



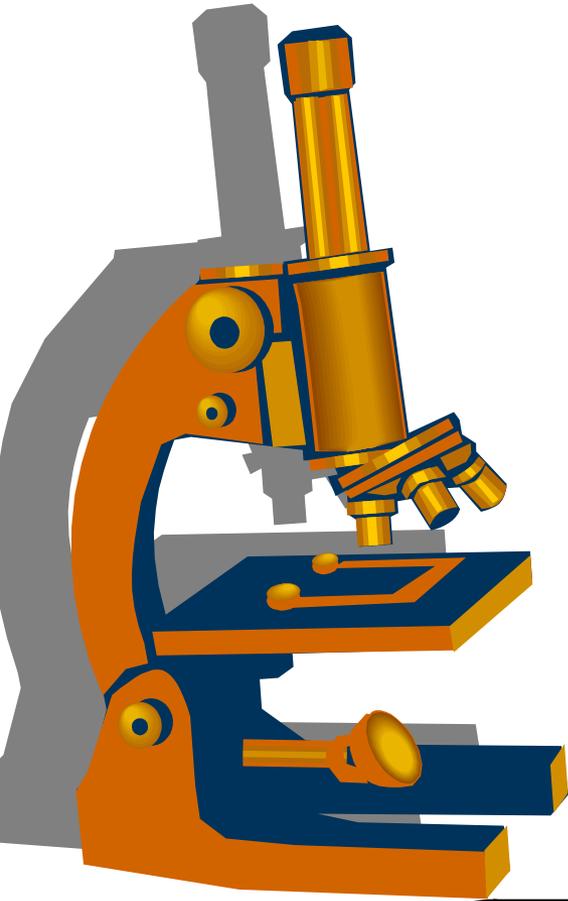
بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

Tooth development



By:
Ass. Prof ; Noura Bakr

Tooth development



- *Introduction*

- *Stages*

- *Morphological stages*

- 1- *Dental lamina stage.*

- 2- *Bud stage.*

- 3- *Cap stage.*

- 4- *Bell stage (early & late bell)*

- *Histological stages*

1. *Initiation*

2. *Proliferation*

3. *Histodifferentiation*

4. *Morphodifferentiation*

5. *Maturation (apposition)*

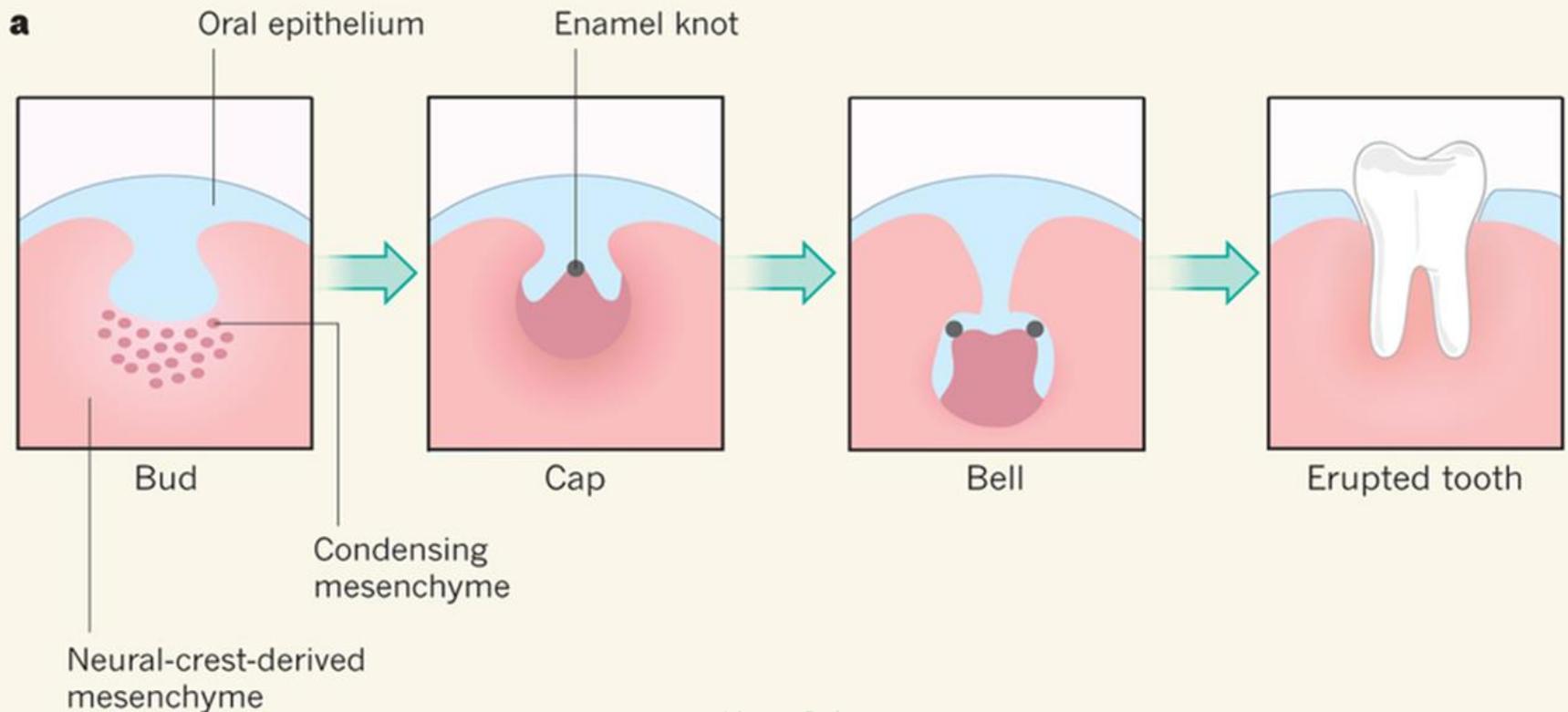
- *Root formation*

- *Clinical consideration*

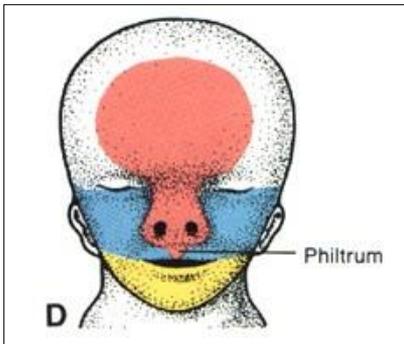
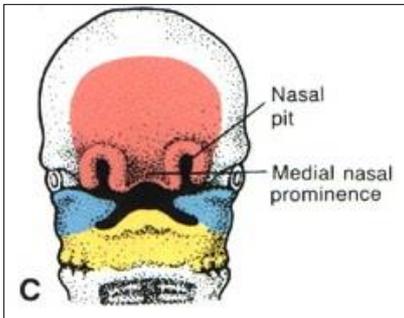
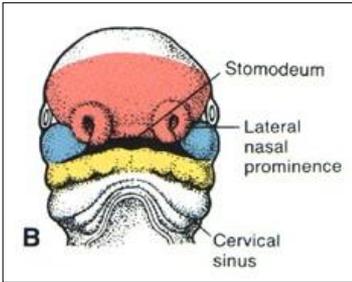
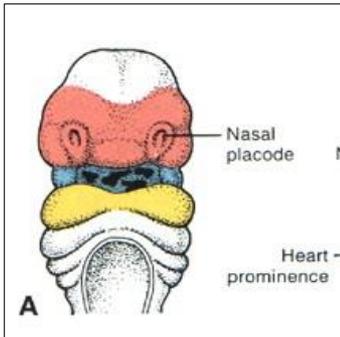
- *Conclusion*

