The origin and formation of the dental follicle : The first memoir on the development of the teeth / By Drs. Ch. Legros and E. Magitot. A translation from the French, with introduction and notes, by M.S. Dean. Authorized and rev. by Dr.Magitot, the surviving author.

Contributors

Legros, Charles, 1834-1873.
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Dean, Mason S.
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THE ORIGIN AND FORMATION

OF THE

DENTAL FOLLICLE.

THE FIRST MEMOIR ON THE

DEVELOPMENT OF THE TEETH.

BY
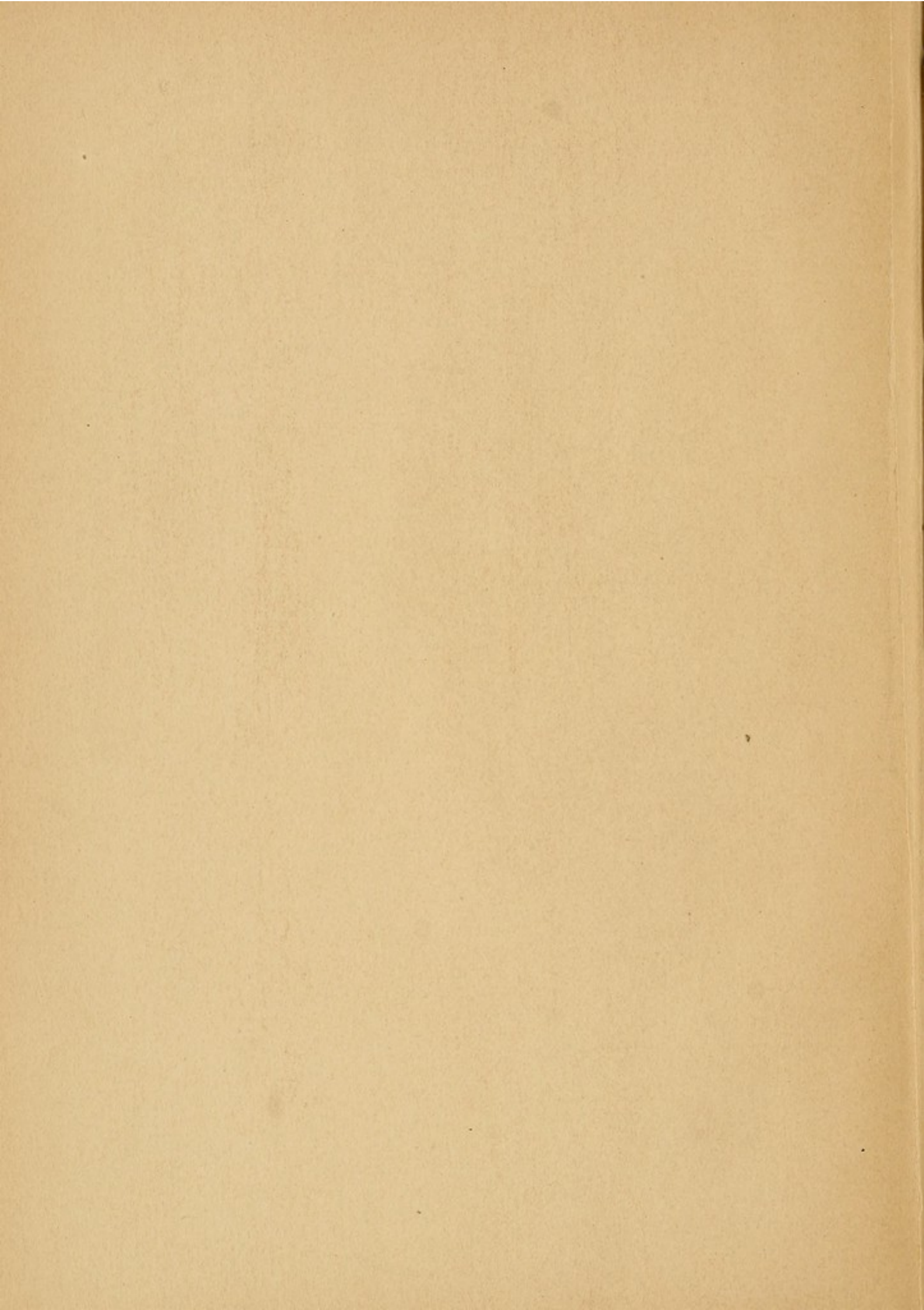
DRS. CH. LEGROS AND E. MAGITOT.

A TRANSLATION FROM THE FRENCH, WITH INTRO-
DUCTION AND NOTES,

BY M. S. DEAN.

AUTHORIZED AND REVIEWED BY DR. MAGITOT, THE
SURVIVING AUTHOR.

INCLUDING ALL THE ILLUSTRATIONS OF THE FRENCH WORK, WITH A
NUMBER OF ADDITIONAL ILLUSTRATIONS, SELECTED AND ORIGINAL.

TRANSLATOR'S PREFACE.

AN apology will reasonably be expected for presenting this translation to the profession. It will require but few words, and I cheerfully offer it. The deficiency and inaccuracy of the literature, in our own language, on the origin and development of the "tooth-germ" and its associate parts, render it almost worthless, as compared with the more recent researches of foreign investigators. The only exception I would make is that of the valuable work of Professor Tomes. If anything more is required, I refer the reader to the following pages, which, so far as I have been able to do justice to the authors, will be their own apology.

Some of you will remember that, nearly twenty years ago, one of the authors of this memoir, Dr. Magitot, in connection with Dr. Ch. Robin, wrote a treatise entitled, *The Genesis and Development of the Dental Follicle, to the Epoch of the Eruption of the Teeth*, a large portion of which was translated for the *Dental Cosmos*.

While the writers of that treatise gave a detailed and elaborate account of the development of the jaws and their anatomical constituents, that portion devoted to the origin and formation of the dental follicle was in many respects incomplete, and in some particulars erroneous.

The improved methods of preparing sections for microscopic examination which have since been adopted, together with the experience gained by many years of study, which one of these authors has since devoted to this and kindred subjects, has enabled him, with the aid of his eminent colaborer, not only to correct the errors of that work, but also to describe these parts more minutely, and with greater exactness than had been hitherto possible.

While the present work traverses a portion of the ground gone over by the previous writers, it is, nevertheless, a distinct memoir, rendered more comprehensive, and more complete in detail, by the study of the development of the dental system not only in man, but in many other mammifera.

Although the work may not be considered as a " practical treatise," in the ordinary acceptation of the term, yet it contains valuable lessons which may be applied in preventing the disastrous consequences of those exanthematous diseases which are so liable to arrest or pervert the nutritive supply to these developing organs, and which often result in the disfigurement, and sometimes in the entire loss, of the teeth. Hence its suggestions should not be confined to the dental surgeon alone, but should be made available by the medical practitioner, who, at the present day, retains almost undisputed possession of this sadly neglected field of practice.

The illustrations, including copies of all those contained in the original, were executed by *Baker*

& *Co.*, of this city; and, while all of them, I think, compare favorably with the woodcuts found in similar works,— some of them showing the minute detail of the parts during the different stages of development,— are remarkably faithful to nature.

How well the work of the translator has been done must be left for others to decide. It may be proper to state, however, that it has been submitted to Dr. Magitot, and meets with his unqualified approval.*

The conversational style in which many of the notes have been introduced, may be regarded by some as unsuited to the character of a severely scientific work. However this may be, it certainly affords the translator opportunities of presenting, in an easy and familiar manner, the views of different authors, and some other valuable matter, which he believes could not otherwise be introduced without apparent abruptness. He believes, also, that the plan here adopted will relieve the monotonous strain upon the less scientific reader, and that the facts thus brought out will be more vividly impressed upon most minds than if presented in the ordinary way. If this be so, no other defense is necessary.

The adjectival terms denoting the species of embryos — as *equine*, *bovine*, etc., and corresponding to that of *human* — which have been adopted

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* Extract from his letter, Paris, Sept. 8, 1879: "*Je trouve cette traduction parfaite, et je reconnais que votre* 'Translator's Introduction' *est très ingénieuse pour préparer le lecteur à l'intelligence du mémoire.*"

in the translation, I think, cannot be regarded with disfavor; the propriety, if not the necessity, of their employment in works of this kind seems to me unquestionable.

My labors upon this work have been lightened by the encouraging words of many leading members of the medical, as well as the dental, profession; and to my esteemed friend and eminent fellow-practitioner, Dr. G. H. Cushing, I am indebted for much kind assistance in preparing this treatise for publication. And especially to Dr. Magitot, the illustrious author of many scholarly contributions to science, I must offer my grateful acknowledgments for the cheerful aid he has so promptly rendered me in the execution of this work.

M. S. D.

34 MONROE STREET, CHICAGO:
    October, 1879.

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TRANSLATOR'S INTRODUCTION.

[TEACHER AND HIS PUPILS, CASPER AND FRANK.]

TEACHER: I propose to consider the Origin and Formation of the Dental Follicle in Mammals; and for this purpose I shall read the valuable memoir of Drs. Legros and Magitot, which furnishes the most complete account of these phenomena of any work within my knowledge. I shall use this treatise as a text, elaborating as we proceed, whenever suggestions may occur to me, or in response to questions from you. In this manner we may hope to arrive at a satisfactory understanding of the subject.

§ I.—MUCOUS MEMBRANE.

You are presumed by these authors to be acquainted with the general anatomy and physiology of the parts from which the teeth are

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directly derived. Indeed, without this knowledge you cannot obtain a very clear idea of the origin and evolution of the tooth-germs, even from the minute description given in these pages. I think it will be well, therefore, before commencing our readings, to hastily review the parts immediately concerned in the production of the teeth, and especially the epidermis or epithelium, which constitutes the external layer of the mucous membrane.

CASPER: I ought to have a pretty fair knowledge of these parts; if not, it is no fault of mine, for I have faithfully studied Biesiadecki, Kölliker and Klein; and yet I must confess that my knowledge is badly confused, especially in regard to the mucous membrane; for these authors do not represent this tissue by descriptive figures, as they do the skin. Besides, the names given to the different strata are a good deal mixed; so that I think a review of the subject will not be a waste of time.

TEACHER: The difficulties you have encountered do not surprise me; for I have myself had considerable trouble in determining even the location of the layer which some authors have described under that name. For example:

(1) According to some authors, the *epidermis* alone constitutes the mucous membrane (Guillot and others).*

(2) According to others, the mucous membrane consists of *three* membranes, viz., "an epithelium, a proper mucous, and a fibrous coat." "The second coat, the *proper mucous membrane*, is apparently *without texture*. The third coat corresponds to the corium of the skin."

This is Prof. Hand's definition of the mucous membrane, and essentially that of Prof. Leidy. Here we have the term mucous membrane used both in a general and a special sense, as a whole and as an integral part; the mucous membrane consisting of *three layers*, one of which is the *proper mucous membrane*, and the latter seems, from its description, to be identical with the "basement membrane" of Todd and Bowman,

* Prof. Wedl, in his "*Pathologie der Zähne*" (Leipzig, 1870), under the heading of *Development of the Teeth*, designates the mucous membrane as an *epithelial* structure, and calls the enamel-organ a follicle of *mucous cells:* "Dieser Schleimzellenschlauch wurde von Kölliker als Schmelzkeim bezeichnet." This phraseology, to one who had studied Frey, Magitot, Kölliker, Flint, Klein, and many other physiologists who have described the mucous membrane, would render Wedl's description unintelligible.

the "intermediate membrane" of Henle, and the "membrana propria" of Kölliker and others.

(3) According to others, again, the layer situated immediately *beneath* the *stratum Malpighii* (and which corresponds with the corium or dermis of the skin) is "the proper mucous membrane" (Kölliker, Klein, Flint, Frey and others). These authors, however, designate the lower portion of the epidermis of the skin by an equivalent term, *mucous layer;* but occasionally they use the expression mucous membrane in its *general* sense.

(4) Again, Dunglison and many other authors employ the term mucous membrane in its broader sense, as *including* the "epidermis" and the subjacent layers.*

You see, therefore, that the study of this membrane is rendered unnecessarily difficult by the numerous and often contradictory terms which different writers use in describing it.

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*Dunglison says: "In the mucous membrane the same superposition of strata is generally considered to exist as in the skin, viz., epidermis or epithelium, rete mucosum, corpus papillare, and cutis vera."

M. Flourens divides all the mucous membranes into three layers—the derma, epidermis and corpus mucosum.

Kölliker and those of his school divide the mucous membrane (as a whole) into the following layers, counting from the external:

(1) *Epithelium;* (2) *membrana mucosa* (the proper mucous membrane); (3) *submucosa* (submucous membrane), *tela mucosa,* etc.

FIG. 1.

		1st Class.	2d Class.	3d Class.	4th Class.
Mucous membrane.	Epidermis. { Strat. corn.				Mucous
	Strat. Malp.	M. memb.			
	Basement memb.		M. memb.		
	Dermis { Pars pap. / Pars ret.			M. memb.	memb.
	Subdermis.				

FIG. 1.—The above diagram shows the relative position of the different layers which are designated the mucous, or "proper" mucous membrane by various writers. The column on the left gives the names, and location of the strata of the mucous membrane as we think they should be designated. The horizontal lines show the relative location of these layers, without any regard to their thickness.

Some of these authors call the external portion of the "membrana mucosa" the chorion, corium or derma. They also divide the "proper mucous membrane" into two layers, the *papillary* and the *reticulary.*

Huxley says the skin and mucous mem-

brane "may be distinguished into *three* por-
tions; a central plane of indifferent tissue [the
basement membrane], from which, growth and
metamorphosis take place externally, to consti-
tute the representative of epidermis or epithe-
lium, to which we propose to give the name of
ecderon ; while internally, growth and meta-
morphosis take place from the central plane, so
as to constitute the representative of the derm
or 'mucosa,' which we have termed the *en-
deron."**

Now, since the terms employed by different
writers to designate the layers of the skin and
of the mucous membrane are so various, and
sometimes conflicting, I shall apply the *same
terms* to the corresponding strata in both of
them, as follows:

(1) The term *epidermis* will comprehend the
whole of the external epithelial layer, whether
it be of the skin or of the mucous membranes.
(2) The term *dermis* will be applied to the
stratum immediately subjacent to the epidermis,
and which is known by the various terms, cu-
tis vera, corium, mucosa, proper mucous mem-

*Appendix to the Sydenham edition (4th edition) of
Kölliker's *Histology*.

brane, etc. These two layers will be subdivided,— the epidermis into two strata — the *corneous* and *Malpighian*;* the dermis also into two parts, the *papillary* and *reticulary*.

The tissues next subjacent to the dermis will be known as the *subdermis*, corresponding to the subcutanea, submucosa, tela mucosa, etc.

In thus applying these terms I make no new departure in our nomenclature, but merely employ the old ones more systematically, and, I think, more rationally.

It must be confusing to the student to find the *lower layer of the epidermis* of the skin, and the layer that lies *beneath the epidermis* of

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* The Malpighian layer, as defined by most authors, includes those epithelial cells (of the epidermis) that lie subjacent to the horny layer, whether their form be columnar, polygonal or otherwise; but some authorities, among whom are Legros, Magitot, Tomes and Küss, limit the term *stratum Malpighii* to the lowest layer of cells, which stand vertically, like palisades, upon the surface of the dermis. This single layer of columnar, or cylindrical cells, as they are sometimes called, is also termed the *prismatic* layer by Legros and Magitot,— a term which is, to my mind, definite and not liable to mislead the student; and hence will be employed in the following translation wherever it occurs in the original.

the mucous membrane,— parts which are locally, anatomically, and functionally, different,— both designated by the same name; and *not* to find a *dermis beneath* the epidermis. The term *dermis* cannot be objected to, as applied to a layer of the *mucous membrane*, since the growths originating in this stratum are universally denominated *dermal* tissues. '

For the reasons here stated, I believe I am justified in adopting the simple system of terminology indicated above.

With this designation of terms, we will proceed with our description of the mucous membrane, and *more especially* the exterior layer — the *epidermis*, from which the tooth-germs directly originate.

The *mucous membrane* and the *skin* are anatomically analogous and continuous structures. The first clothes the internal, and the other the external, surfaces; and the description of the one will, with slight modifications, apply to the other. In a general sense, they are composed of two strata or layers, the *dermis* and the *epidermis;* yet for convenience of description, rather than for any other reason, they have been variously subdivided.

The external stratum, the *epidermis*, composed entirely of epithelial cells, has been described as consisting of two layers — the external being termed the *corneous* and the internal the *Malpighian*. The "scarf-skin" raised on the external surface of the skin by a blister, and the pellicle detached from the palate by hot drinks, represent the corneous layer of the epidermis; by some authors this is called the "true epidermis," and by some the "cuticle." This layer is composed of the old epithelial cells which have ceased to perform any of the vital functions. The subjacent layer, formed of living epithelial cells, which vary in form and size, is denominated (among many other terms) the *stratum Malpighii*.

Underneath these two subdivisions of the epidermis of the mucous membrane (according to the nomenclature here adopted) we shall find the *dermis* (*derm* or *derma*). But lest I should mislead you I will mention here that there is a transparent amorphous pellicle which separates the lower stratum of the epidermal cells from this latter layer. This structureless tissue is described by Todd and Bowman under the name of *basement membrane*, and by Henle under that

of *intermediate membrane.* Now, although the existence of a "membrane" here is disputed by many, yet there can be no doubt that a homogeneous structure is interposed between these layers, and that in some parts it presents the character of a *membrane* of considerable thickness. This membrane is of peculiar interest to the dental physiologist, since the dentine-bulb and the enamel-organ will be found on the opposite sides of it. In this situation it constitutes the *membrana præformativa* of Raschkow. This tissue is not usually reckoned among the layers of the skin and mucous membrane; and its further discussion here, as a preformative membrane, would be but to anticipate what will follow in the body of this work.

Inasmuch as the elements of the epidermal membrane (the epithelium) play the most important part in the development of the teeth, as will be seen, hereafter, a more minute description will be given of them than of those of the subjacent stratum.

These elements are derived from the *external germinal* layer — the corneous leaf or plate, (Remak), or the *epiblast,* as it is now more generally called. They are developed at an earlier

period in embryonal life than are the connect-ive-tissue cells of the middle or intermediate layer — the *mesoblast*, from which the dermis originates.

As early as the 35th day (as nearly as I am able to ascertain) the epidermis presents two layers of cells; but at this period it cannot be regarded as a membrane composed of two lam-inæ, for the external cells have not yet attained the requisite age to mature them into the horny bodies that constitute the corneous layer. The cells constituting the epidermis must, therefore, though differing in form, be regarded, at this stage, as belonging exclusively to the Malpigh-ian stratum (in its broader sense). But soon the transforming hand of time will convert them into the corneous layer; when the oral epider-mis will be, like that of the skin, divisible into two laminæ.* If we examine these two epi-

* In his last edition (5th), under the head of "*Epithe-lium of the cavity of the mouth*," Kölliker remarks that "the elements that constitute this epithelium [epidermis] are not divisible, like the epidermis [of the skin], into two clearly distinct laminæ, but constitute one connected layer, more resembling the mucous layer, but representing also the corneous layer."

It may be true that in some portions this epidermis

dermal strata of the mucous membrane more closely, we shall find them composed of quite regular layers of epithelial cells, which (commencing with the lowest) may be described as the *infant* cells, the *youthful* cells, the *adult* cells, the *aged* cells, and the *dead* cells.

The cells composing the *stratum corneum* belonged in their *infancy* to the lowest layer of the stratum Malpighii; in their *youth* to a more external layer known as the "prickle," "spinous," "ridged," "aculeated," or "imbricated" cells (all of which terms are applied to cells represented in Fig. 2). In their *middle life* they belonged to the polygonal

FIG. 2.

FIG. 2.—" Spinous," "ridged," or "imbricated" cells. (From *Frey*.)

cells ("pavement, or tessellated epithelium"), which lie still nearer the surface; and in their *old age*, to the elongated, flattened cells, in which the nuclei have nearly disappeared; and finally,

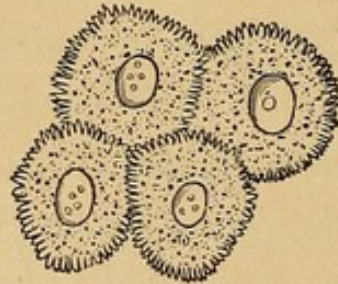is not so *readily* divisible as that of the skin; but it is known with what facility a pellicle may be raised from the palatal portion — the rugæ for example — by drinks that are not sufficiently hot to produce the same effect upon the skin.

as *dead* cells, they occupy the most outward, the corneous layer of the epidermis.

The cells of the lowest layer (the infant cells) stand vertically, like palisades, upon the basement membrane (*c*); which latter separates the epidermal from the dermal stratum of the mucous membrane; or in other words, the basement membrane separates the epithelium from the "mucosa," "proper mucous membrane," or "corium." These cells, which may be likened to the blocks of a Nicholson pavement when set in position, constitute what is called variously the prismatic, columnar, cylindrical, and, perhaps less properly, the Malpighian layer. They have large oval nuclei, and are said to be destitute of a cell-wall. In the embryo (according to Henle) they appear like a stratum of protoplasm regularly studded with nuclei. This layer of prismatic cells offers additional interest to the dental student, since it constitutes the peripheral portion of the enamel-organ, including that *spe-*
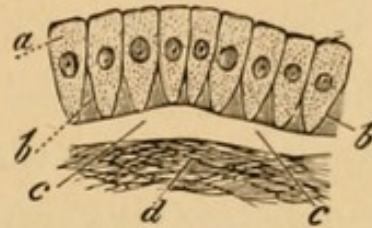

FIG. 3.

FIG. 3.— *a*, cylinder, columnar or prismatic cells of the mucous membrane, or "infant cells"; *b*, intermediate matter; *c*, basement membrane; *d*, fibrous tissue of the dermis. (From *Frey. Diagrammatic.*)

cial area which, during the course of development, will be known as the "*enamel-membrane*" ("*internal epithelium* of the enamel-organ" of Kölliker, or "membrana adamantina" of Raschkow), and which here either is *converted* into enamel or *produces* it. But more of this anon. The next layer or layers of cells (the youthful) have grown larger, and, besides their imbricated appearance, are surrounded by a thin cell-wall, *periplast* (Huxley), or *formed material* (Beale). The cells external to these assume larger proportions and are more polygonal in form, and represent these cells in their *middle life*. The cell-wall, or periplast, has increased in thickness, while the nucleus has proportionally diminished in size.
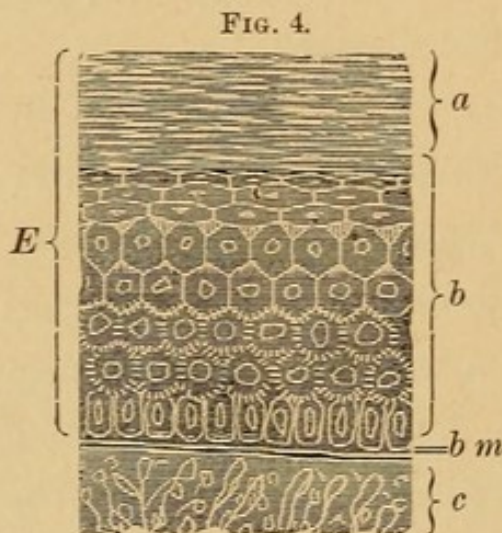
FIG. 4.

FIG. 4.—This cut was designed to illustrate the cells of the epidermis. *E*, in some of their various phases, as described above. *a*, Stratum corneum; *b*, stratum Malpighii, with its *prismatic* or columnar layer resting upon the basement membrane *b m*; *c*, the upper portion of the dermis. The papillæ are not represented in this figure, nor is the subdermal layer.

The cells still external to these are the *aged cells*, and the nearer they approach the corneous stratum the larger will be the amount of "formed material" that surrounds the nucleus; till at last only a trace of the latter is visible, or it entirely disappears, and these cells enter the horny layer and become the *dead cells* — a lifeless protecting covering for the living elements that are growing up beneath.

Thus these cells, during their passage from the *internal to the external surface*, have undergone all these changes, until from prismatic or columnar cells they have finally become *thin, lifeless scales*, which are continually cast off as foreign or effete matter. During the entire life of a person these cells are continually passing away; and hence the production of new generations of them must be equally incessant. This reproduction takes place from the lower layer of vertical cells, *i. e.*, the cells that constitute the prismatic or columnar layer; at least this is now the most generally accepted opinion of physiologists, though with some respectable exceptions.

The external layer (*stratum corneum*) of the mucous membrane, unlike that of the skin, is

permeable by various kinds of liquids; which, after passing through the softer portions of the epidermis and the basement membrane, may be absorbed by the vessels of the *dermis* (proper mucous membrane, corium).*

Now, lest your patience be too heavily taxed, we will take only a very hasty glance at the subjacent layer of the mucous membrane, ignoring, for the time being, the existence of the basement membrane.

Lying immediately beneath the epidermis we find a fibro-vascular membrane of variable thickness, which we call the *dermis* (the proper mucous membrane, the mucosa, mucous layer,

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* Kölliker (Loc. Cit., 5th ed.) says: "The epithelium of the mouth, though thick, is very pervious, a characteristic which distinguishes it from the epidermis [of the skin], of which the mucous layer [stratum Malpighii] alone possesses this quality. It allows the various kinds of liquids to pass through it from without inward, which, when brought in contact with the *mucous membrane* [the dermis], may be absorbed by the vessels, or become cognizant to the nerves received by this membrane."

Kölliker does not recognize the existence of nerves in any part of the epidermis. If the experiments of Langerghans and Podcopaëw are reliable, the liquids need only enter the Malpighian layer to be brought in contact with the nerve filaments that penetrate this soft layer.

cutis vera, corium, chorion, etc.) This is continuous with the dermis of the skin, and gradually merges into the *subdermal areolar tissue,* with which it is strongly and intimately connected. The external portion of the dermis is known as the *pars papillaris* (papillary part), and the subjacent portion as the *pars reticularis* (reticulary or netted part). But we cannot dwell upon these particulars, which do not, in fact, exist in the dermis at the early period of embryonal life when the development of the teeth commences. I will say, however, that the prominent constituents of the dermis are the connective-tissue elements; but, as before stated, the cells of the *mesoblast,* to which this layer belongs, are not developed at so early a period as those of the *epiblast,* from which the epidermis is derived. For example, till the forty-fifth day of gestation, and perhaps later, the *dermis* is represented by a nucleated mass of embryonal tissue, in progress of evolution, while at the same stage the *epidermal* cells are completely developed.

From the external surface of the dermis rises the *dentine-bulb,* or *dentinal papilla;* though many authors state that the papilla originates in the "submucous" tissue. This latter tissue or

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membrane corresponds with what I have termed the *subdermal tissue.* But to me it is evident that the dentinal papilla first appears as a little nodule upon the surface of the layer subjacent to the basement membrane — *the dermis.*
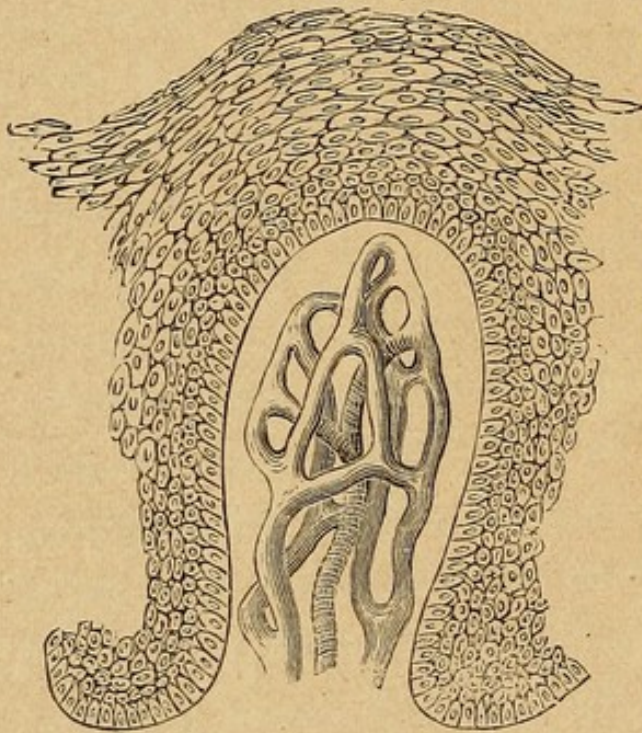
FIG. 5.

FIG. 5.—This cut is taken from Kölliker's *Man'l of Hist.* It has been widely copied by histological writers, and represents "a simple papilla [of the mucous membrane] with manifold vessels and epithelium, from the gums of an infant, magnified 250 diam." It is given here principally to show the epidermal covering, though the cells are represented only approximately correct, the figure being designed mainly to illustrate the vessels of the papilla. It will be observed that the "ridged" cells do not appear in this.

With this imperfect description, which has been confined mostly to the situation of the layers, and to some of the more conspicuous elements of the mucous membrane, I must drop this fascinating subject; hoping, however, that what has

been said will repay the time it has occupied, and more especially that the little information you have thus gained will stimulate you to seek a more thorough knowledge of this very important, and very extensive, branch of histology and physiology.

§ II.—THE EARLY DEVELOPMENT OF THE JAWS; AND MECKEL'S CARTILAGE.

As *Meckel's cartilage* is alluded to in the first pages of the following treatise, perhaps I had better anticipate your questions in regard to it; for a description, that would be at all satisfactory, would make too long a break in the text.

FRANK: I have seen this cartilage mentioned in various works, but never described; and I am curious to learn something of this, to me, mysterious organ.

TEACHER: Since our medical and dental literature is so reticent in regard to this important embryonal structure, and the authors of this work scarcely more than allude to it, I will give you a very brief historical account of it. The facts that I shall give you regarding it have been gathered mainly from a treatise written by Drs. Magitot and Robin (the first named being one

of the authors of the present work), in which this subject is very fully elaborated, and from which most of the illustrations here given are copied.

I will commence at a period some ten days anterior to the origin of the cartilage, and briefly sketch the progressive development of the jaws till it makes it appearance; and then trace their phenomena together to the time when it disappears.

If we examine a human embryo of fifteen to eighteen days (total length, little over half an inch), we shall find two tubercles which proceed from the first visceral arch, and which, when developed, will constitute the lower jaw. These *tubercles, processes, tongues, apophyses* or *bourgeons* (take your choice of these terms) gradually approach each other until they unite at the median line, and, at a *later period*, become ossified.

This union takes place about the twenty-eighth day, at which period the embryo has attained perhaps three-fourths of an inch in length. But coincidently with the growth of these two processes, two other bourgeons, or buds, shoot out from the same " visceral arch " to form the superior maxilla. (Fig. 6, 5, 5). (Fig. 7, g, g).

The growth of these is also toward each

other; but, unlike the former two, they never unite with each other nor meet at the median line; for there is still a *third pair* of bourgeons, called the incisive or intermaxillary, which arise from the forehead or frontal apophysis; and these, in their downward growth, occupy the central portion of the open space between the maxillary processes. This will be seen by a glance at Fig. 6, 4, and Fig. 7, H, although
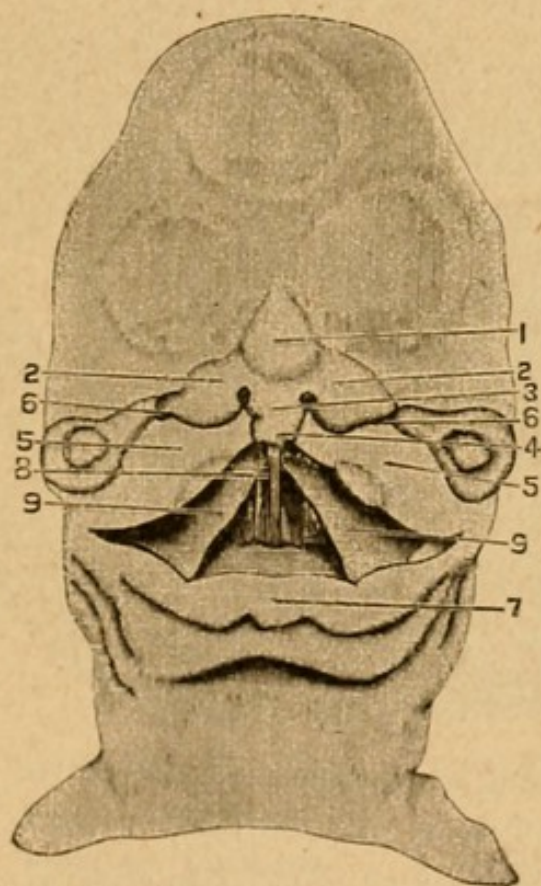

FIG. 6.

FIG. 6.—Mouth of an embryo of forty days. (Coste.) 1, First appearance of the nose. 2, 2, First appearance of the alæ of the nose. 3, Appearance of the closure beneath the nose. 4, *Middle or median portion of the upper lip formed by the approach and union of the two incisive processes;* the little notch in the median line still indicating the primitive separation of the two processes. 5, 5, Superior maxillary processes forming the lateral portion of the upper lip. 6, 6, Groove for the development of the lachrymal sacs. 7, Lower lip. 8, Mouth. 9, 9, Lateral halves of the palatine arch, already nearly approximated in front, but still widely separated behind.

they have, in these cuts, already united with *each other* at the median line. These last-named processes, when ossified, will constitute the *intermaxillary* bones. A line, faintly representing the point of union of these two processes, may be seen in Fig. 7, but is not portrayed in the
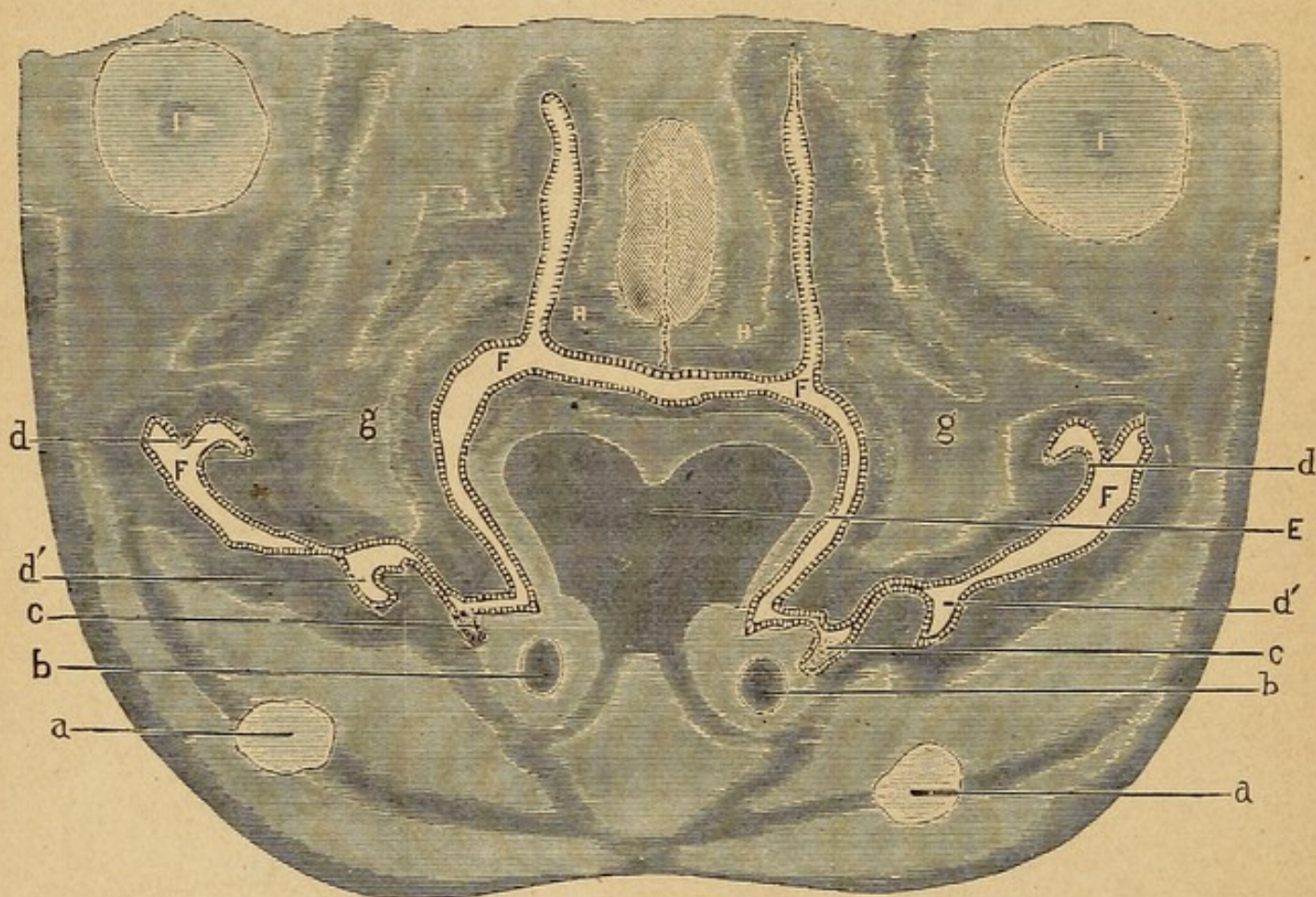
FIG. 7.

