Development of tooth

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Introduction

Development of the tooth involves many complex biological processes, including epithelial mesenchymal interactions, morphogenesis and mineralisation. In the human beings, 20 deciduous and 32 permanent teeth develop from the interaction between the oral epithelium cells and the underlying mesenchymal cells. The basic developmental process is similar for all teeth but each developing tooth develops as an anatomically distinct unit.

How does the tooth development begin?

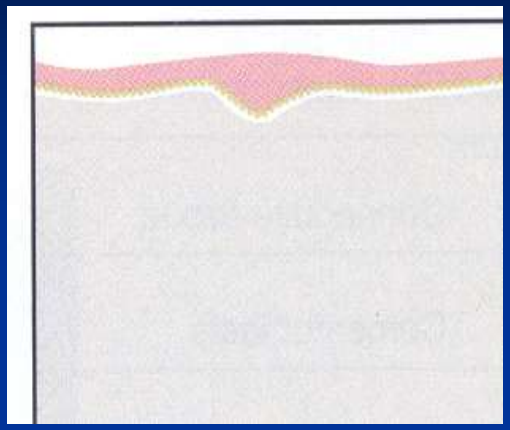
On the ***27th day*** of intra uterine life the buccopharngeal membrane ruptures and the POC comes in contact with the foregut.

Connective tissue underlying the oral ectoderm is ***Neural Crest Cells*** **or** ***Ectomesenchymal*** in origin, which induces the overlying ectoderm to start tooth development.

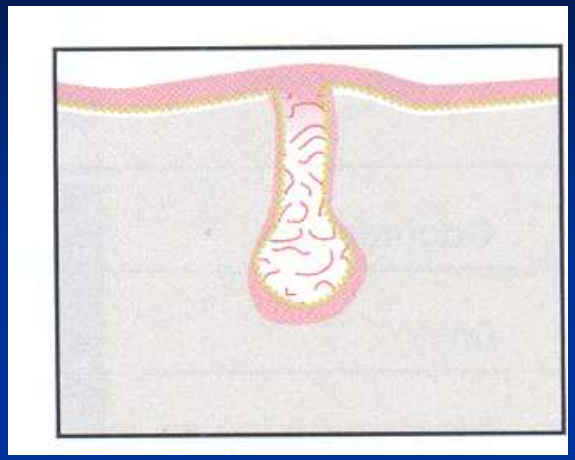
Phases of tooth development

- *Initiation*
- *Proliferation*
- *Histodifferentiation*
- *Morphodifferentiation*
- *Apposition*

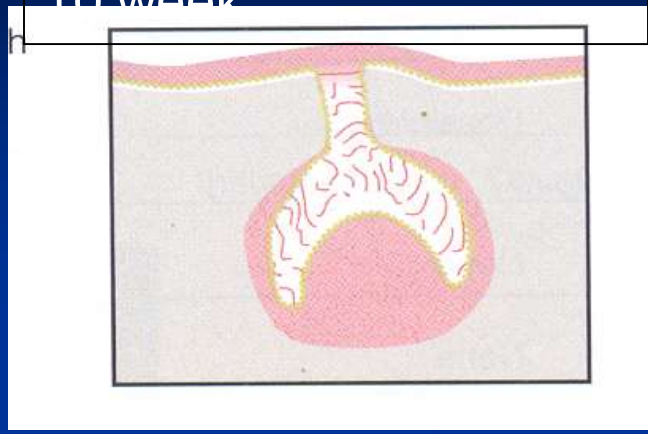
Induction and initiation stage 6 to 7 week



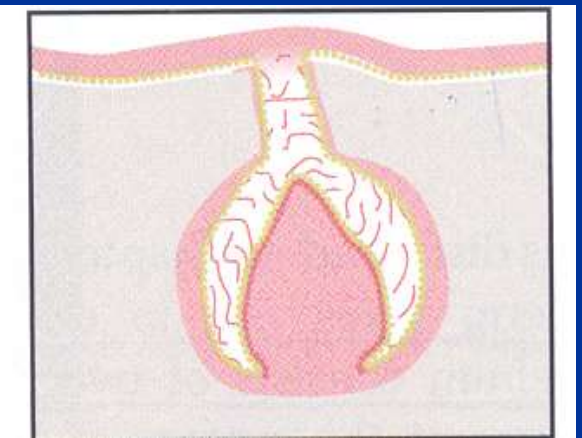
Proliferation and bud stage 8 week



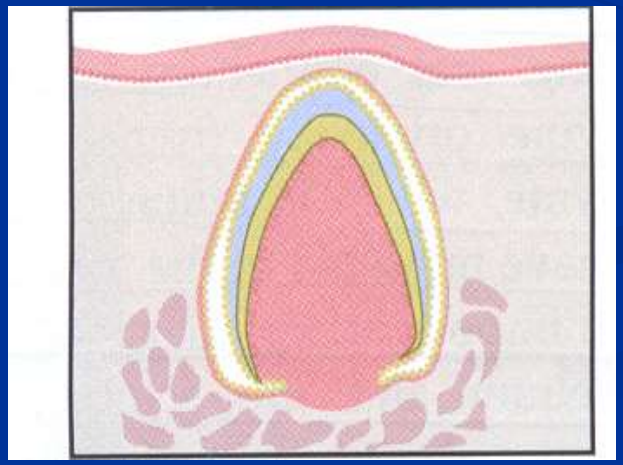
Proliferation, differentiation,morphogenesis and cap stage 9 to 10 week



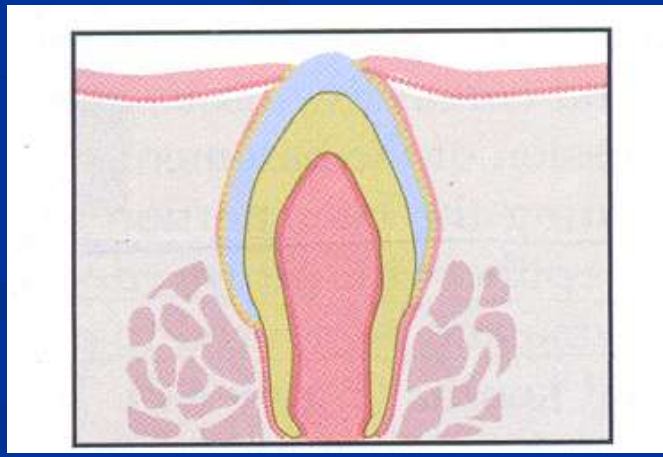
Proliferation differentiation,morphogenesis bell stage 11 to 12 week



Induction,proliferation and apposition stage varies per tooth



Maturation,varies per tooth



INITIATION

The epithelial ectomesenchymal interaction is essential for initiation induction.

If there is a lack of initiation ,it results in the absence of either a single tooth or many teeth.

Abnormal initiation may result in the development of single or supernumerary teeth.

PROLIFERATION

It is characterized by regular changes in the size and shape of the developing tooth germ.In this stage the tooth germ has a strong affinity to differentiate into various structures.

Histodifferentiation

Histodifferentiation shows maximum development in the early bell stage of tooth development .It is during this stage that the formative cells of the tooth germ undergo definite morphologic as well as functional changes and acquire their functional roles. The cells differentiate and give up their capacity to multiply.

Morphodifferentiation

Proliferation is essential for morphodifferentiation.

The basic anatomic form of tooth is established in the late bell stage after active histodifferentiation .

In this stage the dentinoenamel and the cementoenamel junctions are developed by the continuous deposition of enamel,dentin and cementum from ameloblasts,odontoblasts and cementoblasts respectively,resulting in the establishment of a complete morphologic pattern ,size,and shape of a tooth.

If any disturbance occurs in the morphodifferentiation , it affects the form and size of the tooth , but the functions of the ameloblasts and the odontoblasts are not affected

Morphodifferentiation

Apposition

After the morphologic pattern of a tooth is established, an additive growth of the hard dental tissues occurs.apposition is characterized by the rhythemic,layer-like deposition of an extracellular matrix of enamel and dentin.

PRIMARY EPITHELIAL BAND

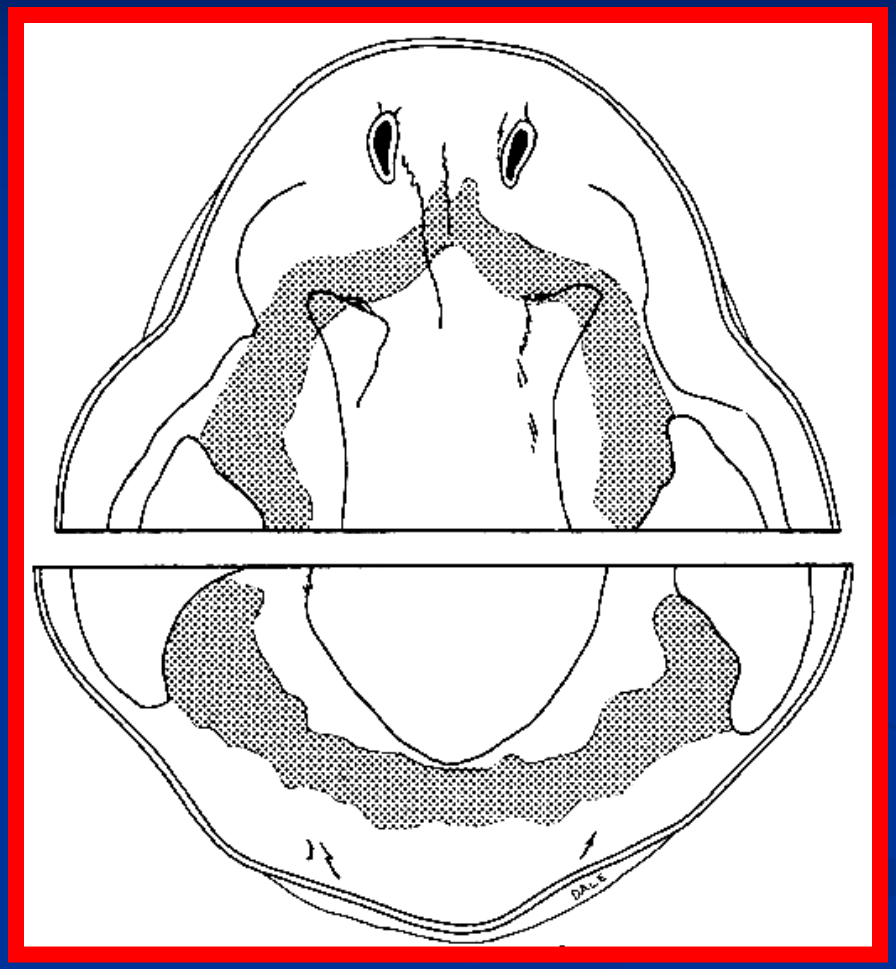
After 37 days of development, a continuous band of thickened epithelium forms around the mouth in the presumptive upper and lower jaws.

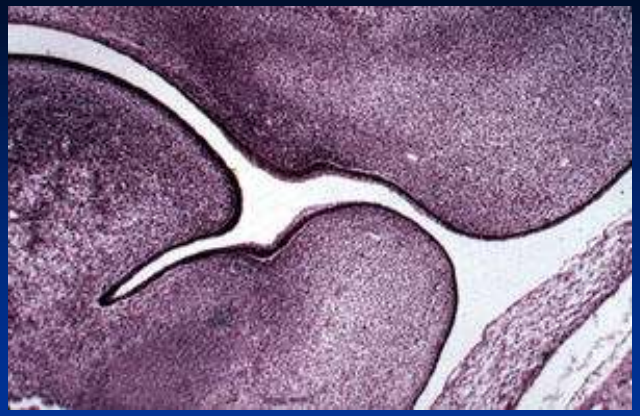
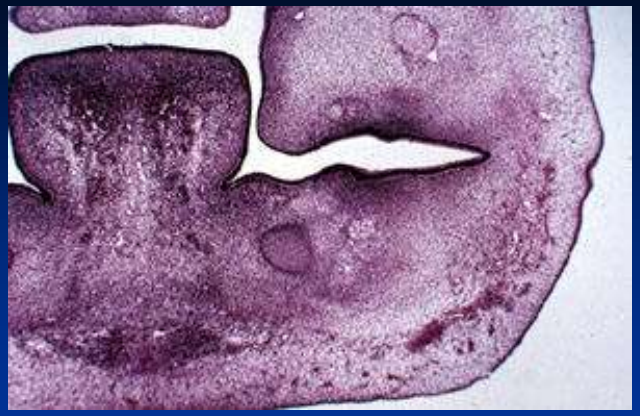
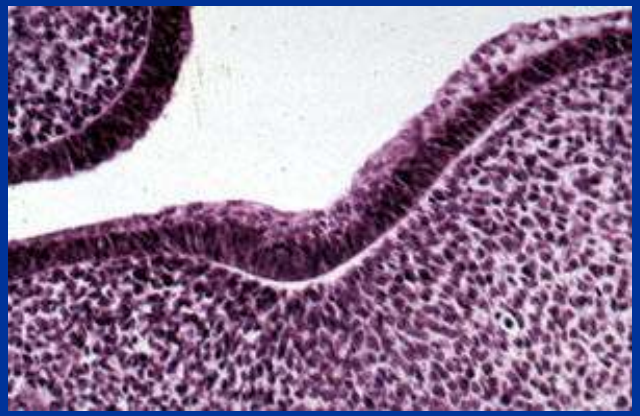
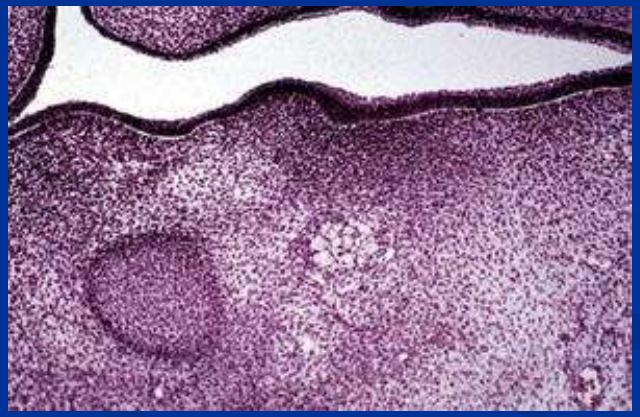
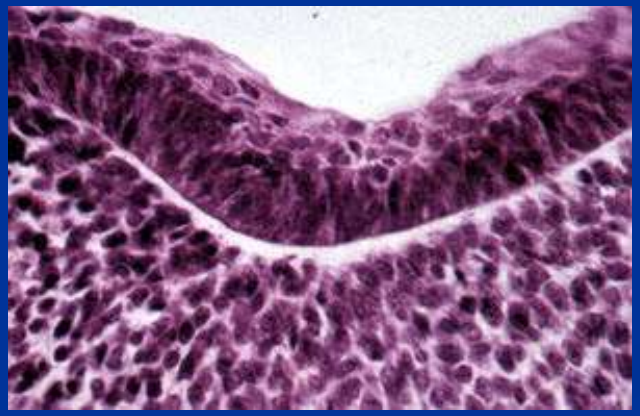
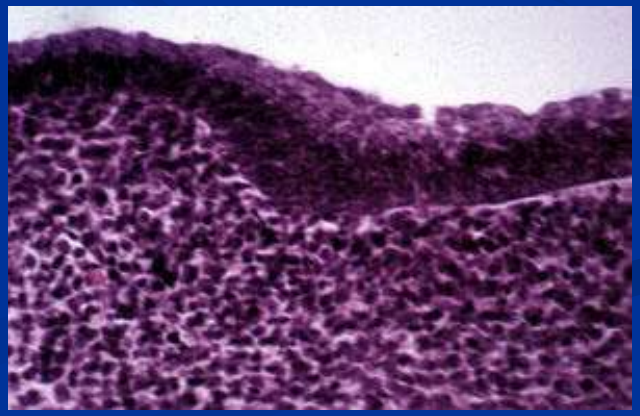
These bands are roughly horse shoe shaped and correspond in position to the future dental arches of the upper and the lower jaws.

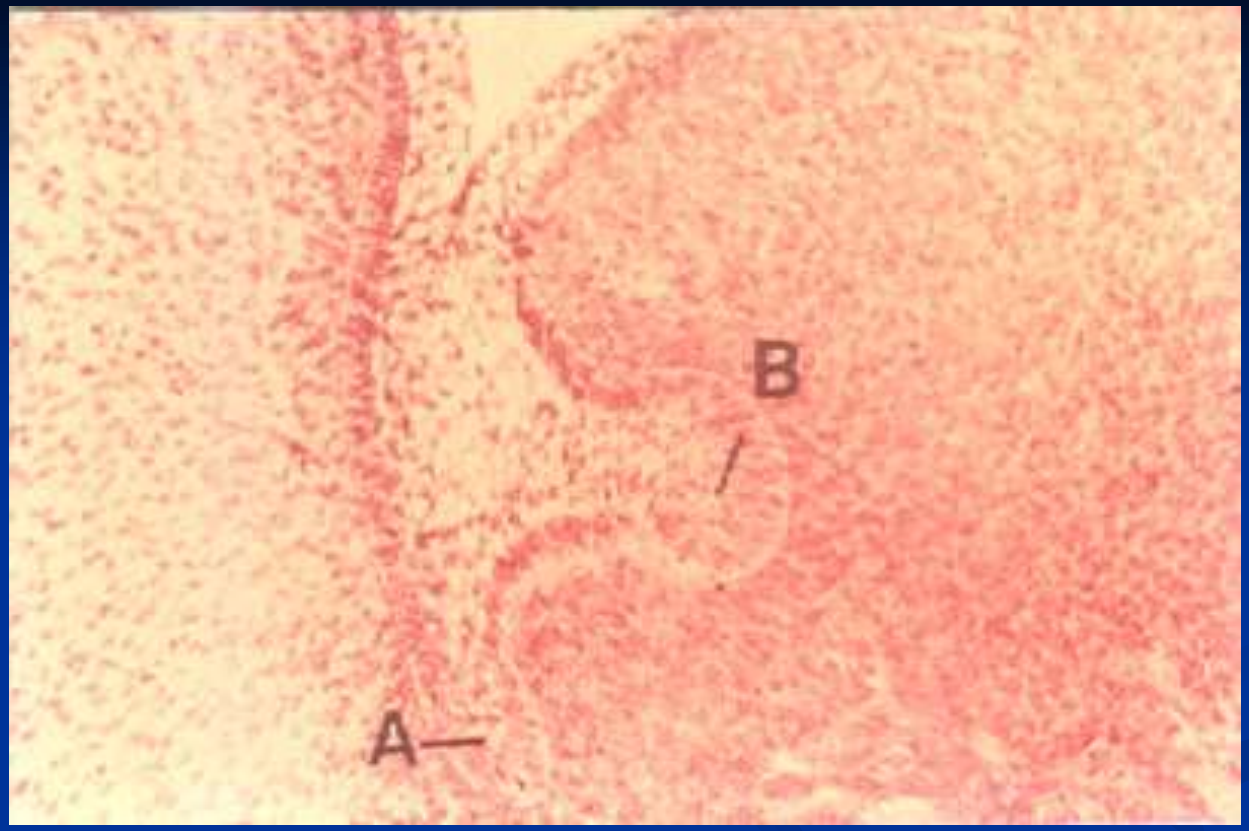
Each band of epithelium called the PEB gives rise to 2 subdivisions

- ***The buccaly located vestibular lamina***
- ***The lingually located dental lamina***

Primary Epithelial Band





A = Vestibular lamina

⬇

Oral vestibule

B = Dental lamina

⬇

Tooth bud

DENTAL LAMINA

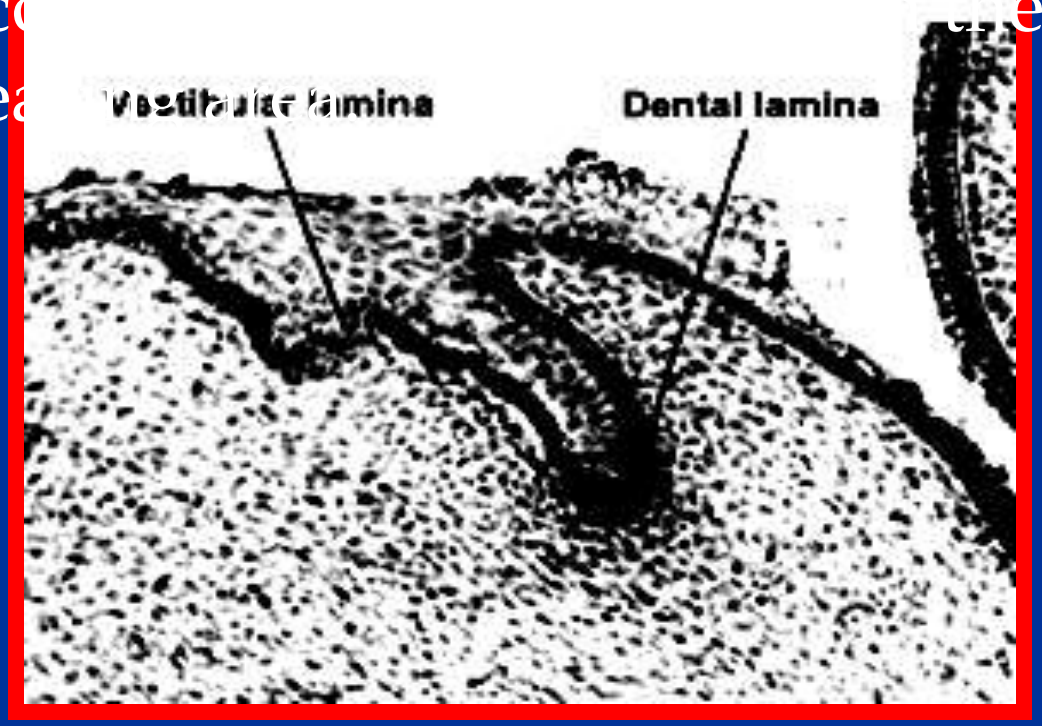
Dental lamina is the band of epithelium which has invaded the underlying ectmesenchyme along both the horse shoe shaped future dental arches

It serves as the primordium for the ectodermal portion of the deciduous teeth.