- *Referances*

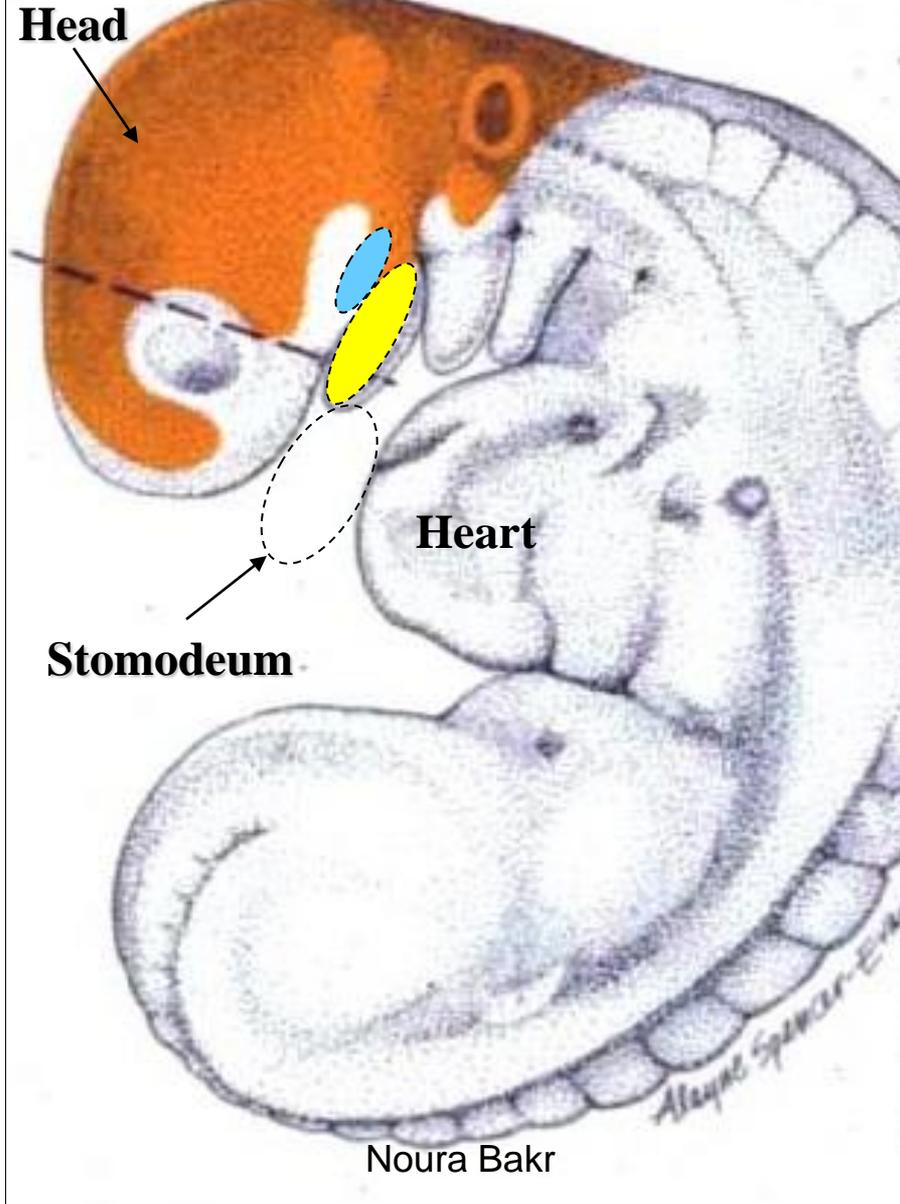
- Tooth formation (ODONTOGENESIS) a series of reciprocal interactions between the oral epithelium and the underlying ecto-mesenchyme (cranial neural-crest-derived mesenchyme)



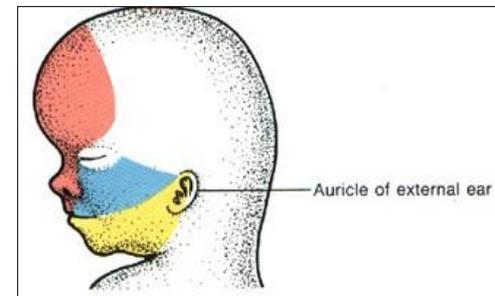
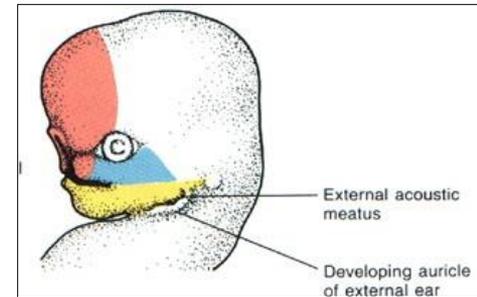
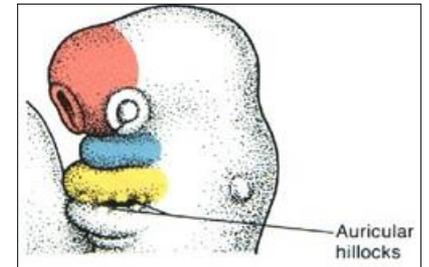
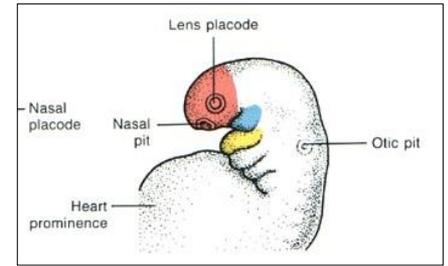
Front view