FIG. 7.—A vertical section of the anterior part of the face of a human embryo of forty to forty-five days. Magnified 80 diameters. (Magitot.) *a, a,* Meckel's cartilage; *F, F, F, F,* the mouth; *g, g,* superior maxillæ; *H, H,* incisive, or intermaxillary processes; the perpendicular line showing their point of union with each other.

original plate. It is added here to avoid giving you the impression that this is a *single* process. There is a slight notch or cleft still remaining at the lower margin, between the intermaxillary processes (Fig. 6, 4), which in a subject a few days older would have been closed.

Soon after the intermaxillary processes have become united with each other (say in five to eight days), their free lateral margins form a juncture, and coalesce with the advancing superior maxillary processes, thus closing the vertical clefts seen in Fig. 7 (above the letters F), with the exception of two small apertures for the nostrils. (Fig. 6, 2, 2.) All these processes are outgrowths from the mesoblastic layer, clothed externally with a coat of epithelium from the epiblastic.

From this brief sketch of the mode of development of the maxillary and intermaxillary processes you will readily comprehend the origin of that common malformation known as harelip. When from any cause one of the maxillary bourgeons fails to unite with the intermaxillary process, we have "simple hare-lip"; a similar failure on both sides results in "double hare-lip." If, in addition to these lateral fissures, one occurs at the median line (which is not frequent), we

have "complicated hare-lip." Occasionally there is the central fissure alone, in which case the intermaxillary processes have failed to coalesce with each other — a rare occurrence.

We will now return to the lower jaw. As before stated, the processes (sometimes called the *mandibular*), from which this maxilla is developed, meet, from about the twenty-fifth to the twenty-eighth day, and form a union with each other at the median line. (Fig. 6, 7.) Very soon afterward a little *cartilaginous band* makes its appearance (" by direct genesis "), and occupies the central portion of the embryonal mass that now represents the lower jaw. This is

MECKEL'S CARTILAGE

in its incipient stage of development. It is a small whitish cord, lying in a bed of soft transparent tissue, and may be easily distinguished by the aid of a low magnifying power; and by careful manipulation it may be removed entire from the surrounding mass for examination. This cartilage was first noticed and described (in 1820, I think,) by the celebrated German anatomist whose name it bears. It gives *form* and *stability* to the lower jaw of the embryo, serving as a temporary

skeleton, from an early period till it is no longer needed for that purpose. It is composed of two symmetrical or homologous parts (corresponding to the right and left sides of the jaw), which soon become united at the *mental symphysis*. From this point of juncture they extend, one on either side, to the frame of the *tympanum*, where they terminate in the malleus. (Fig. 8, *b*.)
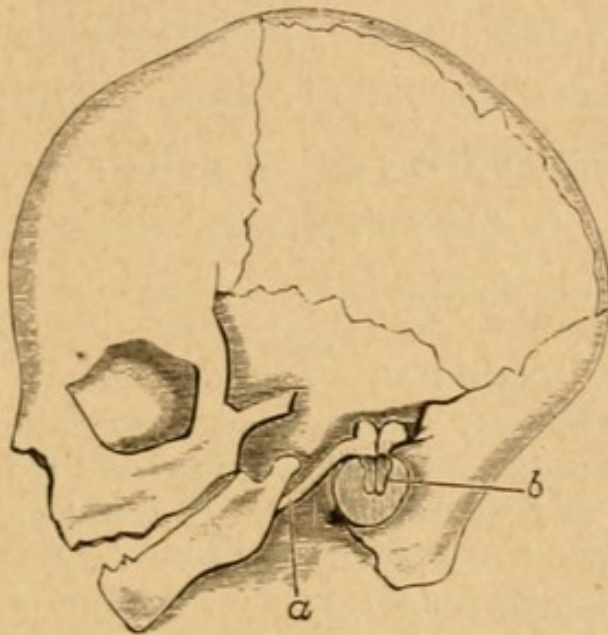
FIG. 8.

FIG. 8.—Cranium of a human fœtus of four months, natural size. Dissected for the purpose of showing the membrane of the tympanum at this age, with the cartilages of the incus and of the malleus (*b*); also, the extra-tympanic portion of Meckel's cartilage (*a*). (*Magitot and Robin*).

This cartilage is said to constitute the first solid structure that appears in this visceral arch; and from its commencement (about the twenty-fifth day), until it entirely disappears,* it undergoes a constant series of modifications.

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* Although Meckel, Valentin, and some others, extend the existence of this cartilage to the eighth month in the

It has scarcely attained its full growth (which period corresponds to the commencement of the ossification of the malleus),* when it begins to waste away and disappear.

Between the thirty-fifth and the fortieth days of embryonal life, slight traces of ossification show themselves at points nearly equidistant between the symphysis and the angle of the future jaw. This extends rapidly, both anteriorly and posteriorly, along the external face of Meckel's cartilage, in immediate contact but not uniting with it; and at about the sixtieth day of gestation a miniature jaw-bone is formed, though not yet perfected. (See figure below.)
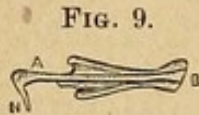
FIG. 9.

FIG. 9.—Taken from a human embryo of about sixty days. Natural size. Soft parts removed, showing Meckel's cartilage and the inner, or lingual face of the jaw-bone, left side. The cartilage has much the appearance of a very large hog-bristle. The main object in presenting this figure is to show the stage of development at this early period. *b*, Symphysis; *a*, extra-tympanic portion of Meckel's cartilage; *n*, manubrium mallei. (Original figure.)

human fœtus, yet Drs. Magitot and Robin state that they have never been able to find a trace of it later than the sixth month. As for myself, I have never succeeded in finding the slightest vestige of it, even at the symphysis, at the end of the fifth month.

* The latter part of the third month of embryonal life.

At this epoch the skeleton of the lower jaw is composed of two arches (if we may include Meckel's cartilage in the term skeleton),—an arch within an arch, an *internal cartilaginous* and an *external osseous* one. (Figs. 9 and 10 represent one of its bi-sections.)
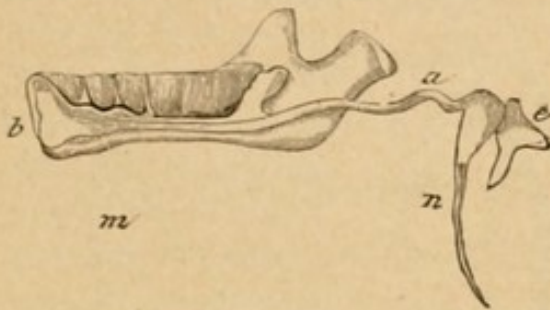
FIG. 10.

FIG. 10. — Internal face of the right inferior maxilla of a human embryo of about three months, showing the natural size and the relative position of Meckel's cartilage ; as also the dental follicles, from which the internal face of the bone is lifted off; *a*, the extra-tympanic portion, often flexible beyond the orifice of the dental canal; *b*, the symphysis of the cartilage; *n*, the *manubrium mallei* (or handle of the hammer), with a little fibrous prolongation; *e*, the cartilage of the *incus* (or anvil). This figure represents the *internal* surface of Meckel's cartilage, or the interior of the arch. (*Magitot and Robin*).

In an anatomical view this cartilage consists of two parts — a *transitory maxillary*, or *extra-tympanic*, and a *persistent auricular* part. The former, after it is no longer needed to sustain the jaw, begins to waste away ; while the latter, which represents the malleus, gradually becomes ossified.
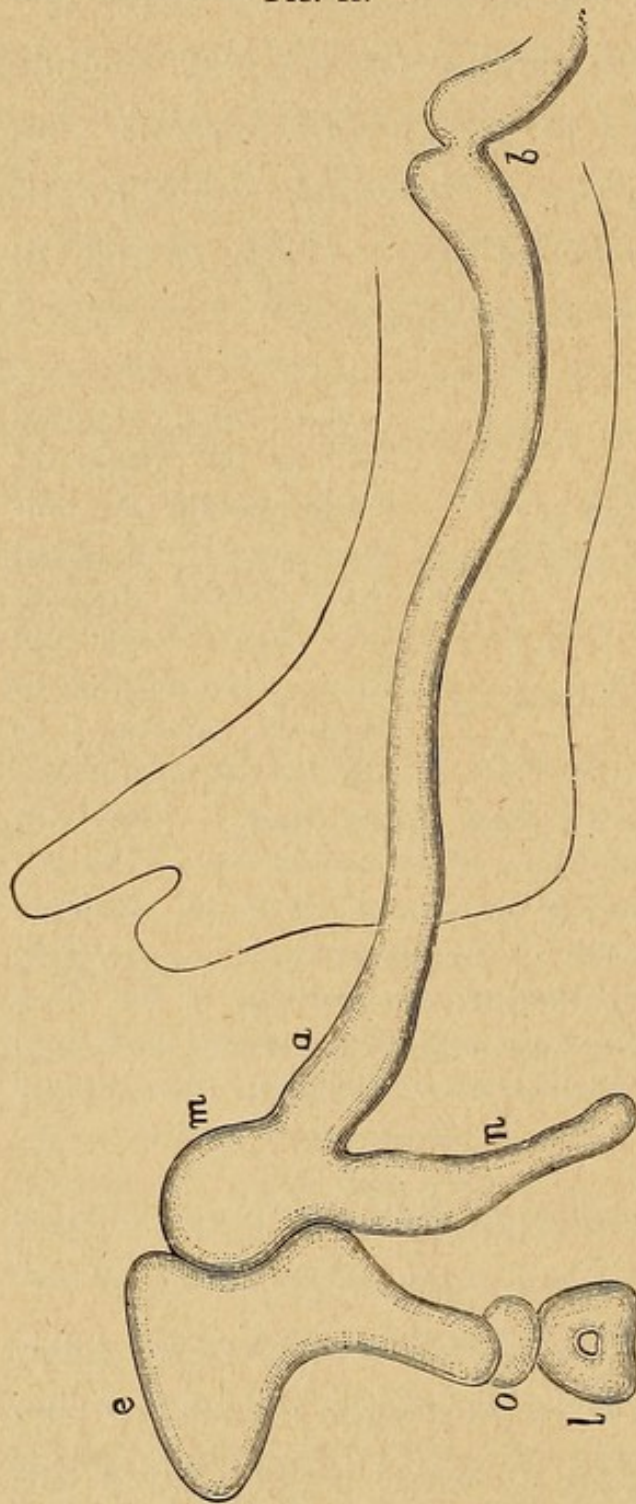
Fig. 11.

Fig. 11. — Meckel's cartilage, from a human embryo of forty to forty-two days, and before the appearance of the maxillary bone; magnified twenty-five diameters. *a,* Enlargement of the cartilage near its union with the neck of the malleus; *b,* a slightly enlarged portion of the cartilage in the form of a spatula, but contracted at the median line, where it unites with that of the opposite side; *m,* head of the malleus; *n,* handle of the malleus; *e,* cartilage of the incus; *o,* cartilage of the os lenticulare; *l,* cartilage of the stapes. [The outline of a jaw has been added to this figure to show the relative position it will occupy when ossification takes place.] (*Magitot and Robin.*)

This ossification of the *auricular*, and absorption of the *transitory*, portions commence at the end of the third month of intra-uterine life; the former with the malleus, the latter at points corresponding with the middle portion of each jaw, whence atrophy extends in both directions; and, toward the latter part of the sixth month, according to these authors, the cartilage, from the simphysis to the malleus, entirely disappears, leaving for a time on the surface of the bone a slight groove to mark the place it occupied.

FRANK: I infer that Meckel's cartilage belongs exclusively to the lower jaw of the *human* fœtus.

TEACHER: It is by no means the exclusive heritage of man. All the different species of mammals, reptiles, fishes, and even birds, in embryonal life possess this transitory, cartilaginous support to the lower jaw. But it does not in all these disappear (as it does in man) before birth. In the rodents,—rats and mice, for example,—it remains without sensible change till birth, or a little later.

This brief description, aided by these excellent cuts, will, I hope, give you a sufficiently accurate idea of this cartilage to satisfy you for the present. But if you desire further infor-

mation, I must refer you to the thoroughly exhaustive treatise already alluded to;* for I know of no comparatively complete work upon this subject in the English language.

§ III.—INTER–MAXILLARY BONES.

CASPER: There is another obscure point that I would like to have cleared up before it escapes my mind. In your remarks you have referred to the origin of the "*inter*-maxillary bones." I was not aware that any such exist in the *human* skeleton. Our medical and dental text-books say: "The maxillary bones are *two* in number, *united* on the median line of the face." If this be so, where can we locate the *inter*-maxillæ?

TEACHER: The reason why your text-books do not describe these bones is, probably, because the authors recognize their existence only in early fœtal life, and hence do not deem it necessary. But naturalists consider them very important features in zoological science, since the point where they unite with the maxillæ forms

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* See Mémoire sur un Organe Transitoire de la Vie Fœtale, désigné sous le nom de Cartilage de Meckel. (E. Magitot et Ch. Robin.   Paris, 1862.)

the dividing line between the incisor and canine teeth. It seems to me that an intimate knowledge of these parts is essential to a thorough education in general medicine, and especially in the department of dental surgery.

In fœtal life the upper jaw is composed of four bones, viz., two maxillary and two intermaxillary. In each of the latter will be developed and supported two incisors—a central and a lateral; in each of the former, one cuspid and all the teeth posterior to it.

Although the intermaxillæ are distinct bones in the human fœtus, their external surface is soon covered over with a process from each maxilla, which extends toward the median line, and becomes intimately fused with the former before birth; so that the intermaxillary suture cannot be seen on the outer side; but on the palatal aspect of these bones the suture can always be recognized at birth, and can often be traced even in adult life. (Flowers, Linnæus Martin.)

In many animals these remain permanently as separate bones; and in human subjects, where the jaw is malformed, detached pieces are often found in this situation, probably owing to their arrested development. (Gray.)

By Huxley, and many other authors, these bones are called the *premaxillæ;* these parts are also known as the *incisive region*, from the fact that the incisor teeth are implanted in these bones.*
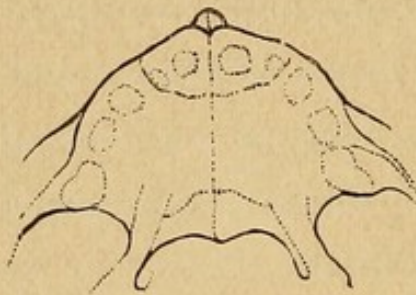
FIG. 11.

FIG. 11.— From a fœtus of about four months; showing the palatal aspect of the inter-maxillary bones, and indicating the points that will be occupied by the teeth when developed; also the inter-maxillary suture separating the canine and incisor teeth.

*Perhaps it is due to the reader that I here state that the existence of these bones in the *human* skeleton is not an altogether uncontroverted question. I had prepared a somewhat extended article, giving a sketch of the treatment this subject has received from the pens of many anatomists and naturalists, from the days of Galen to the present. But on reflection I have concluded to suppress it, together with much other collateral matter, lest the work should be so much cumbered thereby as to render it tiresome or confusing to the student. The fact, however, stands unshaken, (as stated by Prof. Paul Gervais, in his work on the human skeleton, Paris, 1856,) that Vicq-d'Azyr and Goethe have *shown* that these bones exist in the *human species*, as well as in all the other mammalia. The thought that GOETHE, the great poet and naturalist, has made these little bones the object of special scientific

§ IV.—DEFINITION OF THE TERMS FŒTUS, EMBRYO, FOLLICLE AND BOURGEON.

FRANK: I notice that sometimes you employ the term *embryo* and sometimes *fœtus*. I suppose they have the same meaning?

TEACHER: Magitot, Kölliker, Legros, Frey, Gray, and many other reputable authors, use these terms indiscriminately, as words of the same signification. On the other hand, Dunglison, Palmer, Carpenter, Flint, and others, employ the term embryo to designate the rudimental being during the first four months of intraüterine life, after which they style it the fœtus. Some again (including some of the last-named authors) divide the period of gestation into three stages. In the first the germ is called an *ovum ;* when this begins to assume the appearance of

study may, in the minds of some, lend a charm to this subject that it would not otherwise possess.

It cannot be doubted, I think, that these bones originate from separate points of ossification; but they certainly, as a rule, become fused with the maxillary bones, on the *external surface*, at a very early period of fœtal life, sometimes before the fifth month; while on the palatal aspect the suture is often distinct, extending across the external alveolar process after birth.

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a body, it is termed an *embryo;* and about the end of the fourth month (the time corresponding to the period of " quickening ") it is accorded the name of *fœtus*, which designation it retains until birth.

This application of the two latter terms to different periods of gestation is entirely arbitrary, and in some respects objectionable; but I shall generally adopt it, since it possesses some advantages. But sometimes it will be almost unavoidable to speak of embryonal or fœtal life, as equivalent to intraüterine life.

FRANK : While you are defining terms I would like to know just what our authors mean by " dental follicle."

TEACHER : The dental follicle includes the following parts: the *dentine-bulb* (papilla), the *enamel-organ*, and the *sac* that envelops them which is called the *follicular wall*. These three parts constitute the dental follicle.

The word follicle is not used here in its primary signification — *a little bag or sac* — but as *a sac and its contents*. Kölliker employs an equivalent expression, *dental sacculus*, in the same sense. This word follicle is also similarly employed by many other anatomists,— as

"Graafian follicle," "Malpighian follicle," etc.
Tomes, and English and American writers gen-
erally, use the terms follicle, sac, and capsule, as
words of the same meaning. It is unfortunate
that some definite and universal term is not em-
ployed to designate these associated parts of the
developing tooth; but for want of such, I shall
retain the term follicle in the sense that it is
used by the authors of this work. (Fig. 12 very
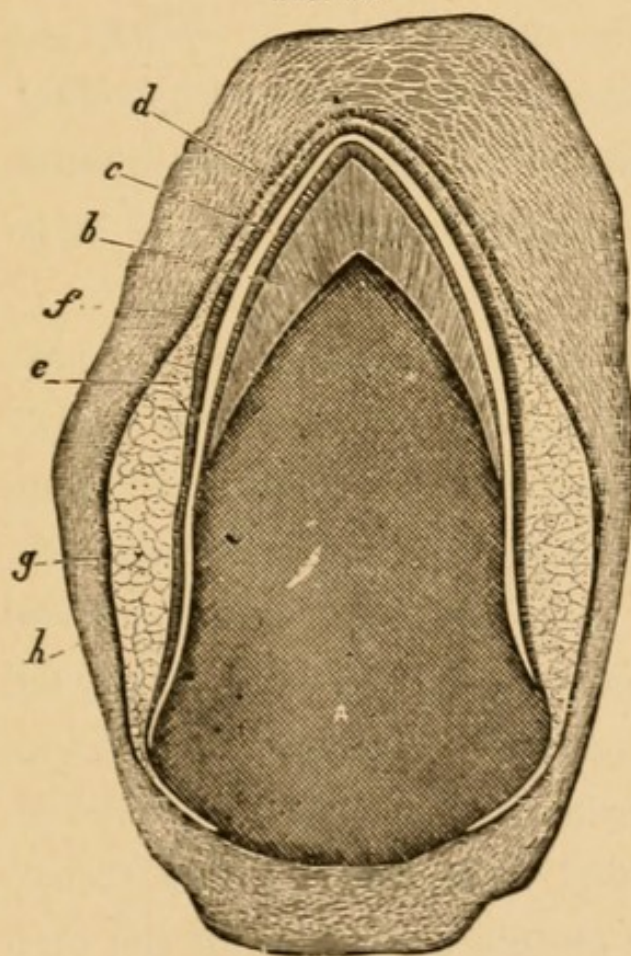well represents a dental follicle.)

FIG. 12.

FIG. 12. — This
cut is taken from
the fifth edition of
Kölliker's *Histol'y*.
Though the enamel
and dentine are al-
ready pretty well
developed, the mass
represented by the
figure is still a den-
tal follicle. It is
from a feline em-
bryo magnified
fourteen diameters.
a, Dentine-bulb; *e*,
enamel-organ; *h*,
follicular wall.

FRANK: Now, one question more. You used the term "bourgeon" several times during your description of the development of the jaws. It is not a familiar word to me, though I suppose it means about the same as process.

TEACHER: The word means *bud, germ, shoot,* or *sprout;* and the primitive outgrowths are called *bourgeons, apophyses, processes,* etc. It is a French word, but has become Anglicized, and may be found in your English dictionary. This term is often employed in the text as signifying enamel-germ, or enamel-bud. When the buddings take place which develop into enamel-organs, these offshoots or buds are denominated bourgeons of the enamel-organ, or simply *bourgeons.*

I cannot close these introductory remarks without a word of apology for the term "cell," which has been used so freely in the foregoing pages. Now although this, or its equivalent, *zellen, cellule,* or *cella,* has been almost universally adopted by anatomists, the word, as applied by them, is manifestly a misnomer. And yet its primitive signification, as first used by Schleiden, has been so modified from time to time, to correspond with our clearer conception of the mor-

phology and nature of the little mass of matter thus designated, that it will require great philological research to discover a substitute which will be as definite and comprehensive as this term, thus modified, has now become. Nevertheless, it is a stumbling-block to the student, and is an example of the many defects in our terminology, that a few scientists, prominent among whom I may name Dr. Atkinson, of New York, are making praiseworthy efforts to remedy.

With a few preliminary remarks from our authors, we shall now be introduced into our main, and most interesting, field of study.

THE AUTHORS' INTRODUCTION.

THE work we publish to-day comprises the first part of a series of studies, which embrace the entire phenomena of the evolution of the dental system of mammals.

This subject, which, as you are aware, is one of the most difficult that we have to encounter in embryology, and which is still involved in very great obscurity, has been made by us the field of extensive investigations, both on the human embryo and on those of the domestic animals. By these studies we have been convinced that the phenomena presented in the series of mammifera have (except in a few minor differences) a perfect similarity in their general physiological facts; the development of the follicle, the anatomical composition of its parts, and the rôle which these perform in the functions of the dental organism, are in all respects similar.

Our researches in this direction have been stimulated not solely by the state of uncertainty and of controversy in which this question is

involved, but also by the perusal of several important works published of late years in Germany by different anatomists,—Kölliker, Waldeyer, Hertz, Kollmann and others.

The results presented by these observers have gained, for certain parts of the question, considerable importance. They have determined some new elements that are a legitimate acquisition to science; while other conclusions which tend to invalidate certain doctrines advanced by several English and French authors, lack, as we shall endeavor to show, sufficient precision and exactness. Besides, there are several questions which remain without any solution whatever.

It is with the hope of throwing light upon this problem, that we have undertaken this series of researches.

Following rigorously the physiological order, we have been led to consider successively:

1. The mode of origin and formation of the dental follicle. 2. The morphology and structure of that follicle at the period of its complete development. 3. The evolution of the tooth within the follicle.

The present memoir will be devoted to the consideration of the [two] first of these questions.

THE ORIGIN AND FORMATION

OF THE

DENTAL FOLLICLE.

CHAPTER I.

THE CONDITION OF THE JAWS OF THE EMBRYO AT THE PERIOD OF THE GENESIS OF THE FOLLICLE. THE EPITHELIAL RIDGE (*BOURRELET*).

THOUGH we do not intend to dwell long upon the general constitution of the jaws at the time of the genesis of the follicle,* still we think we ought to lay special stress upon certain points which are directly connected with our subject.

As regards the *lower* jaw, it is known that at a certain epoch in embryonal life, varying according to the species of animals, the maxillary arch, absolutely destitute of

* See Memoir on the Genesis and Development of the Dental Follicles, by Ch. Robin and E. Magitot, in the physiological journal of Brown-Séquard, 1860.

the least trace of osseous tissue, incloses within its component elements a symmetrical cartilaginous band; and that this, uniting with its fellow at the median line, or the future symphysis, extends not only the whole length of the maxillary arch, but even to the frame of the tympanum.

This is *Meckel's Cartilage,*— an organ which plays only a transitory part in the development of the maxilla, and occupies the interior part of the arch. Thus embedded within the embryonic tissue, it represents, at this epoch of intraüterine life, the only fundamental elements of the jaw. (Figs. 8, 9 and 10, pp. 33–4–5.)

As to the *upper* jaw, the period of evolution corresponding with that which we have just described in the lower, is that at which the maxillary bourgeons have united with the median or intermaxillary bourgeon.*   This phenomenon takes place in

* [These authors speak of the two maxillary bourgeons as uniting with the median or intermaxillary *bourgeon*.   From this it would be inferred that there was but one intermaxil-

the human embryo about the fortieth or forty-fifth day.

The two maxillary arches being thus formed, we soon observe that in the rounded part (which will afterward constitute the alveolar border), there is produced a bed of epithelial cells forming a protuberance or smooth ridge (*saillie ou bourrelet*), and without any fold or depression whatever. This ridge, visible to the naked eye, is still more manifest in a section cut perpendicular with the axis of the maxillary arch, and is composed of a thick bed of cells. It will be noticed that on its sides an epithelial coat is formed of only a few rows (*rangées*) of these cells, superposed upon each other; and sometimes, even of a single row.

The epithelial ridge is thus added to the embryonal elements before they include any

lary bourgeon. They use the singular number here, probably because these bourgeons have already formed a union at their external margins, which connection takes place a little before their union with the maxillary bourgeons.—See Robin and Magitot, loc. cit., p. 9.—Tr.]

other well defined tissues, unless it be some vessels, nerves, and muscle-fibres, in process of evolution.

This epithelial ridge has some peculiarities which are of sufficient importance to demand our special attention, and which one would not suspect from simply examining its buccal or exterior surface. In a vertical section you will notice the smooth and rounded ridge that it presents in the mouth, and which justifies the name we give it — *maxillary rampart* (*Kieferwall* of Kölliker, Waldeyer and Kollmann).
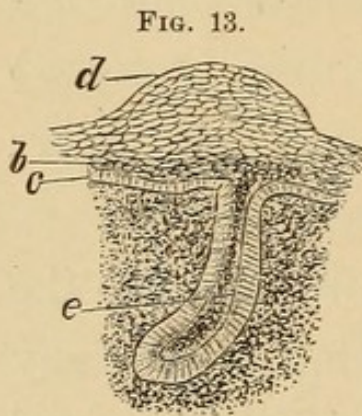
FIG. 13.

FIG. 13.—From Thiersch's preparation of an embryonic pig (copied from Frey). *d*, A mass of epithelium — the "dental ridge," "maxillary rampart" or "Kieferwall" (represented by the same letter in the preceding and following cuts); *b*, younger layer of epithelium; *c*, the deepest layer — the prismatic or columnar stratum; *e*, enamel-germ.

Beneath this external ridge a projection sinks into the subjacent elements, the outlines of which represent nearly the form

of the letter *V*, with the apex slightly in-clined toward the inner side (Fig. 14, d, d).
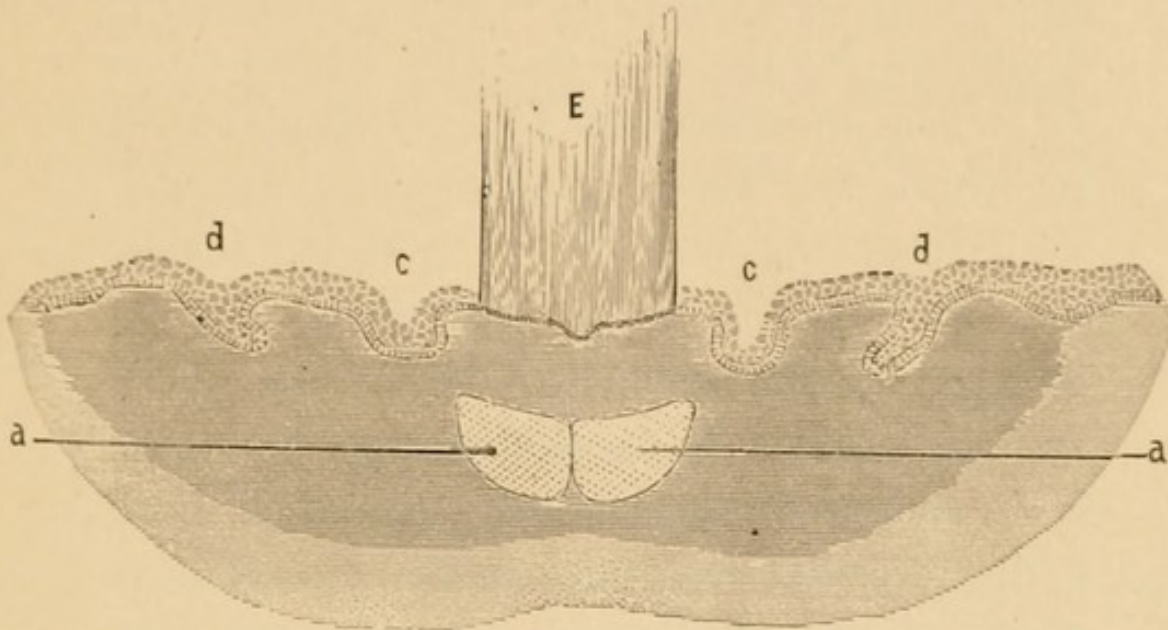
FIG. 14.

FIG. 14.—A perpendicular section taken from the inci-sive region of the lower jaw of an ovine embryo (lamb), forty-two millim. in length (magnified eighty diameters.) *d*, *d*, Epithelial band (*bourrelet*); *a*, *a*, transverse section of Meckel's cartilage near the symphysis; *c*, *c*, depression of the mucous membrane; *e*, section of the tongue. (See same letters Fig. 7, p. 30.)

CASPER: I cannot see the appropriateness of the term "epithelial *ridge*," which is used so often. In the plate it looks more like a groove than a ridge.

TEACHER: This term does not, to my mind, express definitely the thick epithelial bed, which, though it presents on the external surface of the

jaw an eminence or ridge, yet sinks into the substance of the jaw to a greater depth than it rises above the general surface. The word used by the authors is *bourrelet*, which means a rounded pad, or cushion. This structure was for a long time supposed to be cartilaginous in its nature, and hence called *cartilago dentalis*, until Raschkow discovered its epithelial character. M. Guillot (1859) named it the *odontogenic part*, or the generating part of the teeth; our authors speak of it frequently as an *epithelial band*, and we will hereafter so denominate it.

In a vertical transverse section this *band* is represented, as has been stated, by the letter *V*, with the apex bent a little inward. Now fill this with epithelial cells, and *heap them up*, and you have a tolerably accurate idea of the epithelial bourrelet or band. In other words, make a groove the entire length of the jaw, shaped as just described, and fill it "heaping full" of this cellular mass, and it also will represent the epithelial band, as seen in fig. 15.

FIG. 15.
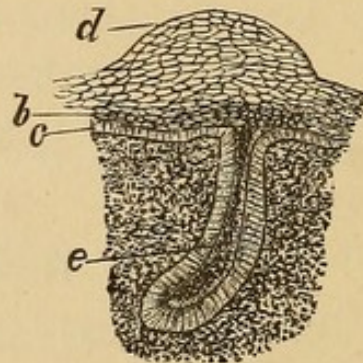
Thus constituted, the *bourrelet* forms, in reality, a continuous epithelial band, nearly vertical, the whole length of the alveolar border. It always exists in the embryos of man and the higher mammalia, and is even found on some parts which will remain devoid of teeth, as in the bar of the solipeds.

FRANK: "The *bar* of the solipeds" is too much for me; soliped, single foot. I did not know there were any one-footed animals!

CASPER: I know that the name *soliped* is applied to the races of animals that have a single hoof — as the horse and ass — but I am stuck on the "bar."

TEACHER: In animals, that interval between the "tusks" and the molars, which is destitute of teeth, is technically called the *bar;* and though the band extends along this portion of the jaw, it is unproductive, and becomes atrophied and absorbed, as we shall see further on. The more elegant term *diastema* is quite commonly employed to denote this vacant space between the teeth of the soliped, as well as those that may occur in the jaws of other animals.

I will give you the substance of a very interesting foot-note from the pen of Dr. Pietkiewicz (a former pupil in the laboratory of Prof. Robin) on the Rudimentary Dental Organs of the Ruminants. It has been inserted here with the indorsement of the authors of this work; but owing to its great length I shall give only a brief summary of its contents, as published in the "Transactions of the American Dental Association," 1878:

You are aware that there is a wide-spread belief, which had its origin in the announcement of Goodsir, in 1839, that rudimentary incisor teeth may be found in the embryonal jaws of Ruminants. This statement, founded upon certain anatomical appearances, was seized upon by Darwin, Hæckel, and other scientists, to sustain their views regarding the changes that had taken place in the successive generations of animal beings; and thus the theory received additional credit and a fresh impulse, until it has now become the prevailing belief, that the upper jaws of the foetus of ruminants contain germs of teeth; which, however, disappear before, or soon after, the birth of the animal.

This conclusion of Goodsir, which was never carefully verified, has recently been severely shaken, if not entirely overthrown, by the researches of Dr. Pietkiewicz.

He says, that in attempting to verify the statement of Goodsir, which had obtained such extensive circulation and credit, he made experiments upon a series of embryos of cattle and sheep, taken in large numbers, from the

earliest period of intraüterine life until they had attained thirty centimeters, or one foot, in length. In this series of investigations, he not only never witnessed the presence of a dental germ, but never found even a trace of the epithelial lamina.

He further states, however, that in the commencement of his work he was led into an error by the deceptive appearance of the sections made entirely from the *anterior* portion of the jaws; for in these he found on each side of the median line an epithelial sac, which extended from the mucous membrane into the depth of the jaw, and which *appeared* to constitute the commencement of dental germs, such as Goodsir undoubtedly conceived them to be. No difference was observed between the epithelium of this sac and that of the mucous membrane, of which it appeared to be a depression. The Malpighian layer constituted its outer investment, while in its interior was found pavimentous epithelium.

From this appearance, he thought one could easily conceive how Goodsir might have been led into the belief that he had discovered dental germs. But in continuing to make sections from these jaws in a *posterior* direction, he found that the little sac assumed the form of a circular canal, and approached the mucous membrane of the nasal fossæ. Around this canal appeared a cartilaginous cornet, and in the upper part was a mass containing vessels. From this he recognized the organ of Jacobson. There was absolutely nothing, he says, that could be, even remotely, compared to the germs of the incisor or canine teeth.
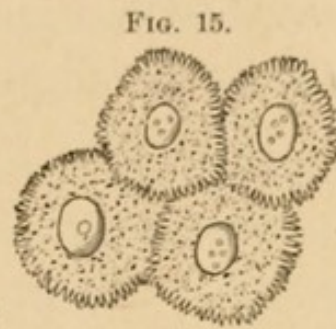
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The form of the epithelial band is the same in the different species of animals; and while it presents its broadest aspect on the alveolar ridge, it grows thinner, and at the same time bends a little inward, as it descends into the subjacent tissues; so that its internal or lingual face presents a concavity, and its labial or buccal face a convexity.

Though the deeper extremity, or apex, of the band is blunt and rounded in the early stage of development, it becomes very sharp at the moment the first trace of the follicle appears.

