect to the root as well as the crown. Supernumerary teeth of this character are usually found in the incisor region, but it occasionally happens that they are found in the molar district, but here, instead of having a single cone for the crown, they are mostly made up of a number of smaller cones resembling many small cusps on the occlusal surface. The number of supernumerary teeth may vary from one to eight or ten. In the latter instance they are usually scattered through the entire alveolar border of the hard palate. As many as ten or twelve teeth thus located have been reported.

Again, certain teeth are frequently missing from the arch. This may be occasioned by delayed eruption, or it may be the result of improper activity within the tooth-germ, so that the tooth may have failed to develop. The teeth most frequently missing are the upper lateral incisors. The probable reason for this lies in the fact that the germs for these teeth are located very near the surface of the bone, and in some instances they are not even protected by a thin layer of bone over the follicle. Being thus situated they are more or less exposed to violence sufficient to destroy the germs and thus render development of the teeth impossible. Lack of certain teeth in the mouth appears to be to some extent an hereditary feature, the condition being transmitted from parent to child. Anomalies as to the size of individual teeth are frequently noticed. When this is the case, it does not usually include the entire set, but is confined to one or two, usually to the same teeth on each side. Teeth that are above the usual size are generally found in persons of large build, but if all the teeth are proportionate in size they cannot be included within the abnormal class. The upper incisors are most frequently affected in this way. Cases have been reported which the central incisors in the upper jaw have been fully twice the size which they should normally have been, and all the remaining teeth in the mouth perfect as to shape and size. Accompanying the abnormal condition it is usual to find the teeth thus affected more or less abnormal in outline, but, notwithstanding this, retaining their form sufficiently well to permit their proper classification.

There are likewise teeth that are deficient in size. This does not refer to teeth all relatively small, as frequently found in persons of small frame and stature. This anomalous condition is often present in the upper lateral incisors and in the third molars. Teeth that are deficient in size generally possess their normal shape.

While the crowns of the teeth are susceptible to the above variations, the roots appear to be anomalous much more frequently and to a more marked extent than are the crowns. Most important among these may be mentioned flexions of the roots. Curvatures in the roots may be found either in single-rooted teeth or in multi-rooted teeth, and the point of flexion may be located either at the center of the root or near its apex, or both of these points may be affected. Flexions in the roots of

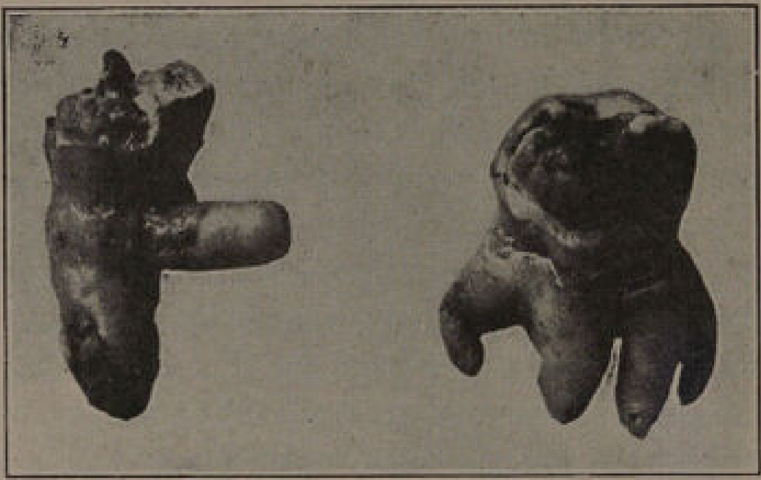


FIG. 356.—Anomalous roots.

the teeth present a great variety in form. A single curve in one direction may be present or a number of curvatures in different directions. In multi-rooted teeth the roots may be so flexed that they will entwine about each other, and the overlapping portions may be or may not be fused. Probably the most important cause for the flexions of the roots of the teeth is delayed eruption, this being particularly true if some positive force prevents the progress of the organ. The roots of the teeth are frequently anomalous in regard to number. These may have the same general form and the same approximate length as the normal root or roots would be, but they are proportionately smaller in diameter. Cases are on record in which the incisor teeth have had two distinct roots, but probably the most frequent location for the multiplicity of roots is found in connection with the third molar. While this tooth when normally developed as to crown is usually supported by three roots, it sometimes possesses five or six smaller roots.

It not infrequently happens that the roots of the teeth are less in number than they should normally be. This is usually brought about by the blending of the roots, which occurs during the developmental stage. This may be of two distinct kinds. In the first place, it may be the result of the conversion of two or more pulp canals into one, or the individual roots may be united by a body of cementum being interposed between them. In the former instance a single pulp canal is mostly found within the blended roots, while in the latter the number of canals is usually normal. With this blending there is generally a line of demarcation between individual roots as they should normally exist, in

FIG. 357.—Fusion of molars.

the way of longitudinal depressions extending through the entire root from cervical line to apex. This anomaly, like that of the multiplicity of roots, is principally confined to the third molars, and is more frequent in the upper jaw than in the lower.