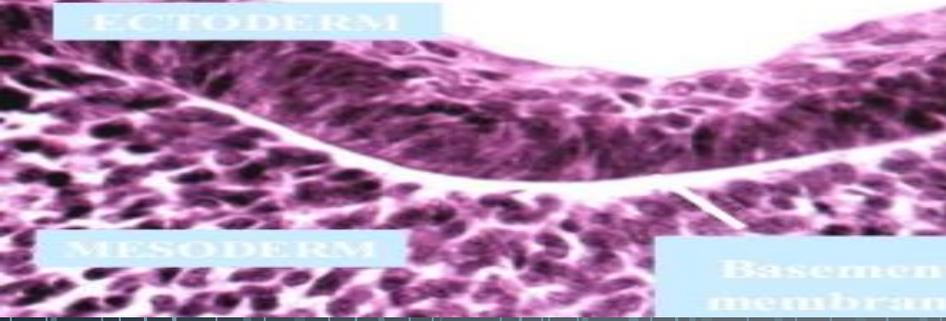


At 5-6 w.i.u. Embryo



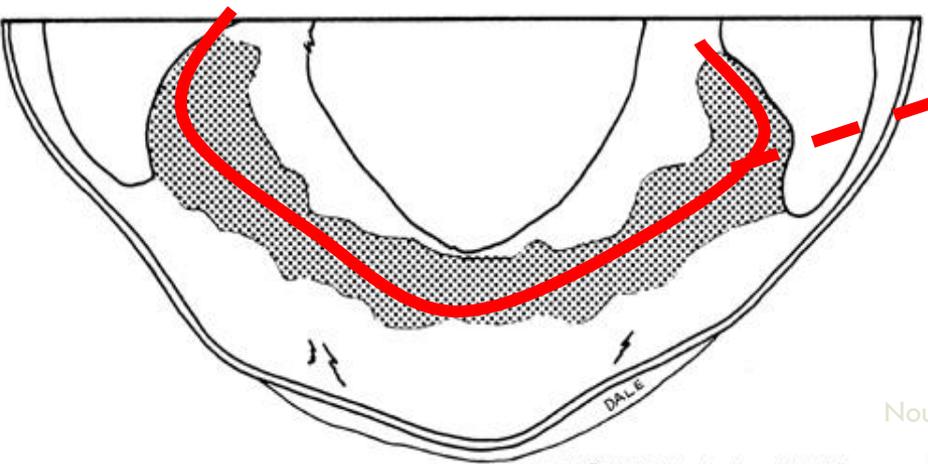
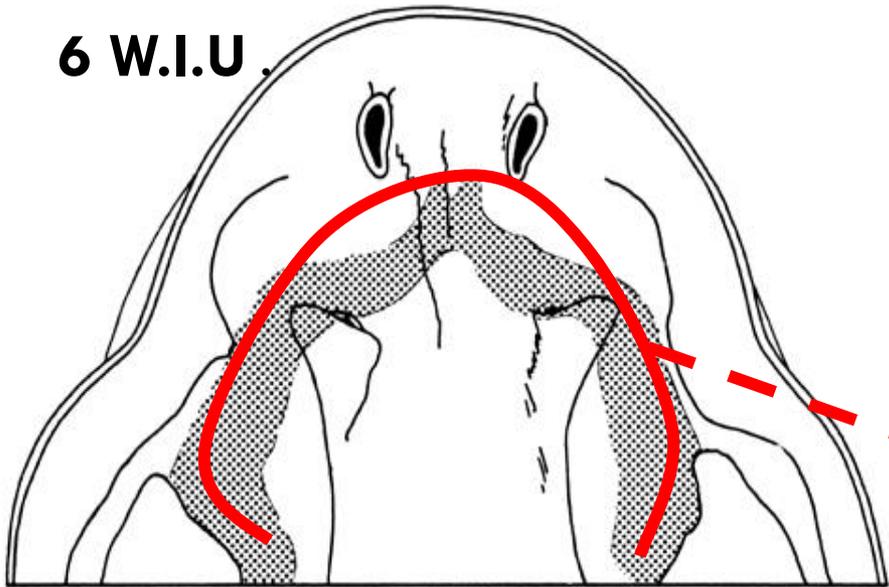
Lateral view





At the age of 5-6 W.I.U.L. the primitive oral cavity is lined by ectoderm composed of 2 -3 layers separated from underlying ecto-myschyme by a basment membrane

6 W.I.U.

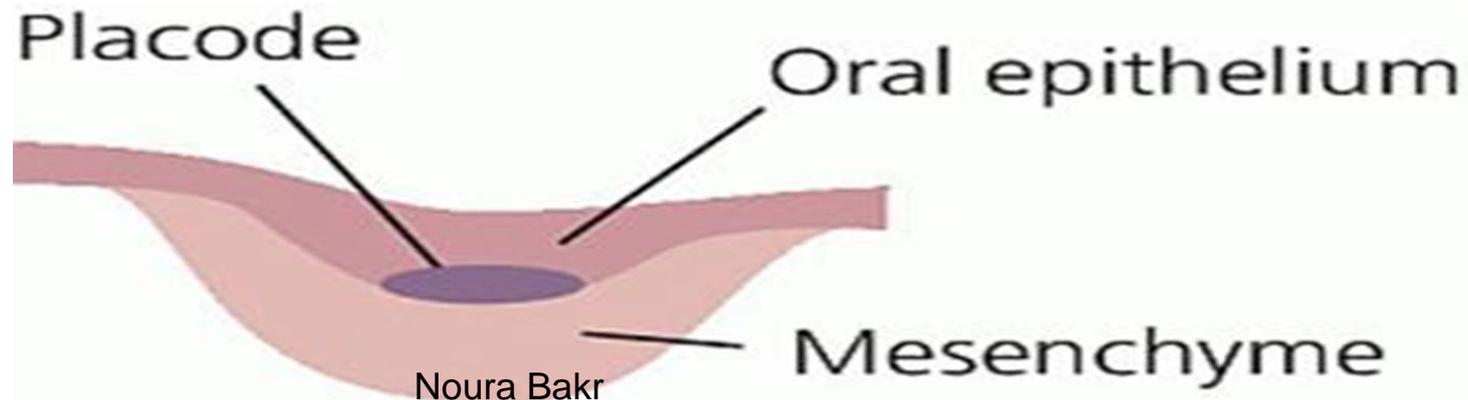


Primary epithelial bands

the appearance of the primary epithelial band, which is a U-shaped band of thickened epithelium formed along the maxillary and mandibular dental arch. (epithelial thickening)

(Dental placode)

- Initiation of tooth development is formation of ectodermal thickening in oral epithelium called (Dental placode), which resemble that all ectodermal placodes (which forming the appendages, nails, hair and all glands) in morphology.