This band is composed of the same histological elements that constitute the epithelial coat of the oral mucous membrane,— that is to say, of nucleated cells, rendered polyhedral in form by reciprocal pressure; and that portion which penetrates the tissues of the jaw is bounded by a continuous layer of prismatic cells. The cells that compose the center of the band often

present at their borders that denticulated arrangement which has been noticed by authors in the cells of the epidermis, and by which the elements interlock with each other. [Cells described in the Introduction, as the "imbricated," "prickle," etc., to which list we will add here the explicatives "thorny" and "heckle." Fig. 15.]

FIG. 15.
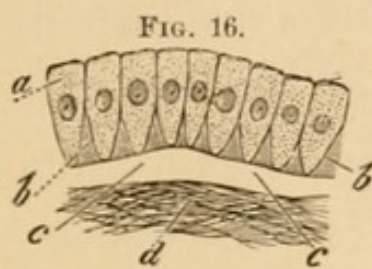
FIG. 16.

As regards the prismatic layer, it does not differ from the *stratum Malpighii*, from which it is directly derived. [Fig. 16, b. From *Frey*.]

From the preceding considerations it is seen that the epithelial band, which we have just described, is simply a prolongation of the epithelial tegumentary layer (*couche*) of the mouth, which, in sinking into the embryonic tissues of the jaws, forms for itself, so to speak, a groove which it exactly fills.

Now, when the embryonal jaw is sub-

jected to a prolonged maceration, the band may become spontaneously detached, thus leaving an empty groove; but at no epoch, in embryonal life, can there be found, on the surface of the alveolar border, any depression, sinking, or perforation whatever, when these parts are in a normal condition.

The well-known theory of the evolution of the teeth advanced by Goodsir in 1837, and afterward adopted by most authors, was founded on a certain mechanism, which consisted in the formation of the follicular sac at the expense of an exterior depression of the oral mucous membrane. The detachment of the epithelial bed by maceration may, doubtless, account for this error; but nothing exists in the normal state of the jaws to warrant any such conclusion. The theory of Goodsir is, therefore, absolutely without foundation in fact.*

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* [For a long time Goodsir's theory of the evolution of the teeth was held to be correct, and his verbal and pictorial representations were copied into our standard text-books on anatomy and physiology, both medical and

dental; and even Kölliker, up to his fourth edition, borrows from that author the cuts illustrating this stage of evolution. Goodsir "believed that, at an early period of fœtal life, there appears a continuous open groove, running round the whole circumference of the jaws; that from the bottom of this groove there arose isolated and uncovered papillæ, corresponding in number to the milk teeth; that these papillæ become covered in by the deepening of the groove and the meeting of its two edges over their tops, whilst at the same time transverse septa were formed, so that the several papillæ become enclosed in their own separate follicles."—*Tomes' Man. of Dent. Anat.*

"This theory of Goodsir was vigorously attacked at a later date in works of the French histologists Guillot, and Magitot and Robin. According to the latter, the tooth-sacs, dental germs, and remaining parts are developed, in the first instance, within the submucous connected tissue (subdermis), quite independent of the epithelium or mucosus."—*Frey*. TR.]

CHAPTER II.

THE EPITHELIAL LAMINA, AND THE GENESIS OF THE ENAMEL-ORGAN.

WE have seen that the part of the epithelial bourrelet, or band, which sinks into the tissue of the jaw, presents two faces — an external convex and an internal concave one; and that it extends the entire length of the alveolar border. Now, as soon as the development of this organ is completed, a thin process shoots out from its internal face, which we shall designate the *epithelial lamina*. (Figs. 17 and 18, E E.)

This lamina is a continuous process, extending the whole length of the epithelial band, from which it emanates about midway between its apex and the epithelial layer (sometimes a little nearer the latter),

and appears to be a kind of diverticu-
lum (or inflexion) of the band itself. , It

FIG. 17.
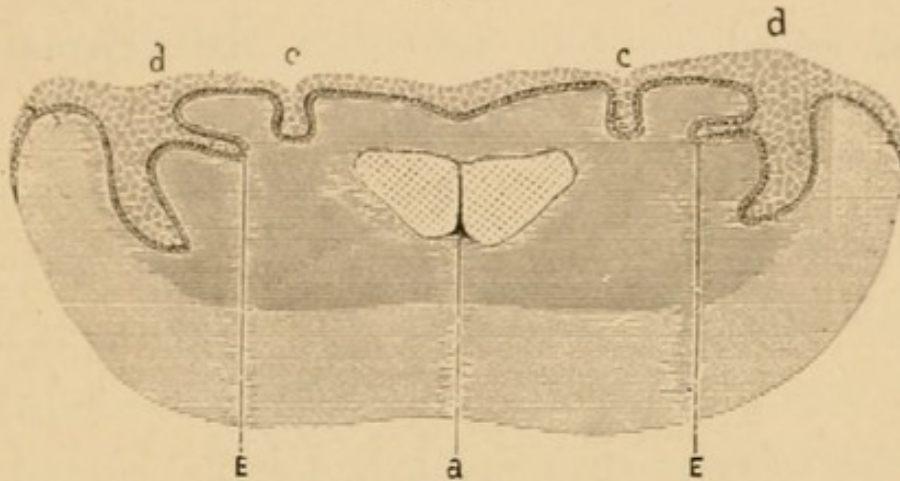
FIG. 17.—Vertical section of the anterior portion of the
lower jaw of an ovine embryo measuring 59 millimetres.
a, Showing the section of Meckel's Cartilage; *d*, epithelial
band (or *bourrelet*); *c*, fold in the mucous membrane; *E*,
epithelial lamina. These letters refer to the same parts in
the foregoing and following figures.

is somewhat flattened from above down-
ward, and its rounded extremity is slightly
bent in the form of a crosier. (Fig. 18, E.)

The elements of the lamina are of the
same character as those which compose the
band, viz., polygonal cells inclosed by a con-
tinuous layer of prismatic cells. As develop-
ment advances, large polygonal cells make
their appearance in the thicker portion of

the lamina, similar to those found in the band, or external epithelium.   These arrangements are important to be noticed; for, as will be seen hereafter, the prismatic

FIG. 18.
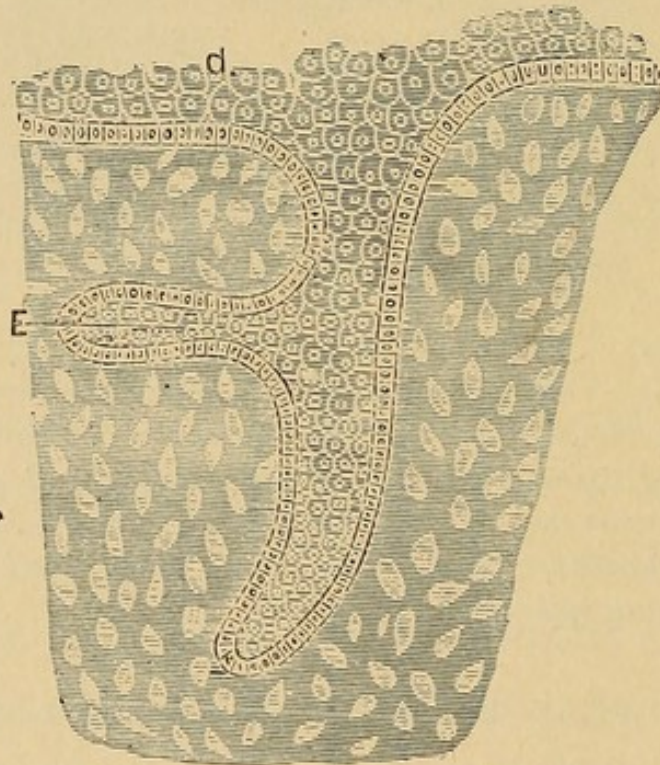
FIG. 18.— Transverse section of the left branch of the lower jaw of an ovine embryo (65 millimetres in length), magnified 260 diameters.   This and the preceding cut show the arrangement of the elements of the epithelial band, and also the epithelial lamina.

d, Epithelium of the mucous membrane, extending nearly vertically into the jaw and constituting the *band* and the *lamina*.   *E, Epithelial lamina*, emanating from the band. The band and lamina are surrounded by the embryonal tissue of the jaw.   This portion of the engraving is faulty, in that the nuclear elements are lighter than the surrounding mass, whereas they should appear darker.

elements which form its outer investment are never found in the *débris* of the lamina, nor in those of the epithelial cord which is derived from it.

The *enamel-organ* — the first trace of the dental follicle — originates from points upon the free extremity of this lamina. They show themselves, at first, as slight tubercles arranged at intervals along the margin of the lamina, and corresponding, in number and situation, to the teeth that will be developed in the first dentition. To these protuberances we give the name of *primitive bourgeon* of the follicle (the first follicular budding, or bud).

[In a foot-note these authors give their theory of the origin of the supernumerary teeth; but, as Dr. Magitot (the surviving author of this work) has since modified his views in relation to this phenomenon, a mere statement of the theory advanced by them will here be sufficient. Drs. Legros and Magitot maintained that the supernumerary teeth originate either from the epithelial lamina, from supernumerary buddings arising *between* the normal number; or that they are off-shoots from the epithelial cord. In the first case the development of these teeth would be precisely similar to that of the deciduous teeth; in the

other, to that of the permanent teeth, with the exception of the *first* molar.

The present views of Dr. Magitot upon this subject (as recorded on pp. 36-7 of his treatise on the *Anomalies of the Teeth*, 1877,) are in accord with those previously advanced by Kollmann; and are based upon the well-known fact, that when the epithelial cord or neck, which connects the enamel-organ with the epithelial lamina, becomes severed by the closure of the follicle, the cells, of which the cord is composed, multiply to a greater or less extent at their severed extremities,—sometimes in great abundance. These epithelial proliferations sometimes continue adherent to the remains of the cord, and to the follicle itself, until they are absorbed; and sometimes considerable masses become detached, and, assuming various forms, wander into the depths of the jaws (Fig. 19). These epithelial proliferations, according to Kollmann and Magitot, may become the enamel-germs from which the supernumerary teeth originate.

Now, in order that a tooth may be produced, a supernumerary *dentine-papilla* must be provided for this adventitious enamel-organ. This would result as a natural *consequence*, if the theory advanced by the translator of this work in a recent Report on Dental Physiology, before the American Dental Association, is correct. (See Trans., 1878, pp. 56-57). In this paper it was maintained that *dentine-papillæ* may originate from any point of the dentinal sheet of tissue (as described by Dursy), with which the epithelial mass comes in contact; that it is solely through the influence of the enamel-organ upon this tissue, that the development of a dentine-papilla is induced. If
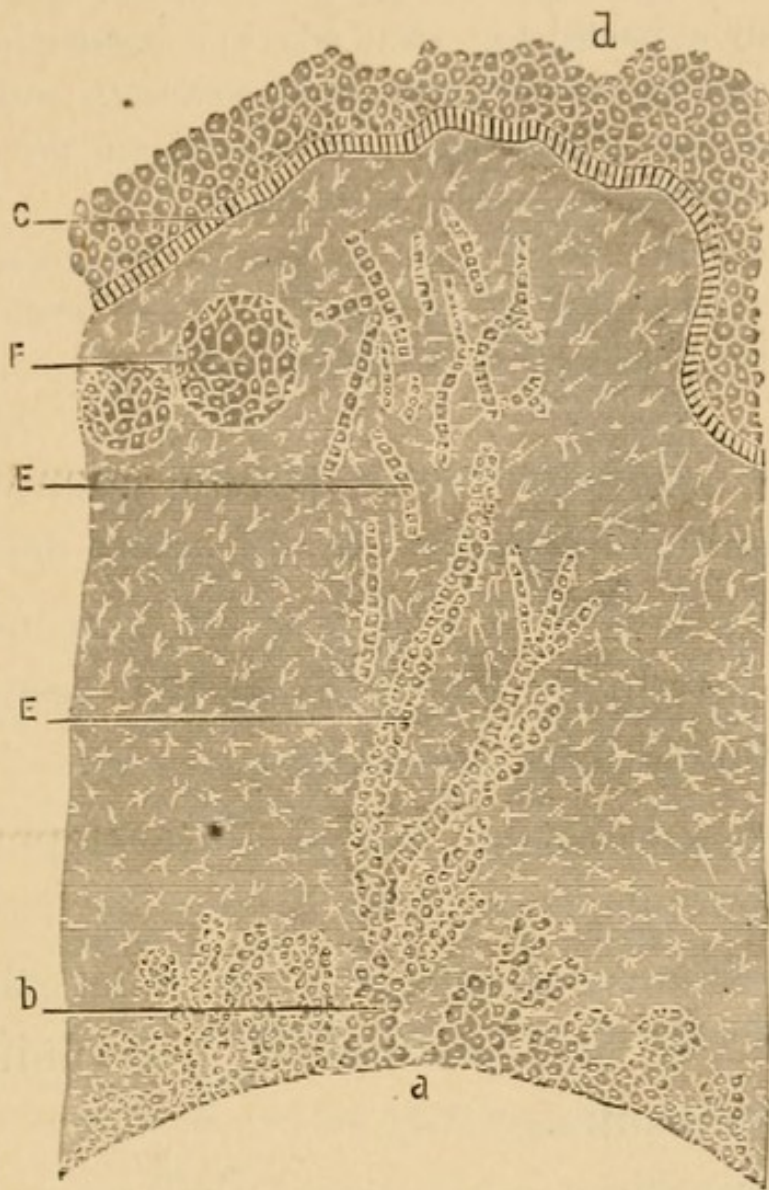
FIG. 19.

FIG. 19.—Taken from a bovine embryo, magnified 100 diameters. This section is taken after the rupture of the epithelial cord, and shows the epithelial proliferations that occur in this region at this period of evolution. The cut represents the territory between the wall of the follicle (*a*) and the mucous membrane (*d*).

b, Epithelial buddings from the follicular wall: *E*, *E*. buddings and débris of the cord; *F*, globular masses from the epithelial lamina.

this be true the origin of a supernumerary dentine-papilla is readily accounted for; while otherwise, special papillæ must originate independently, and coincidently with the supernumerary enamel-organ,—a circumstance that does not come within the range of probabilities.

Thus, also, it seems to me. we find a rational and satisfactory explanation of the origin of those families of dwarfed teeth found in dentigerous cysts.—TR.]

This bourgeon retains its connection with the lamina, from which it is a direct derivation, by means of a slender cord or neck, which gradually lengthens as the terminal mass increases in dimensions.

During the whole course of development this bourgeon constitutes the enamel-organ; while the neck, in its progressive lengthening, only serves as a temporary bond uniting it to the lamina.

At its first appearance the primitive bourgeon presents a nearly spherical form (Fig. 20, E), and is composed of an external layer of prismatic cells (a continuation of those of the lamina), inclosing a mass of polygonal cells; the latter being always

less in diameter than those contained in
the lamina.

FIG. 20.
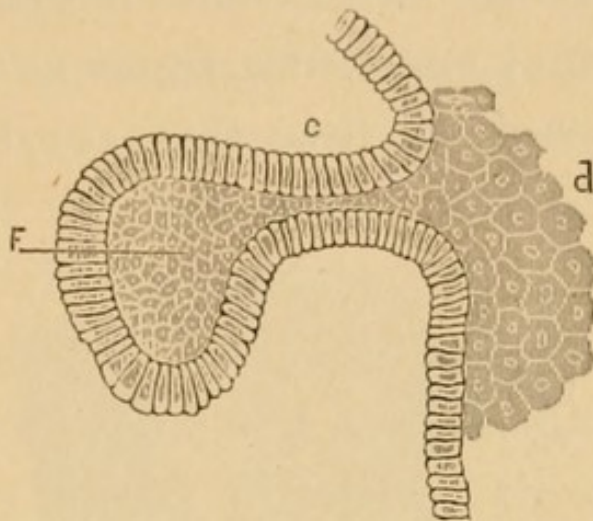
FIG. 20.—A section of the epithelial lamina taken from
an embryonic lamb, a little older than that from which Fig.
18 was taken. (Magnified 350 diameters.)

c, Prismatic or columnar cells,—a continuation of the low-
est layer of the Malpighian stratum; d, large polygonal cells
of the epithelial band (*bourrelet*); E, smaller cells of the
epithelial lamina. This lamina presents an enlarged ex-
tremity, and this enlargement represents the commencement
of the enamel-organ.

[The prismatic and the polygonal cells are beautifully
drawn in this figure.]

(See advancing stage of development, fig. 21.)

Let us here add that during the progress
of evolution these elements (inclosed in
the prismatic investment) undergo a modi-
fication whereby they are transformed into
stellate bodies — a phenomenon that never

occurs in the cells of the cord or of the
lamina. The disparity in the size of these
cells, together with the morphological
changes they experience, seems to us suffi-
cient to establish, from this period, a very

FIG. 21.
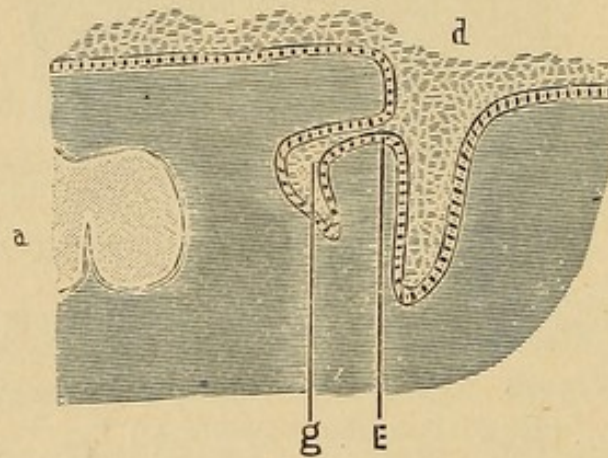
FIG. 21.— A section taken from the lower jaw of an
ovine embryo (left side), measuring 72 millimetres. (Mag-
nified 80 diameters.)

d, E, Same as in the preceding figures. g, Commence-
ment of the enamel-organ.

clear distinction between the constitution
of the *lamina* and that of the *bourgeon*
which emanates from it. We would em-
phasize this point, from the fact that the
more recent authors that have written upon
this subject have confounded these two
parts with each other.

These differences, however, will be more clearly manifest during the progress of evolution, when we shall find the elements of the bourgeon [enamel-organ] undergoing a series of important changes; whereas those of the lamina will invariably retain their original appearance.

In continuing its evolution, the primitive bourgeon, which was at first spherical, becomes somewhat cylindrical, though it still pursues a horizontal course until it has become noticeably lengthened, when, by an abrupt inflection, it takes a vertical direction, and sinks into the depth of the jaw. Thus extending its course, the cord acquires a length which varies according to the species of animal, besides undergoing certain secondary inflections. In man, as also in the dog, the cord always remains short, and in the solipeds it is still shorter. In the calf and in the lamb — animals that are particularly favorable for these studies — it describes divers undulations; but we

have never observed in the *primitive* cord that spiroid arrangement described by some authors,* and for which, as we shall see, the *secondary* cord (that of the permanent teeth) is so remarkable.

These differences in the length of the primitive cord are explained by the disposition of the special parts; and determined, on the one hand, by the species of animals, in which the jaws have a greater or less vertical height; and on the other by the nature of the future teeth. One readily sees how the cord of the follicle of a permanent tooth ought to be longer than that of the temporary, since it must accommodate itself to the longer passage it must make from the place of its origin to its terminus beneath the follicle of the temporary tooth.

The primitive cord, in the course of its progress, presents, moreover, some peculiarities worthy of notice. These are the phenomena of *lateral buddings*, which give rise

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* See Kollmann, loc. cit., Taf. XIV, Fig. 2, v.

to small rounded nodules, in the form of varicosities, which, in their arrangement, resemble an irregular chaplet. (Fig. 22, F.) These little masses are composed exclusively

Fig. 22.
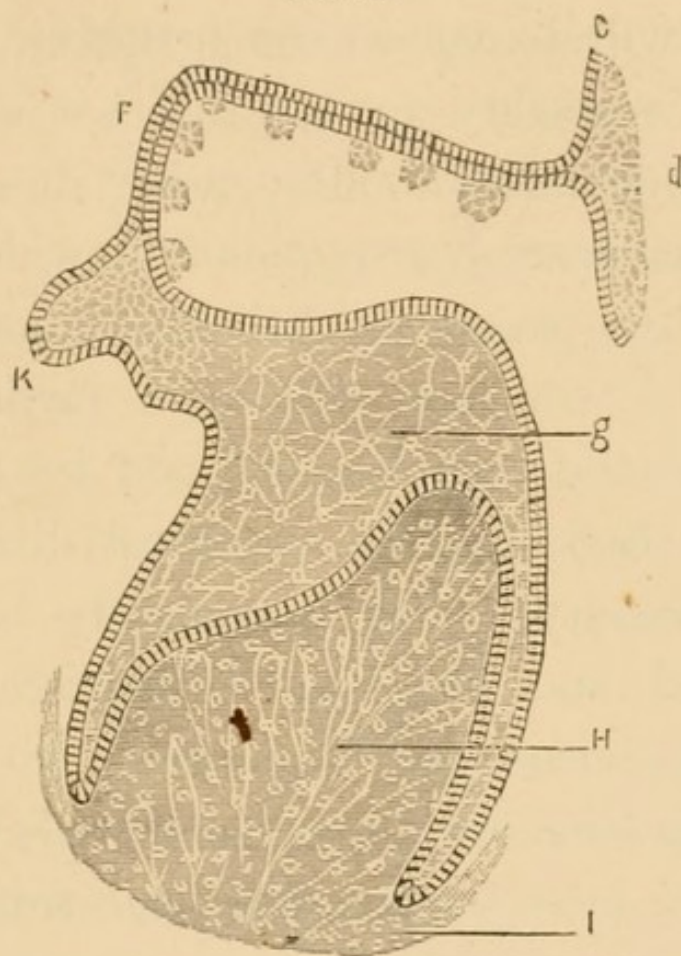
Fig. 22.—Taken from a section of the lower jaw of an ovine embryo, measuring 82 millim. in length. (Magnified 260 diameters.) c, Oral epithelium; F, epithelial cord and the " varicosities " referred to in the text; g, enamel-organ; H, dentine bulb; I, follicular wall rising from the base of the bulb; K, bourgeon from which the follicle of the permanent tooth will emanate.

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of small polyhedral cells, analogous to those contained in the cord itself.*

It is from these masses that, at a later period, after the cord is ruptured, those numerous epithelial prolongations spring, which will be considered hereafter. It is hardly necessary to say that we do not here confound the buddings, just described, with that special production from which the cord of the secondary follicle originates,— a point to which we will return further on.

After the cord has changed its course from a horizontal to a vertical direction, its extremity, which has already become enlarged and club-shaped, acquires still greater dimensions. This results from the multiplication of the polyhedral cells which compose most of its mass, and from the

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* [The cells referred to as being in the cord are not shown in the figure. Only the *prismatic layer*, which forms the outer coat, is represented here. The cord may be compared to a tubular gland, the walls of which are composed of a layer of *prismatic* cells (a continuation of the *stratum Malpighii*), and the inclosed contents, of small polygonal cells. Tr.]

prismatic cells that form the surrounding layer, whose numbers increase in the same proportion. This epithelial body thus occupying the deeper tissue of the jaw soon assumes a somewhat spherical form; the superior pole corresponding with its point of connection with the cord, while the inferior pole points toward the bottom of the jaw, inclining more or less toward the lingual side. This mass represents the *enamel-organ* as fully developed. Shortly afterward the inferior pole becomes slightly compressed toward the center of the enamel-organ, which results in the formation of a concavity in its lower or deeper extremity; and the mass then assumes a shape resembling a hood or cap, but still retaining its connection with the cord.

This phenomenon of compression coincides with the appearance of a new organ in the jaws, *the dentine-bulb* [dentine-papilla]. This, in fact, originates at the inferior pole of the enamel-organ, where

the compression takes place.   It first appears as an opaque point, but it soon assumes a conical form, and its summit produces and occupies the corresponding depression in the enamel-organ.

This reciprocal adaptation of the two organs, which takes place from the first appearance of the dental bulb, continues throughout all their subsequent phases; the enamel-organ always covering the bulb, and exactly fitting its contours, whatever may be its form, or the form, number and disposition of the divisions it may present. No connection of tissue, however, exists between the two organs at any stage of development.   Dissections of these parts, their maceration in coagulating liquids, as well as the examination of sections, all establish this fact beyond question. This simple juxtaposition of the surfaces of these two organs ceases, however, at the base of the bulb, where the enamel-organ turns back upon itself with a rounded border.   (Fig. 22.)

If we now examine the composition of the enamel·organ, [at the period of development represented in Fig. 22,— say about the fifteenth week of the human embryo,] we find that the primitive elements (the polygonal cells which occupy its central portion, and the prismatic cortical layer,) have undergone notable modifications. We discover, in fact, that the middle region of this organ is occupied by some elements of a *new form*, essentially differing in appearance from that of the original cells. *These are stellate bodies,* composed of a central nucleus, sur-

FIG. 23.
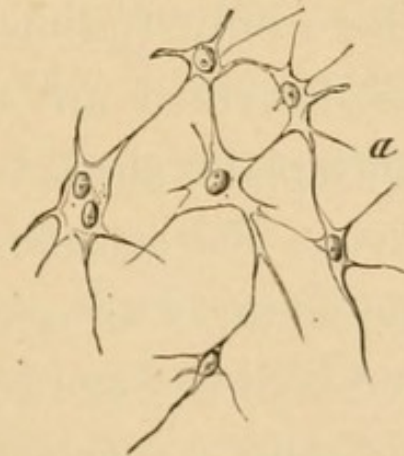
FIG. 23.— Stellate cells of the enamel-organ. (Diagrammatic, from *Frey*). These cells are also very well shown in the preceding figure.

rounded by a transparent or finely granu-
lated mass, which ramifies and inosculates
with the neighboring elements. (Figs. 22–3.)

These star-shaped bodies occupy at first
only the center of the enamel-organ; those
near the periphery preserving their origi-
nal polygonal form, but becoming stellate in
proportion as the dimensions of the organ
increase. It will be noticed, however, that
the anastomosing processes are always much
longer and more ramified, as the cells are
situated nearer to the central portion; while
in the vicinity of the periphery it is some-
what difficult to distinguish these processes,
as they are here only rudimentary. The
elements thus described are immersed in
a translucid amorphous mass, coagulable in
acids, and having the consistence and ap-
pearance of the white of an egg.

These starred bodies — or "stellate cells,"
as they are usually termed,— are formed
directly at the expense of the polygonal
elements composing the internal mass of

the enamel-organ. The process is as follows: The substance mentioned above interposes itself little by little between these originally small polyhedral cells, and thus their walls lose their mutual contact, except at certain points where they still cohere. As a direct result of this phenomenon, the primitive polygonal cells exhibit a number of depressions extending from their exterior surface toward the center, giving them their stellate appearance.

From this transformation the primitive cells would become entirely insulated by the intervention of this new mucous formation, were it not for these connecting processes, which give to this organ, as a whole, its peculiar reticulated appearance, and to each cell its stellate form. It is a remarkable fact that no line of juncture can be discovered where these cells are connected with each other, the various re-agents failing to disclose the least trace of it, so effectually have these parts been cemented together.

According to this theory, the stellate arrangement of the "pulp" of the enamel-organ (the intimate composition of which we do not purpose to describe in this memoir) results from a *simple modification of the form* of the primitive polygonal cells,—a change which they have undergone passively, as it were. These elements of the enamel-organ, notwithstanding their stellate form, must be regarded, therefore, as *absolutely epithelial* in their nature. The mechanism of this transformation, however, differs materially from that given by Kölliker,* and after him by several other anatomists, who contend that these primitive cells might take this stellate form *spontaneously.* Our opinion, however, is in conformity with that of Waldeyer,† who was the first to properly examine and describe this phenomenon; though Huxley,‡ at a much

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* Human Histology, French trans., 1869, p. 497.

† Untersuchungen über die Entwicklung der Zähne, Zeitschr. f. rat. med. 1865.

‡ Quart. Journal of Microscopical Sc., 1854, pp. 55–56.

earlier day, had advanced the idea (hypo-thetically, it is true,) that the enamel-organ had an epithelial origin; but he did not indicate the mode whereby the transforma-tion of its elements was effected.*

Now as to the *prismatic cells:* during the

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* The epithelial nature of the enamel-organ had not till recently been accepted in France; but its elements were described as stellate fibro-plastic bodies (Robin and Magitot, loc. cit., p. 60). This conclusion was based, however, solely upon the *form* that these elements present; and the same argument may be used to controvert this opinion. It is this: that in the enamel-organ the borders of these cells, between the radiated filaments which are drawn out from their periphery, are *always concave,* while in the stellate fibro-plastic bodies these borders present plane or convex surfaces alternating with those that are concave.

[The student must not infer from the above that Huxley was the first to advance the idea that the *enamel* was of *epithelial* origin; for this opinion was held by physiologists long before his day. The discovery accred-ited to Huxley is this: that the cells, constituting the *internal mass* of the enamel-organ (the reticular portion surrounded by the stratum of prismatic cells), are only *metamorphosed* epithelial cells. Heretofore histologists believed these to be stellate connective-tissue cells; but the peripheral layer was then, as it is now, admitted to be composed of epithelial cells. TR.]

early stage of evolution, we have found them identical in character and in dimensions on all parts of the periphery; but the moment the enamel-organ assumes a new form, produced by the development of the bulb, this stratum undergoes some important modifications. At this period, in fact, the cells of that portion of the cortical layer, which occupy the *concave* face of the enamel-organ, and which consequently lie in contact with the dentinal bulb, begin to increase in length; while those constituting the *convex* surface of this organ sensibly diminish in size. This difference in the dimensions of the cells occupying the two segments of the *prismatic stratum* or cortical layer manifests itself more and more during the progress of follicular evolution; and, as we shall see hereafter, the external layer ["external epithelium of the enamel-organ"] disappears long before the complete atrophy of the enamel-pulp; while the other [the "internal epithelium"] still

remains to perform the important functions assigned to it, namely, *the formation of the enamel.*

The prismatic cells of the concave face of the enamel-organ [the enamel-cells, or ameloblasts,*] offer some peculiar character-

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* [The term ameloblast is compounded of *Amel* (from the French *émail*), enamel; and *blast* (from the Greek *blastos*), germ. This compound word has recently been introduced into our nomenclature by Prof. Eames, of St. Louis; and owing to its euphony, its concise and definite expression, and its general relations to the terms osteoblast, odontoblast and others, it ought, as it seems to me, to be adopted by the dental histologist. It will certainly facilitate the description of the parts to which it is applied, and obviate the repetition of long descriptive phrases. I shall, therefore, follow the lead of Dr. Black, and whenever it seems best shall substitute this new term for phrases of equivalent meaning that may be found in the original. The *ameloblasts* are the enamel-cells. They constitute the *prismatic layer* of Legros and Magitot; the *internal epithelium* of Kölliker; and the *adamantine membrane* of Raschkow; namely, *that section of the stratum Malpighii forming the peripheral layer which lines the concave face of the enamel-organ, and lies in immediate contact with the dentine-bulb.* The other section of this stratum covers, or rather constitutes, the convex surface of the enamel-organ, and is generally known as the *external epithelium.* It has probably been

istics, to which we will now call your attention. Originally identical with those of the [lowest layer of the] Malpighian stratum, from which they are directly derived, these cells, besides increasing in length, experience some important changes in form. The extremity that is directed toward the center of the organ, becomes long and slender, forming processes which unite with or are continuous with the filaments that proceed from those neighboring cells which constitute the portion of the enamel-organ known as the *stratum intermedium*.* The

previously noticed that the peripheral layer has been divided into two sections. This has been done simply for convenience of description, there being no anatomical division between these two portions; the cells being alike and contiguous, although at a later period they experience those dissimilar modifications that are fully and clearly described in the text. Tr.]

* [As this portion of the enamel-organ is only incidentally mentioned in this work, a few words of explanation may not be out of place here. It might with propriety be termed the stratum of Hannover since he is its accredited discoverer. This "stratum intermedium" is not represented in any of these cuts, but it consists of a

opposite or peripheral extremity, that is
to say, the *base* of these cells, presents the
regular prismatic form of a hexagon. (Fig.
24.)   If we now examine an underanged

FIG. 24.
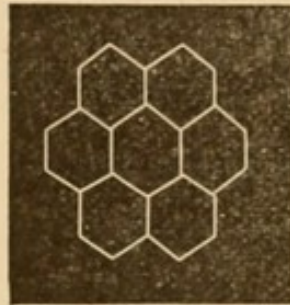
[Fig. 24 represents the basal aspect of a layer of amelo-
blasts.   TR.]

layer of these prismatic cells, or ameloblasts,
magnified about 400 diameters, we shall
find that the free margin of this layer (that
is to say, the part that corresponds to the

few layers of cells that still retain nearly their primitive
form, and lies between the layer of ameloblasts and the
stellate portion of the "enamel-pulp." Prof. Tomes (in
his Man. of Dental Anat., p. 125) describes it thus: "The
'stratum intermedium' consists of cells intermediate in
character between those of the bordering epithelium and
the stellate reticulum; they are branched, but less con-
spicuously so than the stellate cells, with which on the
one hand they are continuous, on the other with the
enamel cells." The special functions of these cells is

base of these cells) appears clearer than the bodies of the cells themselves, and in fresh preparations seems like a *continuous line.* If, however, a like examination be made of some hardened preparations, or if careful means be taken to detach this marginal line, which the edge of a section of the plateau represents, from the base of the cells, it will be found that it can be subdivided into as many sections as there are cells in the layer. And yet some preparations may be met with, in which more or less of this clearer line becomes detached in the form of a shred of ribbon. It is this strip, which is evidently made continuous

questionable. Waldeyer believes that, since "the enamel cells may be frequently seen to be connected at their lower extremities with the cells of the stratum intermedium, a multiplication of the enamel-cells from the cells of this stratum in the direction of their length may be admitted to occur" (Stricker's Hist., p. 334); an opinion shared by Hertz and the author first quoted, but differing from that of Magitot and Kölliker. A further description of these cells would more properly come under the head of Development of the Enamel. Tr.]

by artificial means, that has given rise to the hypothesis that a membrane invests or lines the concave face of this stratum of cells, ameloblasts. We shall see, moreover, in examining these peculiarities in detail, that this appearance is not specially and exclusively confined to the cells of the enamel-organ, since it exists wherever we find the prismatic cells provided with what has been termed a *plateau*. The prismatic cells of the intestines are known to be thus supplied. Now it happens, that, whether this plateau remains adherent to *each cell separately*, or whether it becomes adherent to those of the neighboring cells, so that a strip may be detached presenting the appearance of a true membrane, depends entirely upon the mode of treatment to which the preparation is subjected.

FRANK: This, I infer, is the basement, or pre-formative, membrane?

TEACHER: The *edge* of the tissue that forms, in section, the clear line, is not the same struc-

ture described (p. 17) as the *membrana præ-formativa* of Raschkow; the membrane here discussed is situated between the latter tissue and the layer of ameloblasts; and these two structures, thus lying in apposition with each other, correspond with the "double pellucid layer" mentioned by Dr. Black, in his report on Histology (p. 72 Trans. A. D. A., 1878), in which he says: "Just before the calcification, and even before the odontoblasts make their appearance, the ameloblasts, and the tissues of the pulp, are separated by a well marked double pellucid layer; which, in section, appears as a double band," etc. The two white parallel lines A, A, fig. 25, represent this "double band"; the *upper* one being the tissue here described by our authors, and which is identical with the *membrana præformativa* of Huxley; while the *lower* one represents the *basement membrane* of Todd and Bowmann, and the *membrana præformativa* of Raschkow. The clear line referred to in the text as being seen at the edge of a section of a layer of enamel-cells,— namely, the *upper line* of the double pellucid zone, or the preformative membrane of Huxley,— is formed by the artificial union of the *opercula* that cover the dentinal extremities of the ameloblasts.

The figure below is an ideal representation of a dental follicle before it has lost its connection with the epidermis. The object of this cut is to show the relation of the basement membrane and the two different structures (one of which is

FIG. 25.