VESTIBULAR LAMINA

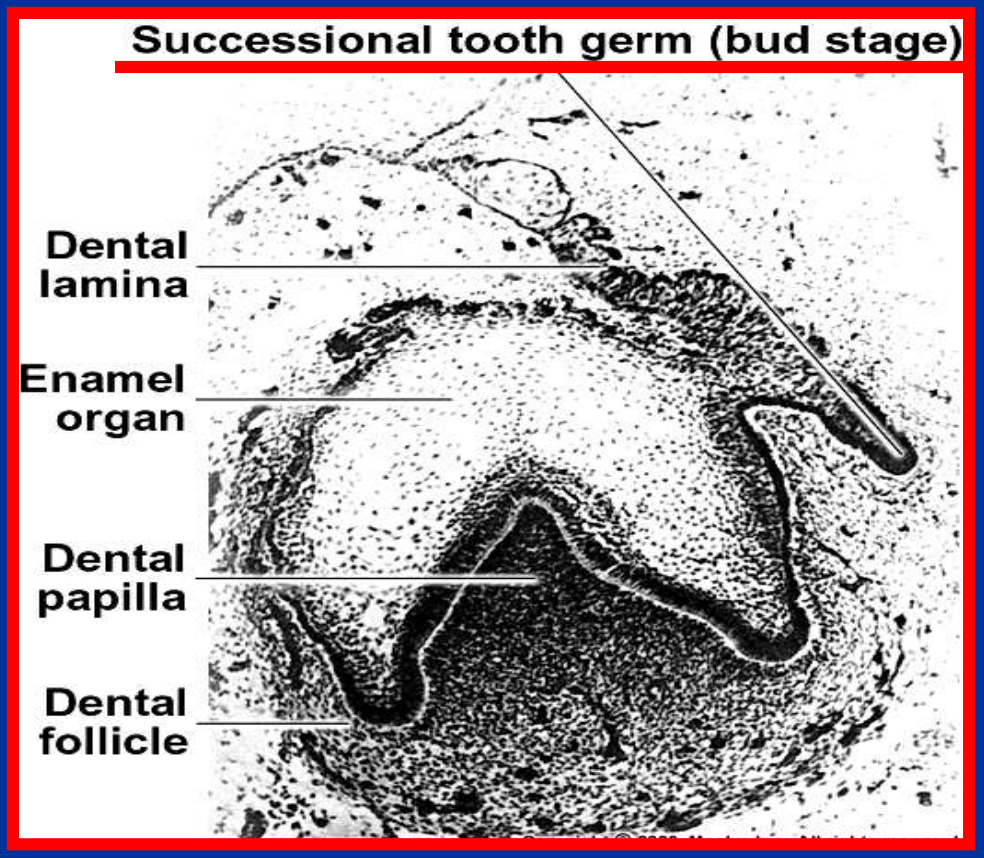
The vestibule forms as a result of the proliferation of the vestibular lamina into the ectomesenchyme.

Its cells rapidly enlarge and then degenerate to form a cleft that bec[illegible] cheek and the tooth- be[illegible]



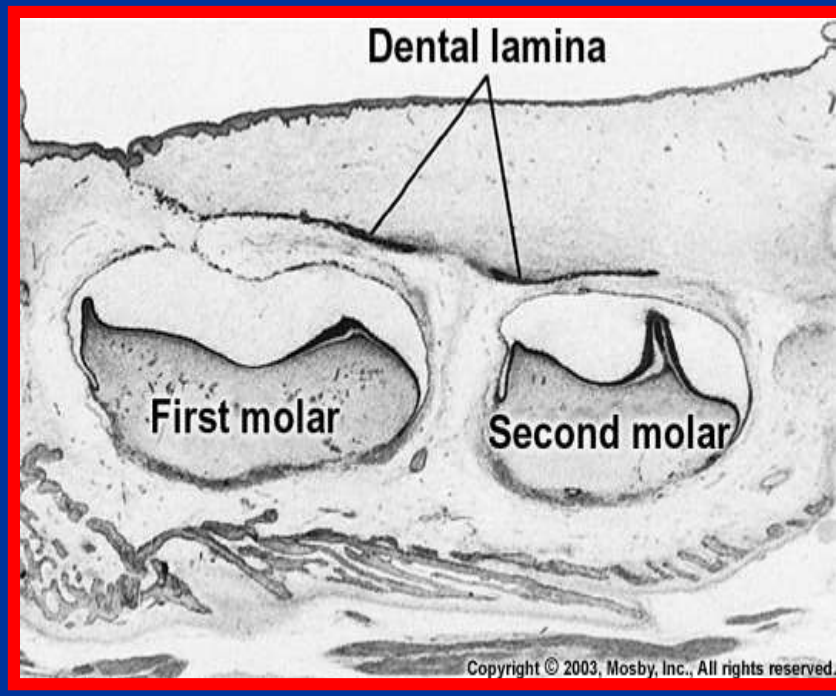
Successional lamina

The free terminal of the dental lamina begins to proliferate in the 4th month of fetal growth. (Crown Rump Length 55-100 mm). This newly formed growth center is known the successional lamina and is destined to form the permanent teeth.

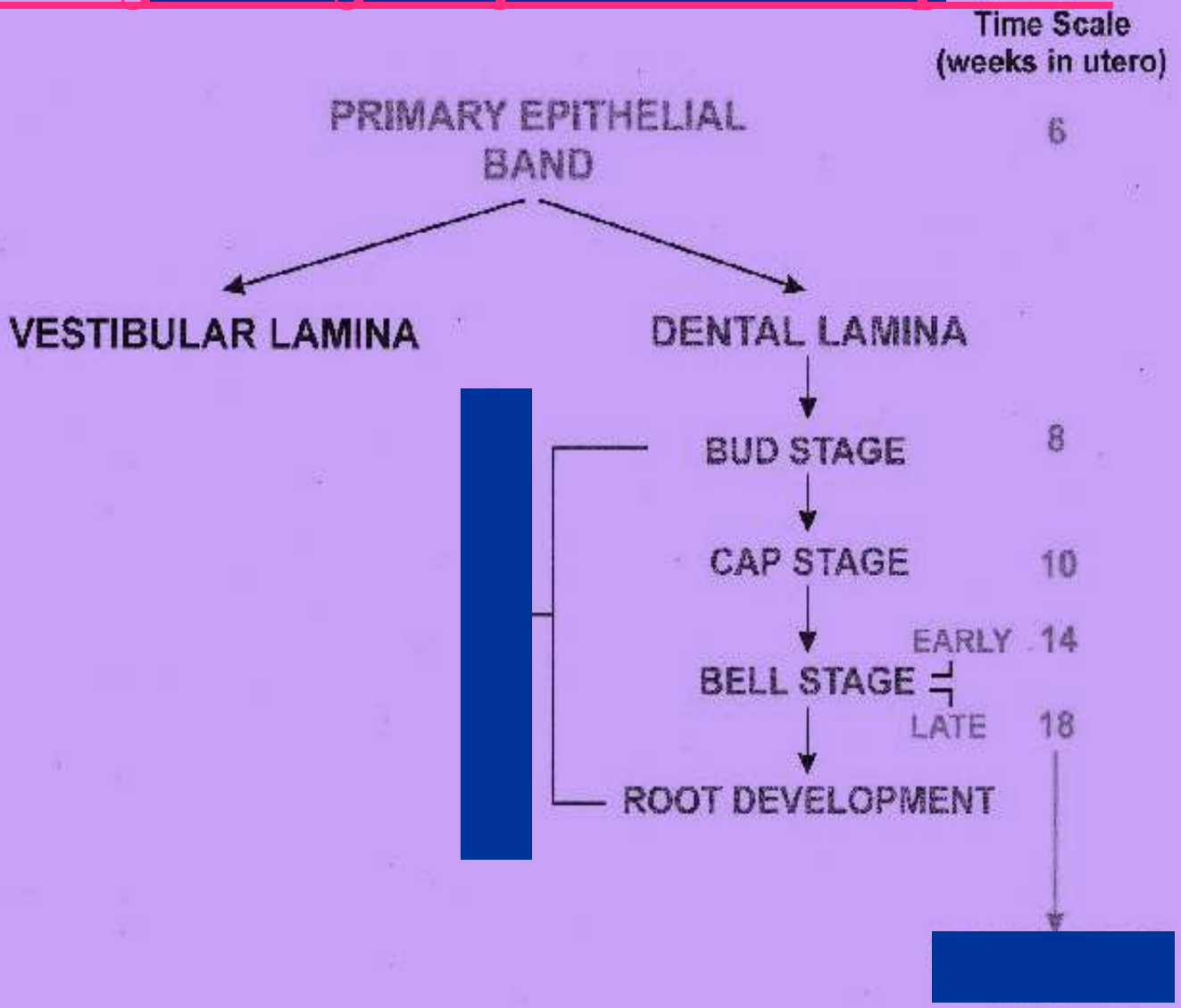


Parent dental lamina (lamina for permanent molars)

The dental lamina providing for the formation of the 1st, 2nd, & 3rd permanent molars may be referred to as the parent lamina



Morphologic Stages of tooth development



Bud Stage *(proliferation stage)*

CR Length= 17.0 mm)

- Bud stage is the initial stage of tooth development, represented by the first epithelial incursion into the ectomesenchyme of the jaw forming tooth buds

- Simultaneous with the differentiation of each dental lamina,round or ovoid swellings arise at the basement membrane at 10 different points.

- The epithelial cells show little, if any change, in shape.

- The epithelium of the tooth bud forms the enamel organ.

- The supporting ectomesenchymal cells are packed closely beneath and around the epithelial bud.

The enamel organ in the bud stage

- appears as a simple,spherical to ovoid, epithelial condensation surrounded by mesenchyme.
- It contains 2 types of cells

1.Polygonal,which are centrally situated

2.Low columnar,which are peripherally situated.

Bud stage

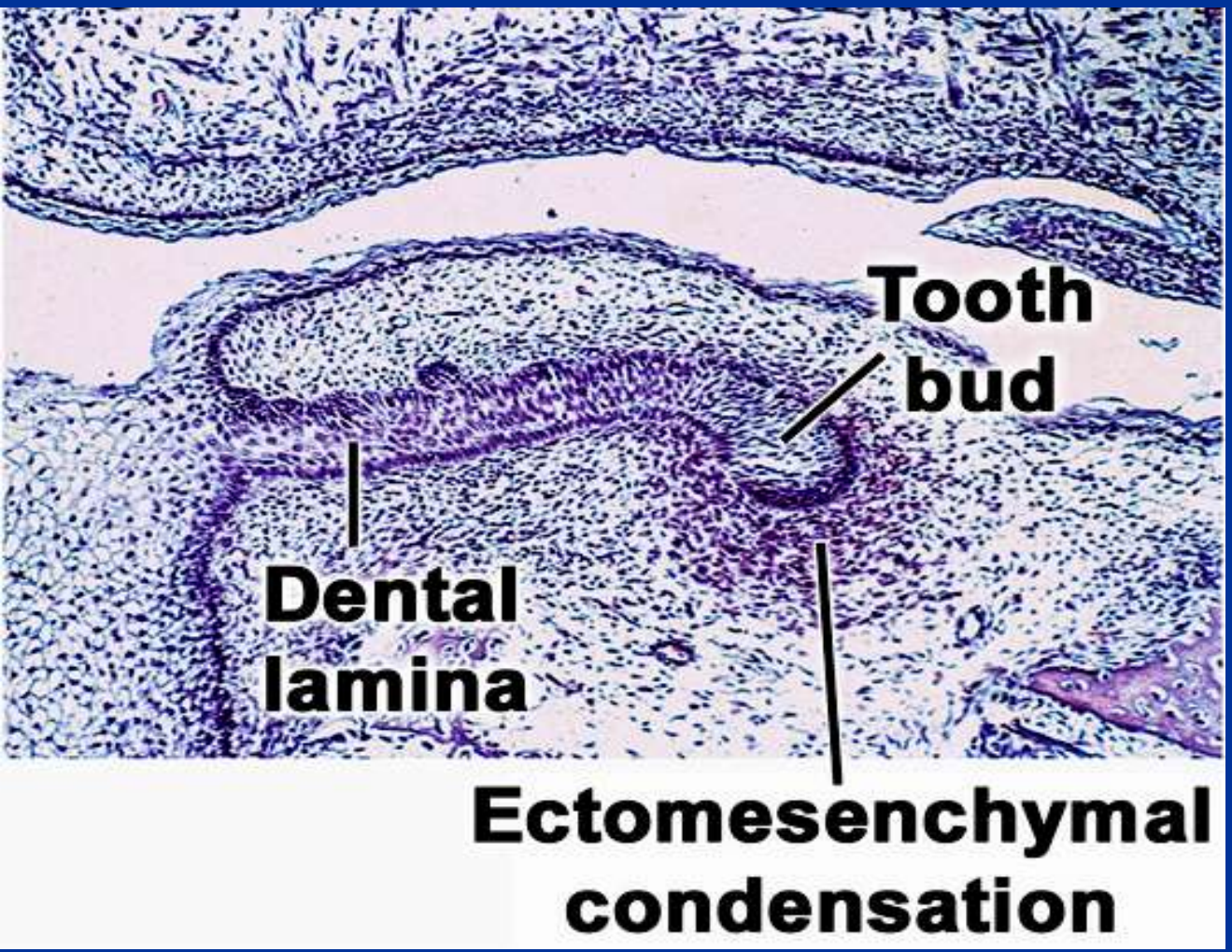
- The cells of the tooth bud have a higher RNA content than those of the overlying oral epithelium,a lower glycogen content and an increased oxidative enzyme activity.

- The area of ectomesenchymal condensation immediately subadjacent to the enamel organ is the ***dental papilla***

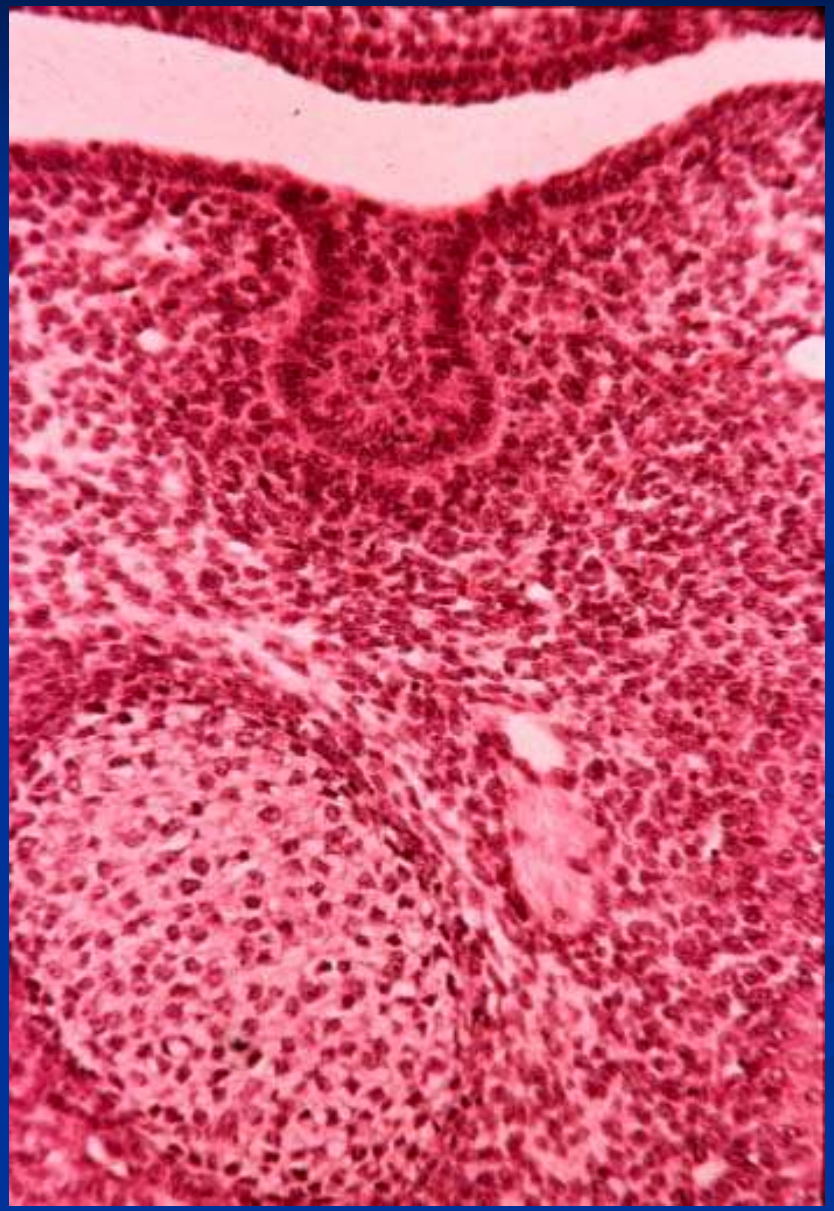
- The condensed ectomesenchyme that surround the tooth bud and the dental papilla is the dental sac.

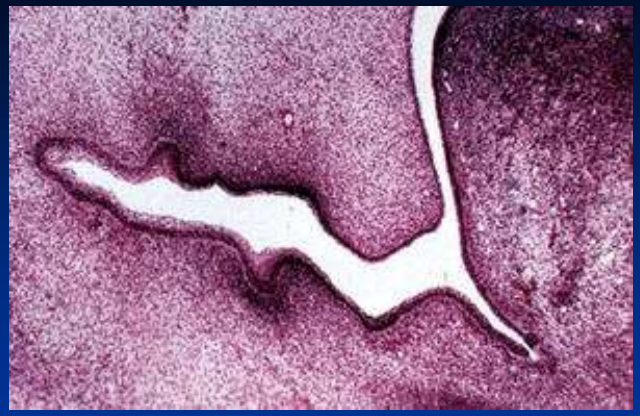
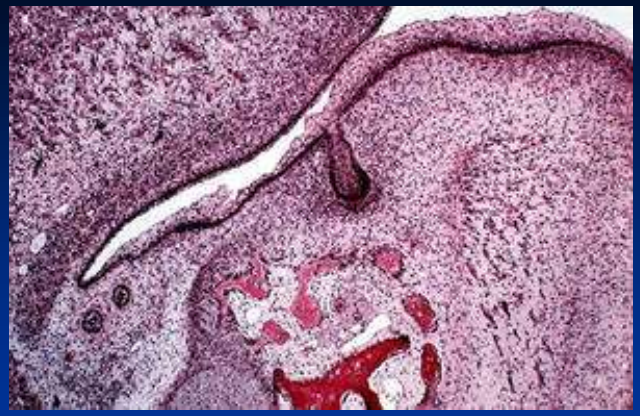
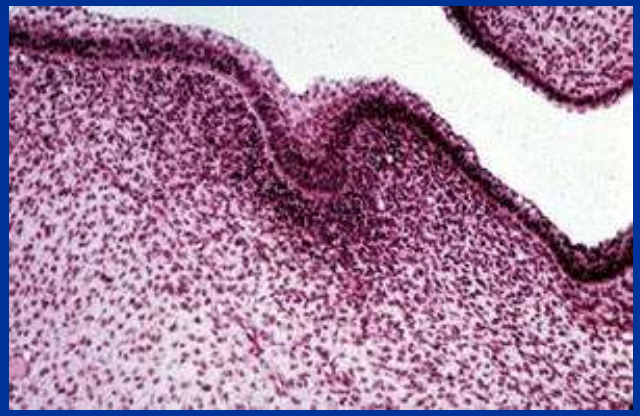
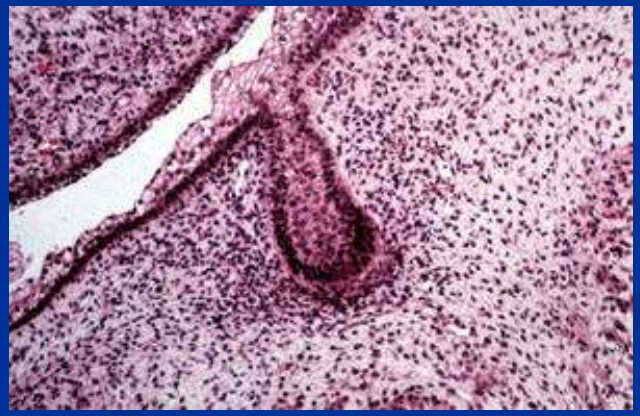
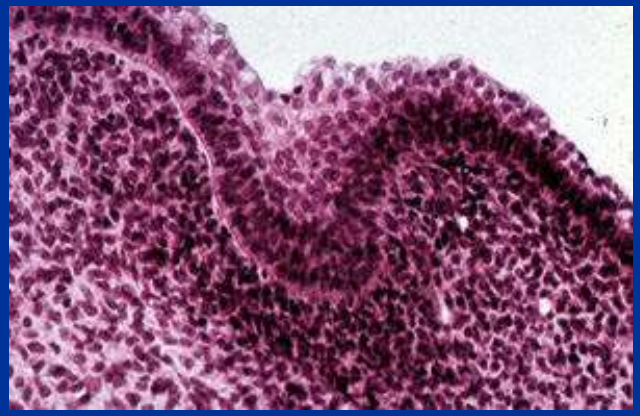
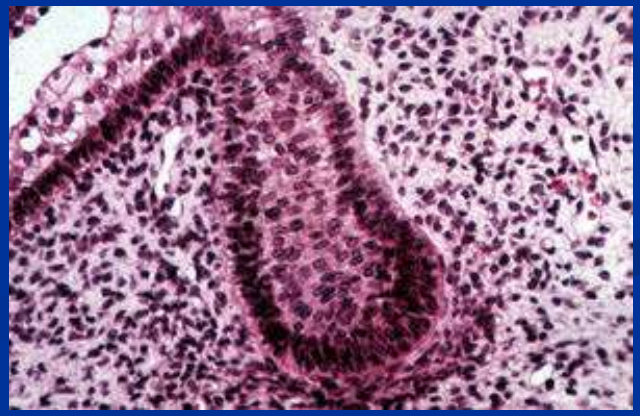
Bud stage