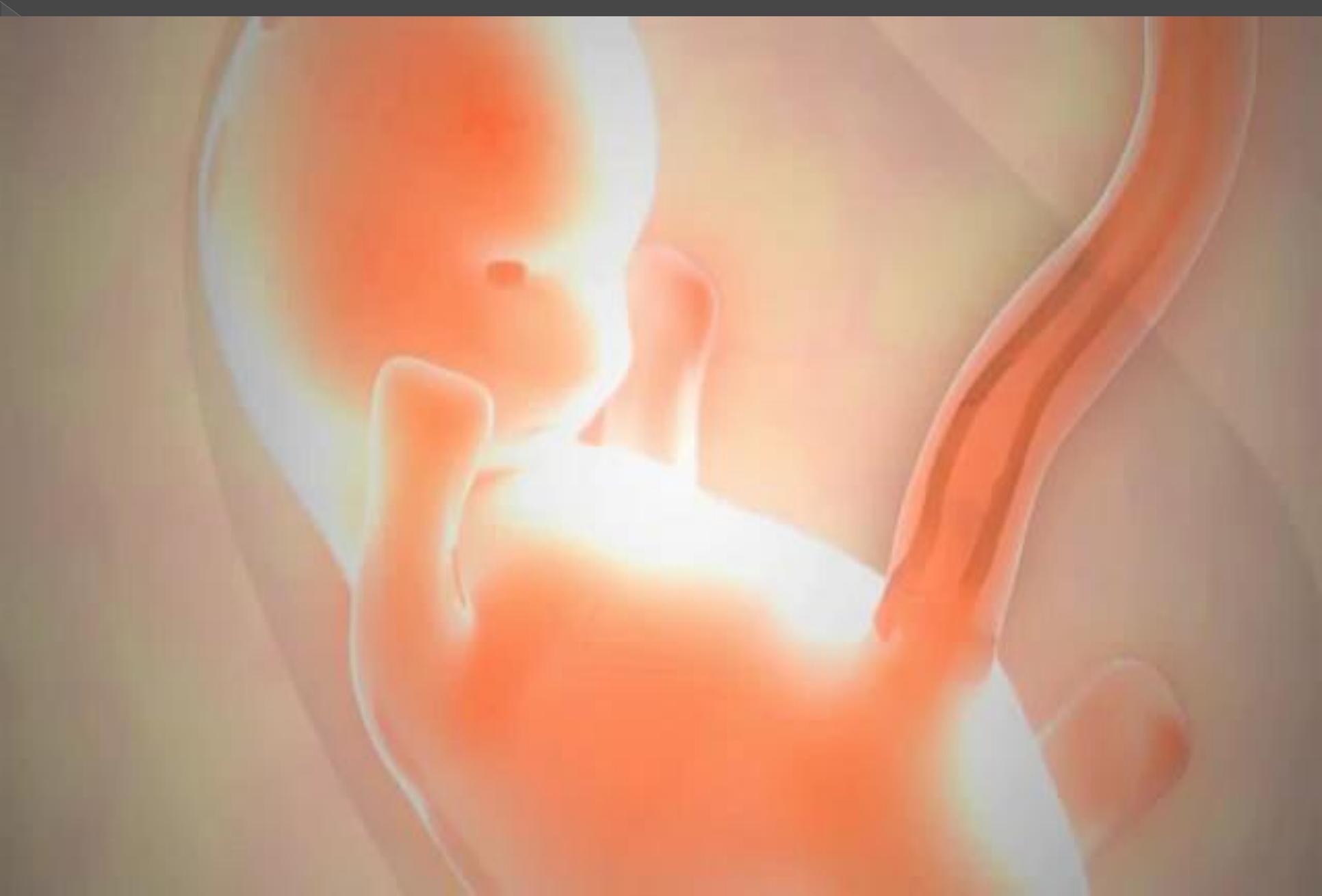


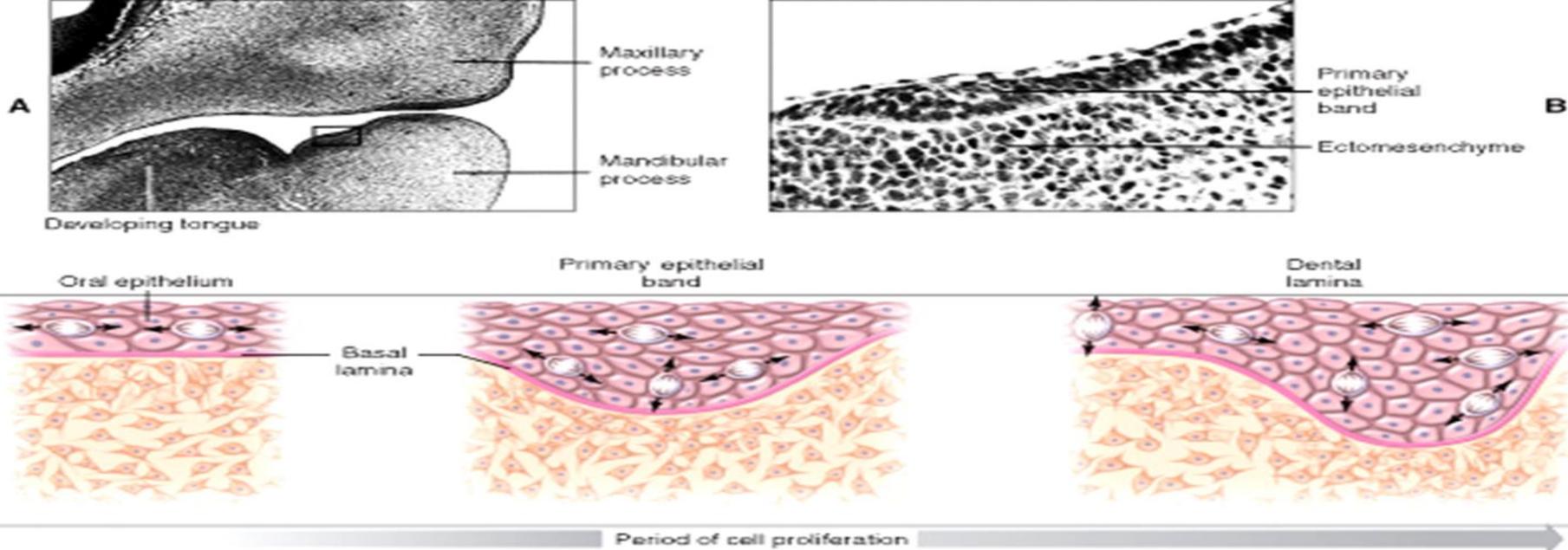
- ◉ Smaller placode than normal missed tooth or small tooth. →