FIG. 25.—*B M*, basement membrane; *N*, neck; *S*, sac or follicular wall; *O*, enamel-organ; *B*, bulb; *E E*, external epithelium of the enamel-organ and the basement membrane; *E C*, epithelial cord; *C T*, connective tissue surrounding the enamel-organ; *Ep*, epidermis or oral epithelium.

The parts embraced between the points where the divergent lines *A A* terminate, are:—(1) the concave face of the enamel-organ, lined with a layer of ameloblasts, or the "internal epithelium"; (2) the membrana præformativa of Huxley, or the tissue composed of the basal coverings of the ameloblasts; (3) the membrana præformativa of Raschkow, or the basement membrane; (4) the dentine-bulb itself. Diagrammatic.

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known as the membrana præformativa of Rasch-
kow, and the other as that of Huxley) to the
adjacent parts. The white line terminating on
either side of the upper portion of the figure
represents the basement membrane, and sepa-
rates the epidermal from the dermal tissues. The
mass embraced within the walls of this devious
line is composed of epithelial cells; that found
on the other side of this line belongs to the
dermal tissue. Now, that portion of the mem-
brane represented by this line, which passes be-
tween the enamel-organ (O) and the dentine-bulb
(B), and which constitutes the peripheral layer
of the latter (A A), is said to assume important
functions in the development of the dentine; and
hence was denominated the membrana præforma-
tiva by Raschkow; a name it still retains, although,
as to its nature and office, physiologists are not
agreed. The upper line running parallel to this
membrana præformativa of Raschkow, as before
stated, represents the membrana præformativa of
Huxley; and by him, Schwann, Kölliker, Magi-
tot, and some others, special functions have been
assigned to it in the formation of the enamel.
But you must not infer from what has been said
that the last named authors *precisely* agree as to

the nature of this membrane, or as to the mode of enamel-development, *amelification*.

CASPER: This term *membrana præformativa* is about as equivocal as that of mucous membrane, for I have already found it applied to three different tissues, one of which is said to line the walls of the pulp-chamber.

TEACHER: The latter consists of a layer of odontoblasts, and is generally called the *membrana eboris*. But we must discontinue for the present the discussion of these tissues, the nature and functions of which (and even the existence of some of them) are still matters of dispute. Nevertheless, these histological facts or appearances will be found useful hereafter in studying the development of the enamel and dentine.

As to the *nucleus* of the prismatic cells [the *ameloblasts*] of the enamel-organ, we find that its position varies in relation to the ends of the cell, according to the period of development; at first it is about equidistant, but it afterward appears to move toward the tapering extremity. This apparent change of place, however, is not real,

but results from the more rapid growth of the *dentinal* end of the cell (which is re-markably active after the development of the bulb), thus causing the nucleus appar-ently to move away from it. This differ-ence in the development of the extremities of the ameloblasts is especially remarkable in the enamel-organ of the incisors of the rodents, in which these elements attain to great length.

CHAPTER III.

ORIGIN AND FORMATION OF THE DENTAL BULB, AND OF THE FOLLICULAR WALL.

AS we have just seen, the enamel-organ soon loses its spherical form and acquires the appearance of a hood or cap; and this change in form is contemporaneous with the appearance of a new component part of the follicle,—the *dentinal bulb*. A slight opacity appears on the point of embryonic tissue of the jaw, that corresponds to the depression in the enamel-organ. This opacity is due to the production of new elements, which are grouped in such a manner as to form at first a little rounded nipple of hemispheric form, the convexity of which corresponds exactly to the de-

pression or concavity of the enamel-organ. (Fig. 26, H.)

FIG. 26.
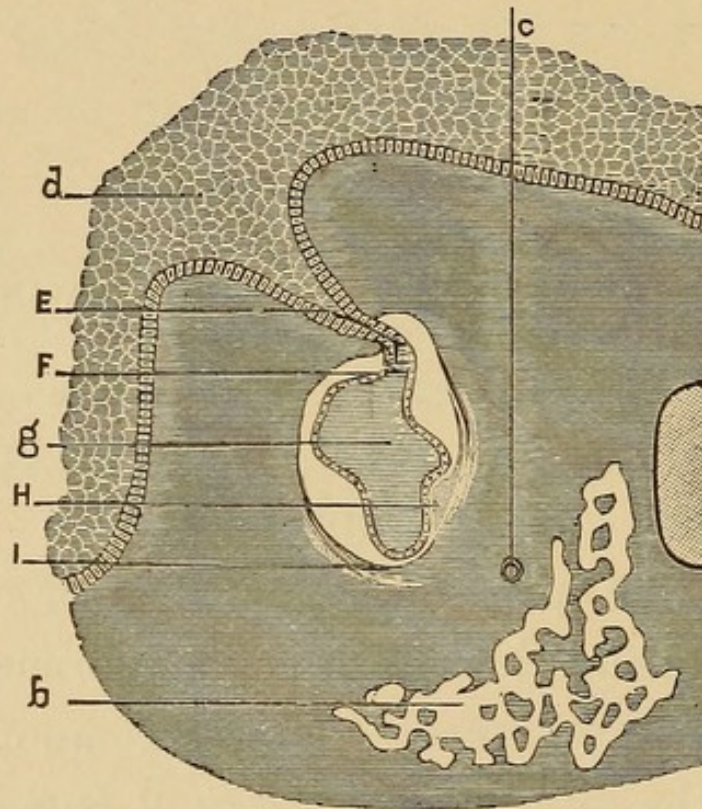
FIG. 26.—Vertical section taken from the incisive region of the lower jaw of an ovine embryo, measuring 115 millimeters, magnified 80 diameters. *a*, Meckel's cartilage; *b*, osseous formation; *c*, section of the dental artery; *d*, epithelial band (*bourrelet*); *E*, epithelial lamina; *F*, cord; *g*, enamel-organ. Meckel's cartilage at the right of the cut.

H represents the incipient dental bulb. The drawing for this cut preserves the defects in the specimen from which it was taken. For example: the space between the enamel-organ and the follicular wall is caused by the shrinkage of the former,— a result of too long maceration of the parts. Similar defects will be found in several of the following cuts.

This little papilla, which represents the incipient dental bulb, is composed at first only of nucleated embryoplastic elements, and soon afterward of fusiform and stellate bodies. It will be noticed, also, that at this early stage of development a vascular loop enters its substance, similar to those found in the papillæ of the skin; but we have not been able to discover in it any nerve-fibres until it has attained a mammillated form. The bulb retains this latter form but a brief period, for it soon shows a tendency to take that of the future tooth; thus, for the incisors and canines, it assumes a conical form; for the molars, in man and the carnivora, the primitive papilla is soon covered with secondary protuberances, equal in number to the cusps of the future crown; and in the compound molars of the herbivora and rodents throws out prolongations which represent also the future divisions of the crown. An analogous arrangement is found in the incisors (*à cornet*) of the soliped.

In all these circumstances the enamel-organ allows itself, as it were, to be moulded by the bulb, so as to exactly conform to whatever configuration the latter may assume.

CASPER: The *dentine-papilla* determines, then, the form or contour of the crown of the future tooth? I inferred from a remark you made (in regard to the supernumerary teeth, I think,) that it was the *enamel-organ* that controls this matter; at least, that this was your opinion.

TEACHER: Whatever views I may entertain as to the influence exerted by the enamel-organ have been mainly derived from these authors, though I have recently given this subject considerable thought. This is one of the points in dental physiology that has been almost entirely ignored by authors who have written upon the development of the teeth. Drs. Legros and Magitot, however, express very decided views in regard to it, though they do not state the reasons upon which their opinion is founded. In a more recent work (Traité des Anomalies, etc., Paris, 1877,) Dr. Magitot, the surviving author of the present treatise, maintains, very

positively, that the *enamel-organ* is endowed with this influence. These are his words:

"It is explicitly admitted that the epithelial cord, or enamel-organ, dominates and determines the *place* and the *form* of the tooth. The genesis and development of the *dental bulb* (dentine-germ), which makes its appearance subsequently to the cord, is absolutely dependent, as a physiological consequence, upon the *presence* and *form* of the enamel-organ itself. One will, nevertheless, be tempted to believe," he continues, "that the nature of the future tooth is under the control of the dentine-papilla, a kind of organic mould upon which the calcific elements are grouped; but it must be remembered that the epithelial cord, which represents the future enamel-organ, always precedes the appearance of the dentine-papilla, which never originates till the cord has advanced a certain distance in its course. Accordingly, we believe that the *epithelial cord* decides not only the *place of genesis,* but the *form* and function of the corresponding tooth."

It will be seen from the above quotation that Dr. Magitot dissents from the general opinion in regard to the influence which these parts (namely, the enamel-organ and the dentine-germ) exercise upon each other.

As for myself, I had supposed that the enamel-

organ was the more *passive* structure, and that its *form*, at least, was determined by the dentine-papilla. But, in considering this subject more carefully, and examining both sides of the question, I discover evidence which strongly confirms the theory of Dr. Magitot. My conclusions rest mainly upon a certain fact in the statement of Dursy, who, according to Waldeyer, says:

"The first germ of dentine appears in the dental *saculus*, as a dark, semi-lunar area at the bottom of the dental groove,— that is to say, of the enamel-germ, — cöetaneously and continuously with which it is developed along each half of the jaw. At certain points, corresponding to the position of the subsequent teeth, the young structure develops in the form of papillæ, projecting against the enamel-germs, while the remainder atrophies. The two horns of the semi-lunar mass (as seen in section) extend from the base of the dental papilla some distance upward, and embrace the dentine-germ and enamel-organ." ·

The particular point in this statement of Dursy to which I allude, and to which I wish to call your special attention, is that referring to *the semi-lunar area* of tissue extending along each half of the jaw, and from which the dentine-germs are developed. If the anatomical description of Dursy

is correct (and I am not aware that it is disputed), a dentine-germ might be developed from any point of this semi-lunar area which should be reached by the enamel-organ. No *particular* point is assigned to the development of any *especial* dentine-germ: that is entirely accidental, and depends upon the course which the enamel-organ takes.

For example: If the epithelial cord of a cuspid should deviate from its normal course, so as to come in contact with this *dentinal sheet of tissue* at a point between the bicuspids, the cuspid would be developed between those two teeth. In fact, whatever point in this tissue the enamel-organ of the cuspid should reach, the future tooth would be a true cuspid.

If this be admitted, the theory of Dr. Magitot must be true,—that the *enamel-organ determines* the *form* and *character of the future tooth*.

If the fact that the teeth of certain fishes are wholly destitute of enamel, *seems* to militate against this theory, we have the statement from high authority that all teeth, whether clothed with enamel or not, are, in the formative stage, universally endowed with enamel-organs. May we not *infer*, then, that in such cases the rudi-

mentary enamel-organ has performed its functions when it has *incited* the development of the dentine-germ, and determined its future *form* and *character?* *

As the dental bulb develops in height, it takes a slightly oblique direction in relation to the axis of the follicle, and at the same time undergoes a certain constriction at its base, thus forming a kind of neck at the line where (as has been already seen) the enamel-organ is reflected back upon itself. (Fig. 27.)

There is, however, one peculiarity in the structure of the bulb which we ought particularly to notice here, and that is the nature of the external surface of this organ.

If you examine the structure of a vertical section of the bulb, you will find that there exists at the periphery of this organ a thin, clear zone, which is easily distinguished from the subjacent tissue by its refraction.

* [Extract from my report on Dental Physiology, read before the American Dental Association, August, 1878.—Tr.]

This zone, to which several anatomists have assigned important functions, is only a thin stratum of amorphous material, which is wholly destitute of anatomical elements and of granulations.

This amorphous layer is not only more transparent, but somewhat denser, than the subjacent tissue of the bulb, so that sometimes it may be detached from the surface of the latter. This fact has led many anatomists to suppose that the bulb was invested with a distinct membrane (the *membrana præformativa* of Raschkow). (Fig. 25, lower parallel line, A A, p. 89.)

We shall describe, in another work, the nature and functions of this structureless layer, but we will say this much in advance, that it is in this tissue that the ivory-cells [odontoblasts] make their first appearance.

As soon as this little mass of new elements, which constitutes the dental bulb, has taken a hemispheric form, two opaque processes, originating at its base, ascend di-

vergently upon its sides; these appear to emanate directly from the tissues of the bulb itself, and they represent the first trace of the wall [sac] of the future follicle. (Fig 22 I, p. 73.)

If, at this period, the constitution of these follicular processes be studied, we find them composed of exactly the same elements as the bulb from which they originate. As the bulb continues to develop, these processes also increase in length, and bend round toward each other, in such a way as to finally embrace in their double concavity not only the bulb itself but also the enamel-organ, which, as you already know, constantly crowns the latter. In this manner the follicular wall, which was at first only a little collar attached to the neck of the bulb, by its gradual upward growth finally embraces and isolates both the enamel-organ and the dentinal bulb.

Casper: We are told, at first, that the follicular wall originates from *two processes*, on

opposite sides of the bulb; but now it is described as a little *collar* fixed to the neck of the bulb — apparently quite another thing.

TEACHER: These authors, doubtless, at first describe the follicular wall as it appears in section. In reality it must be a *circular* process, which, in the diagrammatic figure, presents the appearance of two. Prof. Tomes says, in his *Dental Anatomy:* "From the base of the dentine-bulb prolongations pass outward and slightly upward, so that they in a measure embrace the free edge of the enamel-organ; and, at a somewhat later period, they grow upward till they fairly embrace the whole enamel-organ."

Owen, in his *Odontography*, uses the following language: "By the development of three or four lamellar processes from the opposite sides of the mouth of the follicle, and their mutual cohesion, the papilla is inclosed in a capsule."

Prof. Wedl, in his *Pathology of the Teeth*, says: "The dentinal germ proceeds from the floor of the dental sac which invests it and the enamel-organ."

Kölliker (fifth edition) says: "The dentine-papilla arises from the bottom of the dental sac."

Although the last two authors do not minutely

describe the process of development, they evidently do not mean that the bulb arises from the "bottom" or "floor" of a *formed sac*, but upon the surface of a sheet of tissue which finally forms the sac. They agree with Tomes and the authors of this work, excepting that the former histologists believe that the *base* of the dentinal bulb is *inclosed* within the walls of the sac; whereas the others believe the follicle, from its apex *to* the base of the bulb, to be invested by the sac.

At this period the follicular wall may be compared to a muff inflated in the middle, the lower opening of which corresponds to the base, or neck, of the bulb to which it is attached; while the opposite opening corresponds to the neck of the enamel-organ, that is to say, to the point where the latter is connected with the epithelial cord. Soon afterward the cord becomes severed at this point, by the resorption of its constituent elements; a cessation of continuity due, without doubt, to the compression or strangulation it undergoes from the encroaching

walls, which now unite at this point and completely inclose the follicle. Thus the enamel-organ loses the connection which it had hitherto maintained with the epithelial lamina, and the dental follicle may be regarded as definitely completed. (Fig. 27.)

Fig. 27.
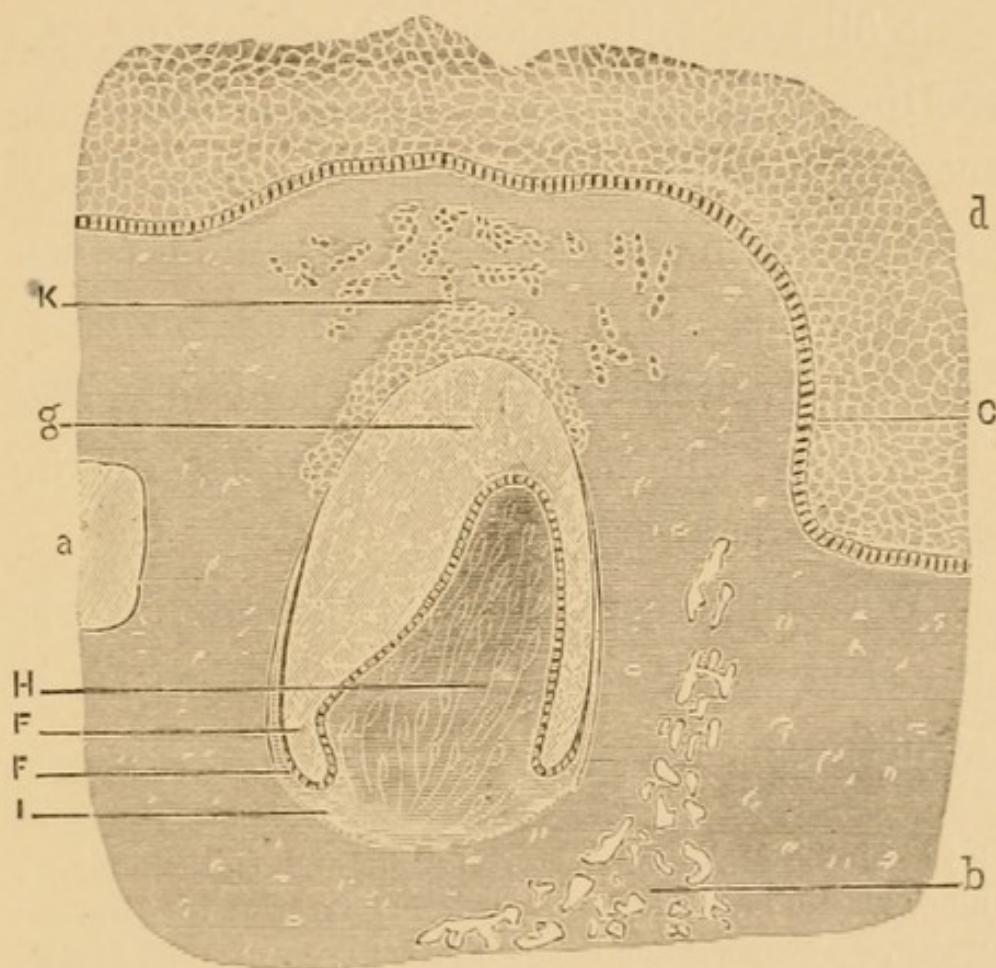
Fig. 27.— Section of the lower jaw of a bovine embryo, magnified 80 diameters; showing the dental follicle, as completed, and the surrounding tissues.

a, Meckel's cartilage; b, traces of ossification; c, lowest

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This wall [sac], composed primarily, as we have seen, of embryoplastic elements, gradually assumes the aspect of a distinct laminated membrane, which may be separated from the adjacent tissues, except at the base of the bulb, to which it remains fixed.

Kölliker, with most other authors, describes this wall as composed of two concentric laminæ; and yet admits, with Huxley, that the transparent stratum which clothes the bulb (*membrana præformativa*) reflects itself back on its internal face, and thus lines the whole inner surface of the follicular wall.

We will reserve, for a forthcoming work, the study of these different peculiarities of structure.

layer of the Malpighian stratum; *d*, oral epithelium; *F*, ameloblastic layer; lower *F*, external layer of the enamel-organ,—a continuation of the internal layer of ameloblasts; *g*, stellate recticulum of the enamel-organ; *H*, dental bulb; *I*, follicular wall (indistinct); *K*, buddings of the cord. The vascular appearance of the bulb does not appear in the original.

FRANK: With my ideas of the parts constituting the follicle, I fail to comprehend how the preformative membrane can line the internal surface of the follicular wall and also clothe the bulb.

TEACHER: Perhaps Kölliker's definition of the follicle, assisted by Fig. 25, may enable you to better understand this matter; and since it is brief, I will give you the benefit of it. In his 5th edition it reads as follows: "The *dental sacs* [follicles] are composed of three parts,— the *sac properly so-called*, the *dental germ*, and the *enamel-organ*. The *proper dental sac* is an envelope consisting of two layers,— an external one composed of dense connective tissue, and a softer internal one, of a gelatinous consistence, containing numerous connective-tissue corpuscles, and also some true fasciculi of connective tissue. This internal layer is limited on its inner surface, toward the enamel-organ, by a homogeneous layer of extreme tenuity, the preformative membrane of the dental-germ" [bulb].

At the period of evolution to which we have arrived in our description, the follicle is completed and closed. If now we examine its general constitution, we shall find it

composed, proceeding from the outside inward —

1st. Of the *follicular wall* which clothes its entire surface,—except the base of the bulb, which remains free. (Fig. 27, I.)

2d. Of the *enamel-organ*, subjacent to the follicular wall, to which it conforms in its whole extent, in such a way that while its external face corresponds to this wall, its lower, concave face is in immediate contact with the bulb. (G.)

3d. Lastly, of the *bulb* itself, which occupies the lower and central portion of the follicular sac. (H.)

Except the three fundamental parts just named, no other substance finds place in the constitution of the follicle. The enamel-organ exactly fills all the space comprehended between the wall [sac] and the bulb, and terminates at the base of the latter in a rounded margin, which forms the dividing line between the prismatic cells that clothe both its concave and convex

surfaces [See Fig. 25, A A]. This bound-
ary, however, is not artificial. It results,
on the one hand, from anatomical differ-
ences that these parts now present, and,
on the other, from the physiological rôle
which the cells of the concave face are
called upon to perform; whereas the exter-
nal layer atrophies rapidly and disappears.*
This prismatic layer of the concave surface
(adamantine membrane), constituting, as we
shall see, the stratum of enamel-cells [amel-
oblasts], remains a long time in the compo-
sition of the follicle; not only after the ex-
ternal layer has disappeared, but even after
the atrophy of the gelatinous part of the

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*[Waldeyer and Hertz believe this external layer of the
enamel-organ, instead of being absorbed, to finally become
the *cuticula dentis*, "Nasmyth's membrane." Tomes, Magi-
tot and Wedl, however, attribute this membrane to another
source, believing its origin identical to that of the cement;
while Huxley maintains that the preformative membrane
(see *upper* line, A A, Fig. 25), after the enamel is completed,
constitutes this thin enamel covering. Though Kölliker
does not assent to the latter theory, yet he believes this
membrane to be a product of the enamel-organ.—Tr.]

enamel-organ.   Let us further add, that in the rodents (whose incisors, as we know, are of continuous growth) this layer of cells [ameloblasts] remains upon a portion of the anterior or convex face of these teeth during the entire life of the animal.

This constitution of the follicle, comprehending, as it does, these three fundamental parts, seems to be characteristic of that of man, of the carnivora, and in general of all the mammals whose teeth are not supplied with coronal cement.   But if the follicle of an embryonal soliped be examined, it will be noticed that for a long time before the formation of the first dentine-cap there exists between the follicular wall and the organs within it a new tissue, very distinct from the neighboring parts — in color, in consistence, and in composition.   This is the organ upon which will subsequently depend the formation of the *cement*.   We will omit the description of the cemental organ here, but will study it elsewhere in

detail; all that we wish to establish at present is its incontestable existence in the follicles of such teeth as are clothed with coronal cement.[*]

This fact is so decisive that by the simple examination of a follicle we can determine, from the presence or the absence of this organ, whether the future tooth will or will not be furnished with coronal cement.

The dental follicle, the component parts of which are all thus grouped and inclosed in one sac, has a general ovoid form. Its

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[*] This cemental-organ, which will always be found in the follicles of the *molars* of herbivorous animals, and in those of the *incisors and molars* of solipeds, has been described for the first time in France, in a work by E. Magitot, entitled " *Developement* de la *Structure des Dents*." (Thèse inaugurale, 1858, p. 80). It was presented anew some years ater by Robin et Magitot. (Loc. Cit. 1861, p. 145 et suiv.) Since that time the existence of this organ appears not to have been recognized by any other anatomist. Indeed, in the last works published in Germany, by Kölliker, Waldeyer, Hertz, Kollmann and others, its existence has been formally denied. We are greatly surprised to see so evident an anatomical fact thus contested; but it will be easy for us to establish again the reality of this discovery, which we propose doing in our second memoir.

size varies greatly in the different animal species, and according to the kind of teeth that are to be developed from it. When the follicle is completely formed, it remains inclosed within the embryonal tissues of the jaws, with which at first it is only feebly connected. Thus isolated in the depth of the jaws, having lost its communication with the mucous membrane [epithelium], by the rupture of the cord, it does not yet form any connection with the maxillary bone; for the formation of the alveolar partitions does not take place until a later period.

The net-work of vessels which ramify the follicular wall and dental bulb is furnished from different sources, and enters these tissues from the surrounding parts; while the enamel-organ, as we know, is non-vascular. The direction of the follicle, that is to say the great axis of the *ovoid*, which it represents, is quite variable. Though regularly vertical in man and the carnivora,

it takes an oblique direction in the herbiv-
orous animals, and this is more particularly
marked in the follicles of the incisors. The
latter, in fact, take an oblique and diver-
gent course, like the spokes of a wheel,
which is moreover in conformity with the
inclination of the alveolar arch. (Fig. 28).

FIG. 28.
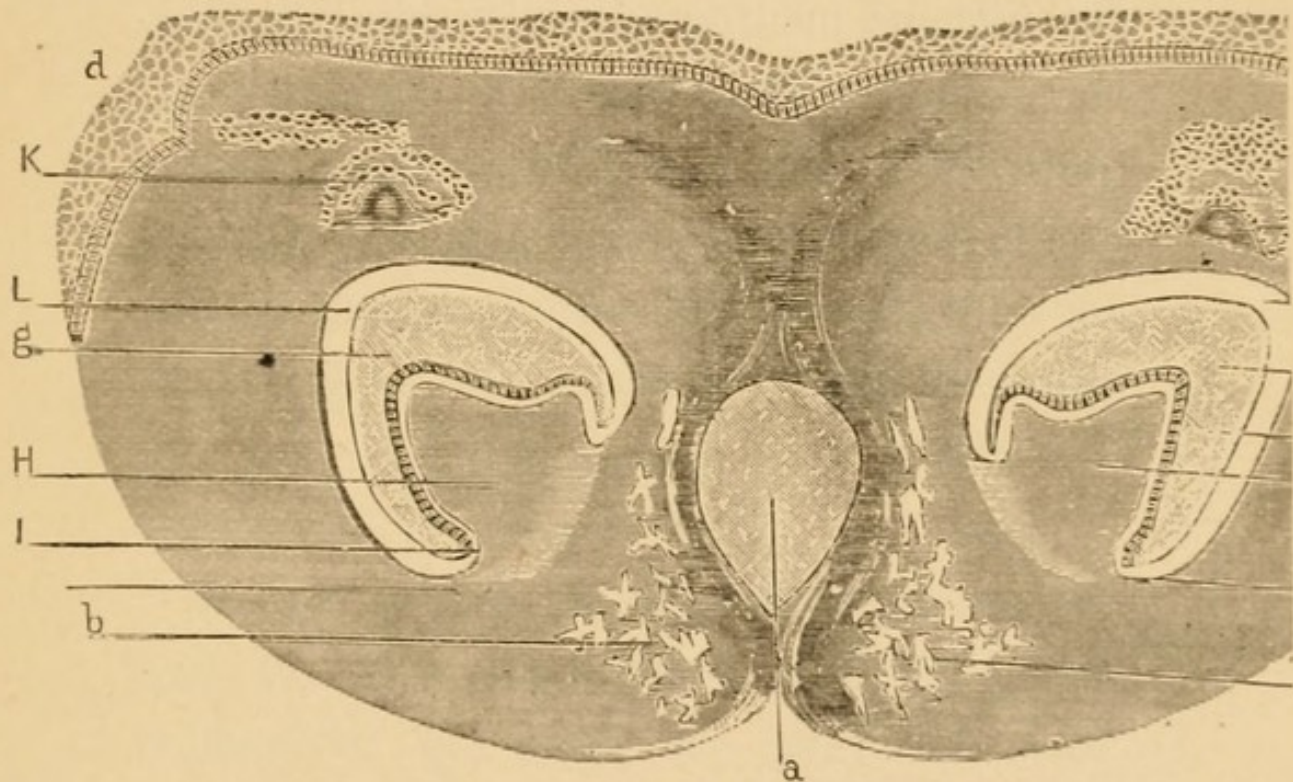
FIG. 28.—Vertical section of anterior portion of the lower
jaw of an equine embryo, magnified 80 diameters.

a, Meckel's cartilage; *b*, traces of ossification; *d*, oral
epithelium; *g*, enamel-organ; *H*, dental bulb; *I*, layer of
ameloblasts (internal epithelium); *K*, permanent follicle;
L, place assigned for the development of the cement.

We may add, however, that the axis of the follicle is generally the same as that of the bulb, and that it strictly corresponds with that of the alveolar border, for each particular species. As to its position in the jaws, it differs in like manner according to the species. In man, the carnivora and the solipeds, it is situated quite near the mucous membrane [epidermis], and in these the epithelial cord is consequently quite short; but it is located more deeply in the bovine and ovine herbivora (cattle and sheep), and the cord consequently acquires a proportionate length.

CHAPTER IV.

PHENOMENA THAT FOLLOW THE FORMATION OF THE
FOLLICLE, AND THE RUPTURE OF THE EPITHELIAL
CORD.

AS soon as the sac is closed, and the follicle becomes isolated by the rupture of the epithelial cord, various phenomena are produced in the embryonal tissues that surround this organ, in the region between the summit or apex of the follicle and the epithelial layer of the gum. These phenomena are principally located in the epithelial lamina and in the cord itself.

In fact, as soon as the epithelial lamina loses its connection with the follicle, by the rupture of the cord, the epithelial cells composing it become greatly increased in number at the severed point. This multiplication of cell-elements results in the formation of irregular buddings, which

wander in different directions into the deeper portions of the embryonal tissue. These buddings vary greatly in form; sometimes they are simple cylinders, retaining their connection with the primitive lamina by pedicles of various lengths, and sometimes this slight connective is absorbed, thus isolating an epithelial mass. (Fig. 19, F, p. 67.)

These masses are formed wholly of large polygonous cells, similar to those found in the center of the epithelial *lamina;* but they are never, like the latter, surrounded by a layer of prismatic cells. Very frequently, however, groups of these elements take the globular form, and are, in every respect, similar to those which are sometimes discovered within the epithelial lamina itself. (Fig. 29, F.) These different dispositions account for the presence of epithelial masses of such varied form; which, until now, were unexplained, and which are found in almost all the sections of the jaws made at this epoch of evolution.

FIG. 29.
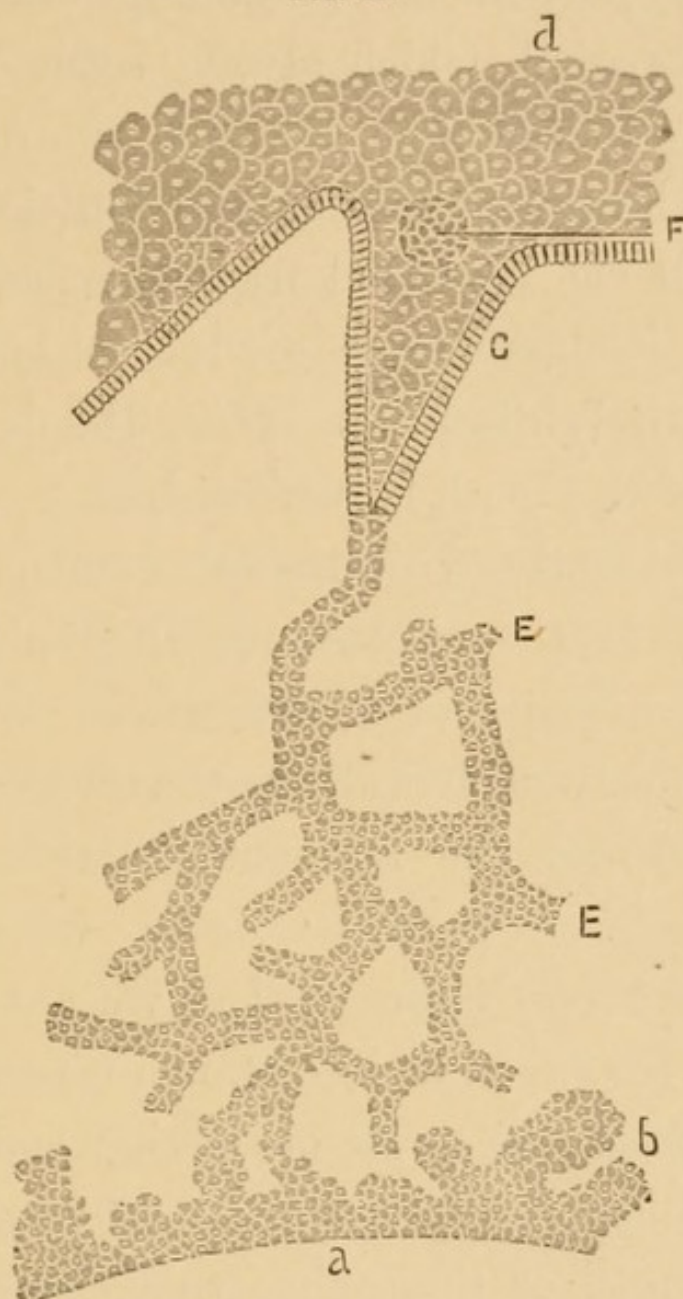
FIG. 29.—This is a section taken from an embryonal calf. (Magnified 260 diameters.) Like fig. 19, it embraces the region external to the follicle (*a*), which latter is not shown on the cut; *b*, epithelial buddings upon the follicular wall; *E E*, buddings of the epithelial cord; *F*, globular epithelial mass in the lamina; *d*, oral epithelium (epidermis); *c*, epithelial lamina "still intact."

These phenomena of buddings cease at a certain period, which always seems to be anterior to the time at which the dentine makes its appearance in the follicle; and then all the epithelial fragments, and the lamina itself, undergo gradual absorption, and entirely disappear before the development of the tooth is perfected.

Coincidently with the phenomena thus effected at the expense of the epithelial lamina, a series of modifications precisely analogous transpires also in the severed cord itself. From the remnants of this cord, buddings, or processes, issue, which, at times, are very numerous; as we have witnessed, for example, in certain preparations taken from the jaws of bovine embryos. These phenomena continue for a considerable length of time, since they can be observed up to a period even verging on the eruptive stage. The general form of these buddings may vary; sometimes they present somewhat the appearance of a bouquet,

(the foot corresponding to the summit of the follicle,) which spreads, opens and continues to expand till it reaches the vicinity of the epidermis (Fig. 27, K); at other times they form, by a multitude of reciprocal anastomoses, a perfect net-work (Fig. 29, E E), in the midst of which are still found some isolated masses.

But these differently grouped or anastomosing buddings do not all follow the direction of the lamina, nor of the cord; in fact their general tendency is evidently toward the surface of the mucous membrane.

The débris of the *cord* are invariably composed of small polyhedral cells lying in juxtaposition to each other, and exactly similar to those of the cord itself; but the cells composing these *débris*, like those of the remains of the lamina, are never invested with a layer of prismatic cells.

The buddings of the cord are also of variable size: some are extremely slender,

and composed of a single string of cells; others assume a strumous or swollen form, and contain several superimposed layers of these elements; but the large cells and the globular masses—the presence of which we have recognized in the *débris* of the lamina — are never found here.

The remains of the cord, like those of the epithelial lamina, after undergoing these multiplications, become gradually absorbed, and disappear, as was previously stated, at or about the period of eruption.

While these phenomena of buddings are taking place, at the expense of the *débris* of the cord, it will be noticed that a similar process is going on at the exterior surface of the follicular wall. These two series of phenomena, as well as those that take place in the lamina, are simultaneous.*

In fact, if a vertical section be made of the region comprised between the summit

* All this array of facts has been presented for the first time in France, by Robin and Magitot. (Loc. cit., 1860, p. 74.)

of a follicle and the external surface of the epidermis, shortly after the rupture of the cord has taken place, it will be seen that the remnants of this cord even extend to and mingle with some of the proliferations which are adherent to the wall [sac]. These have the most varied forms; most frequently they are club-shaped expansions, or cylinders of different lengths, terminating in a rounded extremity; and sometimes provided with a kind of pedicle. They cover nearly the whole surface of that hemisphere of the follicle which is presented toward the epidermis. These buddings, however, are most abundant at the apex of the follicle [the point where the cord was attached], and they gradually diminish as they descend upon its sides. They anastomose transversely both with each other and with those that are attached to the cord; and in such a way that by simply examining the surface of the follicle, without making a vertical section, we perceive a kind

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of plexus with very irregular meshes, super-posed upon the follicular wall.   (Fig. 29, b.)