Bud stage



Bud stage



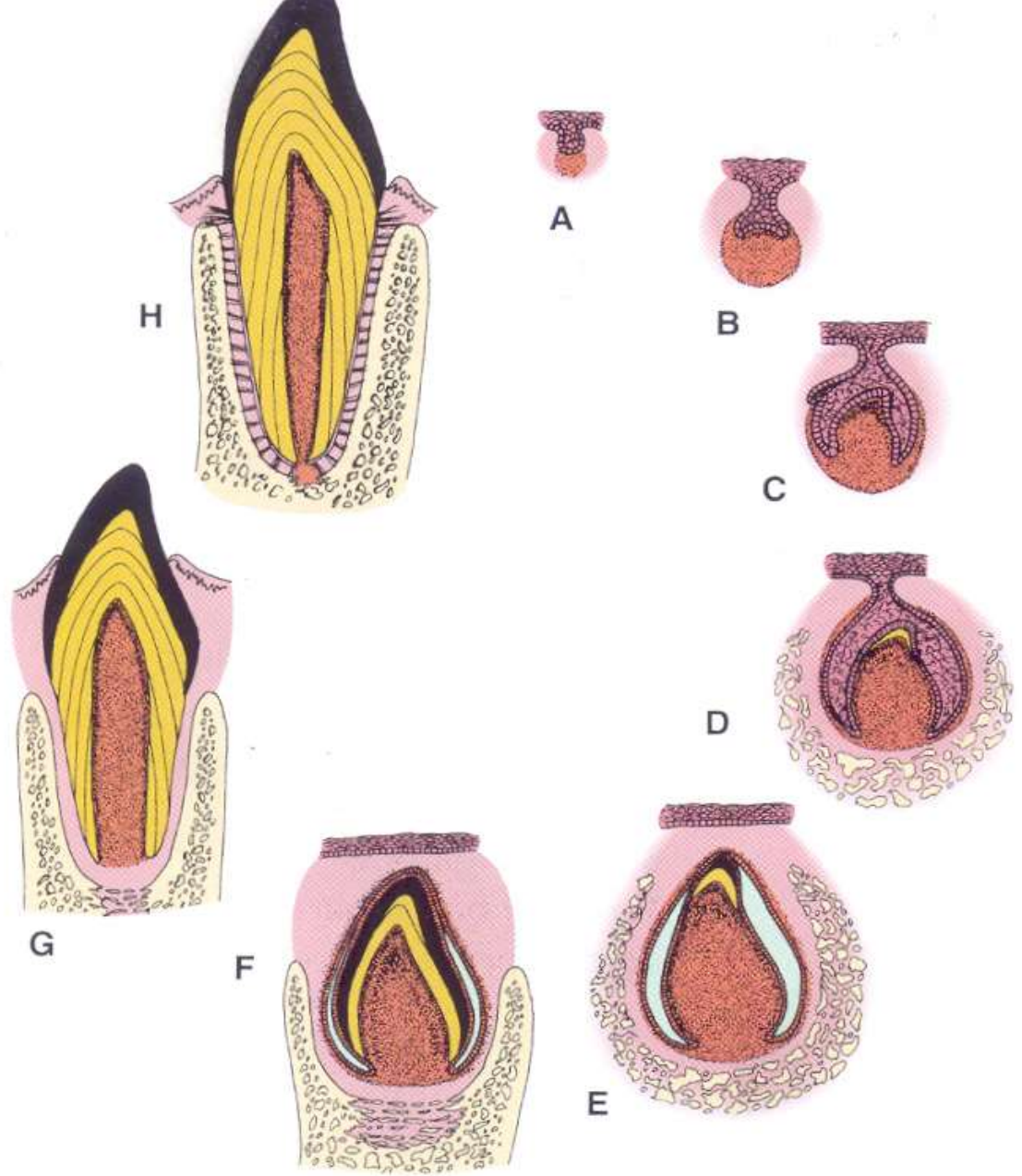


Fig. 5-1 Stages of tooth development. A, Bud. **B,** Cap. **C,** Bell. **D** and **E,** Dentinogenesis and amelogenesis. **F,** Crown formation. **G,** Root formation and eruption. **H,** Function.


Great Minds
Think Alone.

CAP STAGE

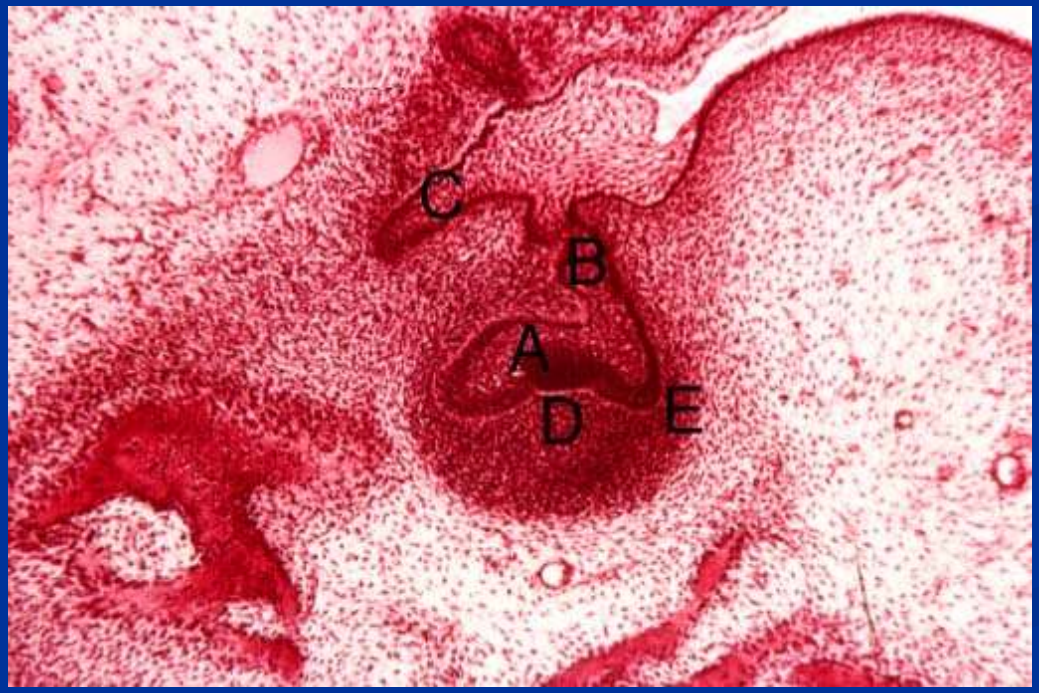
WHY IS IT CALLED CAP STAGE & HOW IS IT FORMED?

A = Bud stage

B = Dental papilla

Cap stage

During the ninth week of embryonic development, the tooth bud differentiates into a cap-shaped **enamel organ** extending from the **dental lamina**



A, Enamel organ

B, Dental lamina

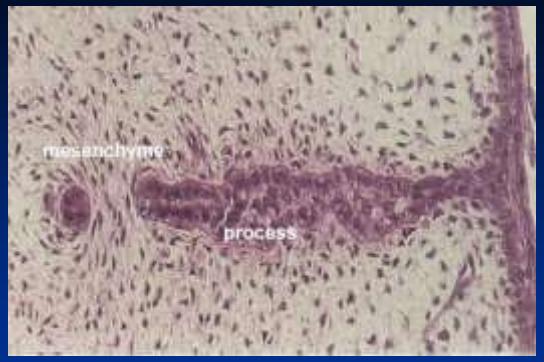
C, Vestibular lamina

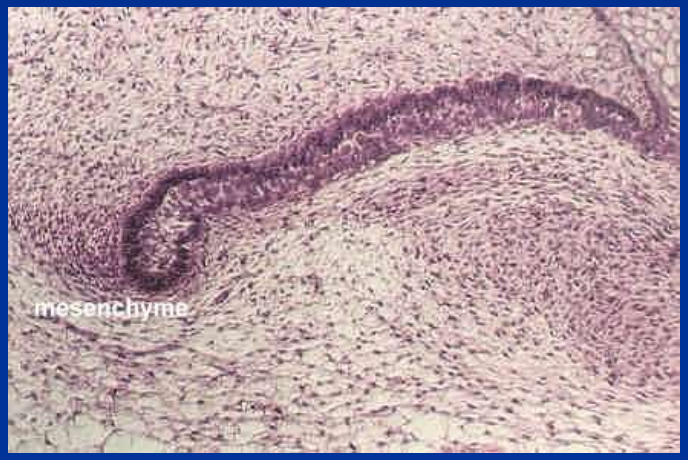
D, Dental Papilla

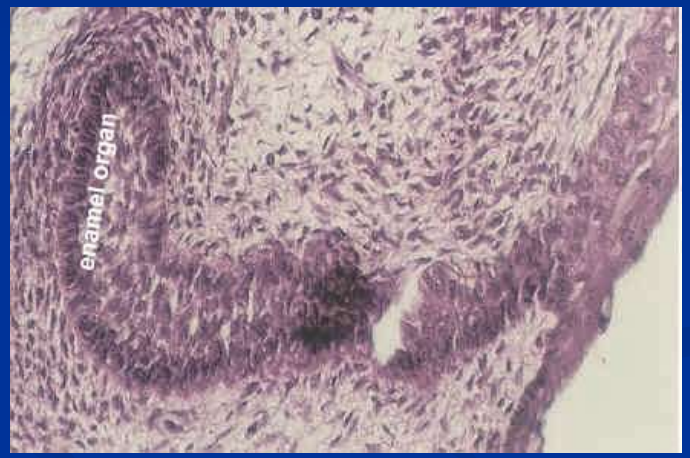
E, Dental sac

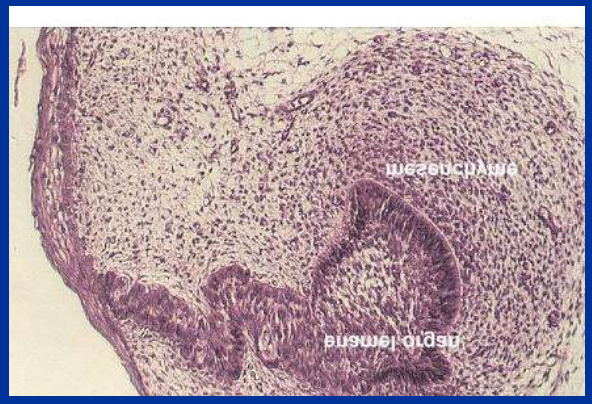

tooth bud

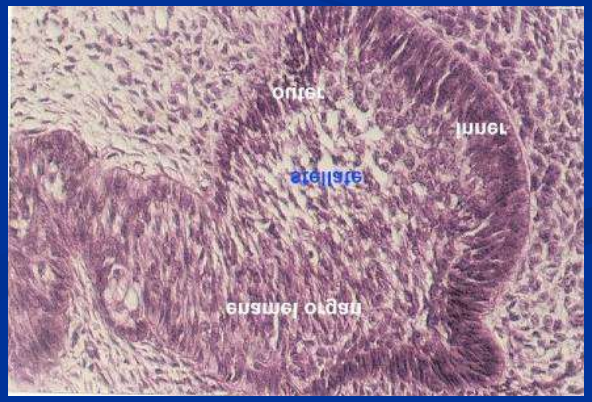

process


mesenchyme
process


mesenchyme


enamel organ


mesenchyme
enamel organ


outer
inner
stellate
enamel organ

A, Stellate reticulum; B, Outer enamel epithelium;

C, Inner enamel epithelium; D, Dental papilla; E, Dental sac

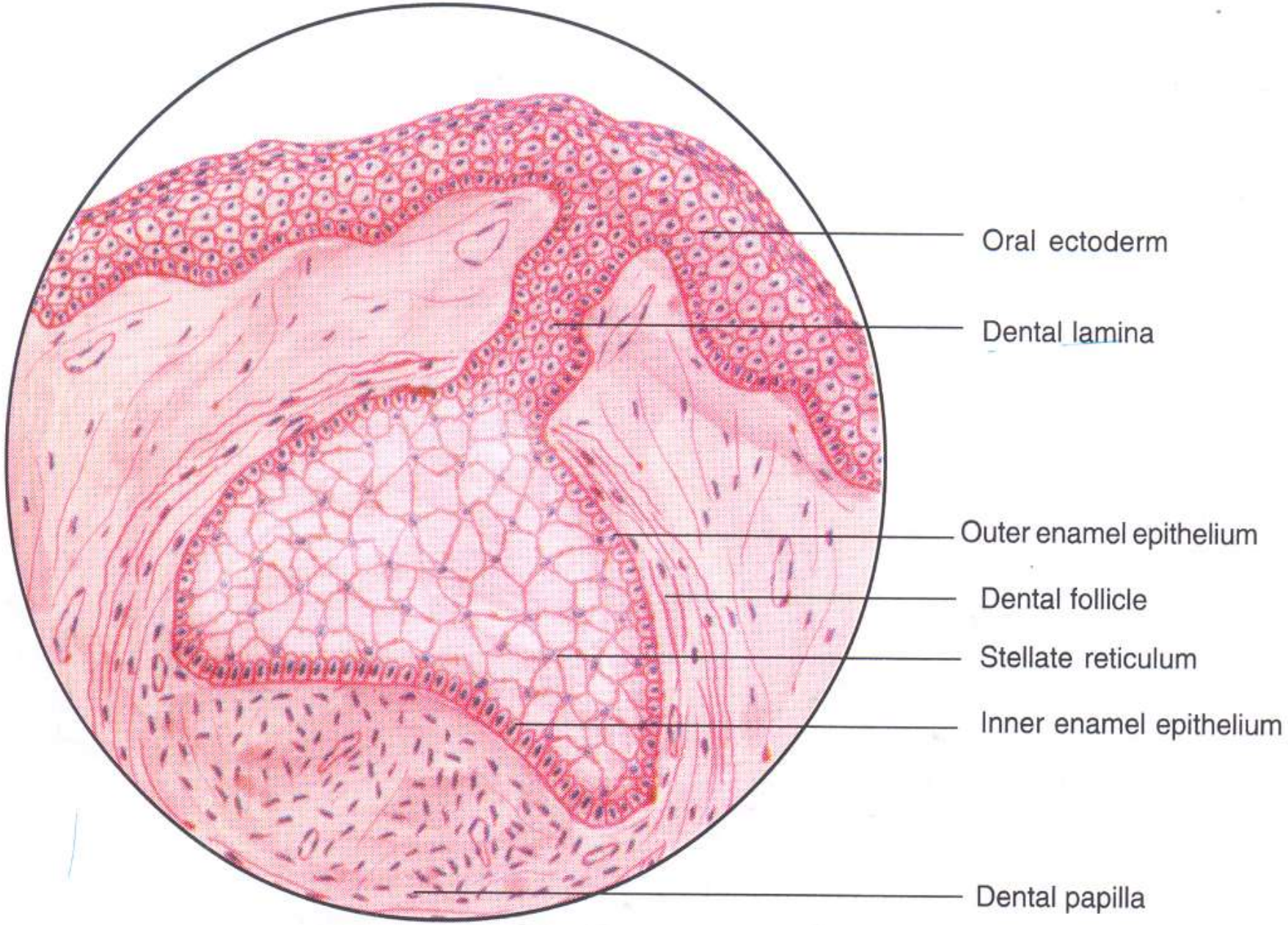
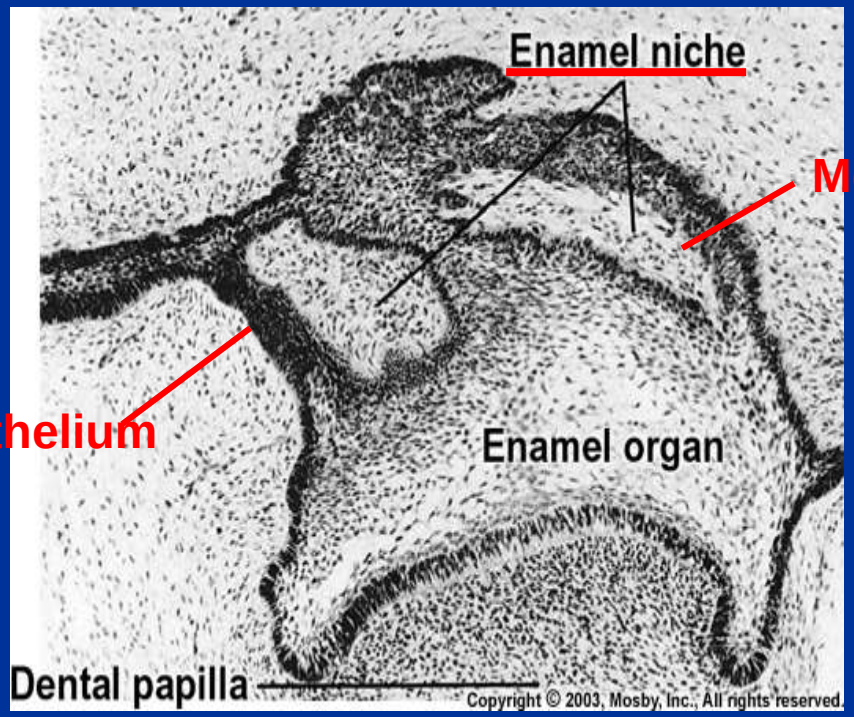


Fig. 3.2 Cap stage of tooth development

EARLY CAP STAGE

(PROLIFERATIVE)

- The epithelial bud continues to proliferate into the ectomesenchyme.
- ***Condensation of ectomesenchyme***
- At this stage, the enamel organ, dental papilla and dental follicle that constitute the ***dental organ/tooth germ*** can be identified.
- The ***Enamel Niche*** is an apparent structure in histologic sections, created because the dental lamina is a sheet rather than a single strand and often contains a concavity filled with connective tissue.

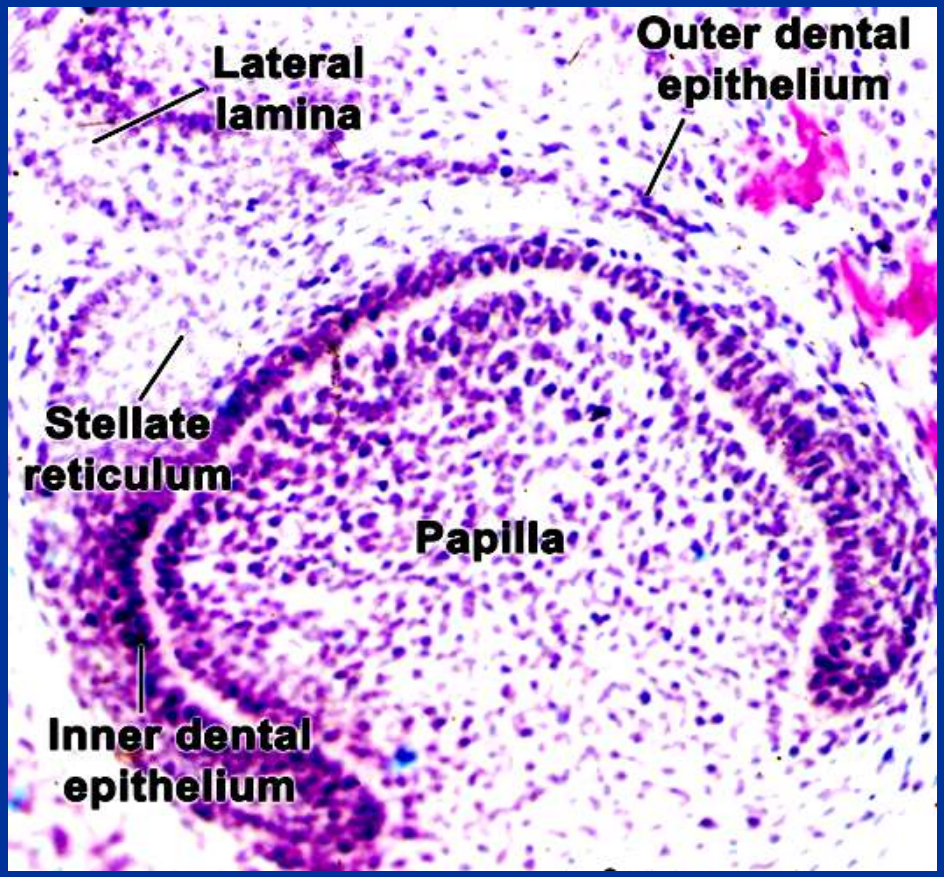


ENAMEL NICHE *is seen where the tooth germ appears to have a double attachment to the dental epithelium. EN appears as a funnel-shaped depression containing connective tissue. The functional significance of EN is unknown.*

LATERAL LAMINA

- As the tooth bud grows larger, it drags along with it a part of the Dental lamina; from that point on, the developing tooth is attached to the Dental lamina by an extension called as Lateral lamina.