- ◉ Larger placode than normal supernumerary tooth or larger tooth. →



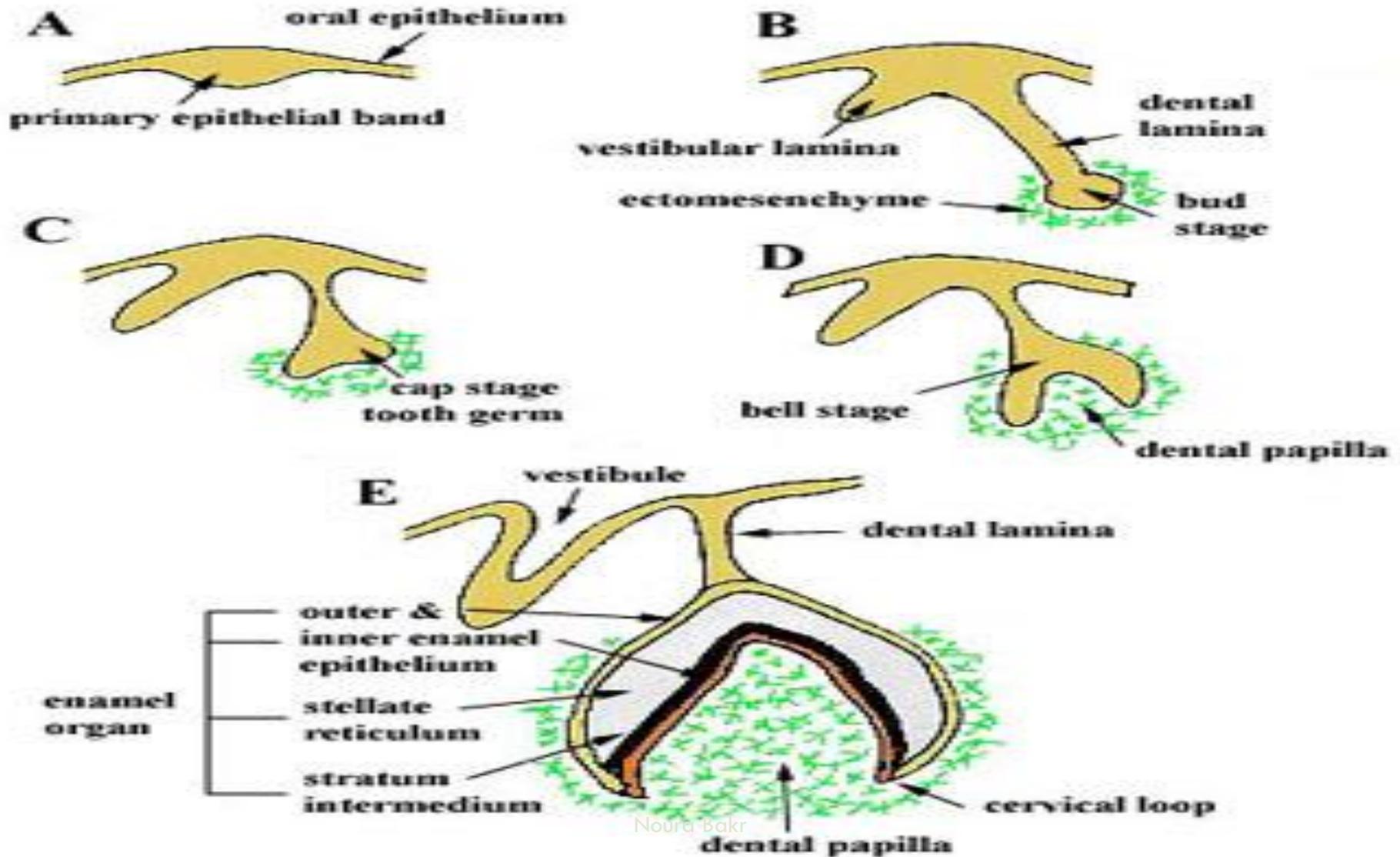




Thickening of epithelial band occurs due to change in orientation of mitotic spindle & cleavage plane of dividing cells.
 (not due to increased proliferation)

PRIMARY EPITHELIAL BAND.
 Quickly give rise to 2 subdivisions :
 vestibular lamina
 dental lamina

The primary epithelial bands divides into two laminae, a buccally located vestibular lamina and a lingually situated dental lamina

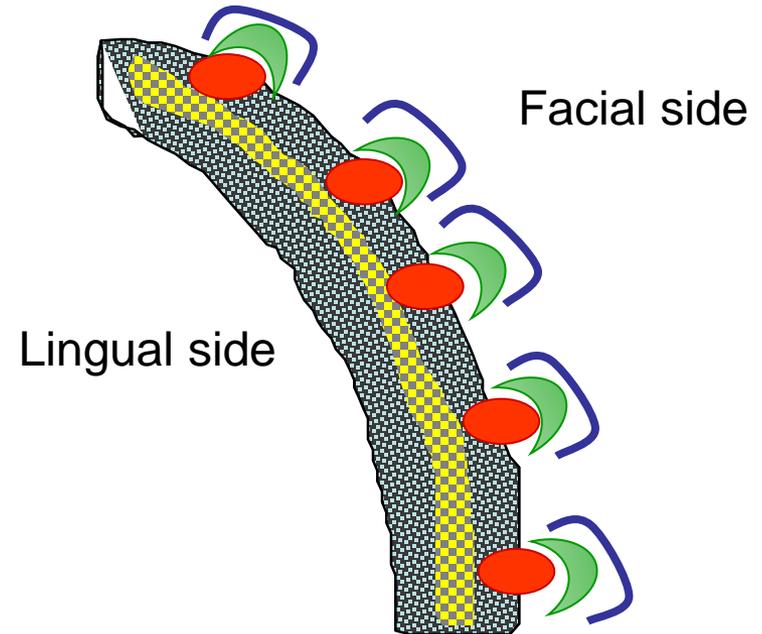


From the facial side ;10 ectodermal swellings for deciduous teeth in each jaw appear having the bud shape which is called the **dental (enamel) organ**.

The supporting ectomesenchymal cells beneath the epithelial bud are called **dental papilla**

Dental sac (dental follicle) encircles the enamel organ and dental papilla.

Dental organ + Dental papilla + Dental sac = Tooth germ.