The anatomic structure of these bour-geons [or prolongations] on the surface of the follicle differs in no respect from those which we have indicated in the proliferations of the cord, being composed of the same small polyhedral cells *minus* the enveloping pris-matic layer. This identity of structure results from the fact that these epithelial masses are derived from the remains of that portion of the cord which is in the nearest proximity to the follicle, and which by propagating themselves thus finally constitute this retic-ular covering of the follicle.

All these phenomena of epithelial pro-liferations relate, therefore, to one and the same process.   Commencing with the lam-ina, these buddings extend to the cord, and finally even to the surface of the follicular wall; they are connected with each other, possess the same anatomical constituents, and all finally disappear by absorption [un-

less it be some masses that may become the enamel-organs of supernumerary teeth. (See p. 66.)—Tr.]

We have indicated in the foregoing the period at which the phenomena of budding commence, namely, when the epithelial cord has finished its course, having conducted the primitive enamel-organ to that point where its subsequent evolution will be effected, and soon after the formation of the secondary follicle; [in other words, immediately after the rupture of the cord of the primitive follicle]. The time of their disappearance varies in the different species of animals. In the human embryo the remains of the cord of the primitive follicles may be found even after the formation of the follicles of the permanent teeth, and it is probably during the process of eruption that these buddings become atrophied: in the canine embryo the facts are nearly the same; in the bovine and ovine embryos (calf and lamb), it has seemed to us that these pro-

liferations disappear at a correspondingly earlier stage; and we think it safe to say that, as a general rule, the complete absorption occurs toward the period of eruption.

The physiological signification of these phenomena appears to us difficult to deter-mine. We have no personal opinion to advance in this regard; nevertheless we will say that, considering their mode of evolution and their structure, no glandular character whatever can be attributed to them, as some have supposed.*

* Serres, as is known, described what he supposed to be special glands, *tartaric glands*, in the mucous membrane; and his views were supported by Kölliker, Todd and Bowman, and others. The anatomical nature of these epithelial masses, and the fact that the production of tartar is connected with quite different phenomena, leaves no foundation for this hypothesis.

[I have not the works of Todd and Bowman at hand, but think Legros and Magitot must be mistaken in regard to the opinion of these authors upon this subject. As to the views of Kölliker, in the fourth edition of his *Microscopical Anatomy*, speaking of the "*gum* in the fœtus," he says: "The bodies of the size of a millet-seed, contained in it, described by Serres, the so-called *glandulæ tartaricæ*, which are supposed to secrete the tartar of the teeth, are

While the modifications just described are being effected at the expense of the epithelial *débris* of the cord and the lamina, the embryonic tissue in which the follicles are immersed also changes its nature, and some laminated elements appear therein, forming a loose and transparent net-work.

The osseous tissue of the jaw (no trace of which is seen at the time of the origin of the primitive cord) makes its first appearance near the base of the follicles, where it soon forms a horizontal layer, separating the groove of the follicles from the canal reserved for the vessels and nerves. Lateral processes then arise from this layer or floor, and form the groove in

aggregations of *epithelium*, and probably pathological." In his fifth, in place of the words "and *probably pathological,*" the following are substituted: "which, according to my recent observations, are the remains of the embryonal germ of the enamel-organ" [*i.e.*, of the epithelial lamina]. The views of Kölliker, and Legros and Magitot are then precisely the same on this point, so far as they are expressed in these works, the only difference being in the *form* of expression.—Tr.]

which the follicles lie for some time without being separated by transverse partitions. But later, after the development of the crowns of the teeth has commenced, bony processes are thrown across this groove, forming cells for the lodgment of each follicle, with an opening toward the epithelial surface.

A rich vascular network of tissue surrounds the follicle, and ramifies the substance of the walls even to the surface of the enamel-organ, but does not penetrate it.

The vessels of the bulb are entirely distinct, forming no anastomosing connection with the preceding plexus. We shall, however, have occasion to refer to these particulars hereafter, in treating of the morphology and structure of the follicle.

CHAPTER V.

THE PLACE, AND MODE OF ORIGIN, OF THE FOLLICLES
OF THE PERMANENT TEETH.

THE origin of the follicles of the permanent teeth is a problem that has received particular attention from the more recent authors who have studied the evolution of the teeth. It is one which we also have examined with the greatest care and patience; and we believe we have succeeded in solving it correctly.

Since the publication of the works of Goodsir — in which that author held that the follicles of the permanent teeth arise from a fold of the sac of the primitive follicle — most anatomists have adopted his theory without examination or verification. This doctrine is no more in conformity with the facts than is the theory that the

sacs of the temporary teeth are formed by an inversion of the mucous membrane. We have already given our views in regard to this hypothesis, and we will refer to it again at the close of this work. The theory of Goodsir will be found as erroneous in regard to the permanent as it is to the temporary teeth.

We ought to mention, however, that Kölliker and Waldeyer have come near the truth in indicating and illustrating certain prolongations of the primitive cord, which are destined to become the secondary cord. But in the most recent work published in Germany, that of Kollmann, the preceding interpretation is not adopted.* According to the views of this anatomist, the cord of the permanent teeth arises from the remnants of the primitive cord, which, after its rupture, produces those several buddings or epithelial masses which we have already described. He believes that

* Kollmann, loc. cit., p. 162, etc.

the enamel-organ of the permanent tooth originates from a mass of those epithelial fragments. In a like manner he accounts for the production of the supernumerary teeth.* This new theory is equally erroneous; and if this German author has been deceived by certain natural appearances, which might favor his opinion, it is because he has neglected to follow out strictly, in their successive physiological phases, the phenomena of this special evolution.

Furthermore, the origin of those permanent follicles that have been preceded by corresponding temporary ones, is altogether different from that of those which had no such predecessors; so that while all of the twenty follicles of the permanent teeth that succeed the twenty temporary ones have a like origin, the twelve other follicles (the molars of the adult) have a different mode of genesis. [By this these authors mean, as will be seen hereafter, that *all* the enamel-

* [See note, pp. 65–6 of this work.—Tr.]

organs of the permanent teeth *except those of the first molars*, originate from the epithelial cords of other follicles, and not directly from the epithelial lamina itself.— TR.]

The facts we are about to advance have been gathered from the examination of a large number of mammalian embryos, comprising a series of successive phases of development. In studying microscopical sections taken from the jaws of human embryos measuring twenty centimetres from crown to heel, a *bourgeon* will be found at the point where the primitive cord merges into the enamel-organ of the temporary tooth. The general form of this bourgeon is cylindrical, terminating in a somewhat enlarged extremity, which gives it a clubbed or gourd-like shape at this stage of evolution (Fig. 30, K), and may be seen quite distinctly with a low magnifying power of 100 to 200 diameters. [Fig. 22, K, represents this bourgeon at an earlier period]. It takes a general

vertical direction, and passes between the
osseous alveolar wall and the primitive fol-

Fig. 30.
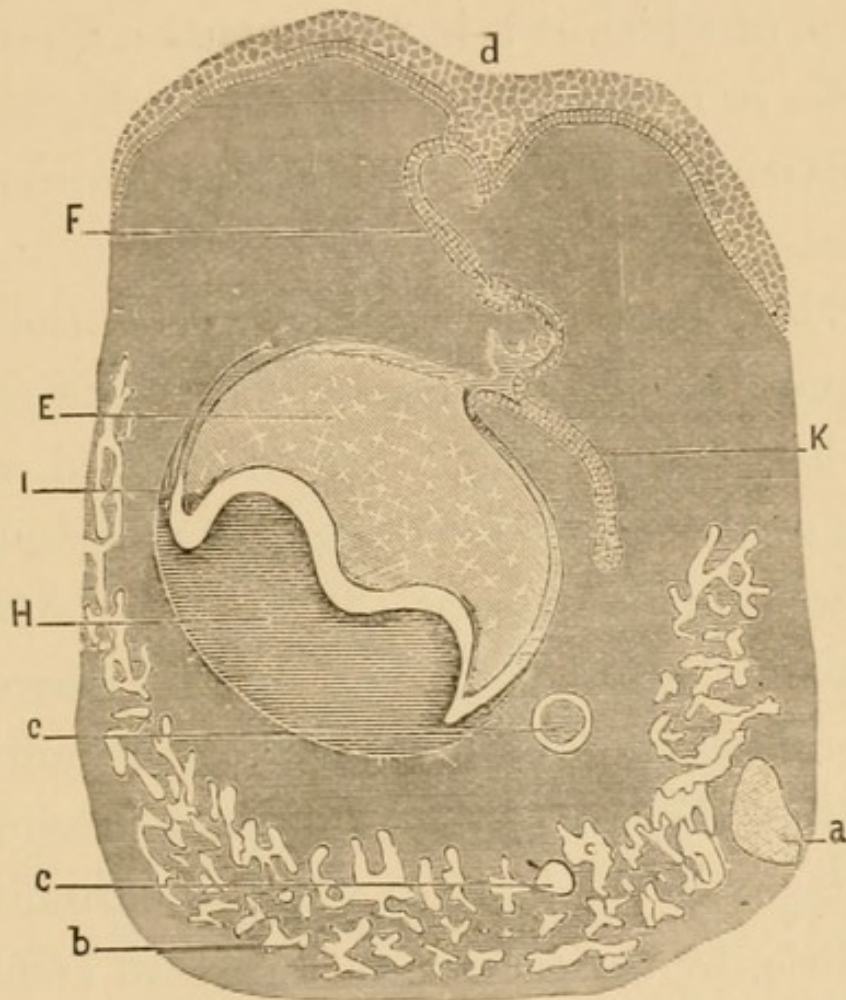
Fig. 30.—Section of the lower jaw of a human embryo,
total length 20 centimeters, or about 8 inches; taken from
the region of the follicle of the temporary molar (magnified
80 diameters).

K, cord of the permanent follicle, "emanating" from
that of the temporary molar; E, enamel-organ; F, cord of
the temporary follicle; H, dentine-bulb; I, follicular wall;
a, Meckel's cartilage; c (upper), section of the dental artery;
c (lower), that of the dental nerve; d, epithelial cells.

licle, along the internal or lingual face of the latter. The elements of which it is composed are the same as those of the primitive cord, of which it is in reality only a *diverticulum* or out-growth; that is, of polygonous cells covered with a single layer of prismatic ones.

This bourgeon or bud represents the beginning of the permanent tooth; and after it has become sufficiently developed, one can easily follow the subsequent phenomena of which it is the seat. It sinks to the bottom of the osseous dental groove, where it soon loses its connection with the primitive follicle, though still retaining its communication with the lamina; while the primitive follicle, by the severance of its cord (which takes place just below the point where the secondary cord branches off), becomes isolated from its epithelial connection and continues its individual evolution. (Fig. 31.)

It was, doubtless, by examining the jaws at the stage of development just referred to,

without taking into account the earlier and later phases, that led to the belief that the cord of the permanent teeth emanated from

FIG. 31.
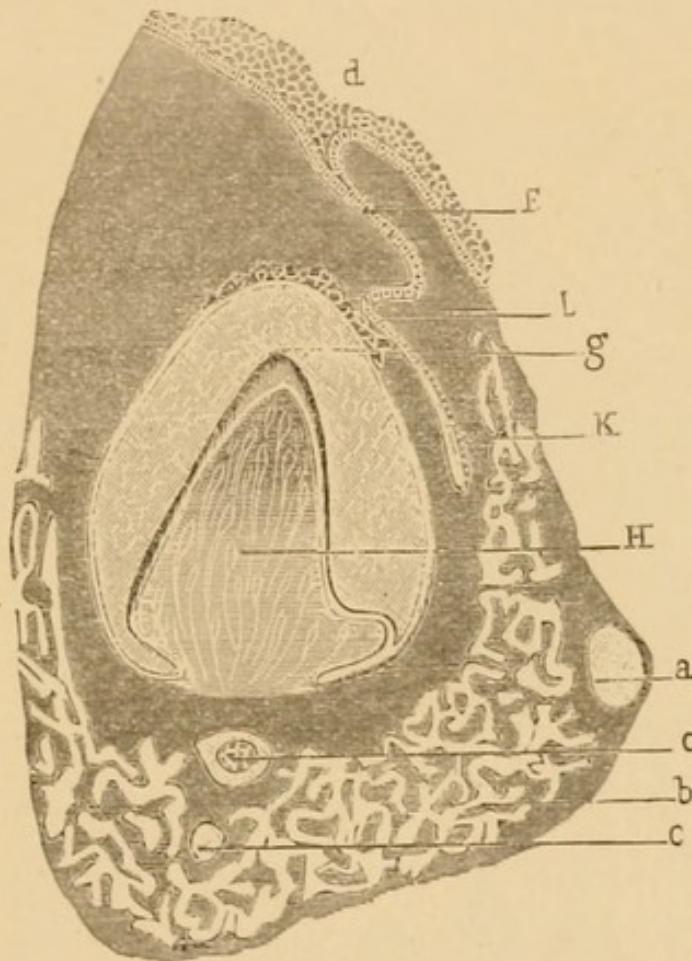
FIG. 31.—Section of the lower jaw of a human fœtus, 23 centimeters in length [or 9¼ inches; corresponding to about the 18th week].

K, cord or bourgeon of the permanent follicle; *L*, point where its separation from the primitive cord is being effected; *g*, enamel-organ; *H*, bulb; *c*, section of the dental artery; *b*, traces of ossification; *c*, (lower) nerve; *a*, Meckel's cartilage.

the *débris* of the primitive cord, or directly
from the epithelial lamina.   (Fig. 32, K.)
The descent of the secondary bourgeon

FIG. 32.
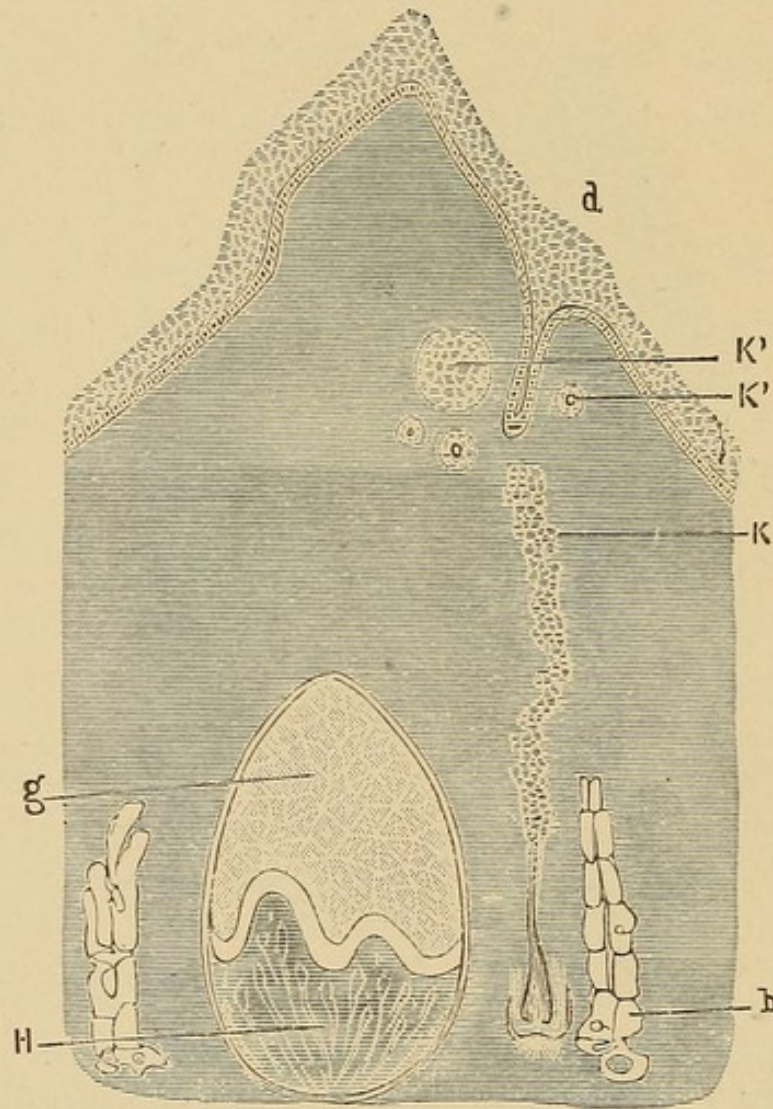
FIG. 32.—Vertical cut of the lower jaw of a human fœtus,
measuring 47 centimeters [18½ inches, and corresponding
to about the 39th week of gestation]. This figure represents
a section passing through the follicle of a bicuspid. *K′ K′*,
epidermal masses; *K*, *débris* of the secondary cord; *g*, en-
amel-organ; *H*, bulb; *b*, bone of the jaw; *d*, epidermis.

into the dental groove is soon followed by the entire series of phenomena which are common to every follicular evolution, . . . [and which are precisely the same as those already described for the primitive bourgeons.] (Fig. 32, K.)

While these phases of development are being accomplished, certain modifications occur in the parts which surround the primitive follicle. The stump of the ruptured cord, which remains attached to the primitive follicle, becomes the source of those fragmentary growths and buddings which have been described at considerable length in a preceding paragraph. These phenomena commence in the human embryo when it has attained about twenty-three centimeters [or nine and one-fourth inches] in length, about the fourth month. These phenomena, which always commence from the moment the cord is severed, seem to occur in the embryos of other mammals a little earlier, relatively, in the period of gesta-

tion. This is the case in equine and bovine embryos. Besides, in the lower animals the secondary bourgeon emanates from the primitive cord at a point a little farther from the primitive follicle than in the human species. This is also the case in the ovine embryo.

CASPER: I have just been reading a treatise styled the *Anatomical, Physiological and Microscopical Researches on the Teeth*, by Dr. J. E. Oudet, a French writer, whose opinion, it seems to me, is entitled to considerable respect. He most emphatically denies that any of the permanent follicles are derived either from the cords or from follicles of the temporary teeth; on the contrary, he claims that they emanate, directly and independently, from the "mucous membrane." It seems very strange that there should be such wide differences of opinion in regard to a simple anatomical fact.

TEACHER: Nearly all of the most eminent histologists of the present day,—Tomes, Kölliker, Waldeyer, Frey, Owen, Wedl, and I know not how many others, entertain essentially the same views in regard to this phenomenon as are here

set forth by Drs. Legros and Magitot. There are, however, a few distinguished writers, foremost among whom is the author you named, who believe that all the permanent teeth originate independently of the temporary set. Then, again, we have one histologist, our neighbor, Dr. G. V. Black, of Illinois, whose extensive observations in this direction have convinced him that, although the epithelial cords of the twenty anterior permanent teeth generally arise from those of the temporary follicles, yet that they do sometimes emanate directly from the epithelial lamina. It would appear from fig. 30, and also fig. 31, in the *Summary of Illustrations* (drawings of which were kindly furnished me by this gentleman), that his views are demonstrated beyond question. The histological specimens from which these drawings were taken have been examined by myself and others; and, saving a few minor and unimportant details, they are faithfully represented in these cuts. I have the assurance of Dr. Black that these were taken by himself from the *incisive region* of *different human* embryos. In these figures the epithelial cords of the permanent follicles appear to emanate directly

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from the lamina; in figs. 32 and 35, from the epithelial cord ; and in figs. 26, 27 and 28, from the primary follicle itself, rather than from its cord. (For these five figures, also, see *Summary*.) If all these figures are true representations of the parts themselves, the secondary cord may emanate directly from either the lamina, the cord, or the follicle itself.

Now, one word as to the place of origin of the third permanent molar. I am not prepared with any positive proof that this does not emanate from the source attributed to it by the authors of this work, and also by the several eminent authors first named, except Wedl. In closing these remarks I will only say that when I consider the *distance* and the *direction* that this cord must pursue,— starting from the point on the lamina from which the *first molar arises*, and extending in a backward, horizontal line to the spot where it eventually is developed; and, when I take into account the *period* of *time* that this cord must retain its *normal attachment* to this remote point in the epithelial lamina before the development of this follicle *commences*,—which cannot be less than three and one-half years; and when I add to

these facts the great morphological changes that occur in the neighboring and rapidly-developing parts during this long interval of time; — in view, I say, of all these unfavorable circumstances, I am not prepared to accept the theory advanced by these celebrated anatomists in regard to the origin of the wisdom teeth, without more positive evidence to sustain it. My own observations on this subject have not been conducted with sufficient scientific accuracy to justify me in placing my conclusions (or convictions) on record here; but I hardly need say that these points in embryonal histology require much careful revision.

Some differences are observed also as regards the direction of this secondary cord in the different species. Thus, while in the human embryo we have noticed that it takes a vertical direction, in those of the herbivora it follows a very oblique course; so that from the external side (not far from its connection with the epithelial lamina), passing above the temporary follicle, it pursues a curvilinear route

to the internal or lingual face of that follicle. This arrangement of the parts may be seen clearly defined in sections taken from the incisive region of bovine, ovine and equine embryos.

The point upon the primitive cord from which this secondary bourgeon emanates, as also the direction it takes, are not necessarily governed by the length of the secondary cord; for in the human embryo, although its direction is vertical, it is longer than in the equine, in which it takes a circuitous course. As a general rule, its length is governed by the height of the alveolar border and the direction of the primitive follicle. In man and the car-nivora this height is relatively more considerable; and besides, the great obliquity that the primitive follicles of the incisors of the herbivora assume, allows the secondary bourgeon to cross directly over the maxilla, and to place itself, after a very short passage, on the internal side of the primitive follicle, where its evolution is completed.

The cord of the secondary follicle, in its descent into the jaws, always assumes a spiral form, and thus perfectly resembles the duct of the sudorific gland in the epidermis. This special disposition is so marked a characteristic in the secondary cord, that it may be readily distinguished from the temporary cord; for though the latter describes some sinuosities in its course, it is never so distinctly spiral as the former. The necessity for this greater *spirality* in the cord of the permanent follicle may be explained by the fact that it must traverse the more developed tissue of the jaw to a greater distance in attending this follicle in its passage to a point beneath that of the temporary tooth; [and also to allow the rapidly developing parts to increase the distance between the follicle and the epithelial lamina, without straining the cord or disturbing the parts to which its two ends are attached.—Tr.]

The spiral character of the secondary

cord is especially obvious near its point of
origin, and in the first half of its course;
but toward its terminal extremity it dimin-
ishes, and finally disappears entirely, giving
place to a rounded club-shaped enlargement
exactly like that which we have described
at the extremity of the primitive cord.
This enlargement or expansion represents
the *enamel-organ* of the permanent tooth.

When the series of evolutionary phenom-
ena has brought the new follicle to the
period in which, in the human embryo, for
example, the bulb becomes *unicuspid* for
the canines and incisors and *multicuspid* for
the molars, the epithelial cord, which has
already been sometime severed from the
primitive follicle, becomes in its turn rupt-
ured. From this period the secondary fol-
licle, as well as the primitive, is found iso-
lated from all connection with the epithelial
lamina during the subsequent phases of its
evolution.

This rupture is soon followed by new

subdivisions in the substance of the cord itself, which seems to separate into fragments of various sizes. These fragments lengthen and bud in different directions to such a degree that these epithelial processes are mingled and confounded with those of the primitive cord, anastomosing with them, to form in this region a sort of plexus, sometimes quite close, and which extends even to the buddings that cover the follicular wall. Finally all these epithelial masses, after having thus proliferated and "vegetated," atrophy and disappear.

Such is the mode of genesis of the follicles of those permanent teeth which are preceded by corresponding temporary ones. Twenty of the teeth thus originate. But we find that the first teeth that appear behind the deciduous set are produced by an entirely different mode of genesis. The *first permanent molar*, the follicle of which becomes considerably developed in fœtal life, is derived from an epithelial cord which

originates *directly from the epithelial lamina.* This cord penetrates the fœtal tissue in a region where no follicle has preceded it. (*Sum. of Illus.,* Fig. 39.)

The origin of the *second molar* is similar to that of the first twenty permanent teeth, the follicle being produced from a diverticulum or outgrowth of the cord of the first molar. In this respect the second molar sustains the same relation to the first, that the permanent tooth does to the corresponding deciduous one. But they differ in the direction taken by the epithelial cords; for, while those derived from the cord of the temporary follicle pass over the lingual face of the latter to a point *beneath* them, that of the second molar takes a horizontal course for some distance, and then by an inflection takes its position at the *posterior* side of the follicle of the first molar, where it is developed in a line with those anterior to it. (*Sum. of Illus.,* Fig. 35.) As regards the *last molar,* or *wisdom tooth,* its origin is

effected in a manner similar to that which we have just described; that is, the epithelial cord that produces its enamel-organ is an emanation from the cord of the second molar. We must acknowledge, however, that in determining the origin of this tooth we have encountered many difficulties, owing to its position and to the alteration in the tissues, caused by the many reactions to which the jaws, after they have acquired considerable size and hardness, must necessarily be submitted. And yet, we have, in several cases, been enabled to determine, with almost positive certainty, that the cord of the wisdom tooth originates in the manner we have already indicated. From these observations we perceive that, while the first molar originates, as we have seen, from the epithelial lamina itself, it becomes, through the medium of its cord, the source from which the follicles of the succeeding molars are derived.

However this may be, with these excep-

tions in the mode of genesis of the follicles, all the evolutionary phenomena are identical, to whichever dentition they may belong; nevertheless the *order* in which their evolution is accomplished and the *duration* of their physiological phenomena differ. For, while the follicles of the first dentition are developed during the period embraced between the latter part of the third month of gestation and the beginning of the fourth year (within forty-two months), most of the follicles of the second dentition require a much longer time for their evolution. For example, though the follicle of the first molar makes its appearance in the fifteenth week of embryonal life (and only a few days after the most of those of the first dentition), yet it does not complete its evolution until about the sixth year. We see, therefore, that though the evolutionary phenomena of the follicles are identical in other respects, they cover periods that vary according to the nature and the temporary or permanent character of the future teeth.

CHAPTER VI.

CHRONOLOGY OF THE DENTAL FOLLICLE, OR THE PERIODS IN WHICH ITS SEVERAL COMPONENT PARTS APPEAR.

IN pursuing our researches on the mode of formation of the dental follicle in mammals, we have constantly kept in view one important question, namely, the determination of the periods at which the several organs that enter into its constitution make their appearance. This study has necessitated the careful examination of a large number of embryos, both human and of the principal domestic mammals. Another fact to be ascertained was, the exact age of the subjects upon which our observations were made. This, in the absence of positive evidence as to the period of conception, must, in most cases, be determined by measurement. Now, while the relation be-

tween the size and the age of the *human* embryo has been determined with great accuracy, by the aid of statistics collected from the reports of various authors; yet, up to the present time no sufficiently accurate data of this nature have been given concerning the other species of mammals in their successive stages of embryonal life. In the human species, (the study of which affords us more interest than that of any other, and may be more usefully applied,) we have made numerous observations upon a series of embryos measuring from 3 to 37 centimetres [$1\frac{1}{4}$ to 15 inches] in length, *i.e.* from the seventh to the twenty-eighth week of intra-uterine life. From these we have been enabled to fix all the periods of the evolution of the follicles of the first, and some of those of the second, dentition. We have established the other phases of the second dentition by the study of subjects in the later stages of foetal life, and at different periods after birth.

The smallest of these embryos, that of 3 centimeters [1¼ inches], (seventh week,) from which we have made vertical sections through the entire face (Fig. 7), has enabled us to determine that at this period no point of ossification is yet found upon any part of the cranium or of the face; the lower jaw alone presents some rudimentary osseous arches in the vicinity of Meckel's cartilage. This fact is in conformity with the observations published in a memoir on Meckel's cartilage, in 1862, by Drs. Robin and Magitot.

At this period in embryonal life the jaws offer nothing for our consideration, relating to the evolution of the follicles, except the *epithelial band*, which is found to be alike in both jaws (Fig. 7), and which we have already described. The follicle has not as yet appeared in these rudimentary parts, nor even the first trace of the epithelial lamina.

The second embryo submitted to our

observation was $5\frac{1}{2}$ centimetres * [$2\frac{1}{4}$ inches] in length, say of two months. From this we ascertain that the formation of the dental groove commences at this period of development, and that the epithelial cords representing the enamel-organs are very clearly defined; the dental bulb has already made its appearance as an opaque point in the region previously designated as its place of origin. This period of development, compared with the preceding, has enabled us to fix the time of the appearance of the epithelial lamina between the seventh and eighth weeks of embryonal life; and the genesis of the enamel-organ from the epithelial cord, about the eighth week.

Moreover, from these examinations we have been able to determine the important fact that development progresses at the same rate in *both jaws*, as well as in all the follicles of the first dentition, whether they be of the incisors, the canines or the

* [A centimetre = 0.39371, or say $\frac{2}{5}$ of an inch; a millimetre is $\frac{1}{10}$ of this, or $\frac{1}{25}$ of an inch.—Tr.

molars.   Upon a third embryo, which measured $7\frac{1}{2}$ centimetres [3 inches], corresponding to the eleventh week, we discovered that the stages of development for each of the follicles of the first dentition were identical, and that the bulb had become *uni-cuspid* for the incisors and canines, and *multi-cuspid* for the molars. The walls which had already risen from the base of the bulb were not yet united at the summit of the follicle, and the epithelial cord was still entire.   The bulb now consists of amorphous matter interspersed with nuclei, though its external surface presents a membranous appearance. The enamel-organ is distinctly stellated, and the cells that constitute the external epithelium are becoming smaller as compared with those of the internal epithelium [the ameloblasts].   No trace of the secondary cord is yet seen.

From our observations on a fourth embryo, of 11 centimetres [$4\frac{1}{3}$ inches], say

of twelve weeks, we ascertained that at this period the follicular walls are not closed, and that no trace of the dentine-cap is yet visible. The next embryo examined (measuring 15 centimetres [6 inches], indicating thirteen weeks,) showed no perceptible difference in development as compared with the former.

In an embryo of 20 centimetres [8 inches] (say at the commencement of the fourth month) we collected some valuable facts in regard to certain ulterior phases of evolution.

At this epoch the primitive follicular cord has not yet become severed, nor the follicle closed. A little cap of dentine is seen very clearly outlined in some, though not in all, of the follicles of the temporary dentition. It is, in fact, at the exact period when a slight trace of ivory is formed that we discovered the first chronological difference in the development of the follicles of the temporary teeth. For while the inci-

sors and the canines are now provided with a cap of embryonal dentine, it does not appear upon the molars until about a week later. The bulb [dentine-germ] has now the exact form of the crown of the future tooth; its base has already become constricted and is embraced by the margins of the enamel-organ, which is already completely constituted, with its internal layer of cells [ameloblasts], and the *stratum intermedium* well defined.

It is also at this period of development that we first see, emanating from the primitive cord, those buddings which are destined to form the secondary cords, or the enamel-organs of the permanent teeth. All these bourgeons (or buds) representing the commencement of the permanent follicles, are, in both jaws, at the same stage of evolution [in other words these enamel-buds start simultaneously].

From an embryo of nearly the same dimensions as the preceding ($23\frac{1}{2}$ centimetres

11

[9¼ inches] in length, and corresponding to the eighteenth or nineteenth week), we have fixed the epoch at which the separation of the secondary cord from that of the primitive follicle takes place. The latter now becomes isolated from the epithelial lamina and continues its evolution without any further connection with this tissue. (Fig. 31, p. 133.) The permanent follicle, however, still remains attached to the cord, and, by the latter, to the epithelium. We direct attention to these facts, because in neglecting to take account of the successive phases of evolution one might be led to believe that the follicles of the permanent teeth originate directly from the epithelial *lamina*, and not from the *cords* of the temporary teeth. This last mode of genesis is, on the contrary, definite and invariable for all the follicles of the permanent teeth which have been preceded by corresponding temporary teeth, that is to say, for twenty of the teeth of the second dentition; viz., the eight in-

cisors, the four canines and the eight pre-
molars [bicuspids]. It will be seen that
the other follicles of the permanent teeth
have a different origin. The sections taken
from the jaws of the embryo (20 centi-
metres in length) have enabled us to deter-
mine positively the period and the mode of
genesis of the cord of the first permanent
molar, which is not, as is known, preceded
by a corresponding temporary tooth. This
genesis takes place at the extremity of the
epithelial lamina; and since, in the embryo
above named, the epithelial cord had al-
ready acquired considerable length, we
may reasonably conclude that its develop-
ment commenced about the seventeenth
week of gestation. (Fig. 39, *Summary*.)

At this epoch, when the separation of
the temporary follicles from the cord of the
corresponding permanent ones takes place,
there appears also the first trace of those
phenomena of buddings and of divers pro-
liferations of the débris of this primitive

cord and of the epithelial masses on the walls,—particularities which were first described in France.* By the examination of other human embryos ranging from 27 to 37 centimetres [10¾ to 15 inches], and upward, we have been able to fix the subsequent phases of evolution, not only of the temporary follicles, but also those of the permanent teeth. These successive studies have thus brought us up to, and even beyond, the period of birth. In this manner we have been enabled to establish two points which remained to be elucidated in this order of researches, namely: the mode and epoch of the evolution of the follicles of the second and third permanent molars.

The results to which we have arrived in regard to these, are the following: On examining sections taken from the jaws of subjects two or three months after birth, we discover in the region occupied by the follicle of the first permanent molar, a pro-

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* See Robin et Magitot, loc. cit., p. 75.

cess or prolongation, cylindrical in form, emanating from the epithelial cord of the latter follicle, and which takes a horizontal and backward direction, terminating in a bulbous extremity. This prolongation is the commencement of the follicle of the second permanent molar. Thus we fix the date of the origin of this follicle at the third month after birth. At about the third year of infancy the epithelial bourgeon that represents the enamel-organ of the third molar originates from the cord of the preceding tooth, that is, the second permanent molar. According to the numerous observations we have made, this date may be regarded as very nearly accurate, though the difficulties of which we have already spoken have prevented us from following out the successive phases of evolution in a very rigid manner. Yet that a little cap of dentine is visible in this follicle about the twelfth year, is true beyond a doubt.

Without continuing further the long

analysis of the many anatomical preparations we have made, we will present a summary of them all in a tabular form. In this are indicated the age and size of various embryos corresponding with the successive phases of follicular evolution. This table is the first which has yet appeared giving these in such a complete and exact manner.

An examination of this table enables one to see at a glance the different phases of dental evolution in man. The indications which it furnishes are founded on the examination of a considerable number of sections; and consequently they appear to us to show great accuracy. Aside from their physiological interest, they not only have an important bearing upon the complex teratology of the dental system, but are especially valuable in a surgical point of view. There will be found, in fact, some valuable data concerning certain anomalies, whether in the position, direction, or in the

different arrangements of the dental system. Besides they throw light upon the pathogony of certain follicular cysts and help to fix the period at which these pathological productions make their appearance, as well as that of certain derangements of nutrition,—the odontomes, for example. We believe, then, that it will be found serviceable in certain cases in practice.

The results of the observations we have made on other species of mammals have been less conclusive; sometimes on account of the head only being placed at our disposal, and sometimes owing to the change of size and form that they have experienced by prolonged maceration; and finally in consequence of the absence of all statistics establishing the correspondence between the age and length of the animal. Certain of them have, however, enabled us to gather some useful data which we will here present.

CHRONOLOGY OF THE DENTAL FOLLICLE IN MAN.