Early Cap stage



LATE CAP STAGE

Important developmental changes begin late in the cap stage and continue during the transition of the tooth germ from cap to bell. Through these changes ,termed histodifferentiation , a mass of similar epithelial cells transform itself into morphologically and functionally distinct components.

The cells in the center of the enamel organ synthesize and secrete glycosoaminoglycans into the extracellular compartments between the epithelial cells.

Glycosaminoglycans are hydrophillic and so pull water into the enamel organ because of which the cells loose water and are forced apart but they retain connections with each other through their desmosomal contacts, and hence become star shaped.

The center of the enamel organ thus is termed ***Stellate Reticulum***

Late cap stage

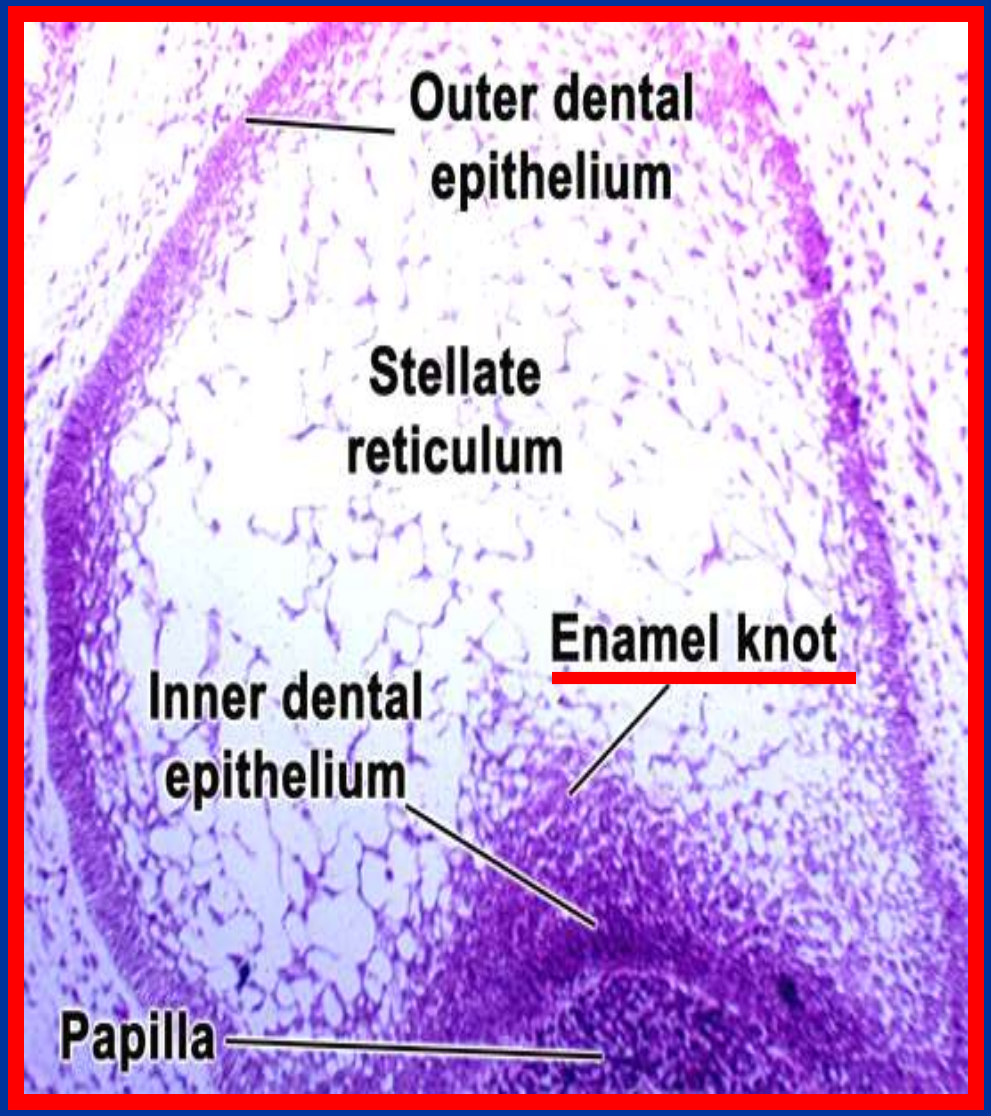
•At the periphery of the enamel organ the cells assume a low cuboidal shape and form the ***outer(external)dental epithelium.***

•The cells bordering on the dental papilla assume a short columnar shape and are characterized by high glycogen content. They form the ***internal dental epithelium.***

•***Enamel knot & enamel cord can be seen.***

Late cap stage

Enamel knot or Ahren's knot



- It is a localized mass of, or cluster of non dividing cells.
- The E K forms a bulge into the dental papilla, at the center of the enamel organ.

Late cap stage

THE ENAMEL CORD

Strand of cells seen at the early bell stage of development, extending from the stratum intermedium into the stellate reticulum.

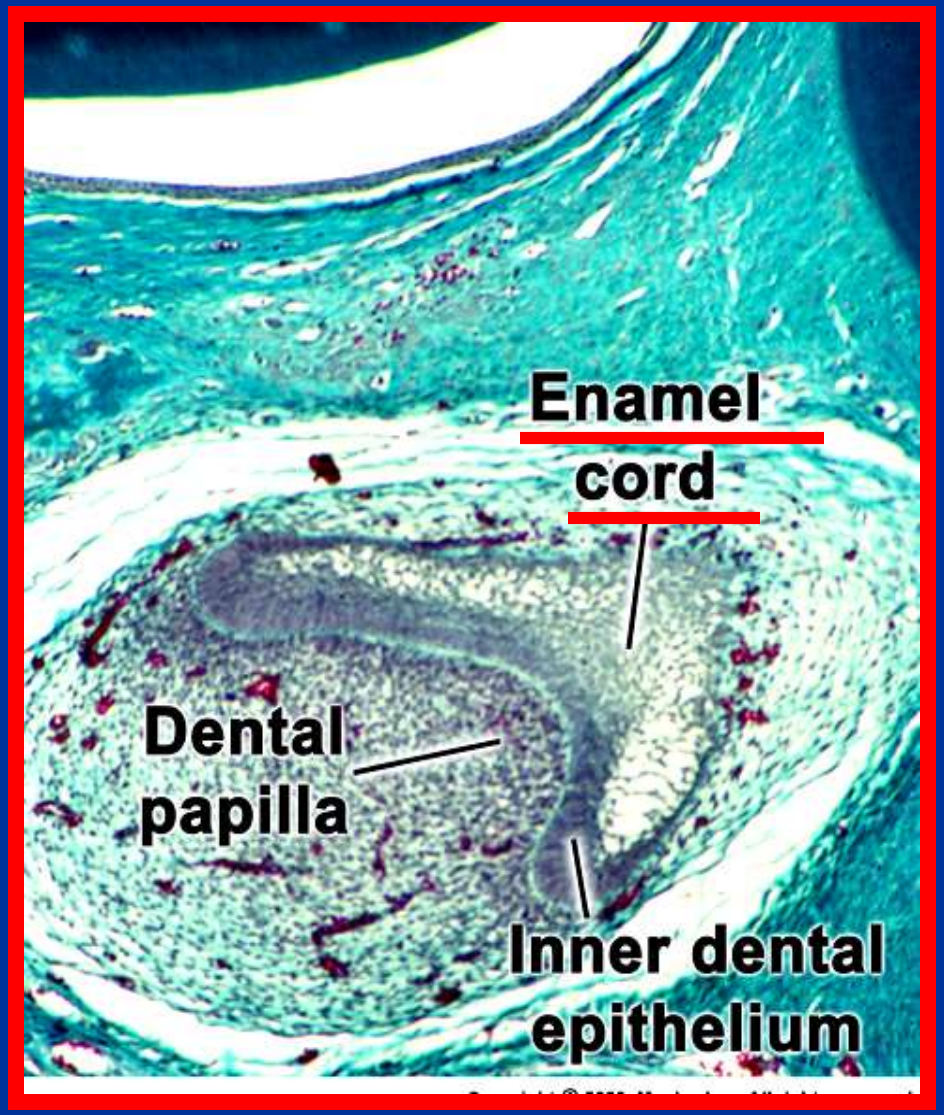
When it completely divides the stellate reticulum into 2 parts,reaching the ODE. It is termed the ***Enamel septum.***

Where the enamel cord meets the OEE a small invagination called the *Enamel Navel* may be seen.

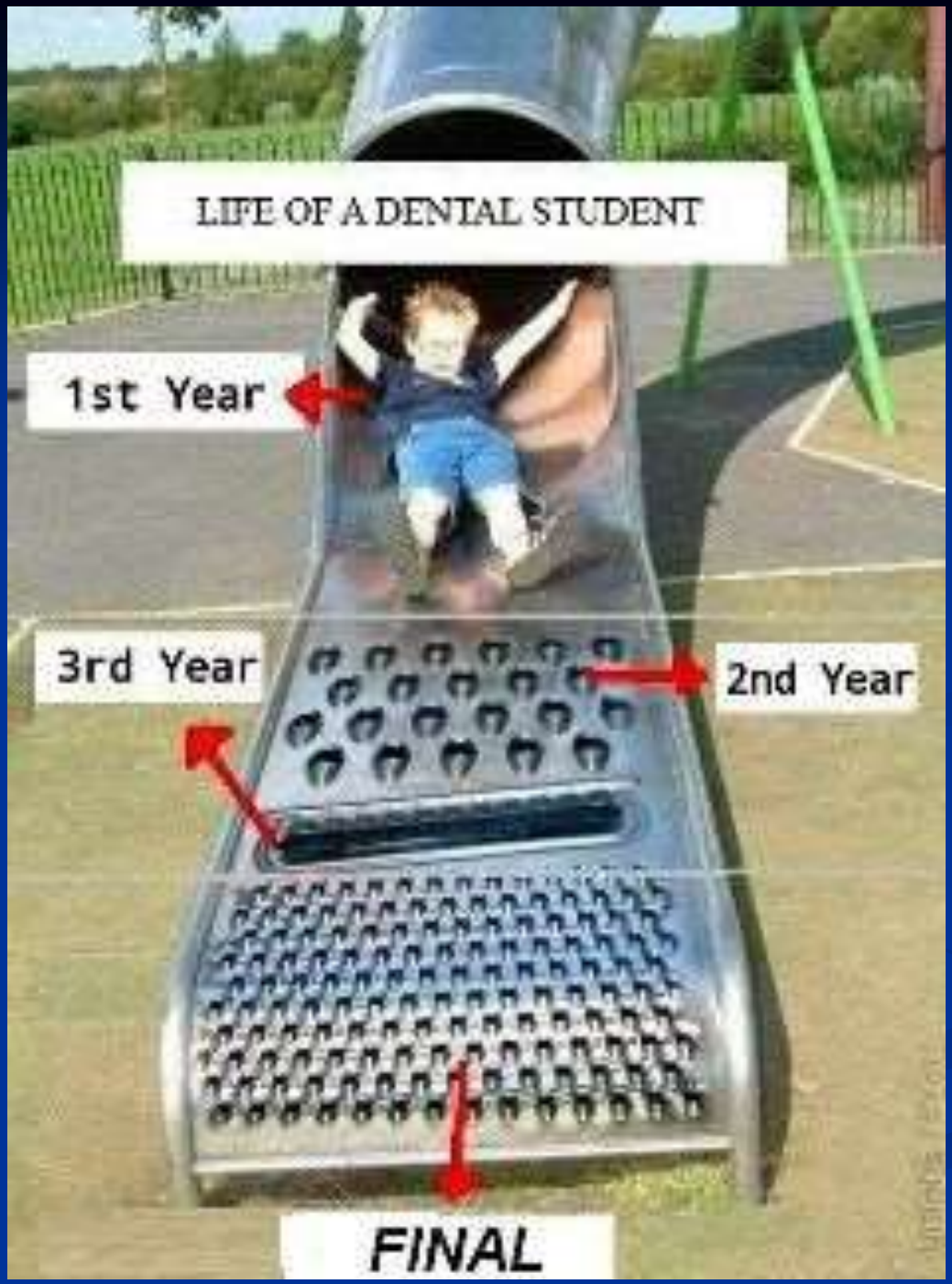
EC may be involved in the process by which the cap stage is transformed into the bell stage.

It is a focus for the origin of the Stellate Reticulum cells.

Late cap stage



Late cap stage

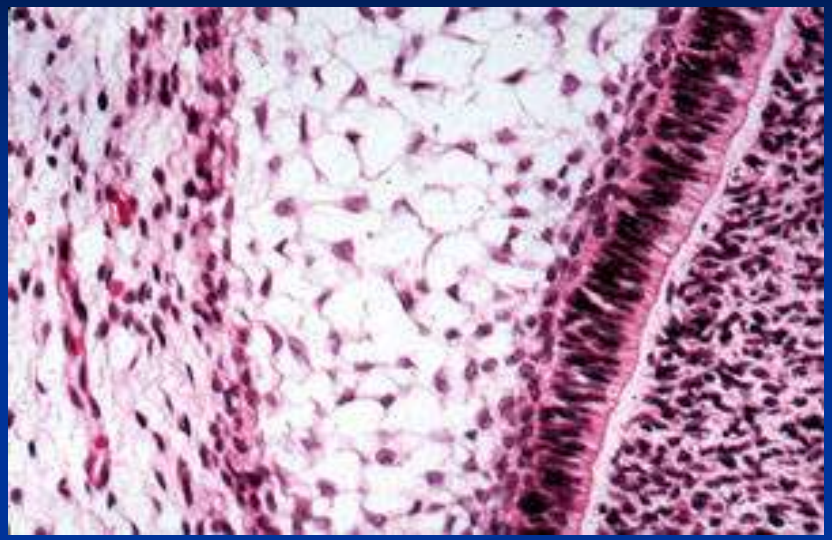

LIFE OF A DENTAL STUDENT
1st Year
2nd Year
3rd Year
FINAL

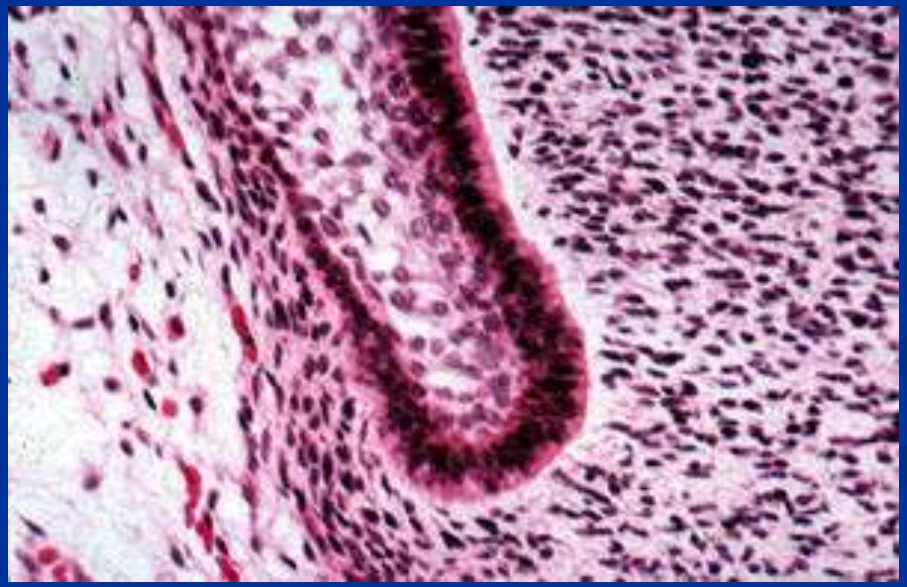
BELL STAGE

- *Transition from cap to bell stage occurs in the embryo which is between 100-160 mm long(CR length)*

Why is this stage called the bell stage?

Bell stage





EARLY BELL STAGE *(CR LENGTH =120MM)*

- Further morphodifferentiation and histodifferentiation of the tooth germ leads to the early bell stage.
- The configuration of the internal enamel epithelium broadly maps out the occlusal pattern of the crown of the tooth.

- A high degree of histodifferentiation is achieved in the early bell stage.

- The enamel organ shows 4 distinct layers:

External enamel epithelium, Stellate Reticulum, Stratum Intermedium, and internal enamel epithelium.

- During this stage,the crown assumes its final shape(morphodifferentiation)and the cells ameloblast and odontoblasts acquire their distinctive shape.(histodifferentiation)

Early bell stage

OUTER OR EXTERNAL DENTAL EPITHELIUM :

- The ODE cells flatten to a low cuboidal form.
- At the end of the bell stage preparatory to and during the formation of enamel, the formerly smooth surface of the outer enamel epithelium is laid in folds. Between the folds the adjacent mesenchyme of the dental sac forms papillae that contain capillary loops and thus provide rich nutrition supply for the intense metabolic activity of the avascular enamel organ.

Early bell stage

INNER DENTAL EPITHELIUM

- IDE consists of a single layer of tall columnar cells,which differentiate into specialised cells called ***Ameloblasts*** ,before amelogenesis.

- The IDE cells are rich in RNA but, unlike the SI & SR do not contain alkaline phosphatase.

- During enamel formation there is reversal of polarity in the ameloblasts in order to derive nutrition through the outer enamel epithelium.

Early bell stage

- The cells of the IDE exert an organising influence on the underlying mesenchymal cells in the dental papilla which later differentiates into ***Odontoblasts***

Inner dental epithelium

(Early bell stage)

STELLATE RETICULUM (ENAMEL PULP)

- It is fully developed at the bell stage.
- Cells of this layer possess little endoplasmic reticulum and few mitochondria. There is a relatively well-developed golgi complex.
- Numerous tonofilaments are present within the cytoplasm, and desmosomes and gap junctions are present between the cells.
- The proteinaceous fluid containing albumen gives a cushion- like consistency to the SR that supports and protects the delicate enamel-forming cells against physical disturbance and maintenance of tooth shape.

Early bell stage

CERVICAL LOOP/ZONE OF REFLECTION

The outer and inner dental epithelia are continuous. The region where they meet at the rim of the enamel organ is known as Cervical Loop

Early bell stage

STRATUM INTERMEDIUM

In the bell stage ,some epithelial cells between the inner dental epithelium and the stellate reticulum differentiate into a layer called the ***Stratum Intermedium***.

- Consists of 2 or 3 layers of flattened cells lying over the IEE. The cells of the SI resemble the cells of the SR but the intercellular spaces are smaller and the cells contain increased alkaline phosphatase levels.

Early bell stage

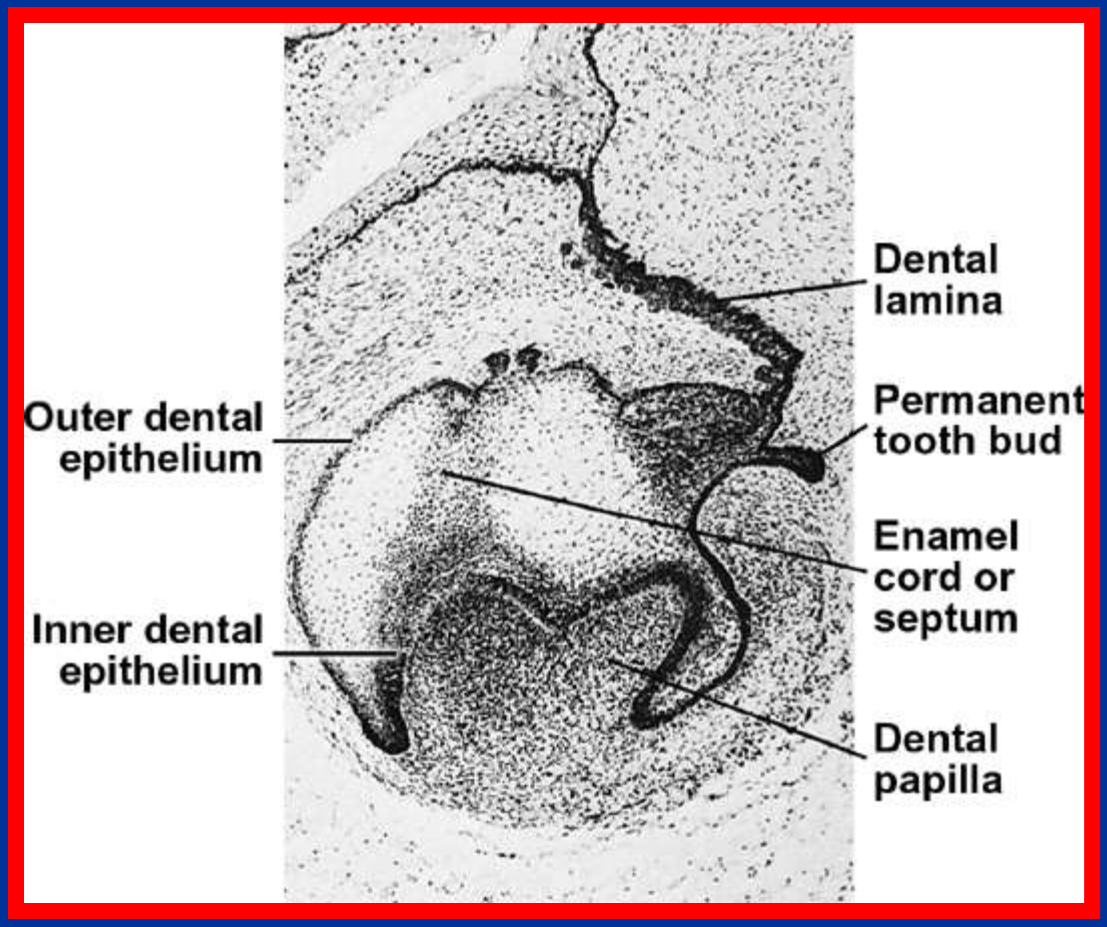
- Well developed cytoplasmic organelles,acid mucopolysaccharides & glycogen deposits indicate high degree of metabolic activity.