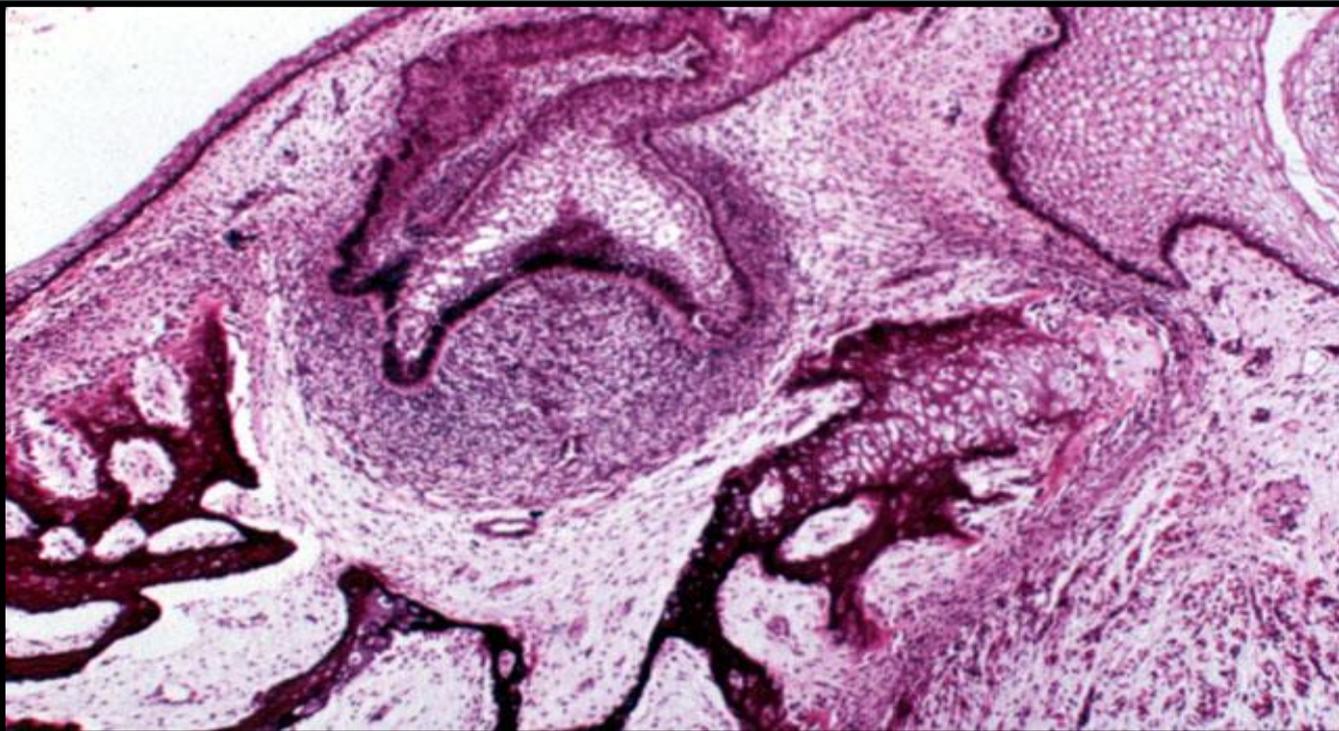
Tooth and its supporting structures formed from tooth germ

Tooth germ = Enamel organ + Dental papilla + Dental sac

Enamel organ gives rise to..... **enamel,**

Dental papilla gives rise to..... **dentin and pulp**

Dental sac gives rise to..... **cementum, periodontal ligament and alveolar bone.**



Note

There are different types of laminae:

• **Vestibular lamina** → Oral vestibule

• **Main dental lamina** → Primary dentition

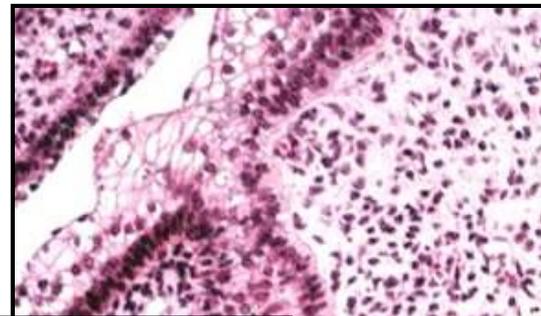
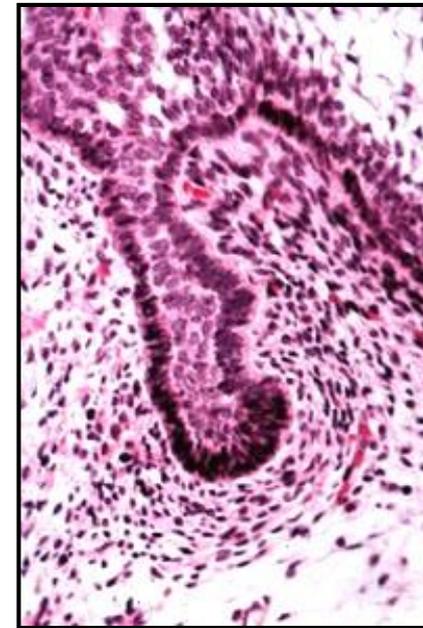
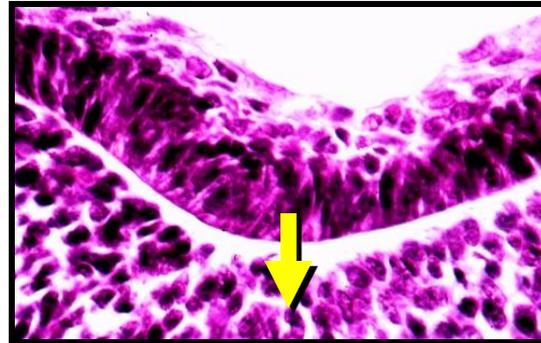
• For permanent molars, posterior extension of the main dental lamina distal to primary second molars.