Designation of the Follicles.	Place of origin of the epithelial cord.	Period at which the enamel-organ first appears.	Period at which the dental bulb appears.	Time of the appearance of the follicular wall.	Closing of the follicle and rupture of the cord.	Periods at which the dentine-cap first appears.	Periods at which the teeth are erupted.	Periods at which the teeth are normally shed.
Temp'ry Dentition.								
Inf. cent. incis.	Epithelial lamina.	From 7th to 8th week.	9th week.	10th week.	Beginni'g of the 4th mo.	16th week	6th month.	7th year.
Sup. cent. incis.							10th month.	7½ years.
Inf. lat. incis.							16th month.	8th year.
Sup. lat. incis.							20th month.	
Inf. cuspids							30th to the 32d month.	12th year.
Sup. cuspids							24th month.	
1st inf. molars						17th week	26th month.	10th year.
1st sup. molars							28th month.	10½ years.
2d inf. molars							30th month.	11th year.
2d sup. molars								11½ years
Permanent Dentition.								
Inf. cent. incis.	Cord of the correspond'g temporary teeth.	About the 16th week.	20th week	21st week.	9th month.	1st month aft. birth.	7th year.	
Sup. cent. incis.								
Inf. lat. incis.							8½ years.	
Sup. lat. incis.								
Inf. cuspids							11 to 12 years.	
Sup. cuspids							9 to 10 years.	
1st inf. bicusp.	Cord of the correspond'g temporary molars.	15th week.	17th week.	18th week.	20th week.	6th mo. of foetal life.	11th year.	
1st sup. bicusp.								
2d inf. bicu-p.								
2d sup. bicusp.								
1st inf. molars	Epithelial lamina.	3d mo. after birth.	1st year.	1st year.	1st year.	3d year.	From 5 to 6 years.	
1st sup. molars								
2d inf. molars	Cord of the 1st perm'nt molars						From 12 to 13 years.	
2d sup. molars								
3d inf. molars	Cord of the 2d perm'nt molars	3d year.	After the 6th year.	After the 6th year.	After the 6th year.	12th year.	From 18 to 25 years.	
3d sup. molars								

In the canine species our observations have been limited to the examination of a few new-born puppies; accordingly the facts concerning the chronology of the dental follicle in this animal are very few. We have, however, ascertained, that at the period of birth, the follicles of the first dentition are already provided with a cap of dentine; that the cord of the permanent incisors has made its appearance, and that in the centrals we can already discern the first traces of the dental bulbs. In the ovine and bovine species our studies have extended to a large number of embryos, but owing to the absence of information we have not been able to determine their exact ages. We proceed, however, to give some of our observations, taking into consideration simply the length of the animals examined. In an ovine embryo of 42 millimetres [about 1¾ inches] in length (Figs. 16 and 19, *Summary of Illus.*) we find on the edge of the jaws only the bourrelet,

or projecting band, with no trace of the epithelial *lamina*. But when the embryo has attained 52 millimetres [2 inches] we perceive the *epithelial lamina* well developed. (Figs. 17 and 18, *Summary of Illus.*) In an embryo of 65 millimetres no additional change is perceptible in the development; yet with a magnifying power of about 300 diameters one can study in this the constituent elements of the lamina. (Fig. 18, *Summary of Illus.*)

When the embryo has attained 72 millimetres [about 3 inches] the extremity of the *lamina* shows a very marked enlargement, which represents the enamel-organ of the future tooth. (Fig 21, G, *Summary.*)

At a little more advanced period, in an embryo measuring 82 millimetres [$3\frac{1}{3}$ inches], the enamel-organ and the dentine-bulb have completed their formation, and the follicular wall has made its appearance at the base of the bulb. (Figs. 26 and 28, *Summary.*)

When the embryo has attained 11½ cen-
timetres [4½ inches] we observe that the
walls are completed, and closed around the
epithelial cord which is about to be rup-
tured.   At this period, also, we discover
the first appearance of the dentine cap.
Such are the facts we have collected from
the embryonal lambs which we have been
able to procure.

In the bovine embryo our observations,
in a chronological point of view, have been
much more limited, the heads only of these
embryos having been placed at our dis-
posal, without any information as to the
period of gestation.   These specimens, how-
ever, have enabled us to furnish some de-
scriptive details which are very distinctly
shown in this animal.   (Figs. 38, 41 and 42,
Summary.)   We will state, however, that in
a fœtus of eight months we have found the
temporary incisor teeth quite fully devel-
oped, the follicle of the permanent incisors
complete, and the dentine-cap beginning to
form.

Our observations have been made upon equine embryos of different ages. From these we have determined certain facts in relation to the various phases of follicular evolution. For the first three embryos we are indebted to the courtesy of M. Raynal, of the veterinary school at Alfort. In the youngest of these (14 weeks) the enamel-organ of the central *nippers* (incisors) are already formed, and the bulb has made its appearance. For the lateral nippers the enamel-organ is just beginning to show itself. These facts indicate that the evolution of the follicles varies in point of time in the different incisors; whereas the evolution of the follicles of these teeth in man and other mammals appears to be synchronous. For the molars, it is found that at this same epoch the bulb has appeared for all the follicles of the first dentition, as have also the first traces of the follicular wall.

In a second embryo (of 27 weeks) the follicles of the central incisors are closed,

while those of the first lateral incisors are just beginning to exhibit the bulbs; and those of the second lateral incisors only the enamel-organ. These facts, as we see, additionally confirm the unequal development of the different incisors in this animal. In the molars the facts are analogous; the follicle of the first temporary molar is closed at this date, while the enamel-organ of the second has only just made its appearance, and no trace of that of the third molar is yet visible. It is at this period, also, that the first indication of the enamel-organ appears for the first permanent molar.

In a third embryo, measuring 255 millimetres [10 inches], corresponding to about $28\frac{1}{2}$ weeks, the follicles of the permanent incisors are closed and complete; the enamel-organ is well developed. The ameloblasts of the interior bed are very large, and the external epithelial layer has already disappeared,* but no trace of dentine yet appears.

* [The above statement, concerning the early disappearance of the external epithelial layer of the enamel-organ, is

The follicles of the permanent incisors have arrived at the period when the enamel-organ already caps the bulb, which is just appearing, but is not yet constricted at its base. (Fig. 29, K, *Summary*.) For the temporary molars the follicles are about equally developed. They are closed and well formed, but without any appearance of the dentine-cap. The organ of coronal cement is already beginning to manifest itself. From the fragments of the ruptured epithelial cord numerous buddings have been produced.

From the fourth (an equine fœtus of $31\frac{1}{2}$ weeks), owing to a very prolonged maceration in alcohol, we were prevented from deriving much advantage. We were only able to determine that the temporary follicles were fully developed and provided with caps of dentine of considerable thickness. Some fragments of the epithelial cord (long since broken, without doubt,) were still re-

evidently erroneous; the sections examined which led to this opinion were probably defective.—TR.]

maining. The organ of coronal cement was fully developed.

We will conclude these chronological considerations with a few notes relative to the rodents: In an embryonal guinea-pig of 2 centimetres [$\frac{4}{5}$ inch] in total length, which appeared to correspond to about the middle period of gestation, the follicle was at the stage when the enamel-organ, in form of a hood, covers the bulb; there was no follicular wall or dentine-cap apparent.

In another embryo of the same species, of 4 centimetres [$1\frac{1}{2}$ inches] in length, the temporary follicles were formed, and their stages of development were nearly the same. They were provided with a dentine-cap, covered with a thin layer of enamel. In the rabbit we discover that, at birth, the incisors have effected their eruption, the molars still enclosed, but already capped with thick layers of dentine and enamel. Beneath the temporary molars we observe the presence of the permanent follicles, already provided

with a thin but distinctly manifest layer of dentine.

We will not pursue these considerations further, which are of less interest in the lower mammals than in man, in regard to whom we have presented a large number of examples.

CHAPTER VII.

CRITICISM OF THEORIES — RÉSUMÉ AND CONCLUSIONS.

THE problem of the genesis and formation of the dental follicle in mammals has, for a long time, been the subject of numerous researches, and has given rise to many theories. The relatively early period in embryonic life at which these phenomena commence; the difficulties attending the preparation of the specimens (the treatment by different reagents to which they must be submitted, etc.), are so many causes which have retarded the progress of exact knowledge regarding the embryogenic evolution of these organs. The question has passed through numerous phases, and, without going back very far in its history, and without presenting the opinions of ancient authors, imbued with preconceived notions

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of the nature of the teeth, or strangers to the processes of investigation of the modern anatomical·school, we will say that in going back no farther than the middle of the last century we find that Hérissant,* having conceived that he found on the surface of the mucous membrane of the gums certain small depressions, considered them to be orifices of canals communicating with the dental follicles. This opinion, which rested on no anatomical fact, was adopted by only a few authors (Bonn, 1773; Oudet, 1835). According to the theory of Hérissant, which we find at a later day more clearly presented by Goodsir, the mucous membrane of the gums would be the point of origin of the follicle, the wall of which would be developed before the follicle itself. In 1835,† in an important work,

* *Nouvelles recherches sur la formation de l'émail des dents et sur celle des gencives. Mém. de l'Acad.* Paris, 1754.

† *Meletemata circa dentium mammalium evolutione Vratislariæ.* In. 4°, 1835, p. 12.

Raschkow advanced the theory that the dental follicle is produced at the inner face of the mucous membrane, without the necessary participation of the latter; however, he does not specify which of the organs of the follicle appears first, nor how the others are produced. Nevertheless, Henle,[*] Bischoff,[†] and Kölliker [‡] (in the first edition of his microscopical anatomy) support his opinion. A few years later appeared the work of Goodsir,[§] in which is formulated that well-known theory according to which both the temporary and the permanent follicles originate directly from the mucous membrane itself. Immediately adopted, without verification by the majority of authors, it is even now nearly the only theory found in the greater number of treatises on

[*] *Anat. gén.* 1845, p. 441 et suiv.

[†] *Traité du développement*, 1845, p. 401–418.

[‡] *Mikroscop. Anat.*, 1856, *traduction française de Béclard et Sée*, p. 490.

[§] *On the origin and development of the pulp and sacs of the human teeth.* Edinburgh "Medical and Surgical Journal," 1838.

anatomy and physiology.   We will not describe here this theory, according to which the follicles of the two dentitions result from a simple introversion of the mucous membrane; it is founded on no anatomical fact, unless it be the formation of a groove which is produced on the alveolar border of the embryo by a prolonged maceration of the preparations, thus effecting the separation of the epidermic bed, which forms the epithelial band, from the groove which incloses it.   It is, then, as we have said, solely by an artificial process, as Kölliker* and Kollmann † have already remarked, that the theory in question can have any appearance of reality; for nothing in the normal condition of the jaws can be found to lend support to it in any way.   Notwithstanding the success of Goodsir's theory, universally accepted in England and Germany, N. Guillot published in France

*_Histologique humaine._   Edit. Trad. française, 1869.
† _Loc. cit._, p. 150.

a work * in which he endeavored to show that the teeth are developed without the slightest participation of the mucous membrane; that it is from a mass originating in the depth of the embryonal tissue that the follicle is produced. This mass he calls the *initial spheroid*, or primitive trace of the tooth. He describes in this "spheroid" three divisions: a central one, which he names the *nucleus*, representing the *bulb ;* an intermediate one surrounding the other, the *enamel-organ ;* and lastly, the external one, which will become organized to form a membrane, he calls the *dental sac.* From this description, as a whole, it is easy to see that N. Guillot has limited himself to the examination and figuring of sections made through follicles which are in an advanced stage of evolution, and that he has not hit upon the mode of origin of the component parts of the organ and their successive

* *Recherches sur la genèse et l'évolution des dents et des Mâchoires.* *Ann. des sc. nat.*, IV° série, t. IX, 1858.

phases of development. This work, then, has thrown no light upon the question.

Several years later (in 1860) appeared in France an extended work, published by M. Ch. Robin, in connection with one of the authors of this work.* This memoir contained a complete theory of follicular evolution, according to which the dental bulb is the first part of the follicle that appears in the depth of the jaws, at the bottom of the groove and in the vicinity of the principal vessels and nerves; afterward the enamel-organ is seen; and then the wall emanating from the bulb, and rising upon the sides of these organs so as to surround them and to unite at the apex of the folli- cle. Whatever may be the accuracy of the descriptions in this work, it is evident that its authors misconceived the true *order* of the genesis of the follicle; for in reality the enamel-organ makes its appearance before the bulb.

* Robin et Magitot, Mémoire cité Journal de physiologie de Brown-Séquard, 1860–61.

Whence comes this error in the interpretation of the very first phenomena of follicular evolution? It results evidently from the too exclusive mode of examination which was adopted; for the observations were made upon preparations of follicles gradually flattened between two plates of glass. Very few sections were made. The authors wished thereby to preserve, in their reciprocal relations all the parts which they dissected, for the purpose of further researches in detail. The fear of deforming the sections and disturbing the relations which sometimes result from cuttings made upon masses of tissues somewhat thick, and we must say the insufficiency of the processes of hardening known at that period,—all these combined singularly to lead these anatomists into the error that they have there committed.

The question was at this point, when Kölliker discovered (1863*) the existence

* *Die Entwicklung der Zahnsäckchen der Wiederkäuer.* Zeitschr. f. Wissen. Zool. 1863. Gewebelehre, 4 Aufl.

of an epithelial band subjacent to the gin-
gival ridge of the mucous membrane, and
which extends the entire length of the
jaws.   This continuous lamina Kölliker
calls the *enamel-organ*; but we regard it
only as a simple dependence of the epithe-
lial band.   The term *enamel-organ* does not
appear to us to be appropriate to a *lamina*
which does not contribute directly to the
formation of the follicle, since it is upon a
certain number of points of this that bour-
geons appear, from which the enamel-organs
are directly developed.   These bourgeons
are in number equal to that of the future
teeth; and in the intervals between the
bourgeons, or enamel-organs, the epithelial
lamina remains unchanged.

Whatever may be said of the interpreta-
tion of them, the views of Kölliker are very
just; and they became the starting-point of
a series of observations which gave to the
question of the evolution of the dental fol-
licle an entirely new aspect.   Two facts

were from that time settled, namely, that
the enamel-organ appears as the first con-
stituent part of the follicle, and that its
origin is epithelial.   Upon this last point
the views previously put forth by Marcusen
and Huxley were confirmed.*   Following
the work of Kölliker are grouped a consid-
erable number of researches emanating from
his pupils, or coming from other German
schools.   Such are the memoires of Wal-
deyer, Hertz, Wendzel, Kollmann, etc. †

* Marcusen, *Ueber die Entwicklung der Zähne. Bulletin
de l'Acad. impériale de Saint Pétersbourg*, 1849.   Huxley,
Quart. Journal of Microscopical Science, 1854, 1855, 1857.

† Waldeyer, *Untersuch. über die Entwicklung der Zähne:*
I Abth. Königsberg und Jahrbücher IV, Bd. 1864; II Abth.
Zeitschr. fur rat.   Med.; III, 24 Bd. 1865.—IV. *Bau und
Entwicklung der Zähne* in Stricker, *Handbuch der Lehre
von den Geweben.*   Leipzig, 1871, p. 333 et suiv.—Hertz,
*Untersuchungen über feineren Bau und die Entwicklung der
Zähne.*   *Virch. Arch.* 1866, Bd. 37; *id., Ein Fall von
geheilter Zahnfractur mit nachfolgender Schmelzbildung.*
Virch. Arch. 1866, 38 Bd.—Wendzel, *Untersuchungen über
das Schmelzorgan und den Schmelz, etc.   Arch. von Hekde.*
1868, p. 97.—Kollmann, *Entwicklung der Milch und Ersatz-
zähne beim Menschen.   Zeitschrift für Wissenschaftliche
Zoologie*, von Seibold und Kölliker; Zwanzigster Band,
Zweites Heft, p. 145.   Leipzig, 1870.

In these different works the idea of Kölliker is taken at the initial point. Waldeyer described exactly the descent of the cord, and the formation of the component parts of the follicle. He indicates, also, that the follicles of the permanent teeth arise from buddings from the primitive cords; but he fails to mention, in regard to them, the different modes of genesis, and also the precise points where this genesis takes place. He points out, moreover, in his last publication,* the unsettled difficulties which exist in these questions, notwithstanding the numerous works published upon this subject. Hertz and Wendel support the opinions promulgated by Kölliker and Waldeyer, without adding anything new to the question of the origin of the follicle. They have, however, advanced some new ideas upon other points of follicular evolution, which we will discuss on another occasion. As to Kollmann, the last German anato-

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* See in Stricker, *loc. cit.* 1871, p. 352 (English Edition).

mist who has studied the question, he adopts unhesitatingly the views of Kölliker and Waldeyer on the subject of the origin of the enamel-organ of the temporary teeth; but in regard to the origin of the permanent follicle, sometimes he derives it directly from the mucous membrane, sometimes from the epithelial débris of the primitive cord, and at others from an epidermic globule. It is also from one of these last that he makes the supernumerary follicles arise, as we have already mentioned.* The German authors are, then, very far from agreeing, as we see, in regard to the mode of origin of the dental follicle. As to the phenomena which take place within that organ after the origin of the bulb, and the formation of the wall, and the transformation of the enamel-organ, they are still in controversy. In our opinion, and we may thus in a few words resume our work, the formation of the dental follicle consists, es-

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* [See p. 66 of this work.—Tr.]

sentially, in the genesis of two organs, one of which is of an *epithelial* nature, emanating from the epithelium of the mucous membrane, the other of an *embryoplastic* nature, originating in the midst of the embryonic tissue of the jaws. The first of these is the *enamel-organ*, the second is the *bulb*, or dentine-organ; thus they are formed individually and then proceed to meet each other. The enamel-organ becomes in a manner the cap of the bulb, while from the base of the latter emanate membranous processes, which envelop little by little the two organs, and at last entirely close the follicle. If one examines the origin and growth of these organs from the point of view of general physiology, he is immediately struck with the extreme analogy they present to the phenomena of the formation of the hair-follicles. In the latter, as well as in the former, one sees on the one hand an epithelial cord which descends from the Malpighian layer into the dermis; then on a

point of the latter appears the bulb, which penetrates the former, and makes of it a cap for itself; while from its base emanate those processes which are to form the walls of the follicle. These facts show the close analogy of these two organs. (Fig. 40.)

Thus we find confirmed, by actual physiological and embryological facts, the theory enunciated a long time since by De Blainville, regarding the analogy in the composition and formation of the *phanères*, as well as the doctrine of the *products* developed with so much precision in the modern anatomical school of Ch. Robin.

CONCLUSIONS.

1st. The dental follicles first appear as a cord emanating from the epithelial layer of the oral mucous membrane.

2d. The cords that give origin to the follicles of the first dentition arise directly from a process of the oral epithelium (epi-

thelial band and epithelial lamina). The cords for those permanent teeth which succeed the temporary ones are *diverticula* or outgrowths from the primitive cords. As for the cords of the other permanent teeth, those for the first molars originate directly from the epithelium of the mucous membrane, and the remaining ones (eight in number) from the cords of the preceding molars. (See table.)

3d. The cord, whatever may be its point of origin, is invariably epithelial; it is composed outwardly of a layer of prismatic elements of the Malpighian stratum, and in the interior, of polyhedric epithelial cells.

4th. The extremity of the cord, which soon takes the form of a club-shaped swelling, constitutes the *enamel-organ* of the future follicle.

5th. The *dental bulb* appears spontaneously in the midst of the embryonic tissue and at a point in immediate proximity to the deeper face of the enamel-organ.

6th. The enamel-organ covers the bulb, serving as a cap for it; an arrangement which continues during all the periods of evolution, preceding the formation of the dentine and the enamel.

7th. The follicular processes emanate directly from the elements of the bulb, and rise from its base to the summit of the follicle, where they unite and constitute the follicular sac.

8th. Synchronous with the closing of the follicles is the rupture of the cord; and from this period the follicle loses all connection with the epithelium of the mucous membrane. The formation of the follicle is now complete.

9th. The evolutionary phenomena of the follicles in both dentitions are identical as to their nature; the only perceptible differences are in regard to the exact point from which the epithelial cords originate, and the length of time necessary to accomplish their successive phases of evolution.

10th. The mode of evolution of the dental follicle and of the pileous follicle is identical.

FRANK : Are, then, our readings to terminate here?

TEACHER : The appearance of the *second memoir* in the series has been long delayed, owing to the death of one of its authors, the lamented Dr. Ch. Legros. Much of the materials for this, I am informed, had been collected before his decease; but the preoccupation of Dr. Magitot has prevented his completing it up to the present time. I am, however, daily expecting the arrival of this treatise, and, should it be found desirable, we may resume our readings.

If you have obtained a clear idea of the phenomena of the origin and growth of the dental follicle from the present work, you have acquired far more than has been hitherto taught in any of our medical or dental schools, or can be found in any other publication upon this subject; and though it will, doubtless, become necessary for you to modify your views in some particulars, as this branch of science progresses, yet the knowledge you have here gained will enable you to readily perceive and appreciate the value of future researches made either by yourselves or by other observers in this field of study.

SUMMARY OF ILLUSTRATIONS

AND A BRIEF

DESCRIPTIVE REVIEW.

All figures not accredited to other sources are copied from the original work.

The dental *bulbs*, in some of the following figures, present a *vascular* appearance, not seen in those from which they are copied. It was believed that by thus representing them, the student might more readily recognize the different parts of the developing follicle.

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FIG. 1.—This diagram shows the relative position of the different layers which are designated the mucous, or "proper" mucous, membrane by various writers. The column on the left gives the names and location of the strata of the mucous membrane as we think they should be designated. The horizontal lines show the relative location of these layers, without any regard to their thickness. *M. S. D., del.* (See p. 11.)

FIG. 2.—This cut was designed to illustrate the cells of the epidermis *E,* in some of their various phases, as described (p. 18 *et seq.*) *a,* Stratum corneum; *b,* stratum Malpighii, with its *prismatic* or columnar layer resting upon the basement membrane, *b m; c,* upper portion of the dermis. The papillæ are not represented in this figure, nor the subdermal layer. *M. S. D., del.* (See p. 18 *et seq.*)

FIG. 3.—The so-called "spinous," "ridged," "imbricated," "aculeated," "prickle" or "heckle" cells. *Frey.* (See p. 59.)

FIG. 4.—Showing the lowest layer of the *Malpighian stratum* (*a*); the intermediate matter (*b*); the basement membrane (*c*); and the fibrous tissue of the dermis (*d*). (From *Frey.* Diagrammatic.) Though the cells of this layer always stand nearly perpendicularly, their form is varied; for example, the basal extremities are truncated in the ameloblasts, somewhat like those seen in Fig. 7, p. 191. (See p. 21.)

FIG. 5.—Stellate cells, such as compose the "stellate reticulum" of the enamel-organ. Diagrammatic, from *Frey.* (See p. 77.)

FIG. 6.—Cut to represent the basal aspect of a layer of ameloblasts; showing their prismatic or hexagonal form. *M. S. D., del.* (See p. 85.)

FIG. 1.

			1st Class.	2d Class.	3d Class.	4th Class.
Mucous membrane,	Epidermis.	Strat. corn.				Mucous
		Strat. Malp.	M. memb.			
	Basement memb.			M. memb.		
	Dermis { Pars pap. / Pars ret.				M. memb.	memb.
	Subdermis.					

FIG. 2.

FIG. 3.

FIG. 4.
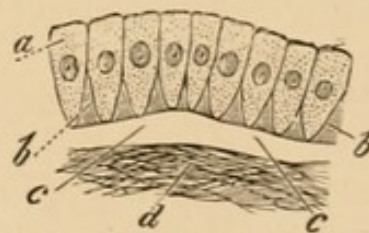
FIG. 5.

FIG. 6.
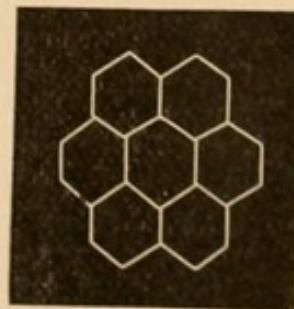
Fig. 9.—Meckel's cartilage ; from a human embryo of forty to forty-two days. (Magnified 25 diam.) *a,* Enlargement of cartilage near the neck of the *malleus; b,* the *mental symphysis* where the two homologous parts unite; *m,* head of the *malleus; n,* handle of the same; *e,* cartilage of the *incus; o,* that of the *os lenticulare; l,* that of the *stapes.* One side of the jaw has been outlined to show the relative position it will occupy when ossification takes place. (For further description of this and following figures, see p. 32 *et seq.*) *Magitot and Robin.*

Fig. 10.—Cranium of a human fœtus of four months; natural size; showing the membrane of the tympanum, with the cartilages of the incus and malleus (*b*); also the *extra-tympanic* portion of Meckel's cartilage (*a*). *Magitot and Robin.*

Fig. 11.—Right inferior maxilla of a human embryo of about three months; natural size. Soft parts removed from the internal face, showing relative position of Meckel's cartilage. *a,* Extra-tympanic portion; *b,* symphysis; *n, manubrium mallei* (handle of hammer); *e, incus* (or anvil). *Magitot and Robin.*

Fig. 12.—From a human embryo of about sixty days; natural size. Soft parts removed, showing Meckel's cartilage and lingual face of the jaw-bone, left side. In this the cartilage has much the appearance of a very large bristle. *A,* Extra-tympanic part; *b,* symphysis; *n,* malleus. *M. S. D., del.*

Fig. 13.—From a fœtus of four months; showing the palatal aspect of the *inter-maxillary* bones. *M. S. D., del.* (See p. 40.)

FIG. 9.
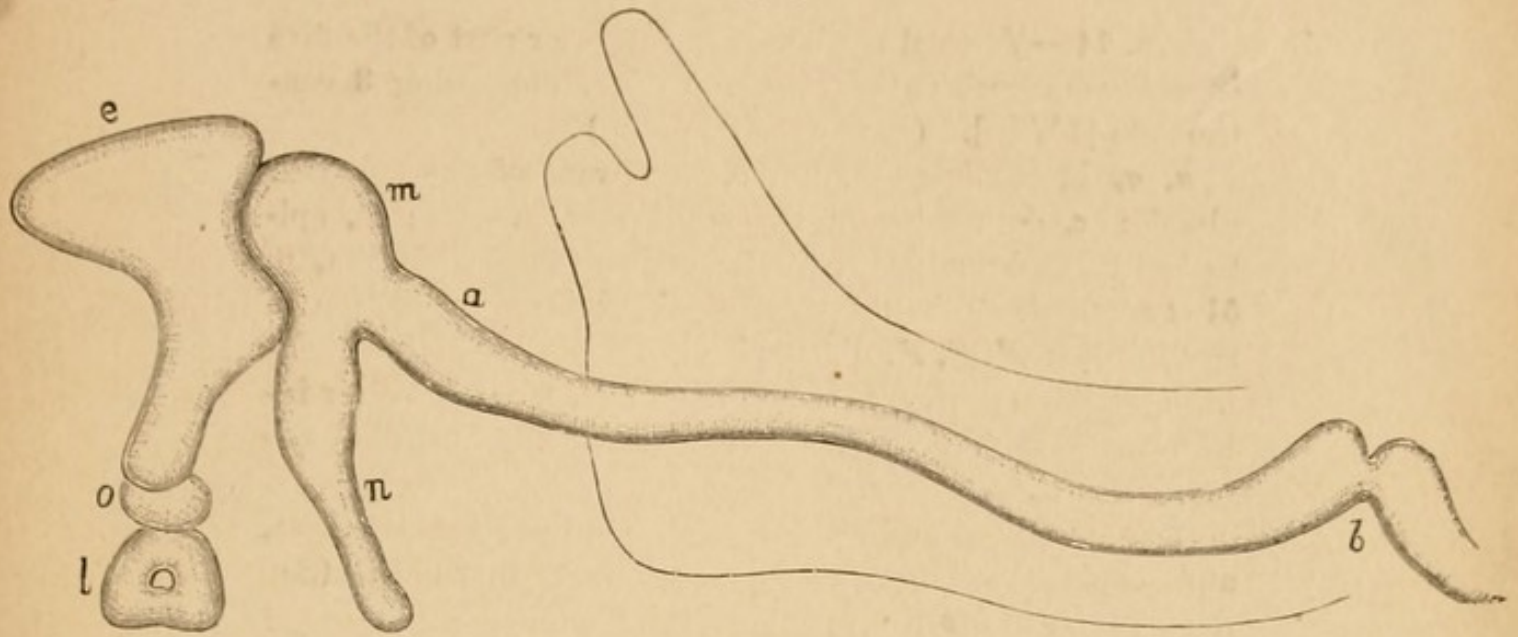
FIG. 11.

FIG. 10.
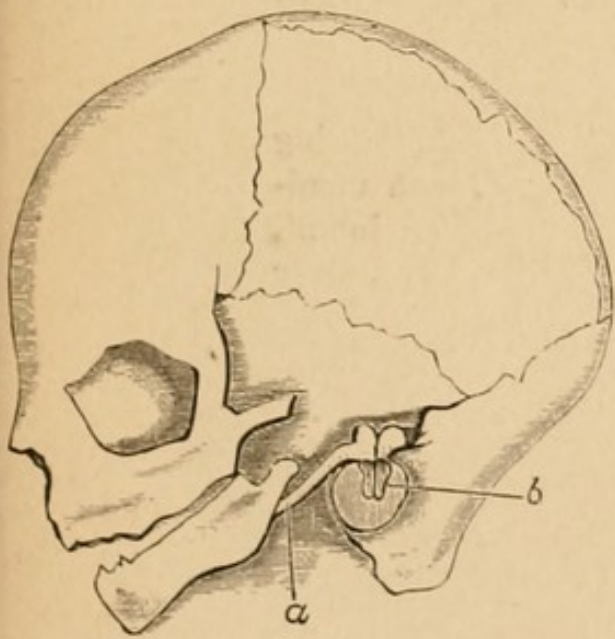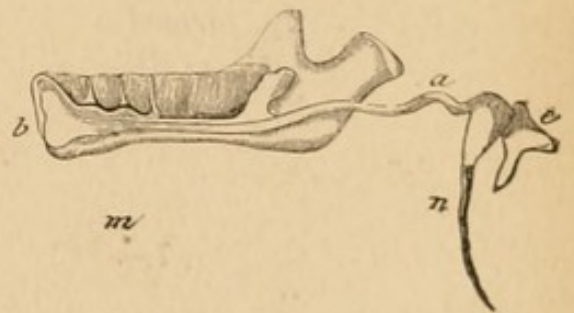
FIG. 12.

FIG. 13.
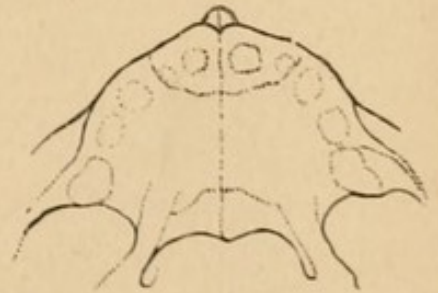
Fig. 14.—Vertical section of the anterior part of the face of a *human* embryo of about 45 days, measuring 3 centimetres [1¼ in]. (Magnified 80 diam.)

a, a, Meckel's cartilage; *b,* first trace of the submax. glands; *c,* depression of the mucous membrane; *d',* epithelial band, *bourrelet* of the lower jaw (see description, p. 51 *et seq.*); *d,* epithelial band of upper jaw; *E,* section of the tongue; *F, F, F, F,* oral cavity, a thin bed of epithelium clothes its surface; *g,* upper jaw; *H, H,* incisive (or intermaxillary) bourgeons, which have already united at the median line.

This central line does not appear in the original figure, and should terminate where it enters the lighter part. (See description, p. 149.)

Fig. 15.— Embryo of 40 days, showing the mouth and palatal region. (Coste).

1, First appearance of the nose; 2, 2, alæ of the nose; 3, closure of the incisive processes; 4, median portion of upper lip, *formed* by the *approach and union* of *the two incisive (or intermaxillary) processes,* the little notch in the median line still indicating the primitive separation of the two processes. (See p. 29.)

Fig. 7.—Taken from Kölliker's *Manual of Hist.,* showing "a simple papilla [of the mucous membrane], with manifold vessels and epithelium, from the gums of an infant. (Magnified 250 diam.)" It is given here principally to show the cells of the epidermis. (See p. 26.)

FIG. 14.
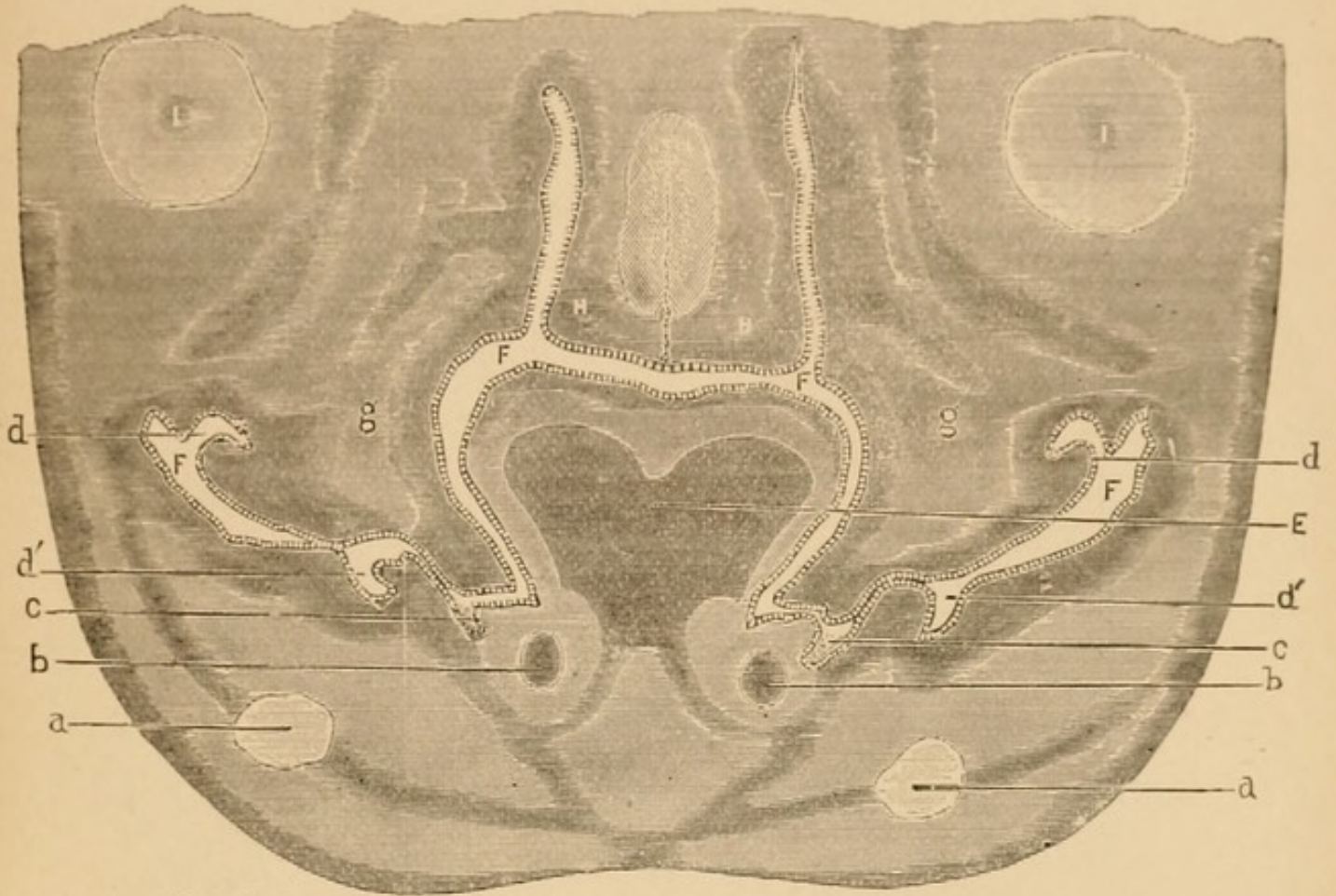
FIG. 15.
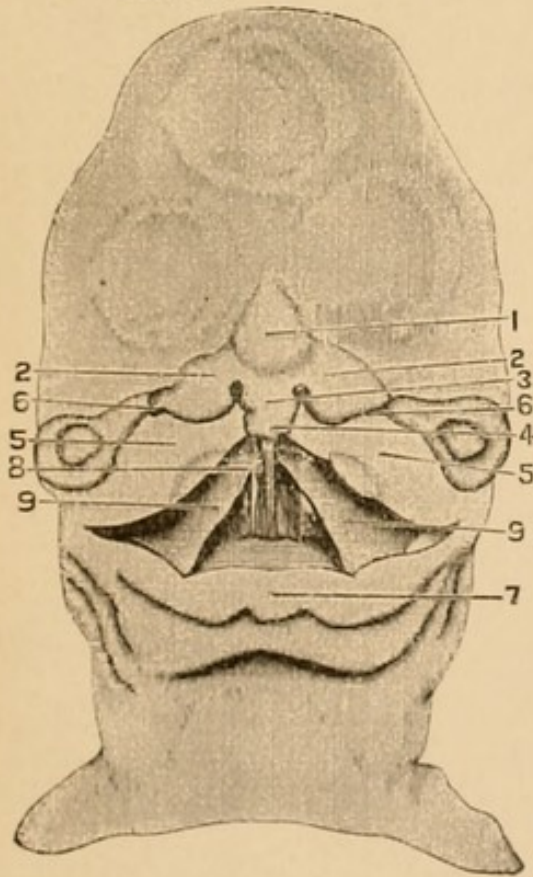
FIG. 7.
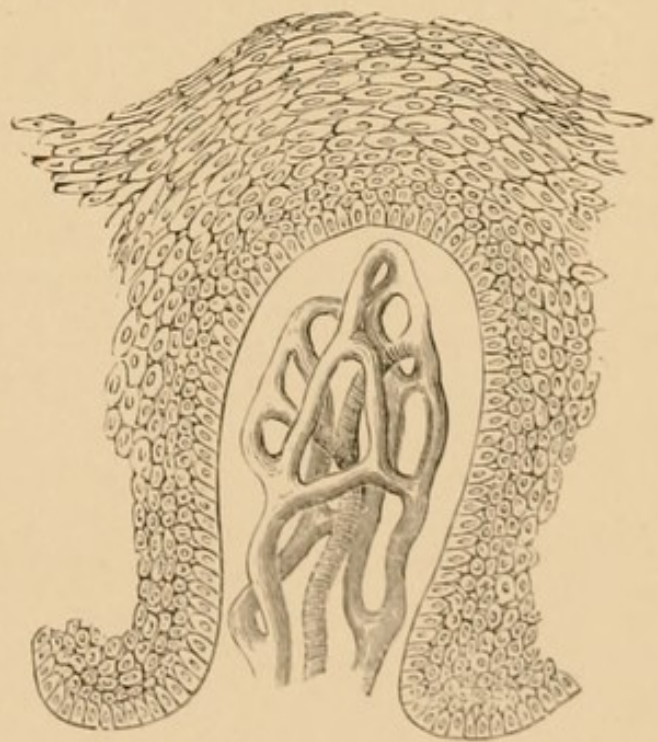
Fig. 16.—Vertical section taken from the incisive region of an *ovine* embryo, 42 millimetres [1¾ inches] in length. (Magnified 80 diam.) *a*, Meckel's cartilage; *c*, depression of mucous membrane; *d*, epithelial band. The close proximity of the parts of the severed cartilage shows the cut to have been taken from the anterior portion of the jaw. (See p. 53.)