- SI is concerned with the synthesis of proteins

- Although these cells are histologically distinct from the cells of the IDE, both layers have been considered as a single functional unit responsible for the formation of enamel.

STRATUM INTERMEDIUM

(early bell stage)



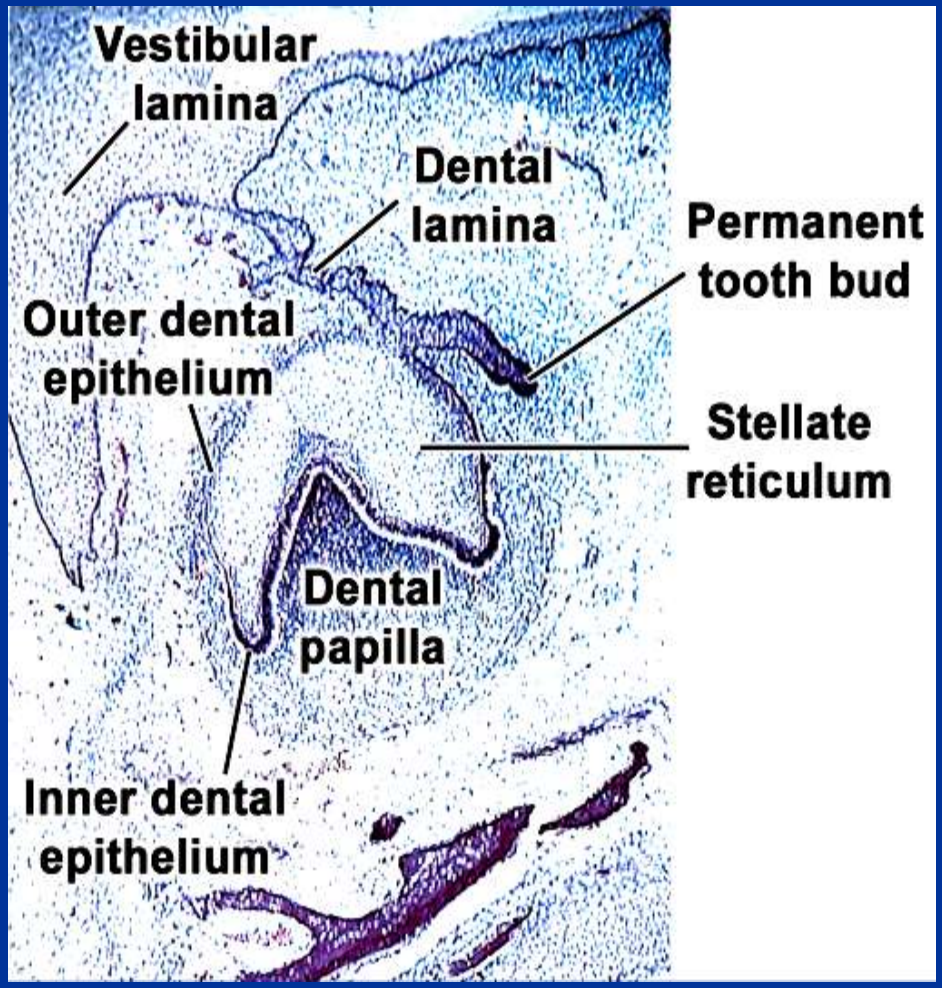
Early bell stage of tooth development .

EO seems to be divided by the enamel septum or cord

DENTAL PAPILLA

- 1st the odontoblasts are cuboidal – shaped and are then elongated to become columnar in shape and laying down of the dentin starts before the inner enamel epithelium lays down the first layer of enamel matrix.
- The dental papilla is referred to as the ***"tooth pulp"*** when the 1st calcified matrix appears at the cuspal tip of the bell stage tooth germ.
- ***Membrana preformativa*** seperates the enamel organ and the dental papilla before the dentin develops.

Early bell stage



Ectomesenchymal cells closely aggregated to form the dental papilla

Early bell stage

DENTAL SAC

Before formation of dental tissues begins, the dental sac shows a circular arrangement of fibers and resembles a capsular structure.

With the development of the root, the fibers of the dental sac differentiate into the peridontal fibers and become embedded in the developing cementum and alveolar bone.

Early bell stage

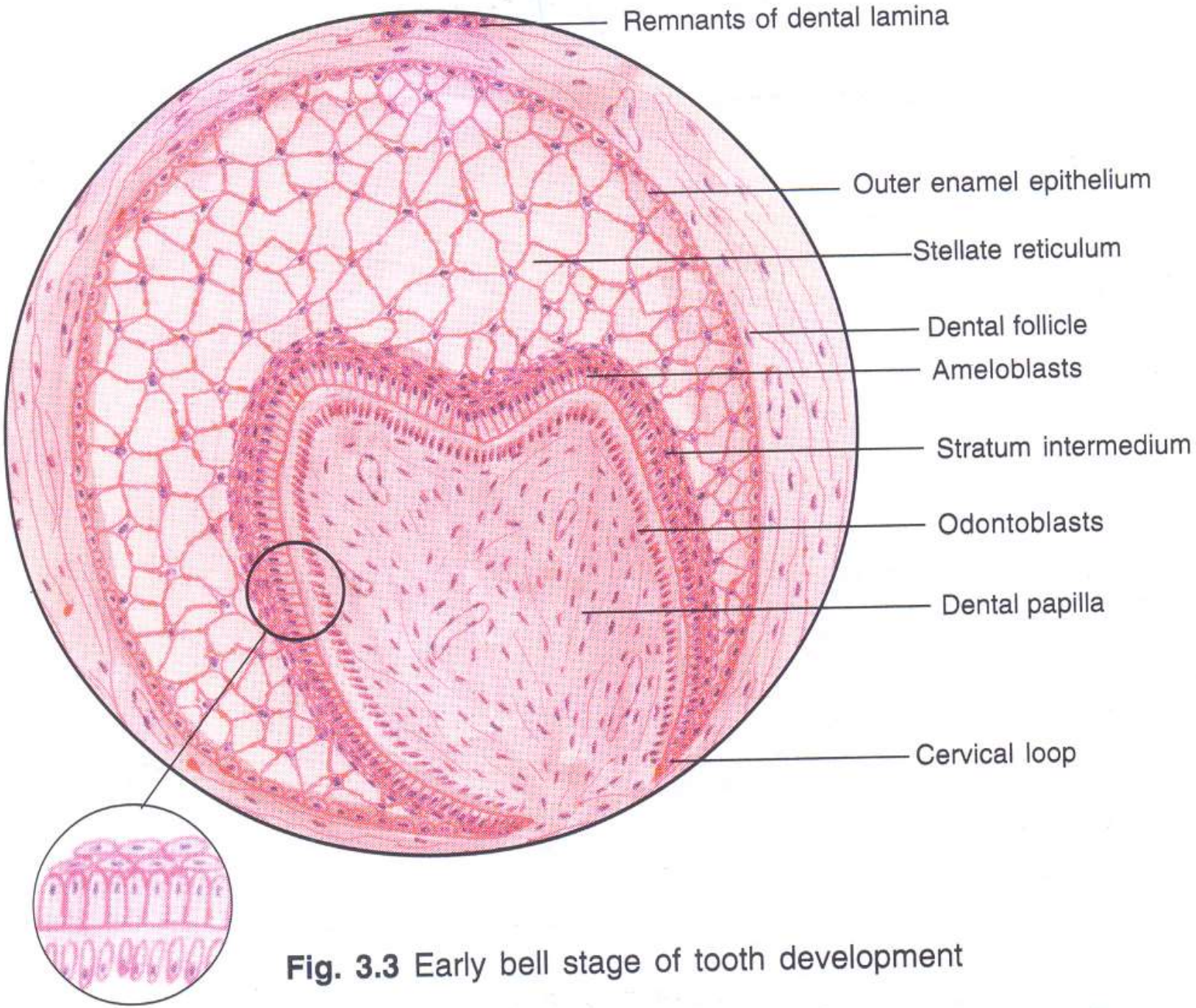


Fig. 3.3 Early bell stage of tooth development

Advanced Bell Stage *(Appositional Stage)*

2 main features seen:

- Future dentinoenamel junction forms from the boundary present between IDE & odontoblasts.

- Hertwig's epithelial root sheath develops from the cervical portion of the enamel organ.

- It is during the advanced bell stage that dental lamina breaks down and the enamel organ loses connection with the oral epithelium.

- At the same time the dental lamina between tooth germs also degenerates.

Advanced bell stage

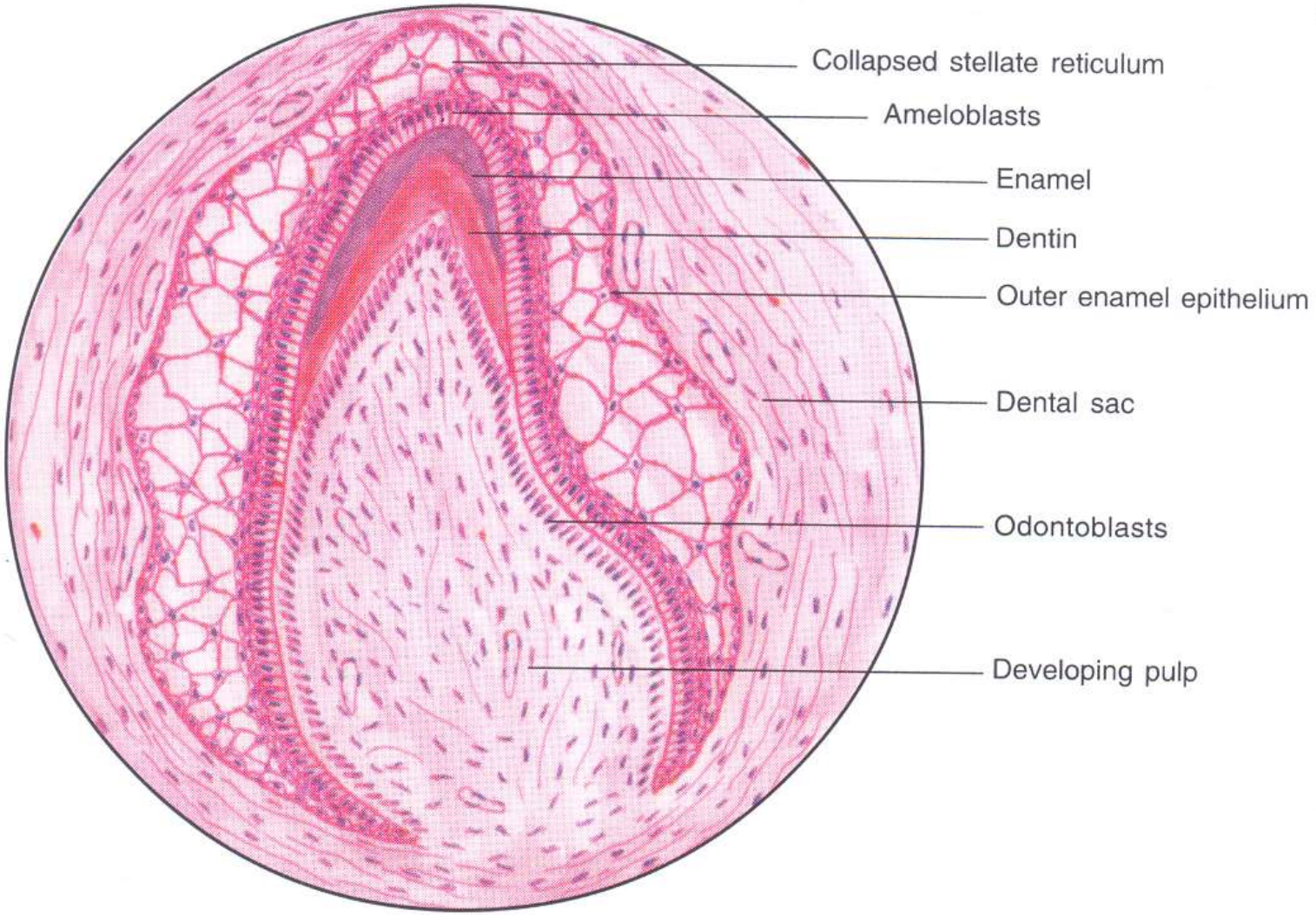


Fig. 3.4 Advanced bell stage of tooth development

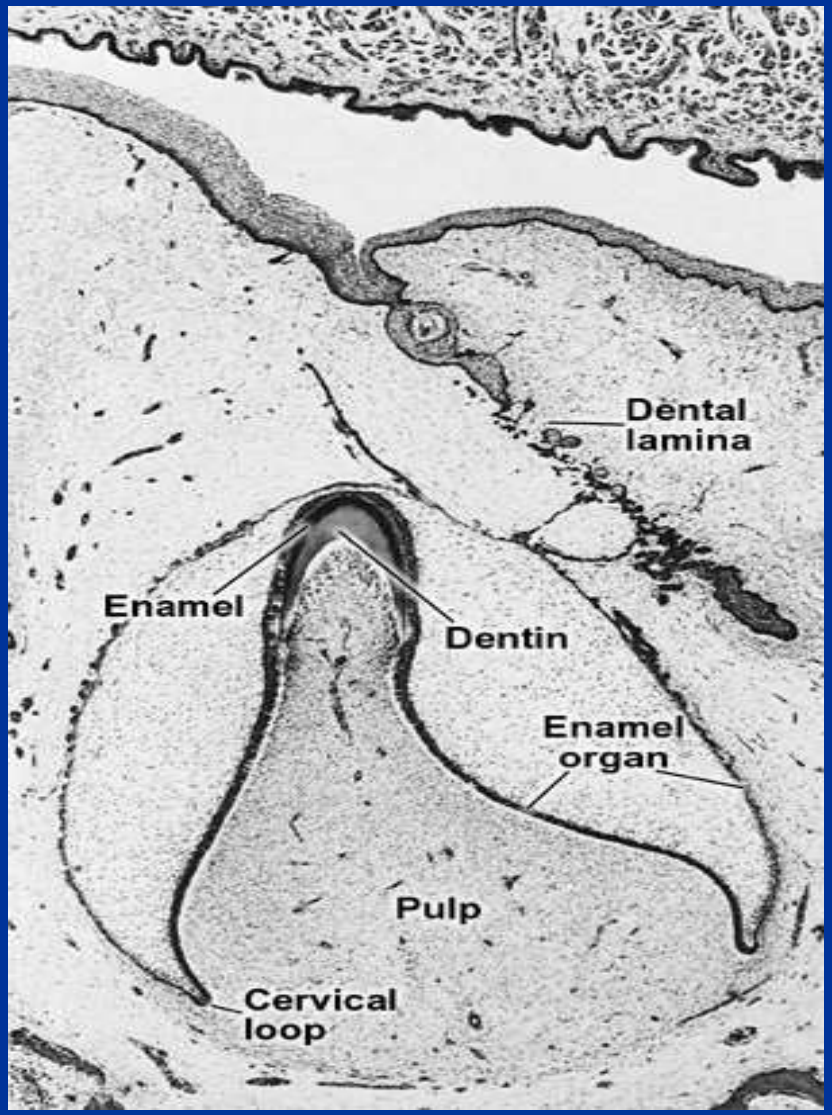
Breakup of dental lamina :

- The Dental lamina and the Lateral lamina joining the tooth germ to the oral epith. break up into discrete islands of epithelial cells which normally degenerate;

If they persist, they are called as epithelial pearls.

- These may form Eruption cysts over the developing tooth and delay eruption or may form supernumerary teeth, & cysts (odontogenic tumours , cyst linings.)

- Remnants of the dental lamina may contain keratin and can be involved in the etiology of cysts.



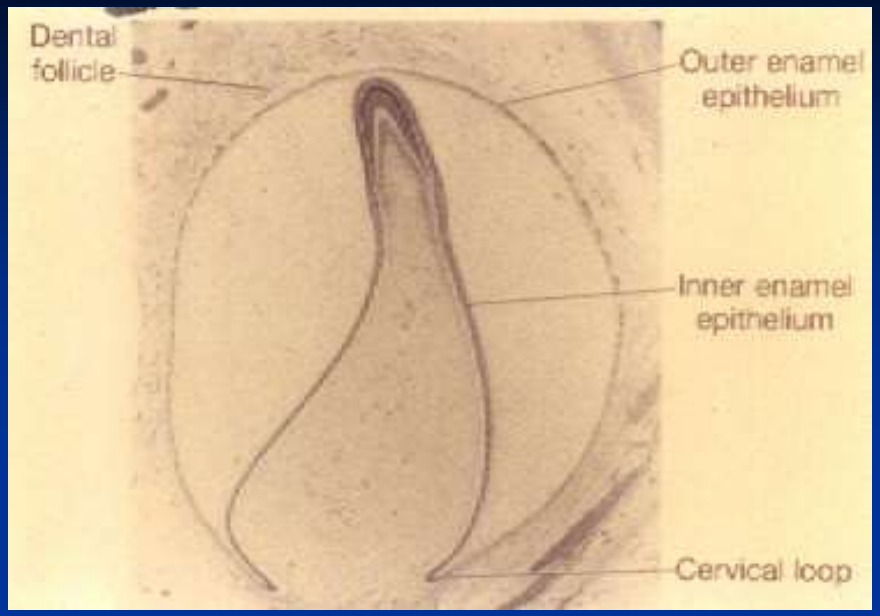
Advanced Bell stage

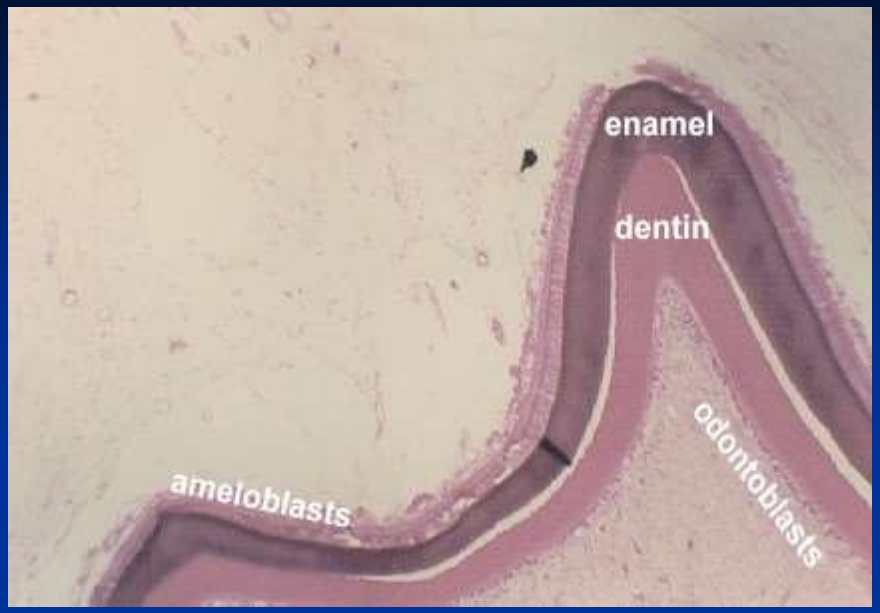
The dental lamina is disintegrating ,tooth divorced from the oral epithelium.

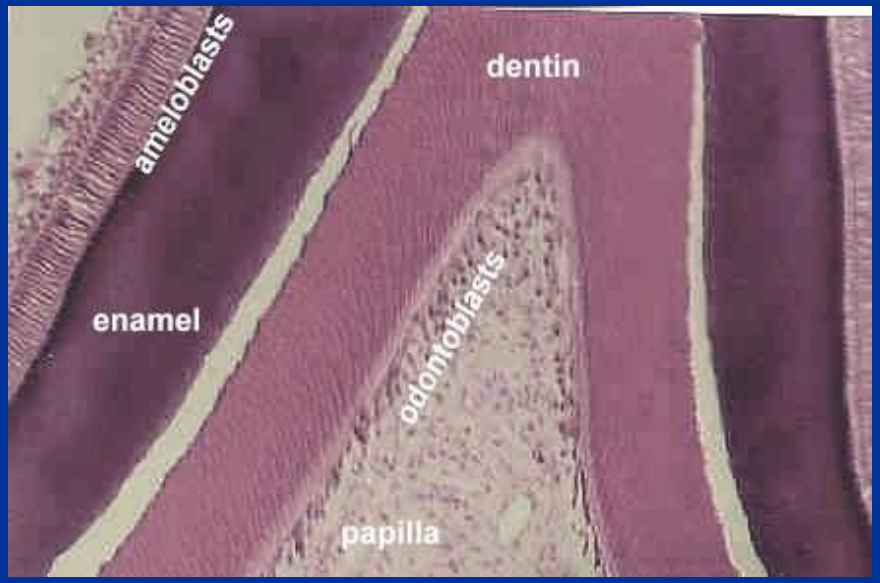
The crown pattern of the tooth has been established by the folding of the inner dental epithelium.