• **Successional dental lamina** → Permanent successors

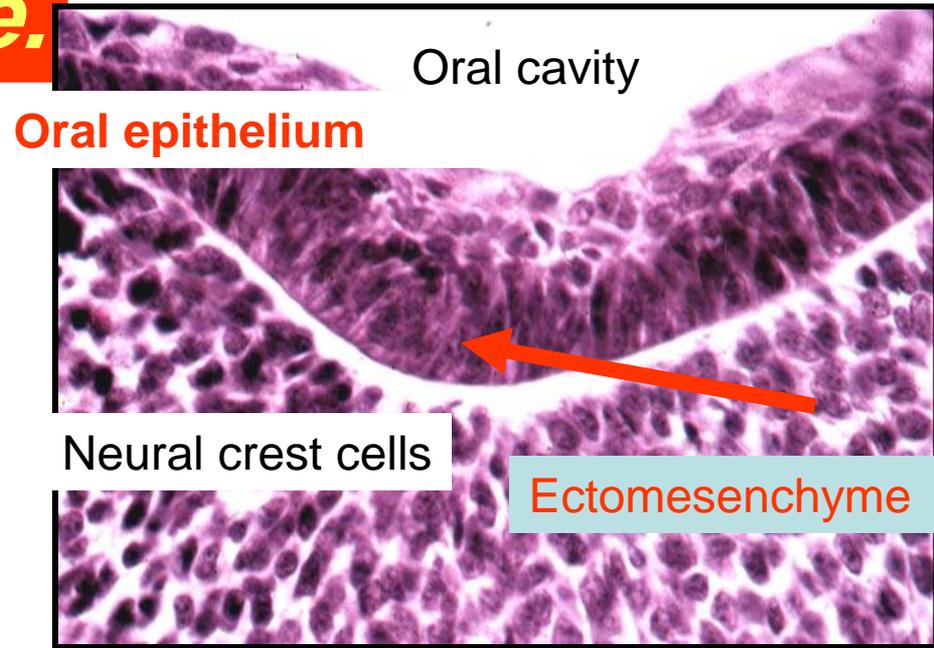
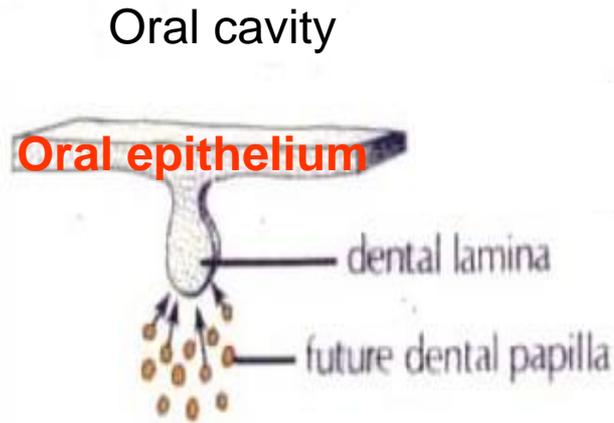
• **Lateral dental lamina** → Connect the dental organ with the main D. L.

Stages of tooth development

- 1- Initiation Stage.
- 2- Bud Stage.
- 3- Cap Stage.
- 4- Early Bell Stage.
- 5- Late Bell Stage.



1- Initiation stage.