Fig. 17.—Vertical section of the anterior portion of the lower jaw of an *ovine* embryo, 59 millimetres [about 2 inches] in length. *E, E, epithelial lamina*, emanating from the epithelial band. The letters *a, c, d* refer to the same parts as in the preceding figure. (See p. 63.)

Fig. 18.—Vertical transverse section of the left branch of the lower jaw of an *ovine* embryo, 65 millimetres. (Magnified 260 diam.) This and Fig. 17 show the arrangement of the elements of the epithelial band, and also the epithelial lamina. *d*, Epithelium of the mucous membrane, extending nearly vertically into the embryonal tissue and constituting the epithelial band, and the lateral process or epithelial *lamina*.

E, Epithelial lamina, emanating from the band. The band and lamina are surrounded by the embryonal tissue of the jaw. This portion of the engraving is faulty, in that the nuclear elements appear lighter, whereas they should be darker, than the surrounding mass. (See p. 63 *et seq.*)

Fig. 19.—From a *porcine* embryo (copied from *Frey*). *d*, Mass of epithelium,—the "dental ridge," "maxillary rampart" or "kieferwall"; *b*, younger layer of epithelium; *c*, deepest layer,—the columnar or prismatic stratum; *e*, enamel-organ. (See p. 52.)

Fig. 16.
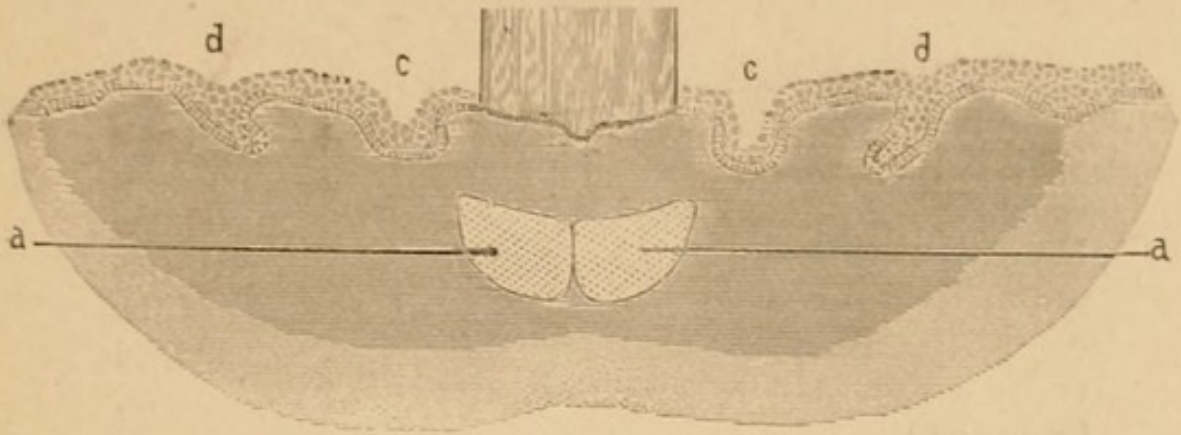
Fig. 17.
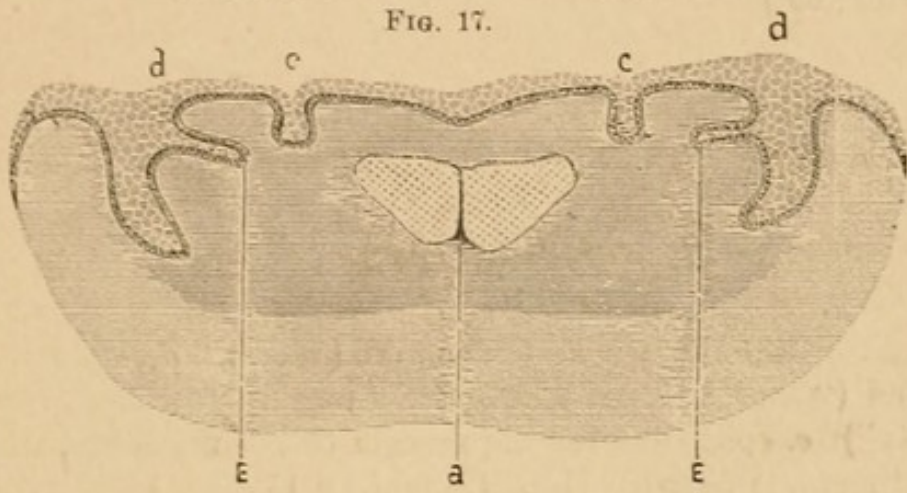
Fig. 18.
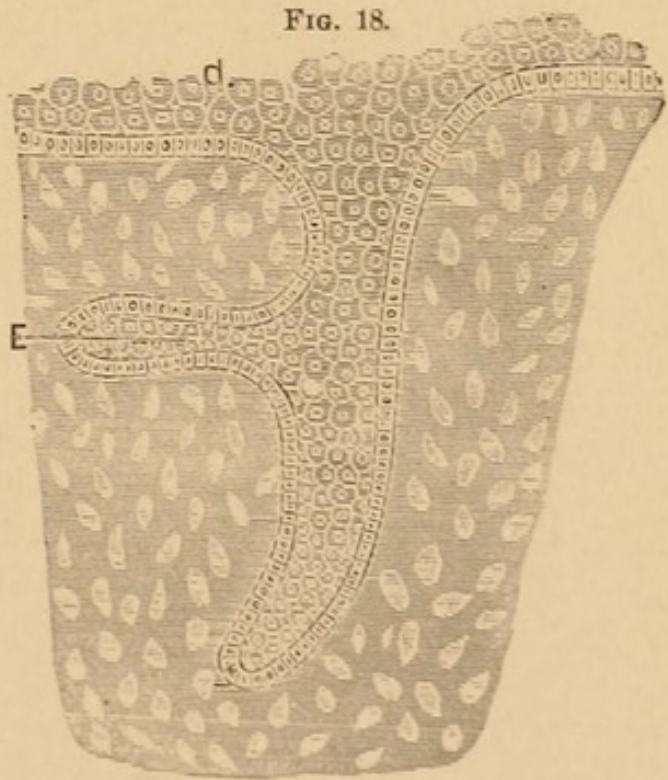
Fig. 19.
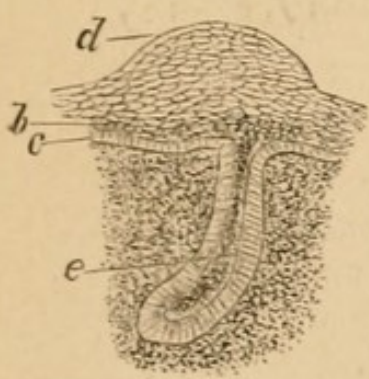
FIG. 20.—Section from an embryonic lamb a little older than that from which Fig. 18 was taken; showing the epithelial lamina. (Magnified 350 diam.) c, Prismatic or columnar cells,—a continuation of the lowest layer of the Malpighian stratum; d, large polygonal cells of the epithelial band (bourrelet); E, smaller polygonal cells of the epithelial lamina. The lamina now presents an enlarged extremity, and this is the rudiment of the enamel-organ. (See p. 69.)

FIG. 21.—From the lower jaw of an *ovine* embryo (left side), measuring 72 millimetres [$2\frac{5}{8}$ inches]. (Magnified 80 diam.) d and E same as in preceding figures; g, rudimental enamel-organ. (See p. 70.)

FIG. 23.—From a *bovine* embryo (Wedl). d, Epithelial band ("dental ridge"); b, enamel-organ ("follicular process"); c, epithelium of the margin of the under lip, with rudimentary hair-follicles. (Magnified 15 diam.)

FIG. 24.—From the incisive region of an *ovine* embryo, lower jaw, 115 millimetres [$4\frac{3}{8}$ inches]. (Magnified 80 diam.) a, Meckel's cartilage; b, osseous trabeculæ; c, c, dental artery; d, epithelial band; E, epithelial lamina; f, cord; g, enamel-organ; H, rudimentary bulb.

In this figure, which has been drawn from nature, as well as all the others, certain defects, which have resulted from too long maceration, have been preserved in the drawings; hence the space seen between the follicular wall (I) and the enamel-organ (g) is artificial, and does not appear in fresh preparations. It will be seen, on the right side of the figure, that the cut was not in line with the follicle, and that only the lamina is apparent.

Fig. 20.
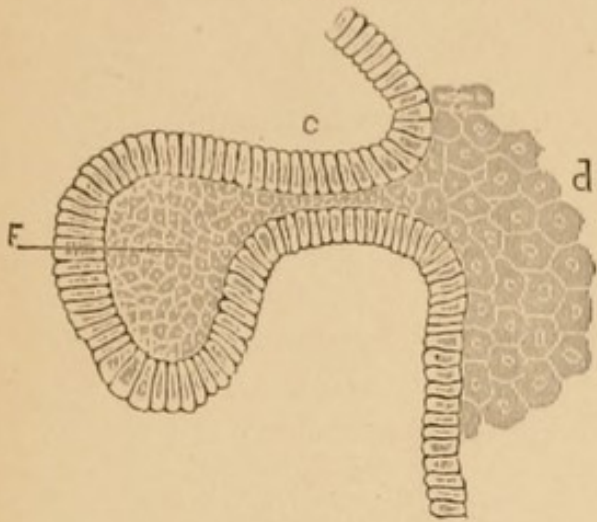
Fig. 21.
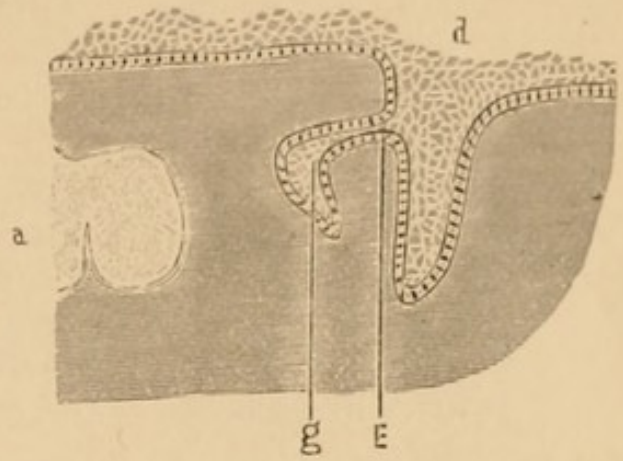
Fig. 22.
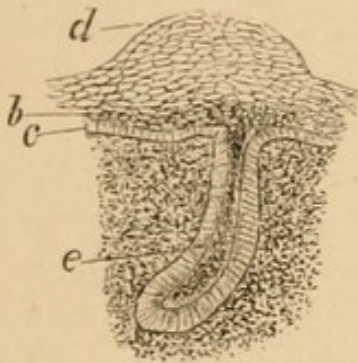
Fig. 23.
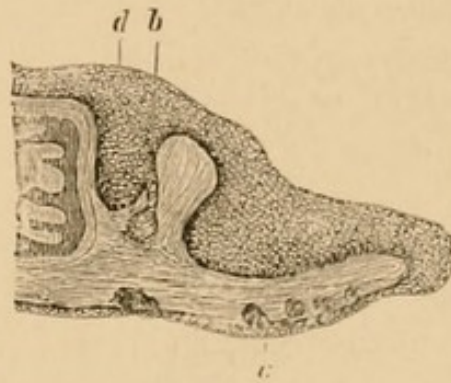
Fig. 24.
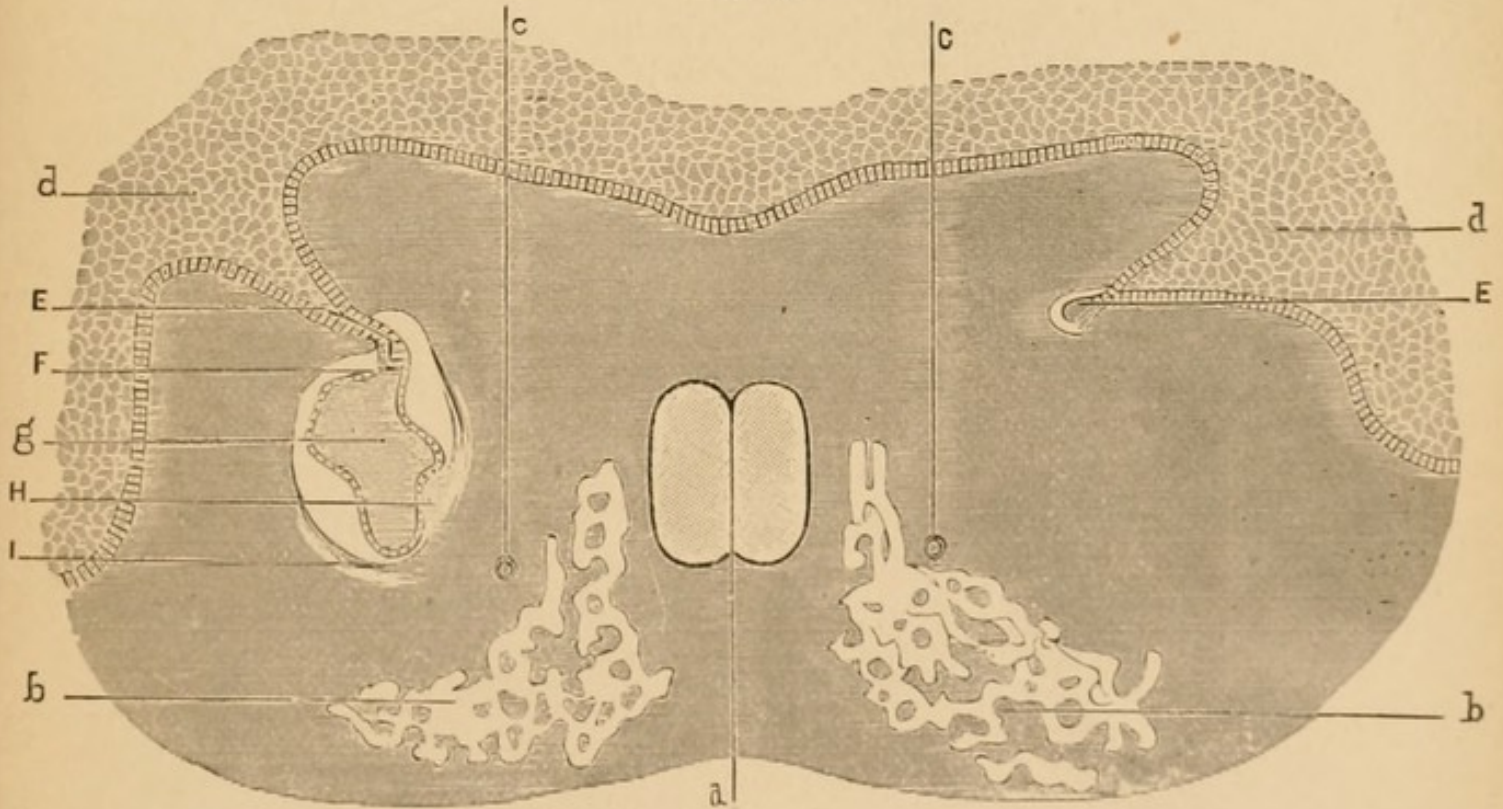
Fig. 25.—From lower jaw of an *equine* embryo, 190 milli-metres [7⅗ inches] in length. (Magnified 80 diam.)

a, Meckel's cartilage; *b*, traces of ossification; *E*, epithelial lamina; *F*, cord; *g*, enamel-organ; *H*, bulb; *I*, follicular wall. This figure shows the same defect alluded to in Fig. 24.

Fig. 26.—From lower jaw of an *ovine* embryo, 82 milli-metres [3¼ inches] in length. (Magnified 80 diam.)

a, Meckel's cartilage; *E*, epithelial lamina; *F*, epithelial cord; *g*, enamel-organ; *H*, bulb; *I*, follicular wall; *K*, secondary bourgeon, from which the enamel-organ of the permanent tooth originates.

Fig. 27.—From lower jaw of a *bovine* embryo, magnified 80 diameters.

a, (in the center of the figure), Meckel's cartilage; *b*, traces of ossification; *d*, oral epithelium; *E*, epithelial lamina; *F*, epithelial cord; *g*, enamel-organ; *H*, dental bulb; *I*, "internal epithelium," or layer of ameloblasts; *I'*, external epithelium of the enamel-organ; *K*, secondary enamel-bourgeon.

FIG. 25.
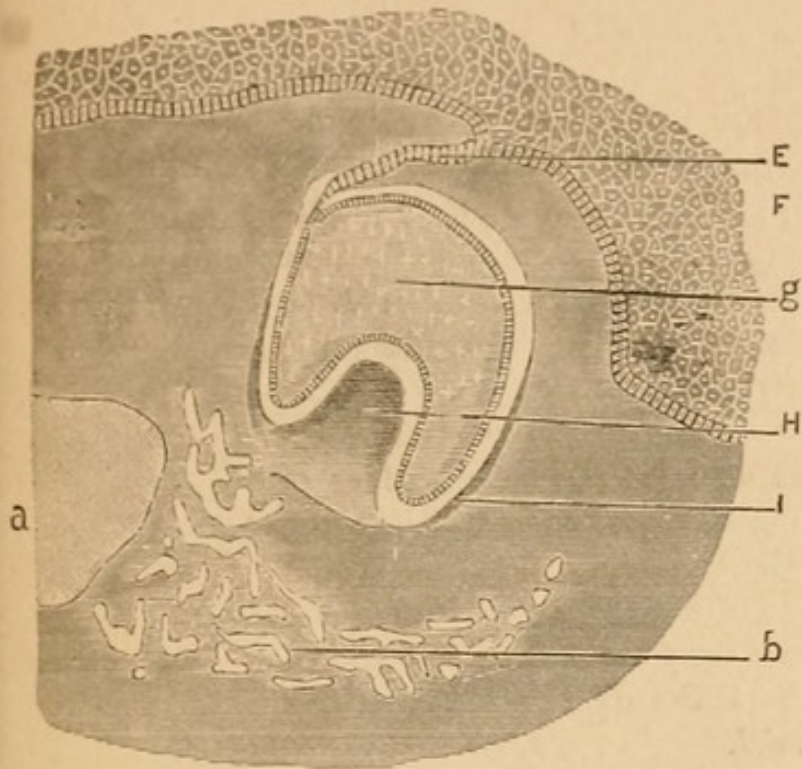
FIG. 26.
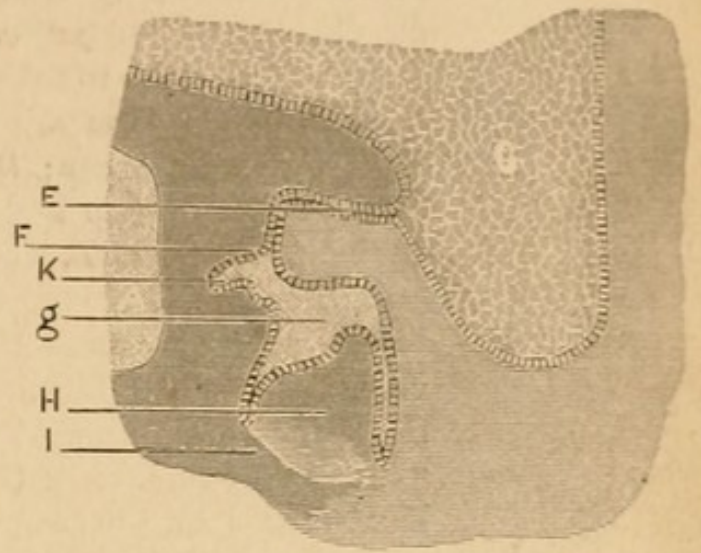
FIG. 27.
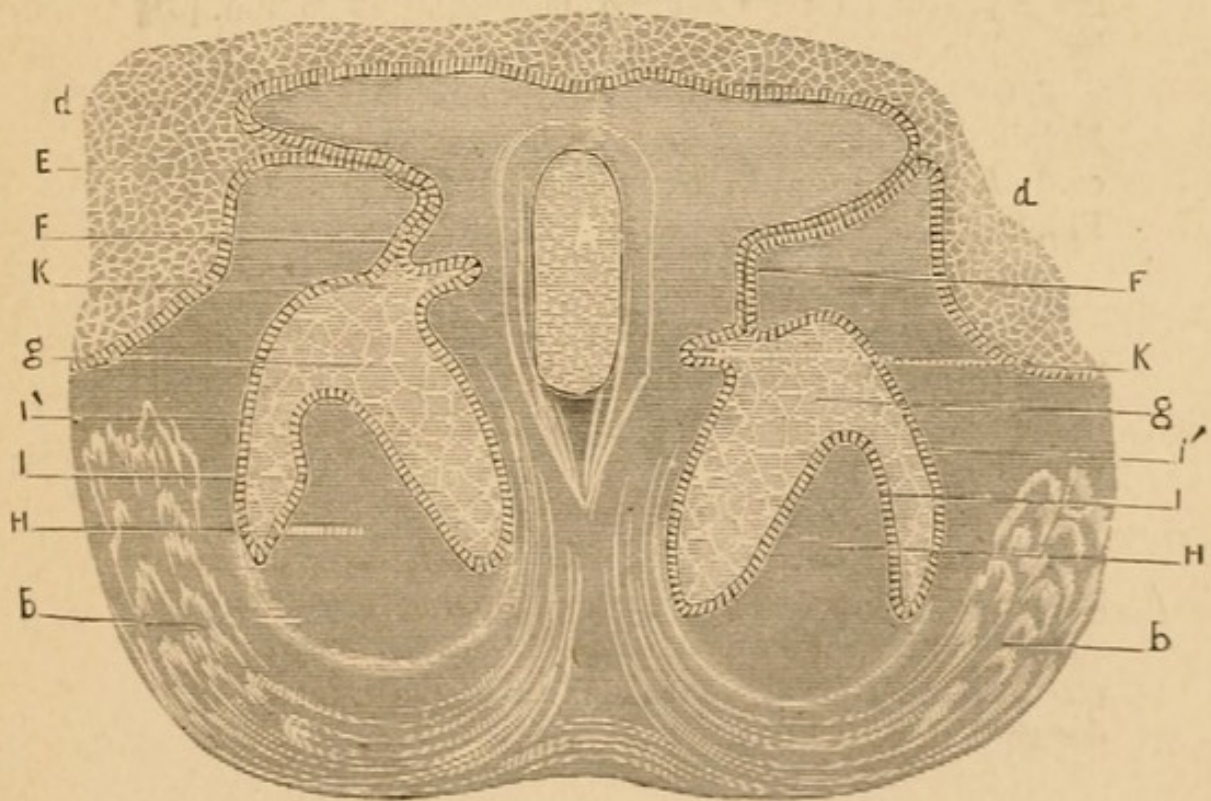
FIG. 8.—Ideal dental follicle, before the rupture of its cord. Drawn solely to show the position of the *basement membrane*, and the *preformative membranes* of Raschkow and Huxley. (For full description, see p. 89.)

B M, basement membrane; *N*, neck; *S*, sac or follicular wall; *O*, enamel-organ; *B*, bulb; *E E*, external epithelium of the enamel-organ and the basement membrane; *E C*, epithelial cord; *C T*, connective tissue surrounding the enamel-organ; *E p*, epidermis or oral epithelium.

The parts embraced between the points where the divergent lines *A A* terminate are: (1) the concave face of the enamel-organ, lined with a layer of ameloblasts, or the "internal epithelium"; (2) the membrana præformativa of Huxley, or the tissue composed of the basal coverings of the ameloblasts; (3) the membrana præformativa of Raschkow, or the basement membrane; (4) the dentine-bulb itself.— (Diagrammatic.) *M. S. D., del.*

FIG. 28.—Section through the incisive portion of the lower jaw of an *ovine* embryo, measuring 82 millim. [$3\frac{1}{3}$ inches] in length. (Magnified 260 diam.)

d, Oral epithelium; *c*, lowest layer of cells in the stratum Malpighii; *F*, epithelial cord; *K*, bourgeon of the secondary cord; *I*, follicular wall; *H*, dental bulb. (See p. 162; also Fig. 26.)

FIG. 29.—Vertical section of the anterior portion of the lower jaw of an *equine* fœtus, 255 millimetres [$10\frac{1}{2}$ inches] in length, and corresponding to about $28\frac{1}{2}$ weeks. (Magnified 80 diam.)

a, Meckel's cartilage; *b*, traces of ossification; *d*, oral epithelium; *g*, enamel-organ; *H*, bulb; *I*, layer of ameloblasts; *K*, bulb of the permanent tooth, capped by the enamel-organ, with some traces of the secondary cord; *L*, place assigned for the development of the cement. (See description, p. 165.)

FIG. 8.
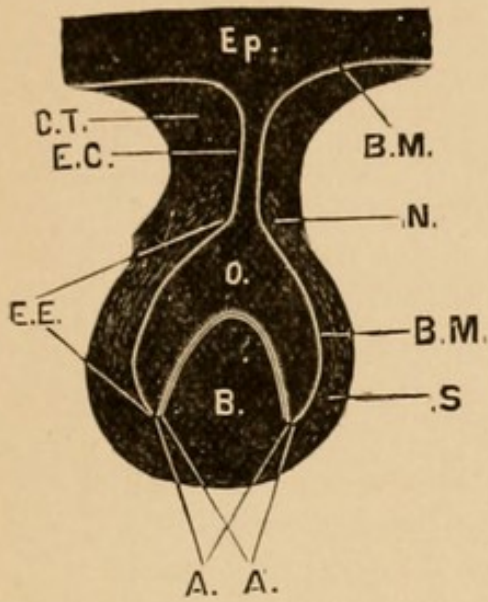
FIG. 28.
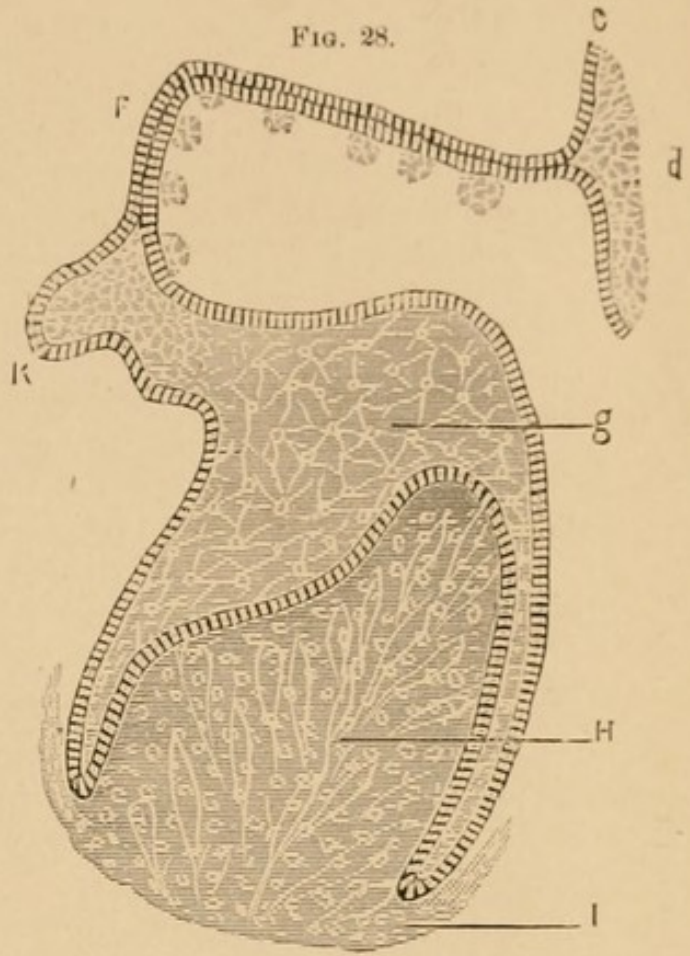
FIG. 29.
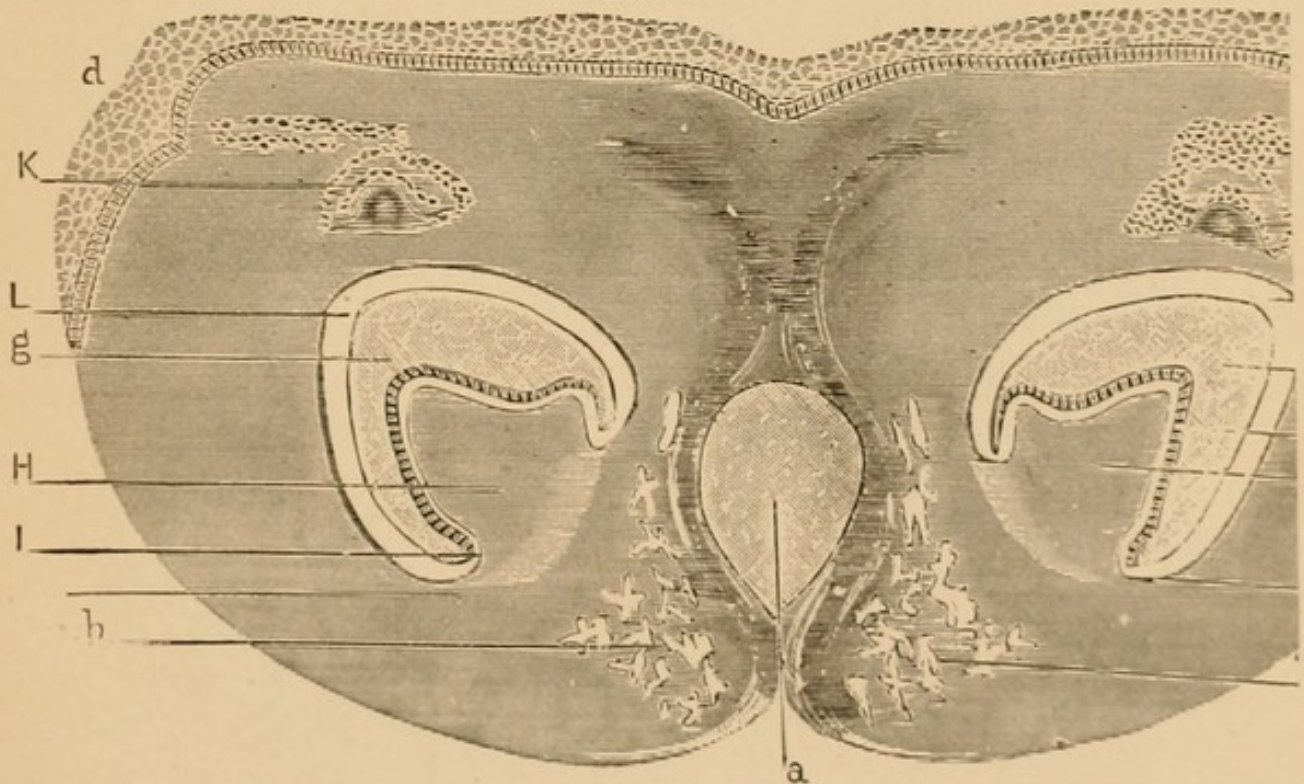
Figs. 30 and 31.—These cuts are taken from the incisive region of different human fœtuses, evidently not far from the sixteenth week of gestation. A detailed description of the figures would be unnecessary. The cuts are introduced here simply because they present one peculiarity that is not represented in the other figures, viz, the origin of the epithelial cords for the permanent incisors *directly* from the epithelial lamina, instead of their being offshoots from the cords of corresponding temporary follicles. These are designated by the letters *E* on the right of the figure.

Though these figures seem to establish the fact that the teeth of replacement are sometimes derived directly from the epithelial lamina, yet we must not regard these as conclusive evidence until they are fully verified by other skillful histologists.

For the drawings of these I am indebted to my friend Dr. Black. (See description, p. 137.)

Fig. 30.

Fig. 31.