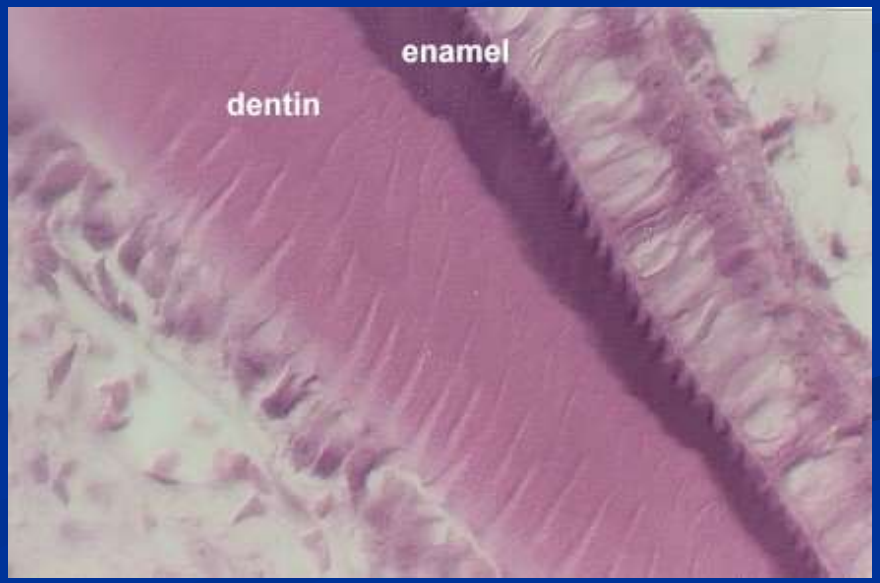
This folding reduces the amount of SR over the future cusp tip.

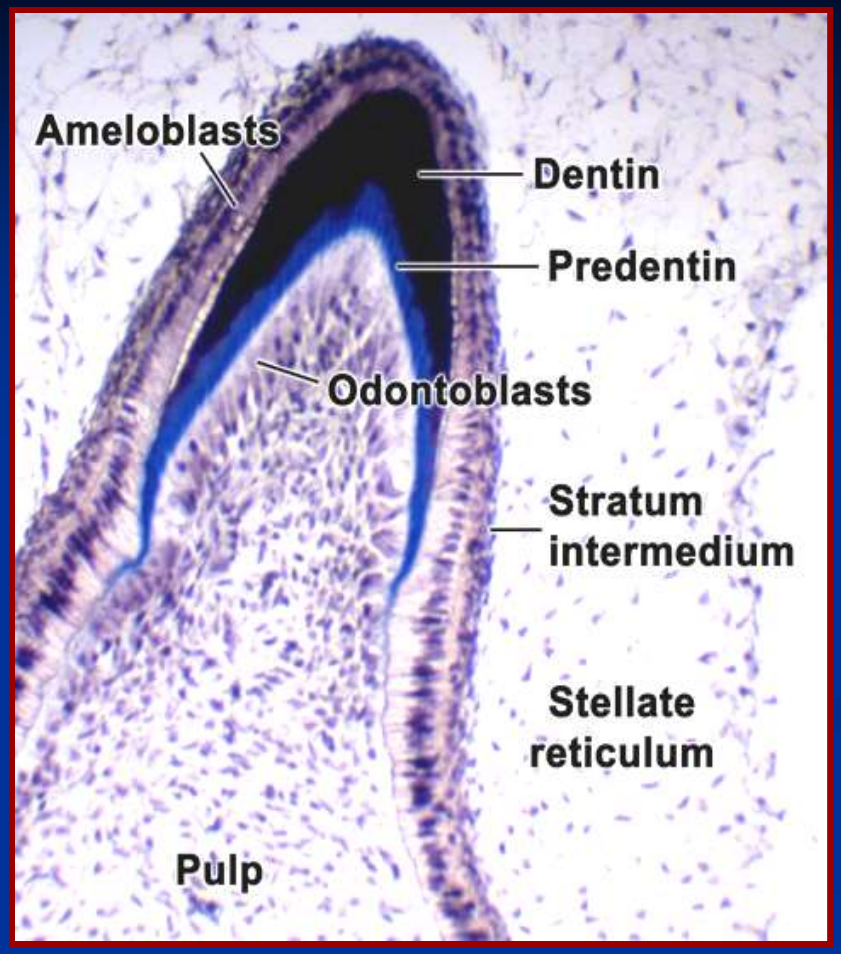
Dentin and enamel formation have begun at the crest of the folded IEE.


Dental follicle
Outer enamel epithelium
Inner enamel epithelium
Cervical loop


enamel
dentin
odontoblasts
ameloblasts


ameloblasts
dentin
enamel
odontoblasts
papilla

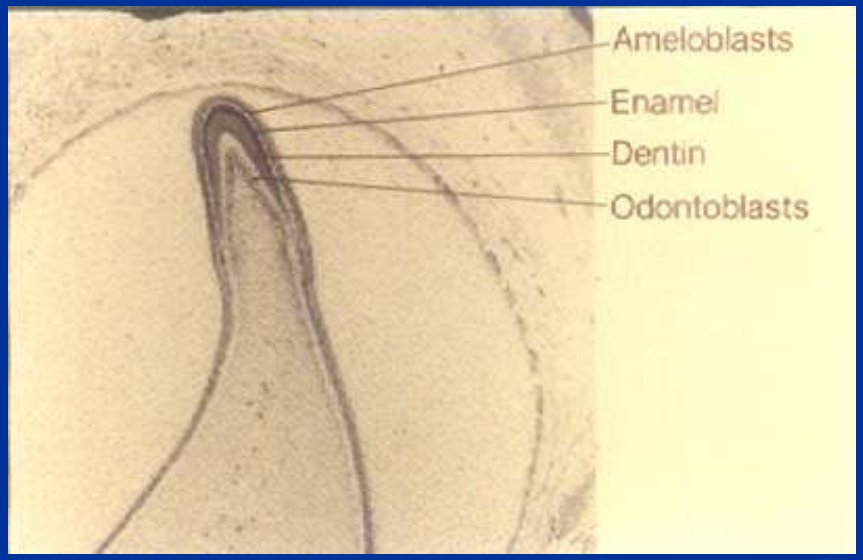

enamel
dentin

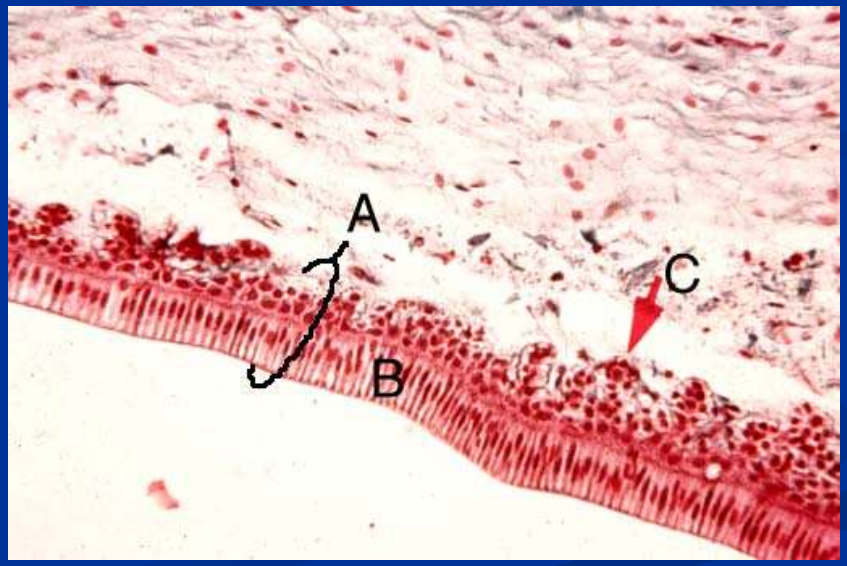


Advanced bell stage

Reduced enamel epithelium

- **The reduced enamel epithelium consists of the mature/protective ameloblasts and remanants of the outer layers of the enamel organ**
- **Numerous capillaries,which had formed to supply oxygen and nutrients to the ameloblasts following dentin formation, surround the reduced**





A, Reduced enamel epithelium; **B**, Maturative/protective ameloblasts; **C**, Capillary

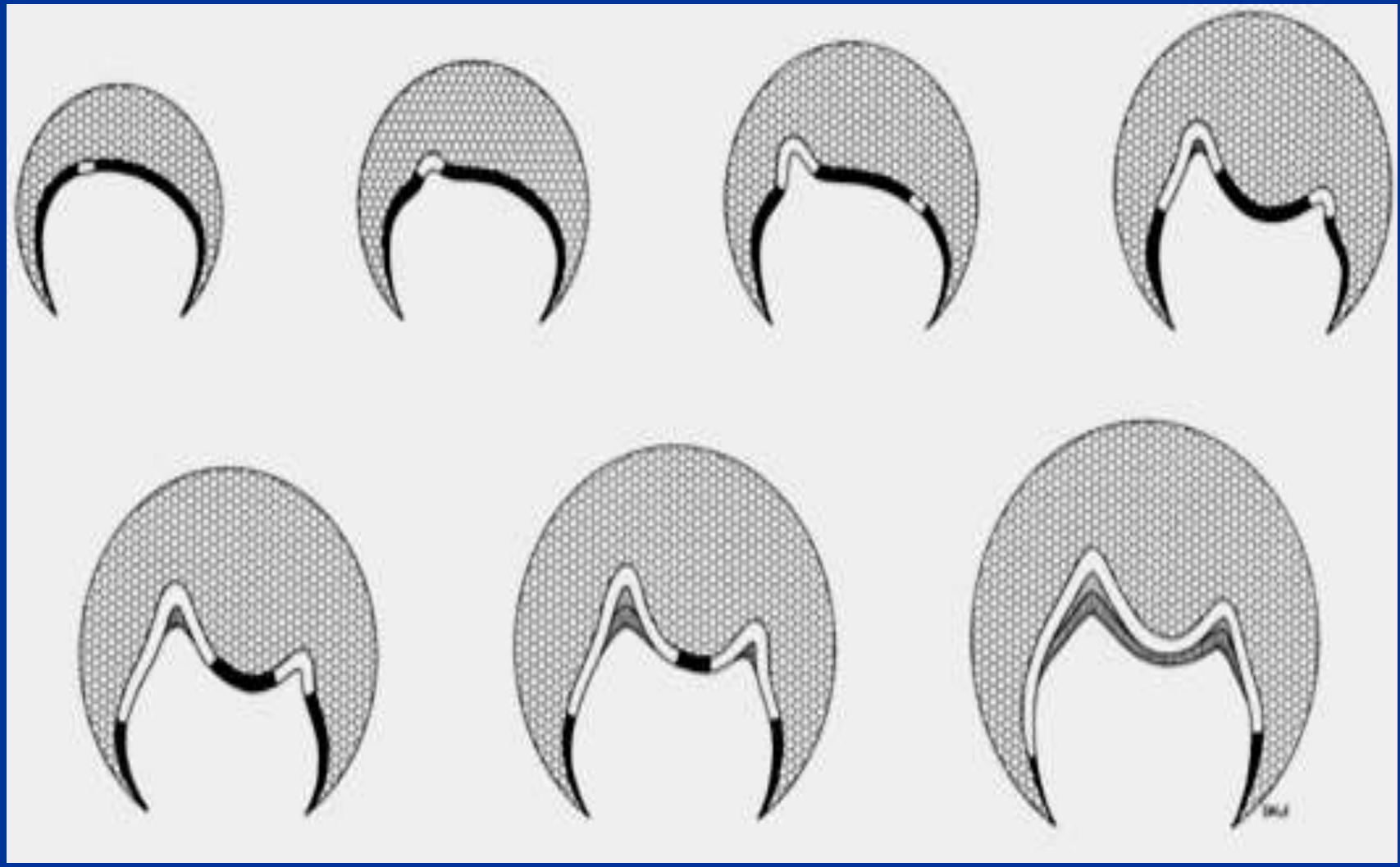
Crown pattern determination :

- The Inner dental epithelium lies between two opposing pressures i.e. from the Stellate reticulum cells of the Enamel organ and from the Dental papilla, and is therefore in a state of equilibrium.

- The folding that occurs as the crown develops results from the differential rates of mitotic division within the Inner dental epithelium.

- When the tooth germ is growing rapidly during the cap to bell stage, cell division occurs throughout the Inner dental epithelium. As development continues, division ceases at a particular point because the cells are beginning to differentiate into Ameloblasts. This represents the site of future cusp development.

- Because the Inner dental epithelium is constrained between the Cervical loop and the cusp tip, continued cell proliferation causes the Inner dental epithelium to buckle and form the cuspal outline.



CROWN PATTERN FORMATION : Darkened area –zone of cell division

White area –cells have differentiated.

Root formation

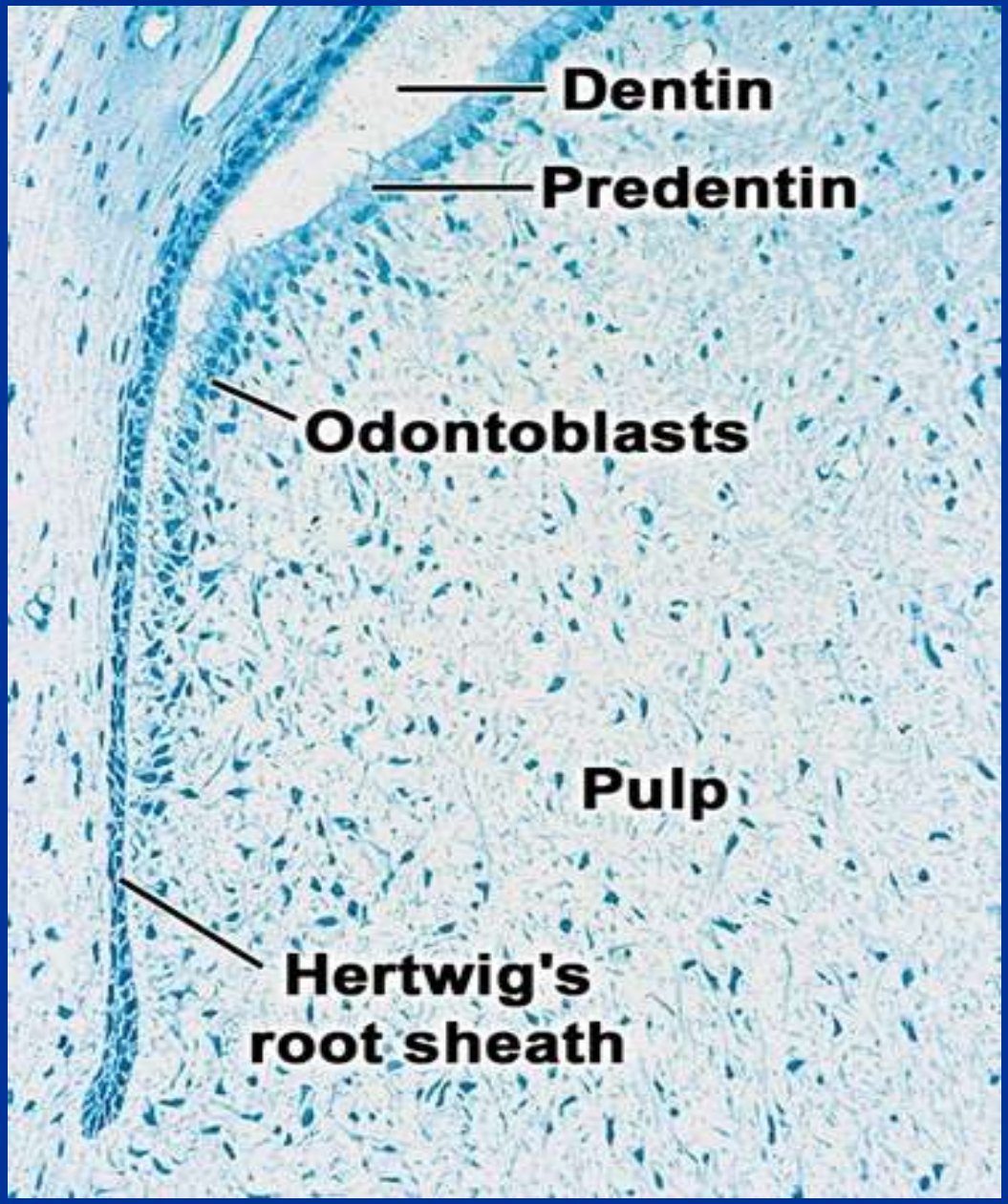
- The development of the roots begins after Enamel and Dentin formation has reached the future Cemento-Enamel junction.

- The Enamel organ plays an important role in root development by forming Hertwig's Epithelial Root Sheath.

- Hertwig's root sheath consists of Outer and Inner Dental epithelia.

- When the inner cells of this sheath have induced the differentiation of radicular cells into Odontoblasts and first layer of Dentin has been laid down, the root sheath loses its structural continuity.

- Its remnants persist as Rests of Malassez. Apparently functionless, they are the source of epithelial lining of dental cysts that develop in reaction to inflammation of periodontal ligament.

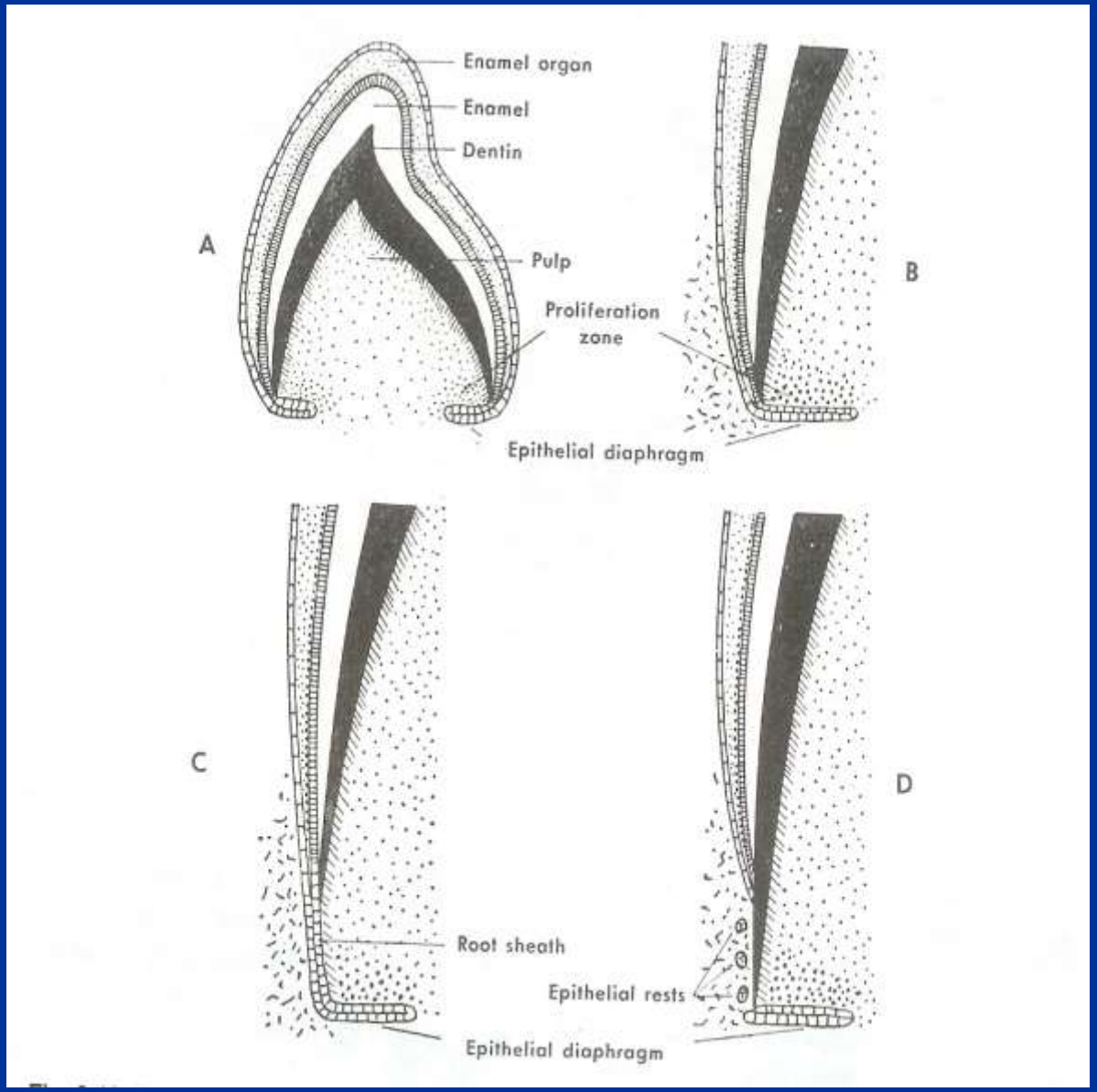

Dentin
Predentin
Odontoblasts
Pulp
Hertwig's
root sheath

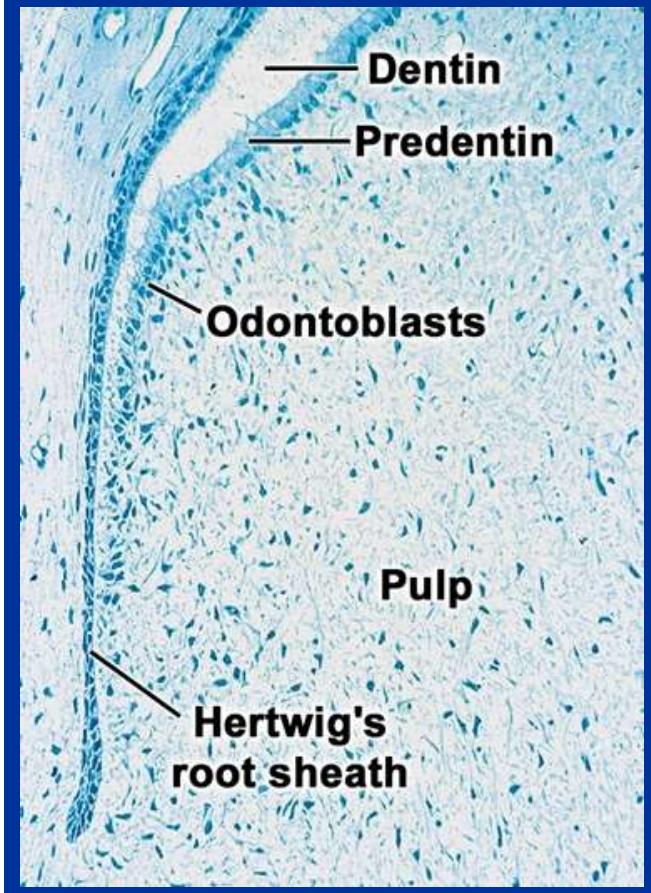
Root formation in single rooted teeth

- Prior to the beginning of root formation, the root sheath forms the Epithelial Diaphragm. The Outer and Inner dental epithelia bend at the future CEJ into a horizontal plane, narrowing the wide cervical opening of the tooth germ.