Fusion and Concrescence.—The union of two or more teeth is known as fusion or concrescence, and may occur either during the development of the organ or after this process has been completed. When union takes place during development, it is characterized as *fusion;* when it takes place after the completion of this process, it is known as *concrescence.* There seems to be but little doubt that fusion of the teeth occurs through some irregularity in the tooth-germ or germs, the beginning of the developmental process taking place generally between two germs and continuing together until the complete calcification of the organs. Teeth thus united may have an internal anatomy corresponding in nearly every respect to two separate teeth, and, on the other hand, they may possess but a single pulp chamber and canal. Fusion may take place in the roots of the teeth alone, when it is called *partial fusion;* but when it is confined to the roots and crowns alike, it is classified as *complete fusion.* The teeth most likely to be affected in this way are the upper incisors and the second and third molars. Some distinction must be made between those teeth which are united by a layer of cementum,

FIG. 358.—Fusion and concrescence.

and those of true fusion, the latter existing only when there has been a union between dentin and dentin.

Concrescence.—In concrescence, the roots of the teeth only can be affected, as the union takes place after the complete development of the

FIG. 359.—Fusion and concrescence.

organ. The roots of one tooth become united to the roots of another through an additional growth of cementum, this growth being sufficiently extensive to cause absorption of the alveolar septa by pressure. Following this there is a resorption of the pericementum. The cemental tissues of the teeth are then brought in contact, and coalescence gradually takes place. Concrescence may take place not only between the roots of two teeth, but between the various roots of an individual tooth, this resulting in the same manner as above described by the destruction of the septa within the tooth socket. When concrescence takes place, the processes usually confined to the apices of the roots, although they may become coalesced throughout their entire length. The teeth most commonly affected by concrescence are the molars and bicuspids, from the fact that the alveolar walls, particularly the septa about these teeth are especially thin, owing to the form and relative location of the roots.

FIG. 360.—Geminous tooth.

Geminous Teeth (Fig. 360).—It occasionally happens that two separate germs are confined within a single sacculus, and from this results two teeth, either similar or dissimilar in size and form. One of the pair may be normal as to form and size, while the other may be much below the normal size, but more or less perfect in outline. Geminous or twin teeth may be united or entirely separate. This condition is most frequently found in the molar teeth, although cases in which the bicuspids and incisors have been thus affected are recorded. Teeth thus formed must not be confounded with those in which fusion is the anomaly. In geminous teeth a single sac contains two tooth-germs from which results two similarly formed teeth; in fusion two follicles coalesce, each of which contains its own germ.

Besides the foregoing, the roots of the teeth are subject to anomalies in size in some instances being abnormally small, in others abnormally large. In the former they may nearly always be characterized as anomalous, but this is not always true of the latter. When the roots are abnormally large, it is somewhat difficult to discriminate between an anomalous and a pathologic condition, the latter usually being the case

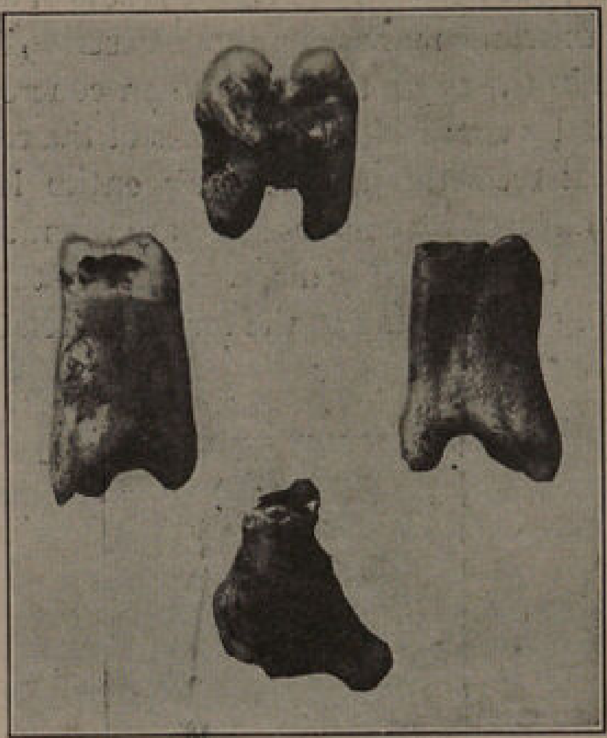


FIG. 361.

when the roots of individual teeth are affected. Roots, to be considered anomalous in size should in a measure retain their normal form, cases

FIG. 362.

of hypertrophy (hypercementosis) usually resulting in the destruction of the normal contours (Figs. 361 and 362).

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