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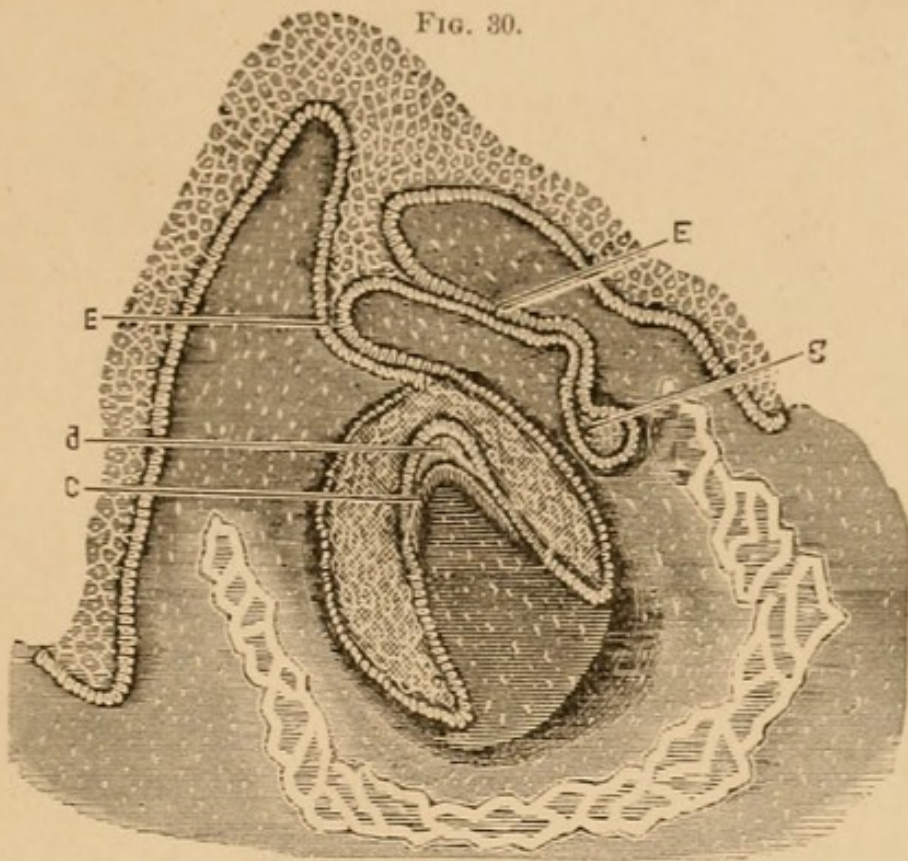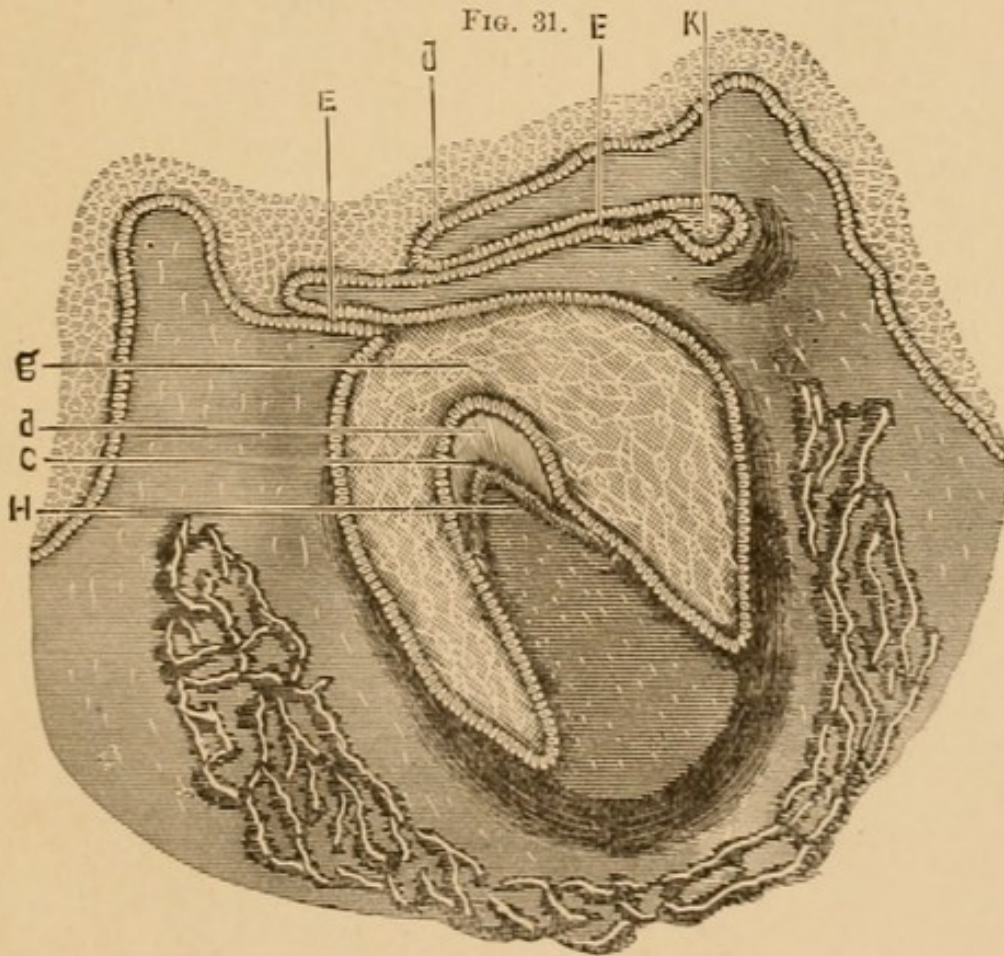
Fig. 32.—" From the upper jaw of a kitten about the time of birth.

a, Oral epithelium; *b*, bone of jaw; *c*, neck of enamel-organ; *d*, dentine papilla; *e*, enamel-cells; *f*, stellate reticulum; *h*, tooth-germ of the permanent tooth, the enamel-organ of which is derived from the neck of its predecessor."—From Tomes' *Man. of Dent. Anat.*

Fig. 33.—A cut through the follicle of a lower temp. molar of a *human* fœtus, 20 centimetres [8 inches] in length; about the seventeenth week of gestation. (Magnified 80 diam.)

a, Meckel's cartilage; *b*, traces of ossification; *c, c*, dental artery and nerve; *d*, epithelium ; *E*, enamel-organ; *F*, cord of the temporary follicle; *H*, bulb; *I*, follicular wall; *K*, cord of the permanent follicle. (See p. 152.)

Fig. 34.—Section of the lower jaw of a *human* fœtus, 23½ centimetres [9⅛ inches] in length; corresponding to about the eighteenth week. (Magnified 80 diam.)

K, Cord or bourgeon of the secondary follicle; *L*, point where its separation from the primitive cord is being effected; *a*, Meckel's cartilage diminished by absorption; *b*, bone of the jaw; *c*, (upper) dental artery, (lower) dental nerve; *d*, epithelium; *E*, originally the cord of the temporary follicle, but now the sole property of the permanent one. (See p. 153.)

FIG. 32.
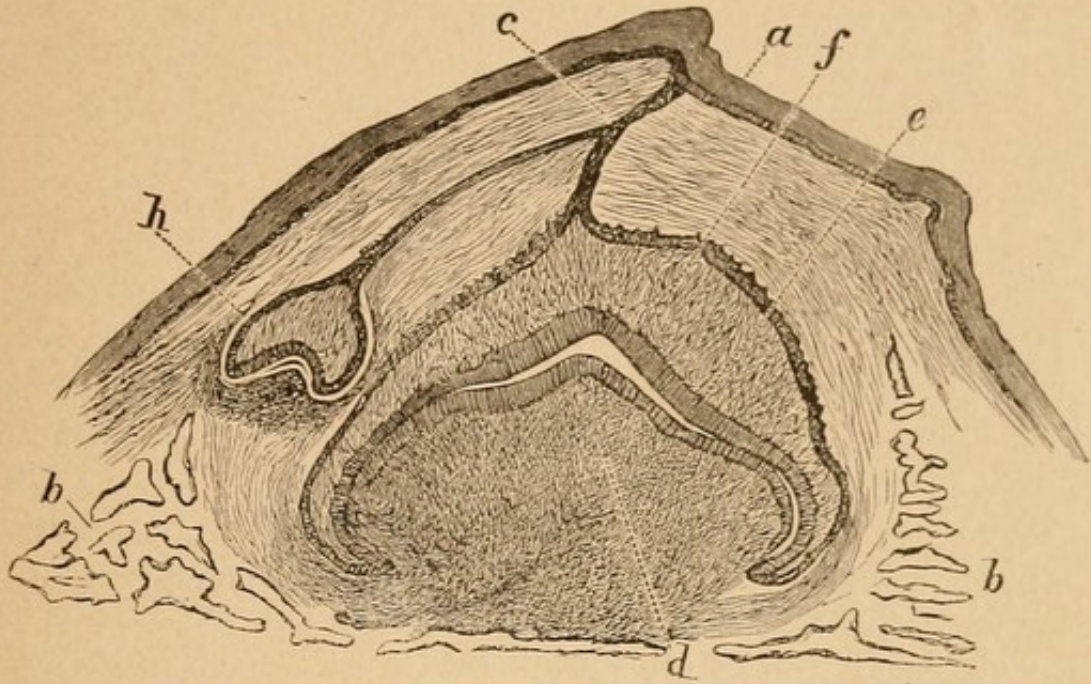
FIG. 33.
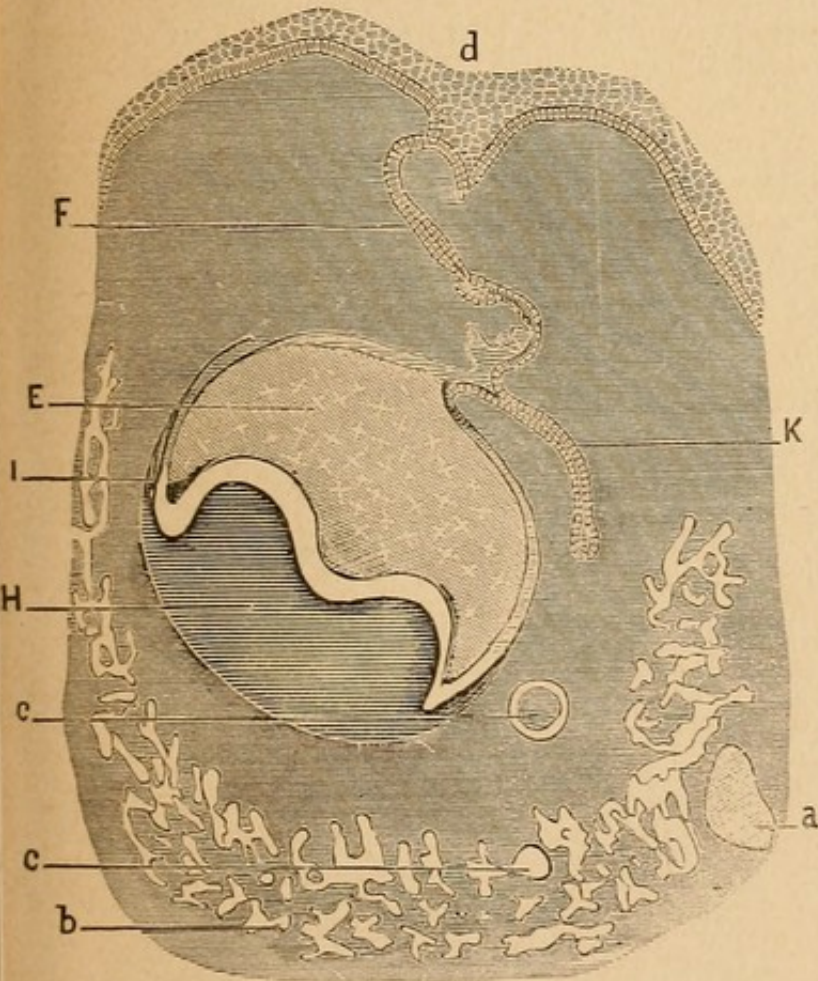
FIG. 34.
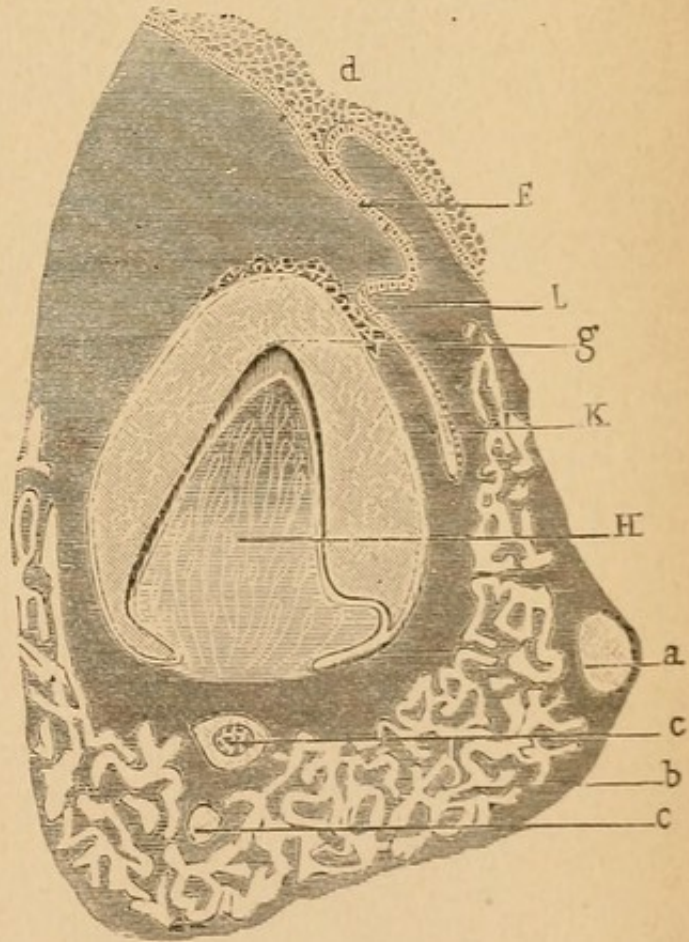
Fig. 35.—Section on a line with the follicle of the first permanent molar. *Human* subject, three months after birth. (Magnified 80 diam.)

b, Maxillary bone; *c, c*, dental artery and nerve; *E*, cord of the follicle of the first permanent molar; *g*, enamel-organ; *H*, bulb of the first permanent molar; *K*, bourgeon of the enamel-organ of the second permanent molar. (See p. 156.)

Fig. 36.—Vertical section of the lower jaw of a *human* fœtus, measuring 47 centimetres [18¾ inches]; corresponding to nearly the thirty-ninth week of gestation. The figure represents a cut passing through the follicle of a bicuspid.

b, Bone of the jaw; *d*, oral epithelium; *g*, enamel-organ; *H*, dental bulb; *K*, *débris* of the cord of a permanent follicle; *K′ K′*, epidermal globules. Follicle for the permanent tooth connected with the *débris* of its cord, *K*.

Fig. 37.—Vertical transverse section through the incisive region of the lower jaw of a *human* fœtus, measuring 38 centimetres [15⅛ inches]. (Magnified 80 diam.)

b, Bony formation; *d*, oral epithelium; *g*, enamel-organ; *H*, dental bulb; *I*, cord of the permanent follicle; *K*, *débris* on the follicular wall of the primitive follicle and from its cord; *K′*, epithelial globule; *L*, enamel-organ of the permanent tooth.

Fig. 35.
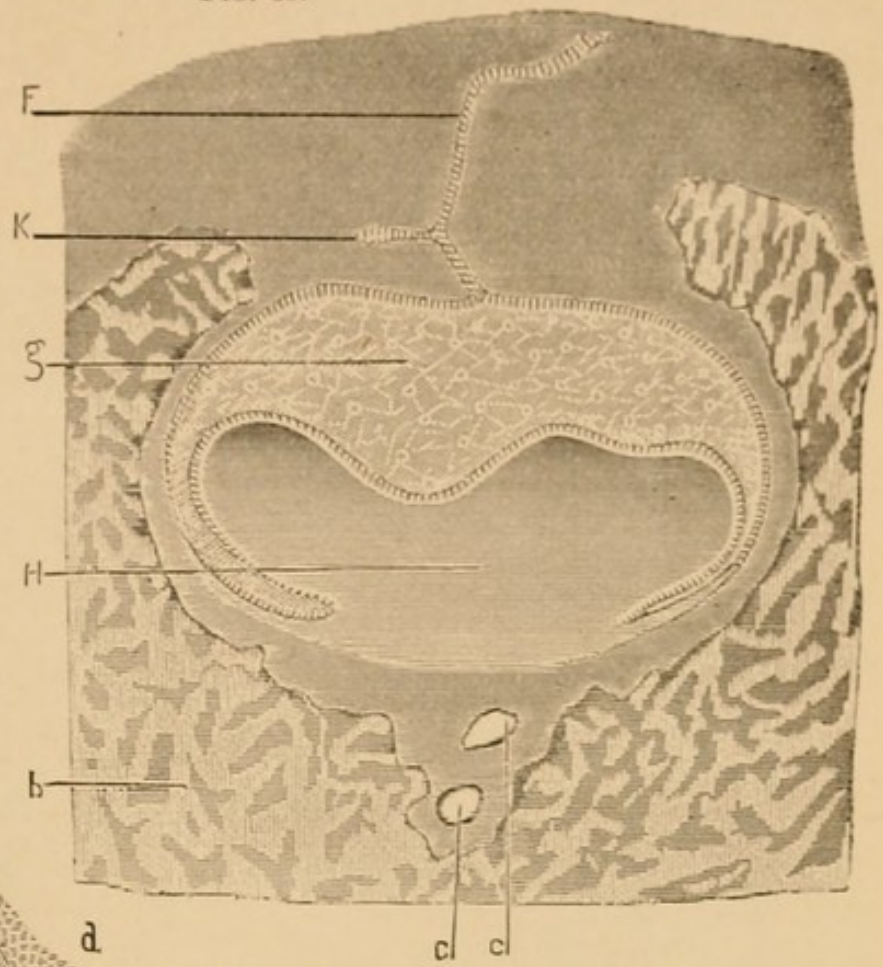
Fig. 36.
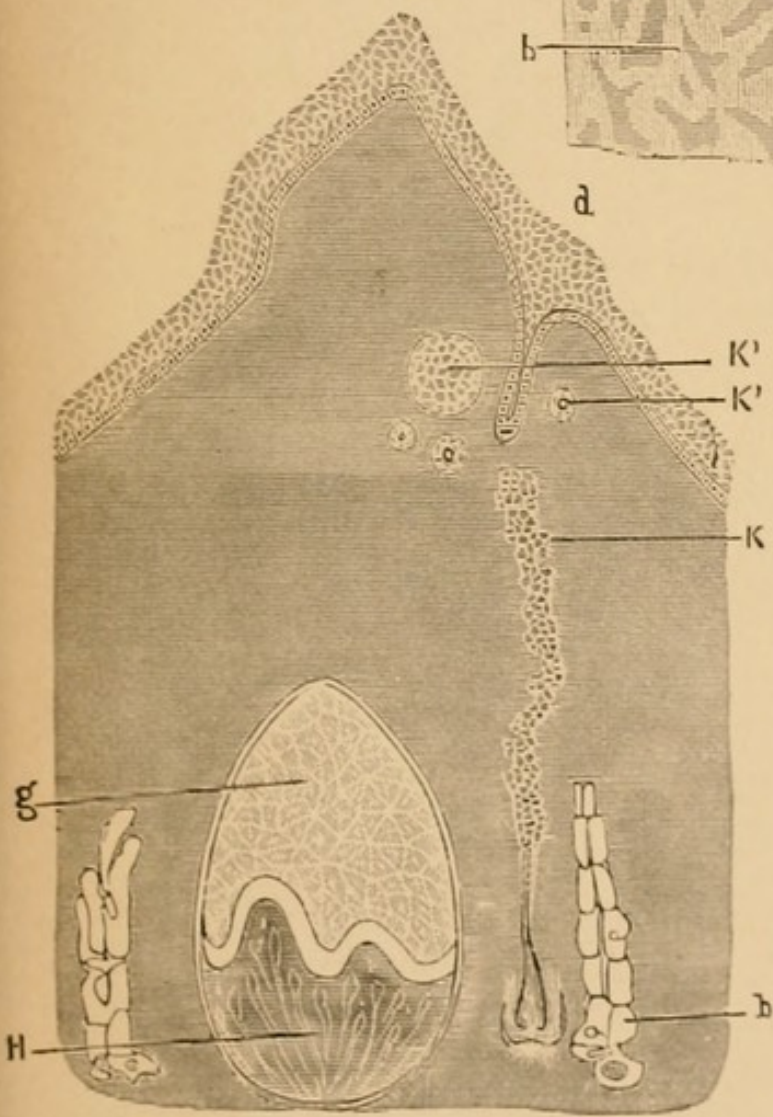
Fig. 37.
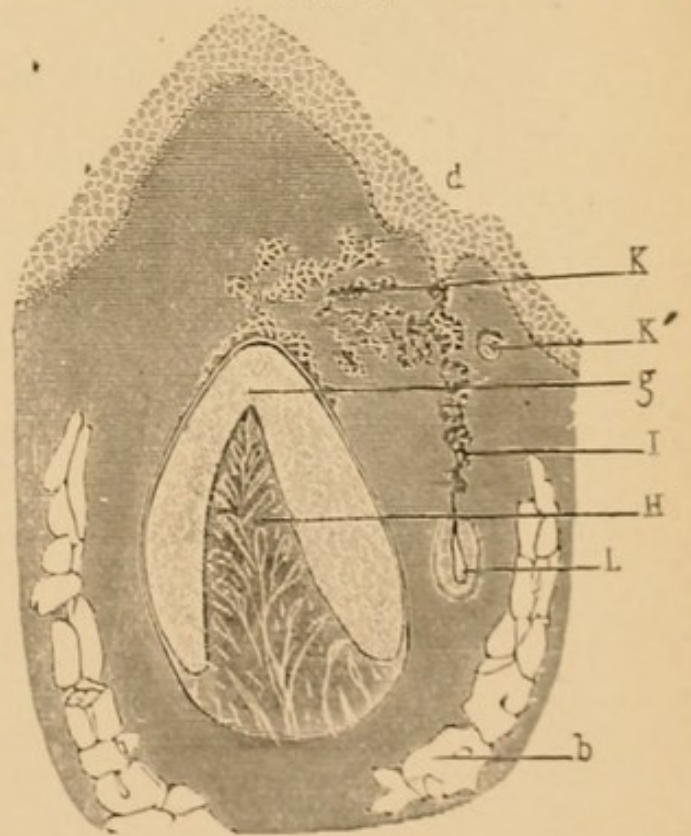
FIG. 38.—From the lower jaw of an *ovine* embryo, magnified 80 diameters; showing the completed dental follicle and the surrounding tissues.

a, Meckel's cartilage; *b*, traces of ossification; *c*, lowest layer of the epithelial cells; *d*, oral epithelium; *F*, ameloblastic layer; *F'*, (lower) external layer of the enamel-organ—a continuation of the layer of ameloblasts; *g*, stellate reticulum of the enamel-organ; *H*, bulb; *I*, follicular wall; *K*, buddings from the cord.

FIG. 39.—From a *human* embryo, 20 centimetres [8 inches] in length. (Magnified 80 diam.)

a, Meckel's cartilage; *b*, bone; *c, c*, artery and nerve; *d*, oral epithelium; *E*, cord of the first permanent molar originating from the lamina; *F*, *débris* of the cord of the preceding follicle; *g*, muscular insertions. (See description, p. 155).

FIG. 40.—A section of the skin of a *human* fœtus, 20 centimetres [8 inches]; about the seventeenth week of gestation; showing the complete analogy in the development of the hair and the teeth.

a, Pilous follicle quite well developed, with its bulb forcing back the epithelial cells and forming a cap for itself; *b*, simple epithelial bourgeon; *c*, epithelial bourgeon, with the bulb just appearing.

FIG. 38.
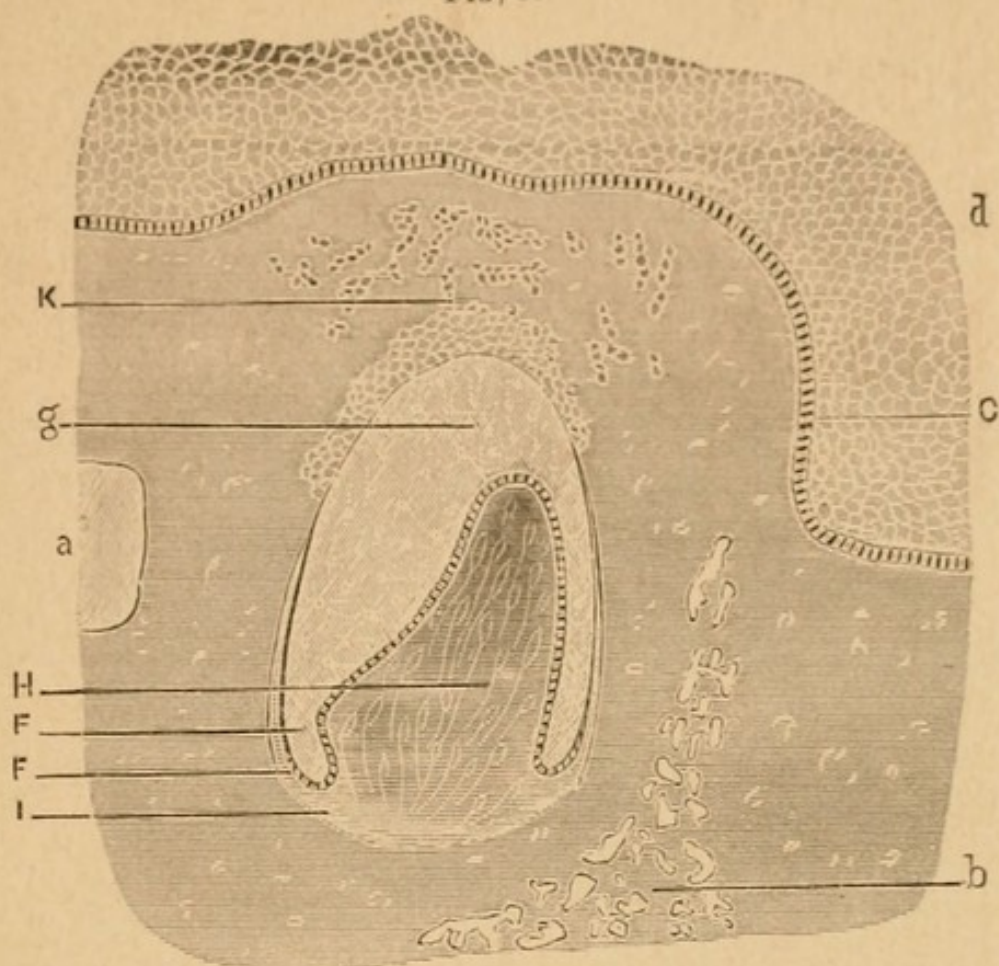
FIG. 39.
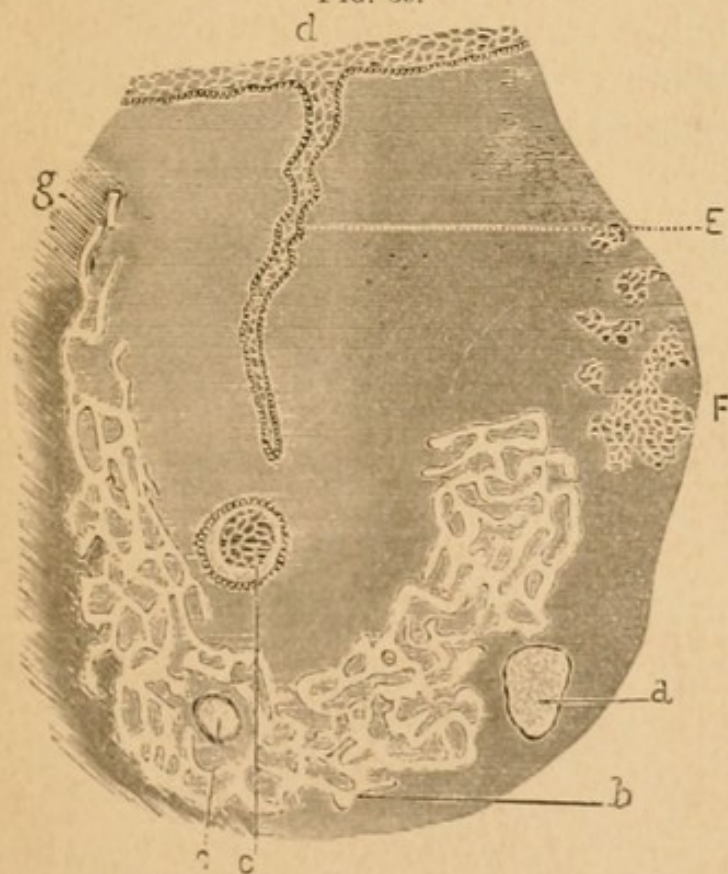
FIG. 40.
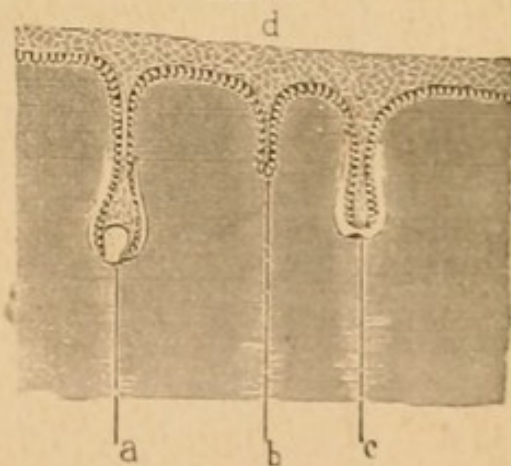
FIG. 41.—Section taken from the jaw of an embryonal calf, after the rupture of the epithelial cord. (Magnified 260 diam.)

This cut embraces the region external to the follicle (*a*), which latter is not represented in this figure. *b*, Epithelial buddings upon the follicular wall; *c*, epithelial lamina, still entire; *E, E*, buddings from the epithelial cord; *F*, globular epithelial mass in the lamina.

FIG. 42.—Section taken from a *bovine* embryo, and embracing the same territory represented in Fig. 41.

a, Segment of the follicular wall; *b*, epithelial buddings upon the wall; *c*, prismatic layer of the oral epithelium; *d*, oral epithelium; *E, E, débris* and buddings of the cord; *F*, epithelial globules from the *débris* of the epithelial lamina. (Magnified 100 diameters.)

For the physiological importance attributed to these epithelial proliferations, see pp. 66 and 179.

FIG. 41.
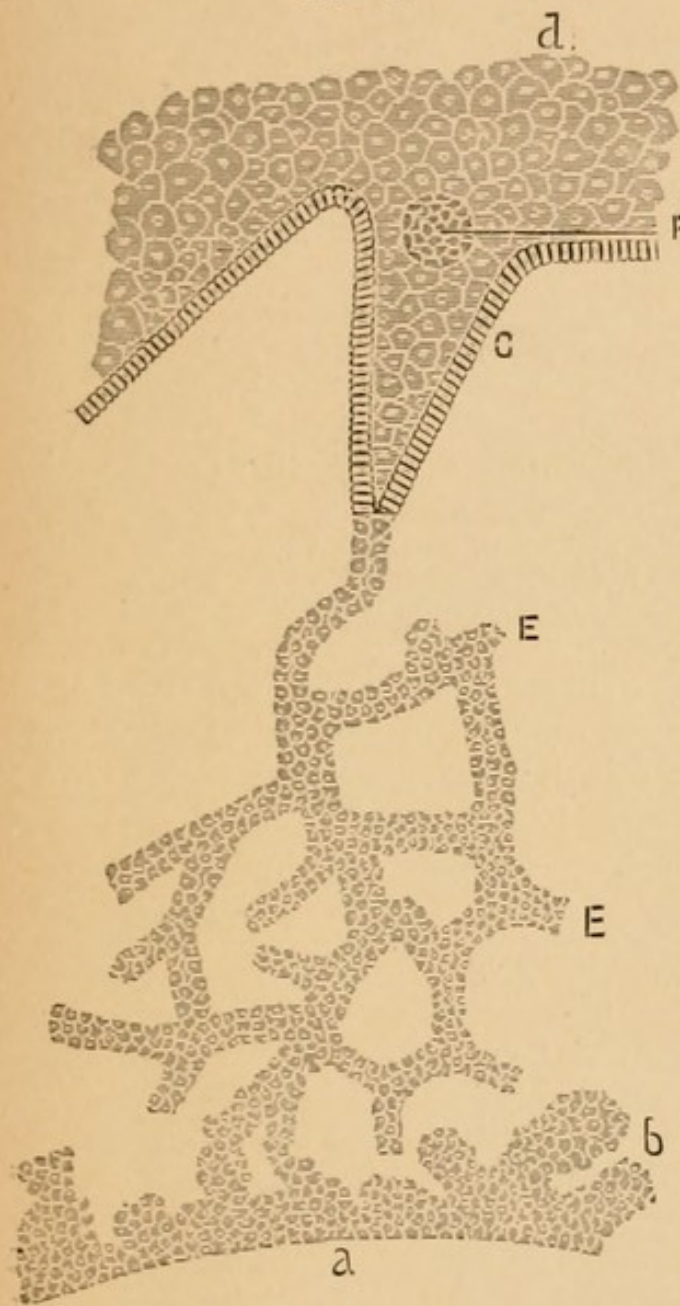
FIG. 42.
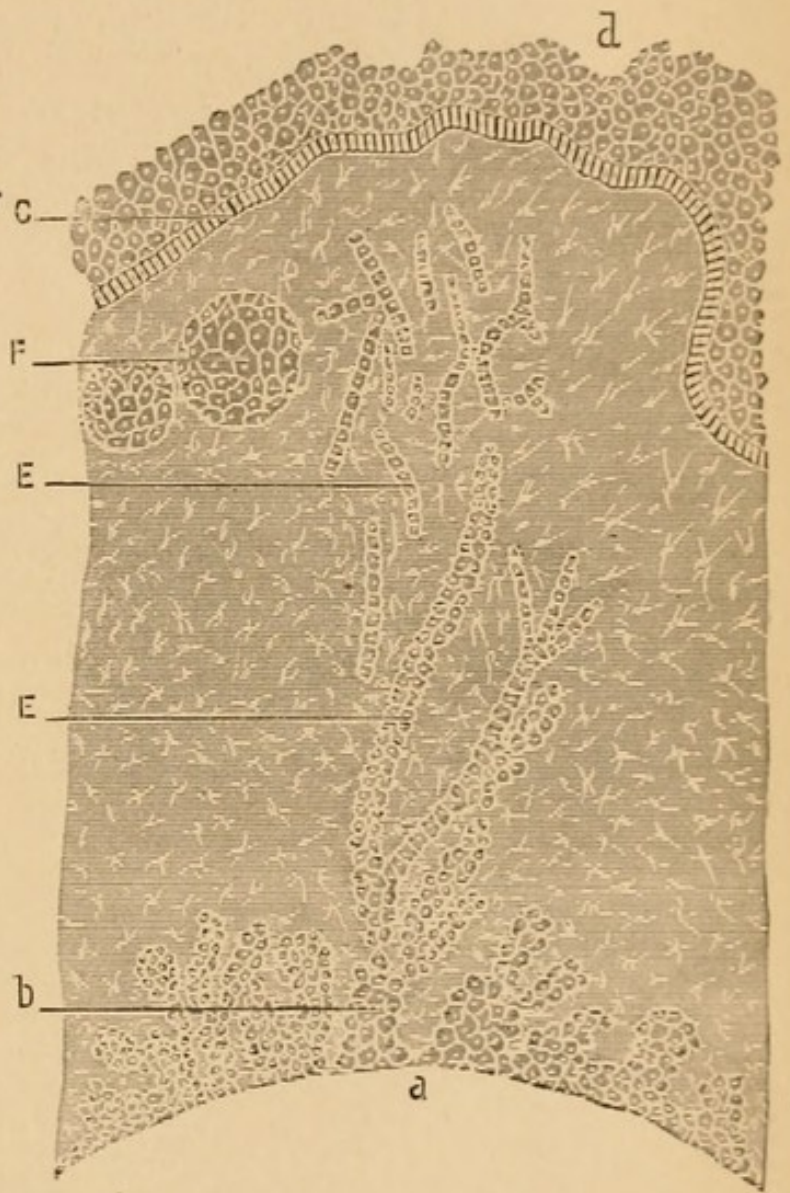
Fig. 43.—Vertical transverse section of the lower jaw of
a *human* fœtus, 56 centimetres [22⅖ inches] in length;
corresponding to about the period of birth. (Magnified 80
diam.)

b, Osseous formation; *d*, oral epithelium; *E*, lowest layer
of the Malpighian stratum; *F*, *débris* of the epithelial
lamina; *g*, enamel-organ; *H*, dental bulb; *I*, follicular
wall; *j*, cap of dentine and enamel; *K*, *débris* of the second-
ary cord; *L*, bulb of the permanent tooth, capped with the
enamel-organ.

Fig. 44.—Dental follicle of a permanent tooth of a cat;
vertical and transverse section. From a preparation of
Thiersch. (Magnified 14 diam.) Taken from the fifth edi-
tion of Kölliker's *Elements of Human Histology*.

A, Dental bulb, the external zone of which is formed by
the odontoblasts; *b*, dentine; *c*, enamel; *d*, "internal epithe-
lial layer of the adamantine organ or adamantine mem-
brane" [the layer of prismatic or columnar cells that we
denominate ameloblasts]; *e*, gelatinous tissue of the en-
amel-organ [stellate reticulum]; *f*, external epithelial layer
of the adamantine organ [enamel-organ]; *g*, internal layer
of the dental sac or follicular wall; *h*, external layer of the
same.

[The white space seen between the layer of ameloblasts
and the developing enamel is evidently accidental. See
remarks on Fig. 24.]

FIG. 43.

FIG. 44.

INDEX.