- The epithelium proliferates coronal to the Epithelial Diaphragm.

Root formation in single rooted teeth





- Differentiation of Odontoblasts and formation of Dentin follow the lengthening of the root sheath.

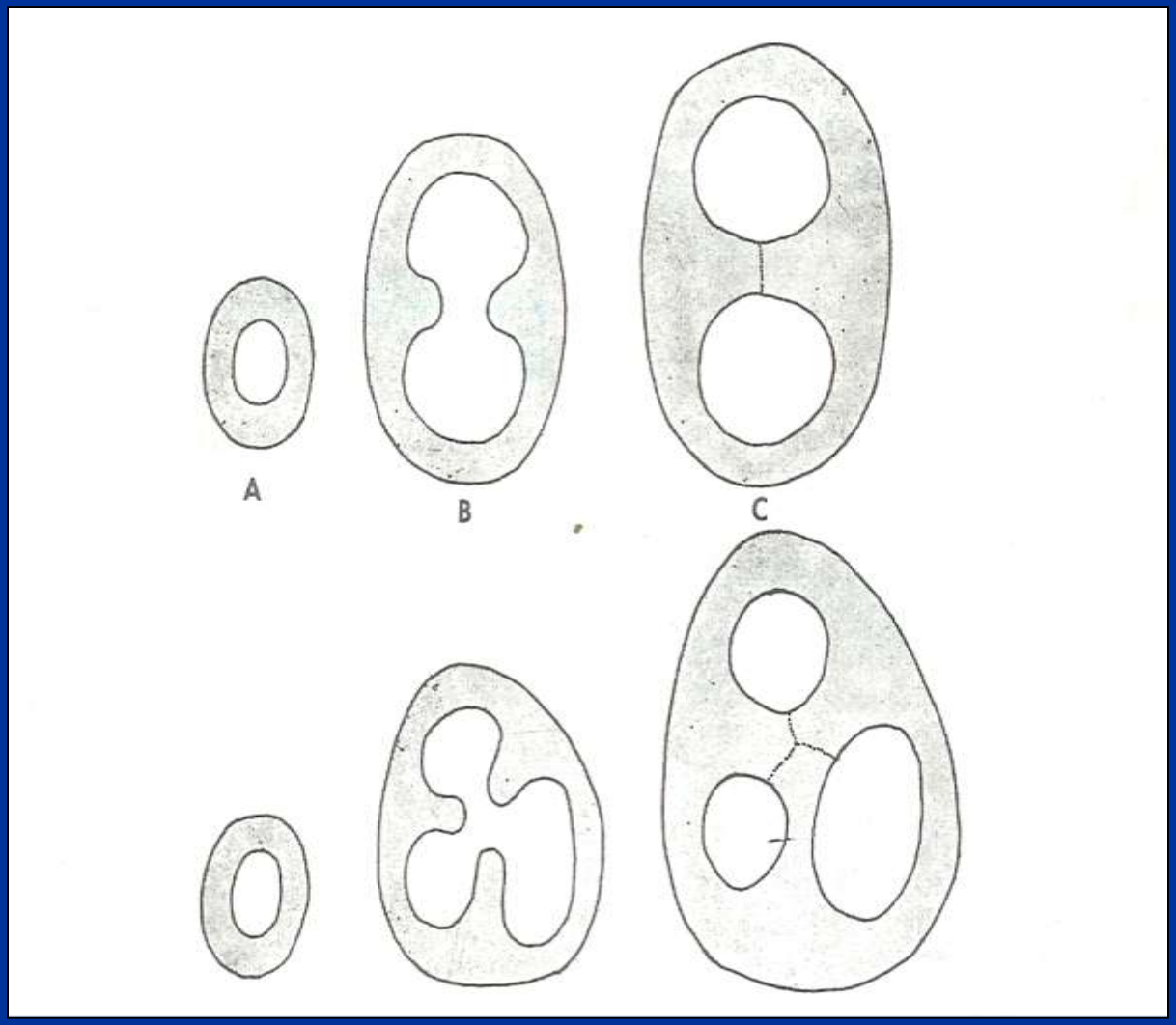
- At the same time, the connective tissue cells of the Dental Sac proliferate and invade the root sheath. These cells come into contact with the outer surface of dentin and differentiate into Cementoblasts that deposit Cementum onto the surface of the Dentin.

ROOT FORMATION

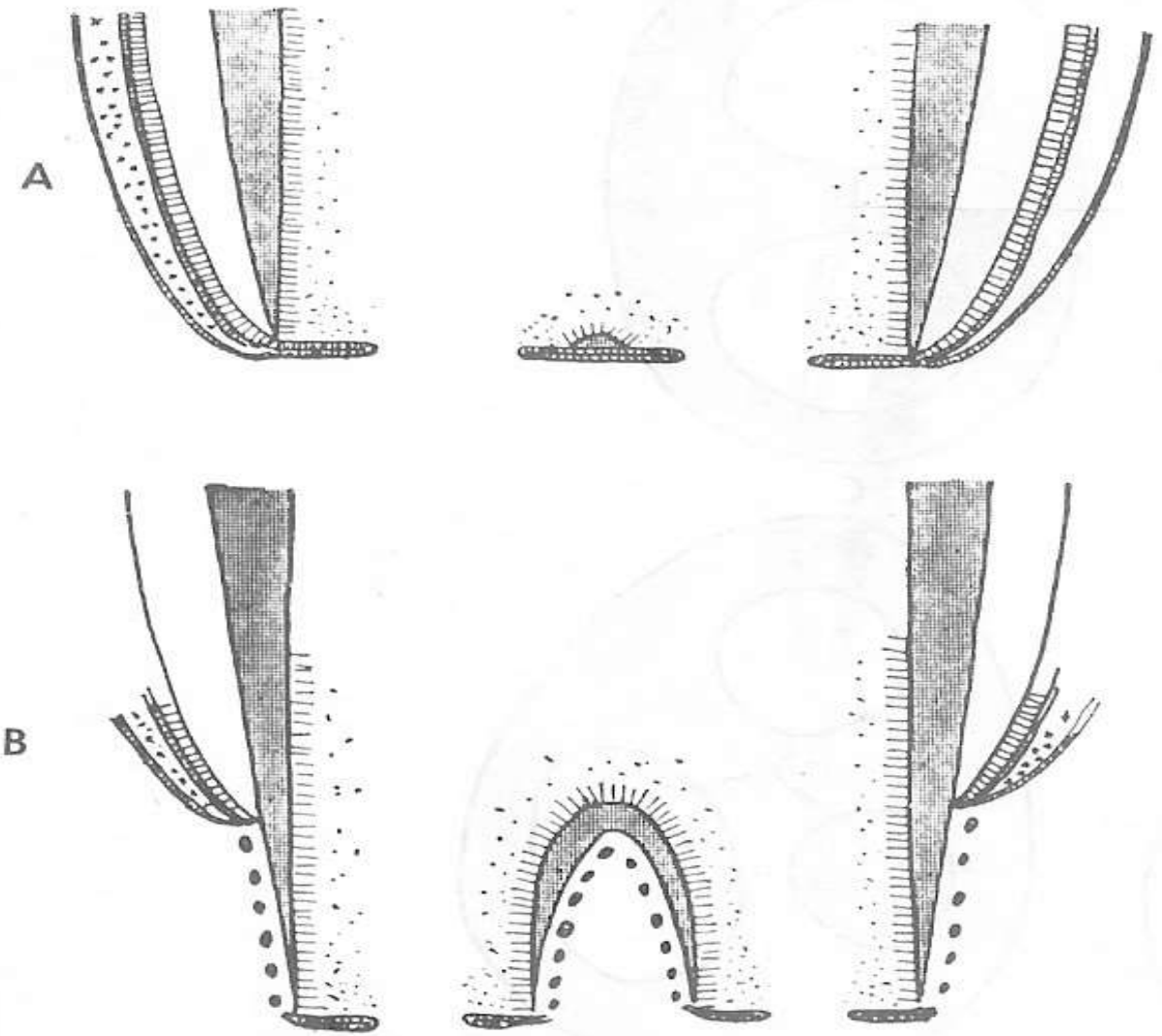
Root formation in multi-rooted teeth :

- During the general growth of the Enamel organ, the expansion of its cervical opening occurs in such a way that long, tongue-like extensions of the horizontal Diaphragm develop.

- The free ends of these horizontal epithelial flaps grow towards each other and fuse. The single cervical opening of the Enamel organ is then divided into two/ three openings.



ROOT FORMATION



ROOT FORMATION

How is dental development initiated?

Nature of the Inductive Message

During tooth development messages pass between the *epithelium* and *mesenchyme* to produce changes of increasing complexity (i.e. *differentiation*) with in the cell layers.

The term *Induction* is used to describe the effect that one cell layer has on another.

Three main hypothesis to explain how information leading to induction may be transferred between epithelium & mesenchyme:

1. A chemical substance (***Short range hormone***) is produced by one cell layer and diffuses across the narrow intervening space to be taken up & cause induction in the other cell layer.

2. Induction is triggered by ***direct cell to cell contact*** & does not involve a diffusible molecule.

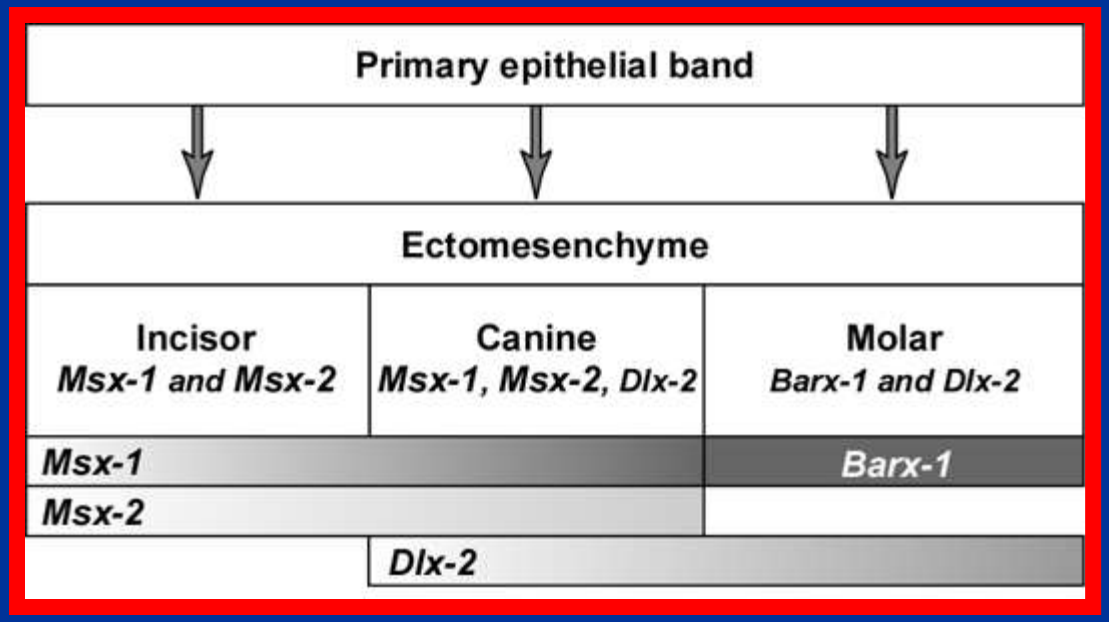
3. ***Induction*** is due to the presence of the initial extracellular matrix, a thin layer situated between the ***Epithelium & Mesenchyme*** and comprising the basal lamina & adjacent region. The extracellular matrix has a complex composition, consisting of collagen, proteoglycans & glycoproteins.

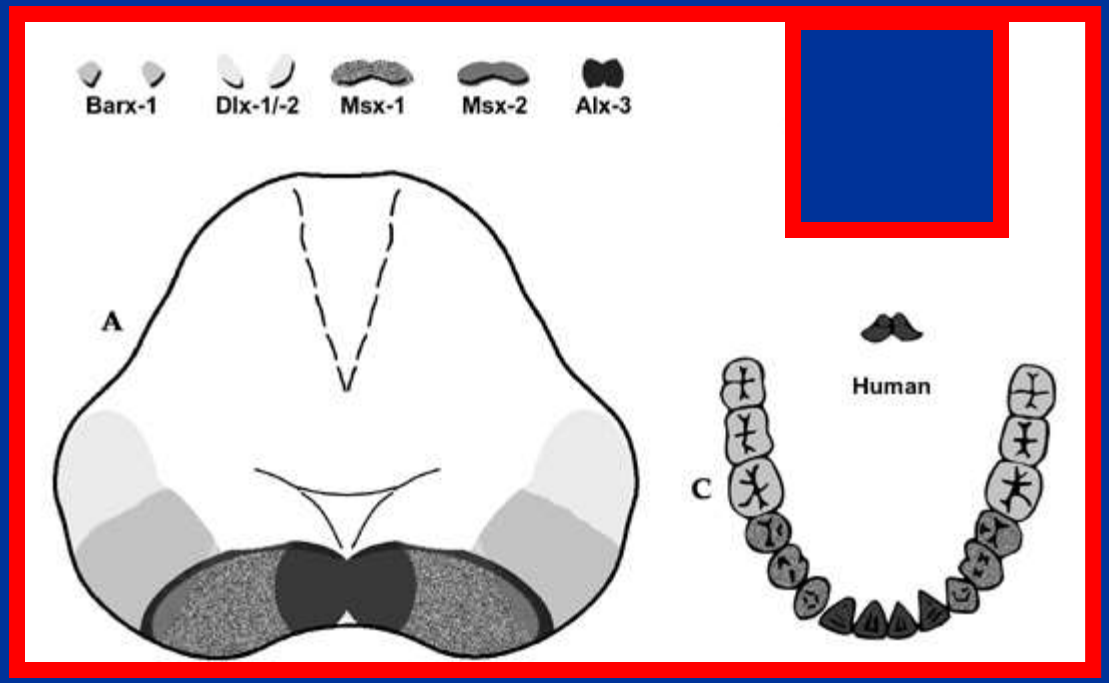
Homeobox Genes

- Genes highly conserved throughout the evolution of diverse organisms.

- All ***homeobox genes*** contain a similar region of 180 nucleotide pairs and function by producing transcription factors that bind to the DNA of other genes, thereby regulating their expression.

- Examples of those involved in tooth development include MSX, DLX, BARX, LHX


Primary epithelial band
Ectomesenchyme
Incisor
Msx-1 and Msx-2
Canine
Msx-1, Msx-2, Dlx-2
Molar
Barx-1 and Dlx-2
Msx-1
Barx-1
Msx-2
Dlx-2


Barx-1
Dlx-1/-2
Msx-1
Msx-2
Alx-3
A
Human
C

What are the signals mediating initial steps in tooth development?

- The earliest mesenchymal markers for tooth formation are Lhx genes i.e. Lhx-6 and Lhx-7 expressed in the ***1st branchial arch.***

- Expression of these genes results from a signaling molecule originating from the ***epithelium of 1st branchial arch*** i.e. Fgf-8.

1st branchial arch epith **+** ***2nd arch mesenchyme***= Lhx Induced

1st arch mesenchyme **+** ***2nd arch epith***=Lhx down regulated

What controls the position and no. Of tooth germs?

- Signals for these aspects appear to originate from the oral epithelium.

- Pax-9 gene plays an imp. role in defining the localization of tooth germs.

- A no. of other genes are also expressed in the oral epithelium e.g. Dlx-2, Msx-1. In fact, to date, more than 90 genes have been identified during initiation of tooth development.

Tooth Type Determination

- The determination of specific tooth types at their correct positions in the jaws is referred to as " patterning of the dentition".

- Two hypothetical models—

  Field model

  Clone model

Field Model (Homeobox Code Model)

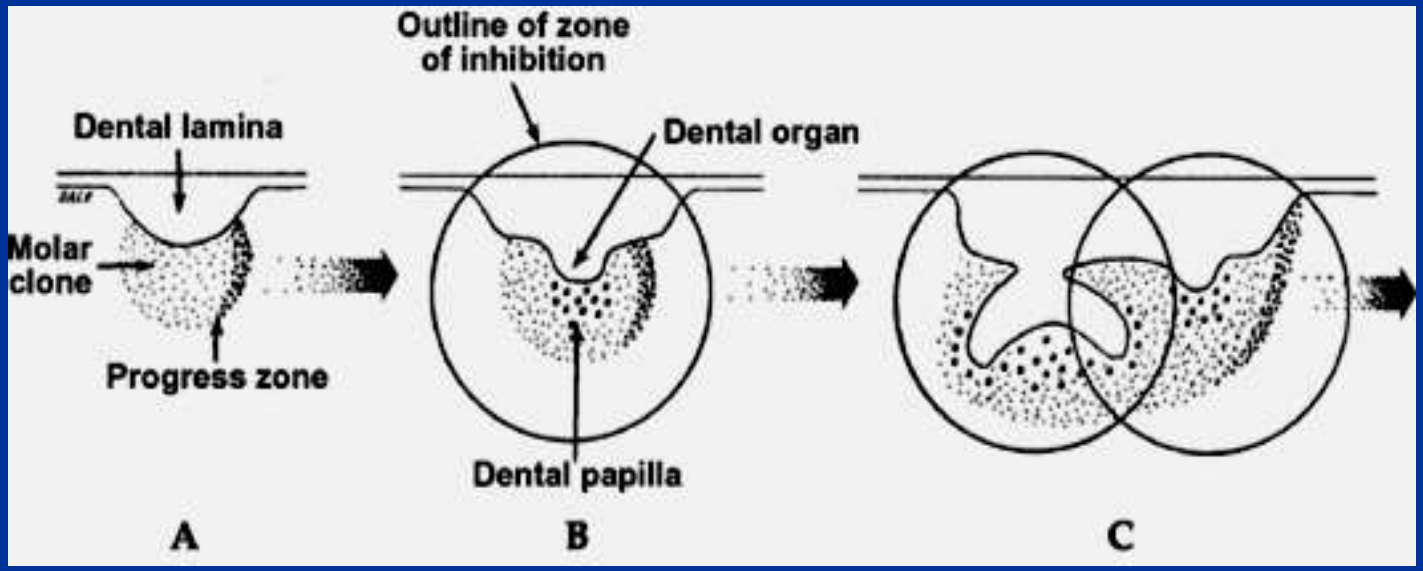
- It proposes that the factors responsible for tooth shape i.e. Homeobox genes reside within the ectomesenchyme in distinct but graded fields for each family.

- The expression of Msx-1 and Msx-2 is restricted to regions where incisors and canines develop while Dlx-1 and Dlx-2 are expressed where multi-cuspid teeth develop.

- Expression of Barx-1 overlaps with Dlx-1, Dlx-2.

Clone Model

Each tooth class is derived from a clone of ectomesenchymal cells programmed by epithelium to produce teeth of a given pattern.



Both models can be combined

For instance, the coded pattern of homeobox gene expression in the ectomesenchyme might be expressed following an epithelial signal.

Ectomesenchyme eventually assumes the dominant role in crown pattern formation.

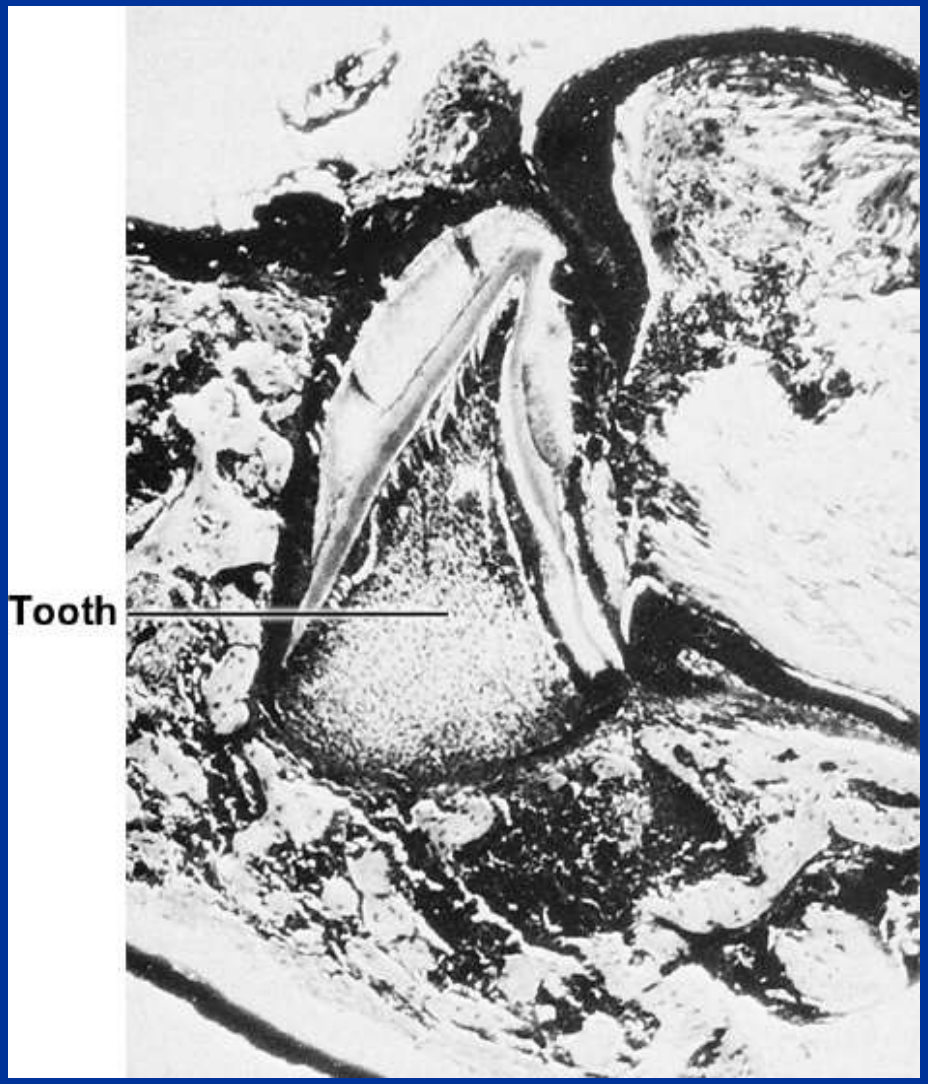
Examples to proove ectomesenchyme eventually assumes the dominant role in crown pattern formation.

Murine ***1st branchial arch epithelium*** combined with ***cranial neural crest*** in the anterior chamber of the anterior chamber of the eye leads to tooth formation.

Epithelium from other sources e.g. ***2nd arch*** does not elicit this response

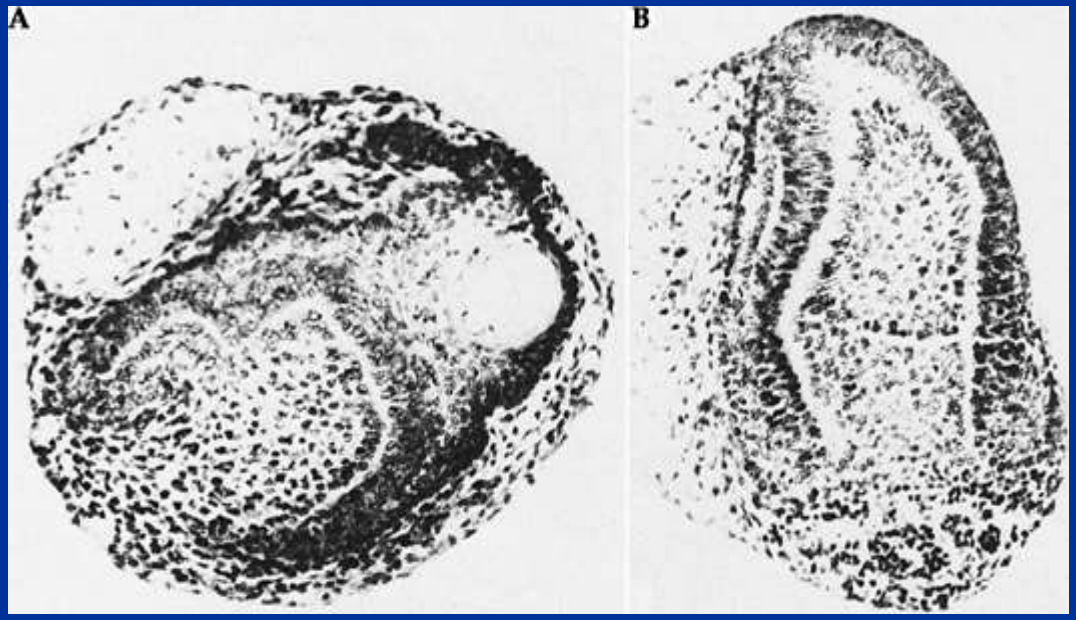
After 12th day of development ,***1st arch epithelium*** loses its odontogenic potential which is assumed by the ectomesenchyme e.g. ***1st arch ectomesencyme*** recombined with embryonic foot epithelium leads to formation of dental organ

Examples to proove ectomesenchyme eventually assumes the dominant role in crown pattern formation.



Tooth that developed from the skin epithelium

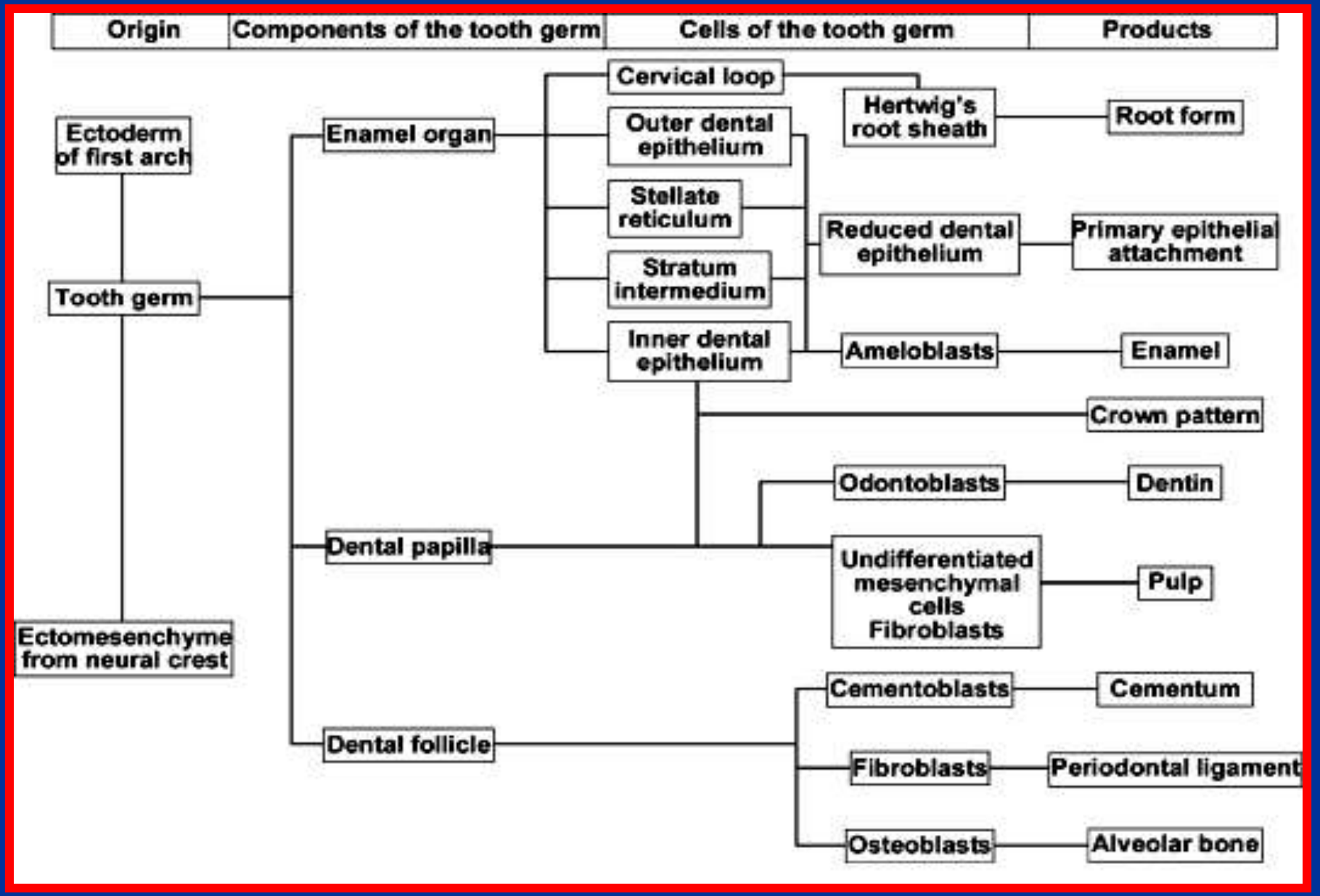
Recombination of dental epithelium and ectomesenchyme



A.Incisor epithelium combined with molar papilla results in a molariform tooth

B.Molar epithelium combined with incisor papilla results in an incisiform tooth

Summary


Origin
Components of the tooth germ
Cells of the tooth germ
Products
Ectoderm of first arch
Tooth germ
Ectomesenchyme from neural crest
Enamel organ
Dental papilla
Dental follicle
Cervical loop
Outer dental epithelium
Stellate reticulum
Stratum intermedium
Inner dental epithelium
Hertwig's root sheath
Root form
Reduced dental epithelium
Primary epithelial attachment
Ameloblasts
Enamel
Crown pattern
Odontoblasts
Dentin
Undifferentiated mesenchymal cells Fibroblasts
Pulp
Cementoblasts
Cementum
Fibroblasts
Periodontal ligament
Osteoblasts
Alveolar bone

Macrodontia

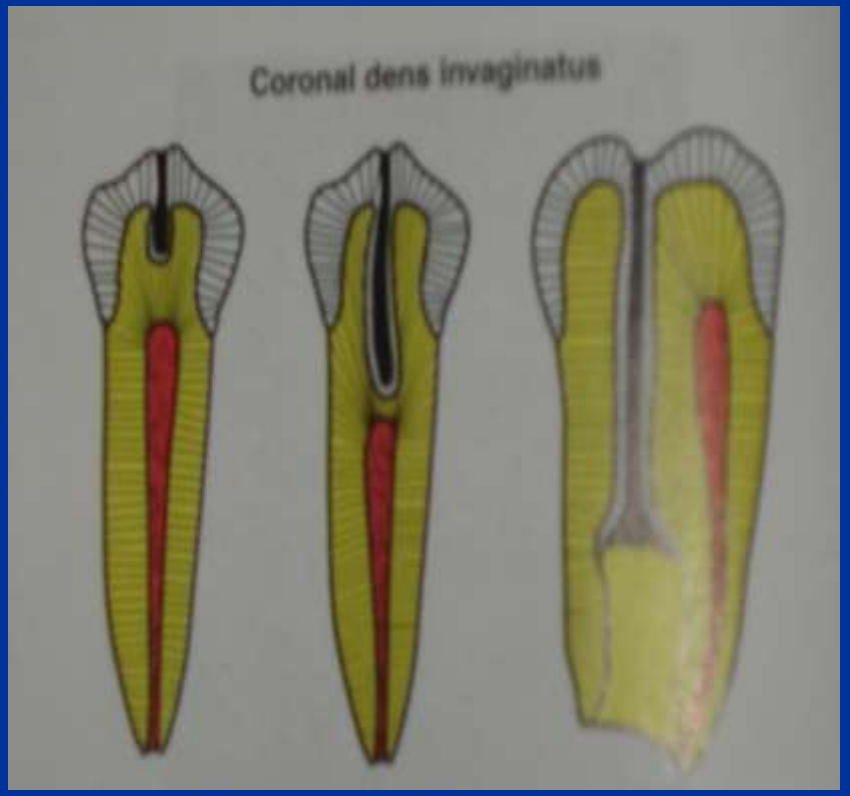
Missing teeth

Anodontia

hypodontia

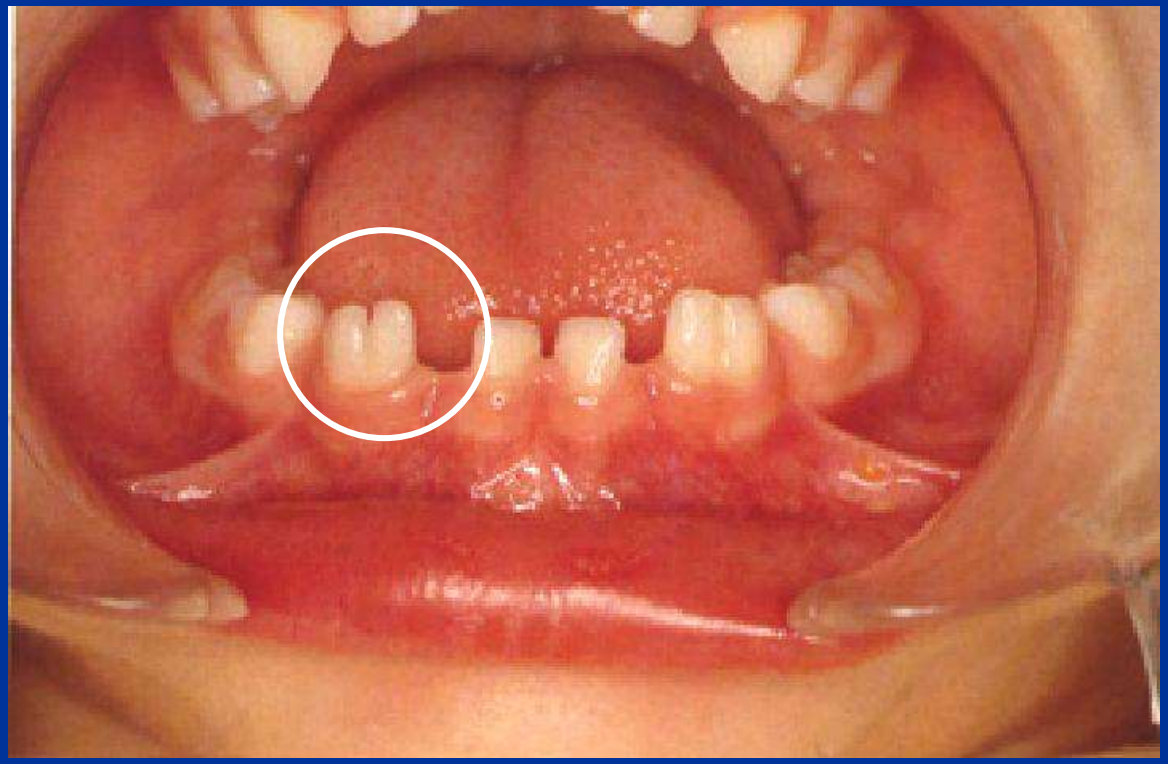
Dilaceration

Dens in dente



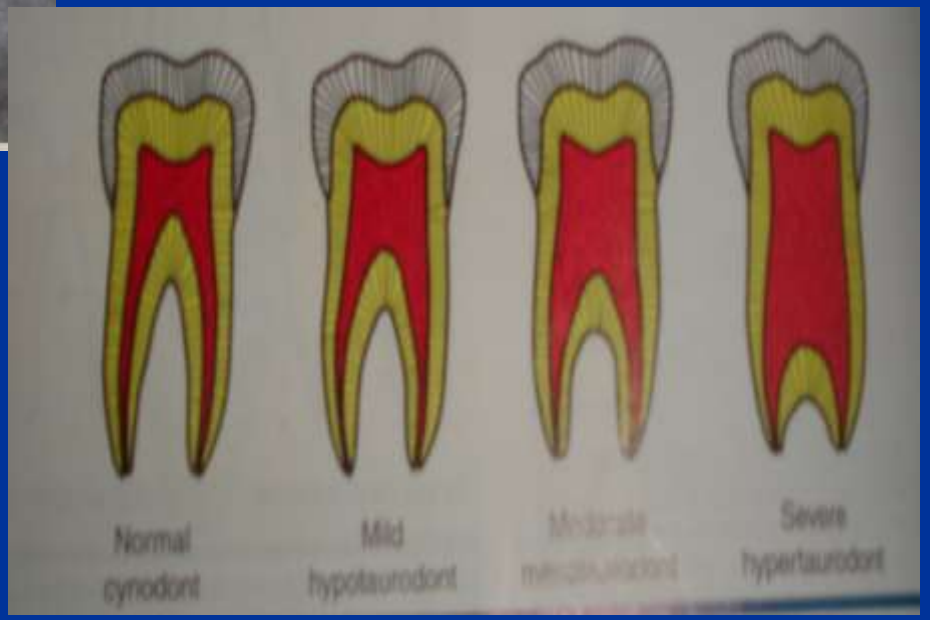
Type I II III

Fusion



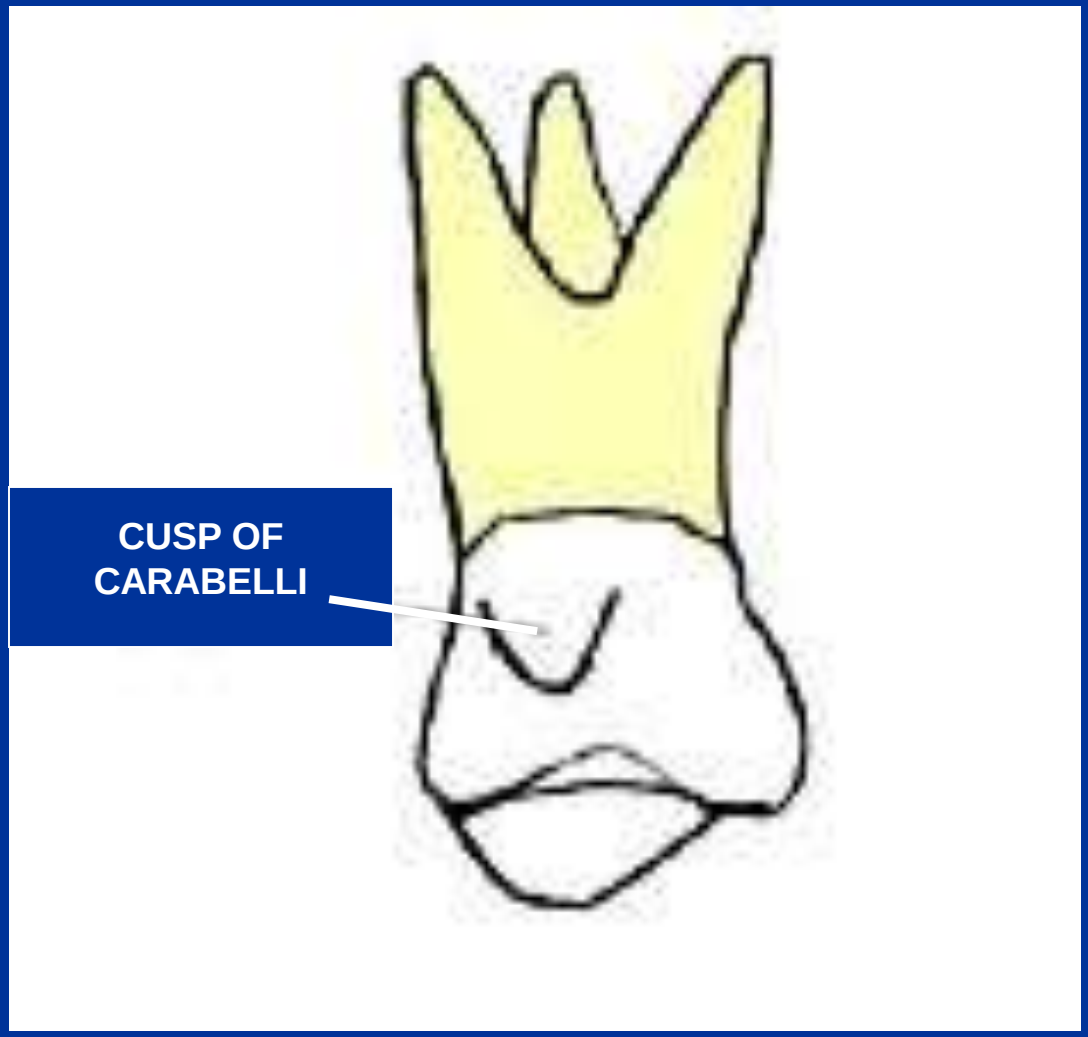
Germination

Taurodontism



Supernumerary roots

Cusp of carabelli



Supernumerary teeth

Enamel pearl

Talons cusp

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CONCLUSION


Thank you!