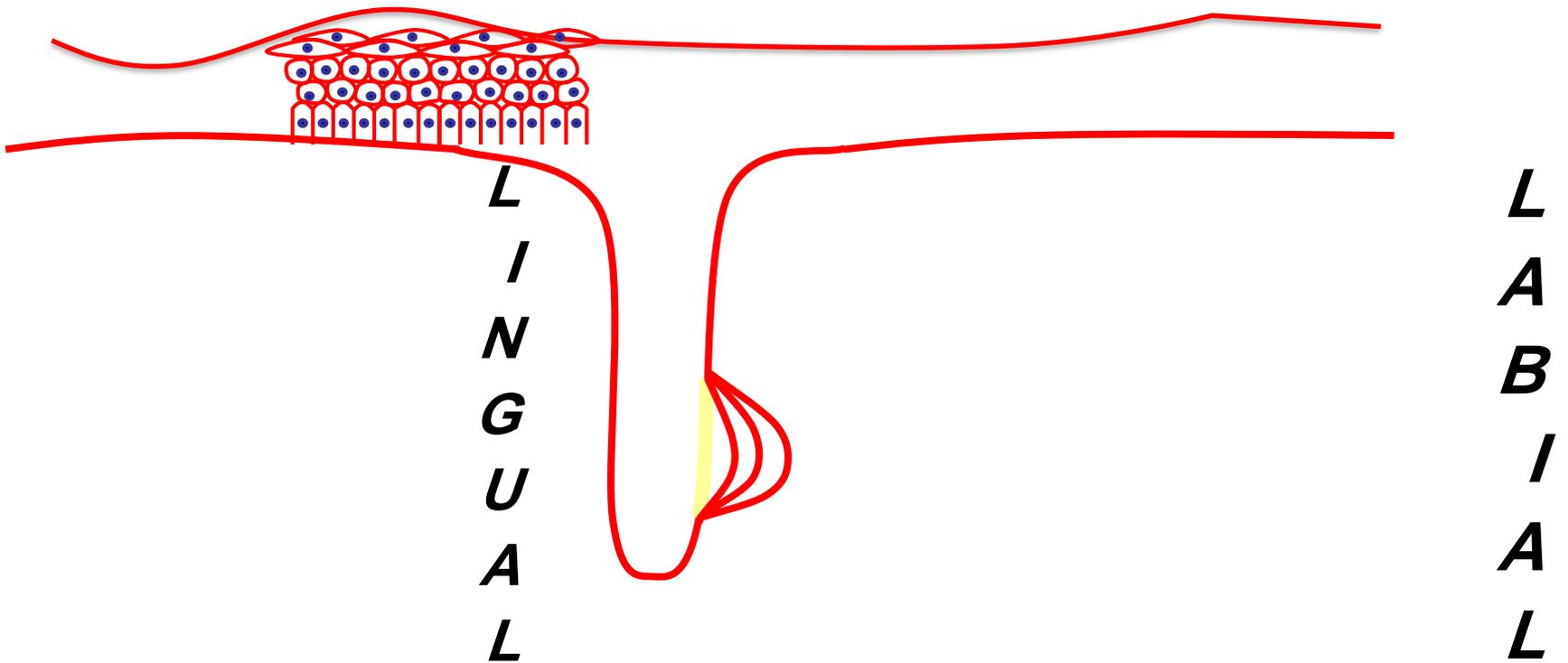
Neural crest cells

Induction

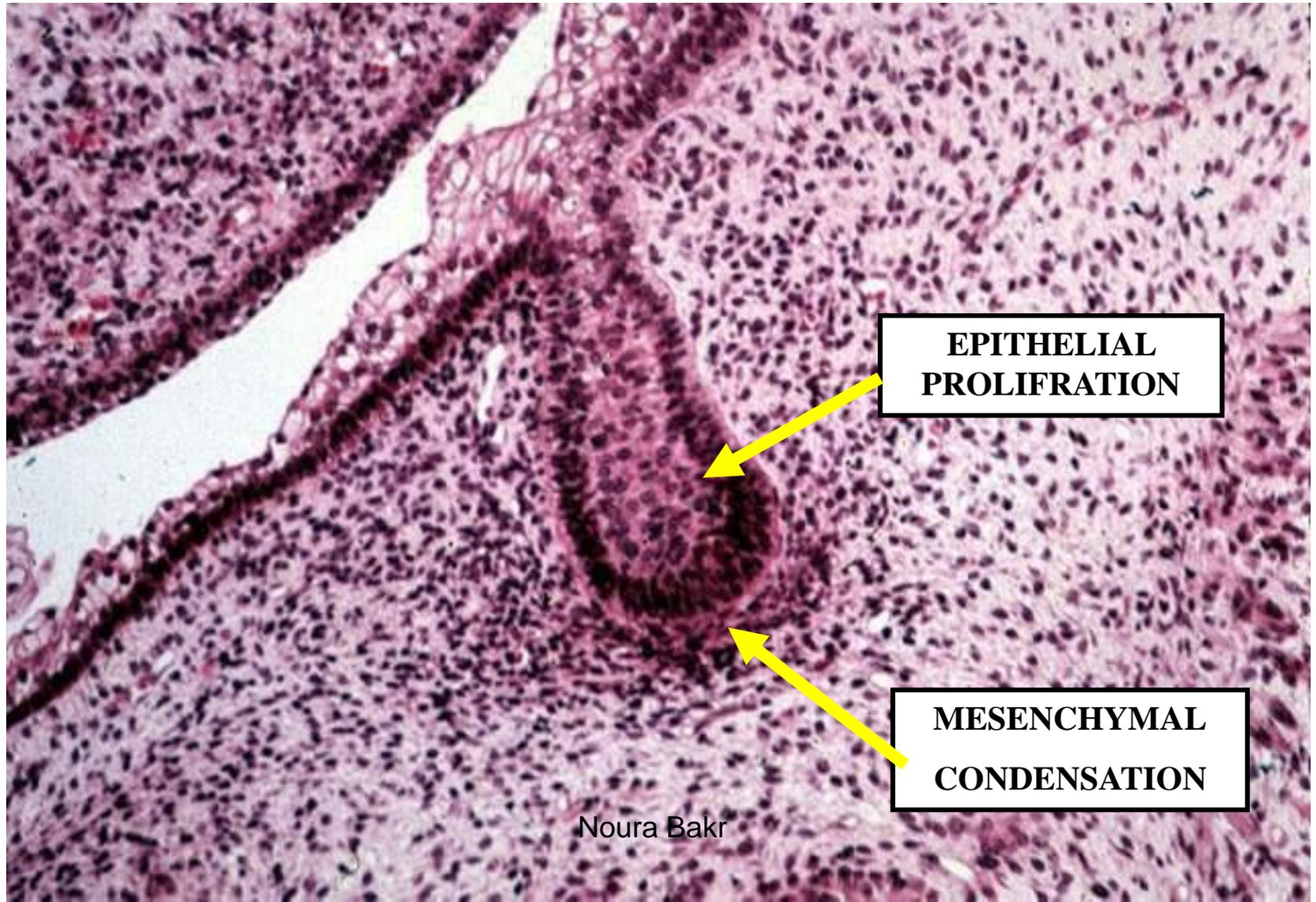
Proliferation of basal cell layer of oral epithelium

Dental lamina

Bud stage



2-Bud Stage

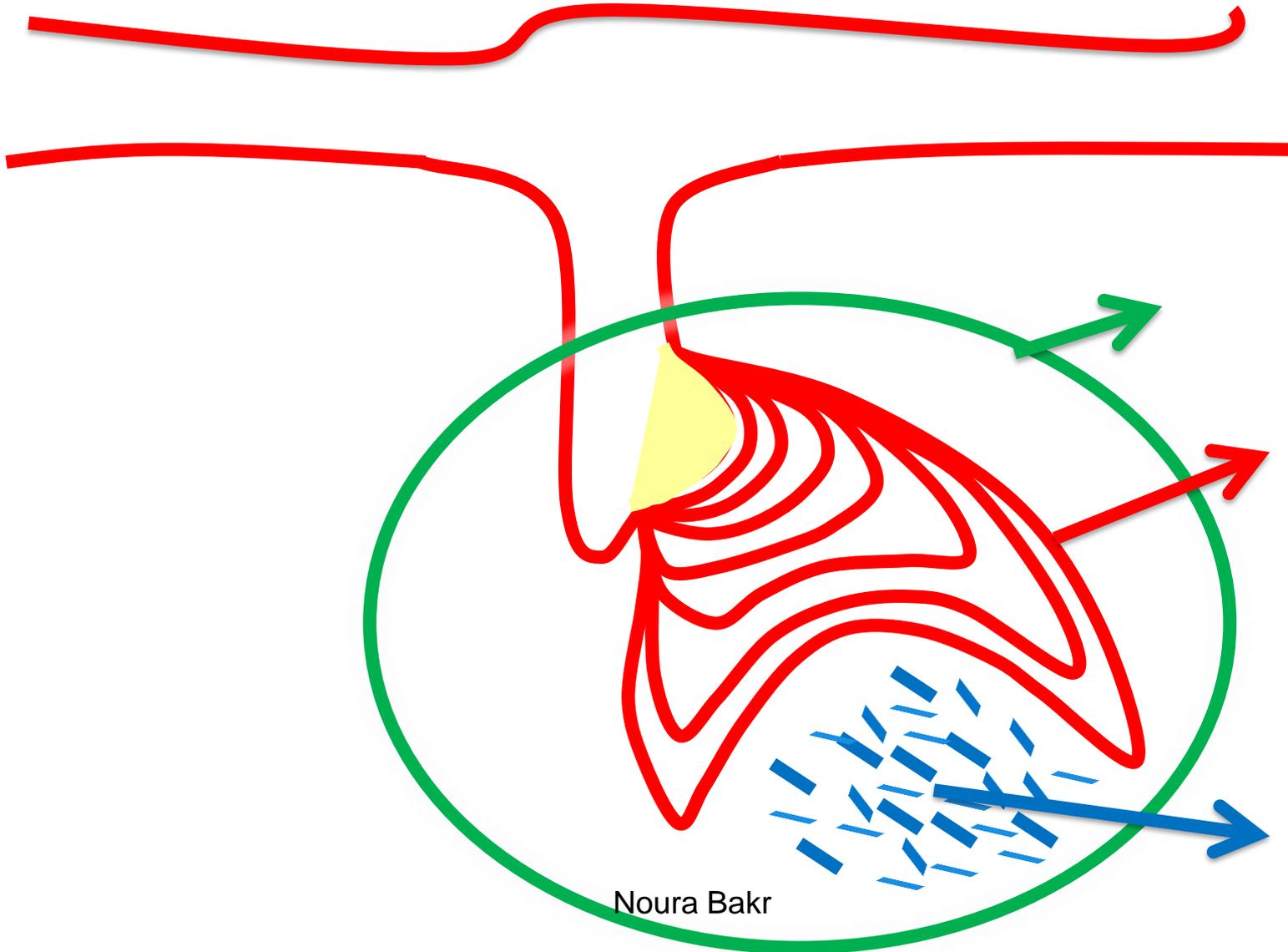


**EPITHELIAL
PROLIFERATION**

**MESENCHYMAL
CONDENSATION**

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Cap stage
“differential growth”



Cap stage

-During this stage the tooth bud does not grow into a large sphere surrounded by the ectomesenchyme. Instead, there is unequal growth in different parts of tooth bud, leading to the formation of a cap shape attached to the dental lamina by broad connection.

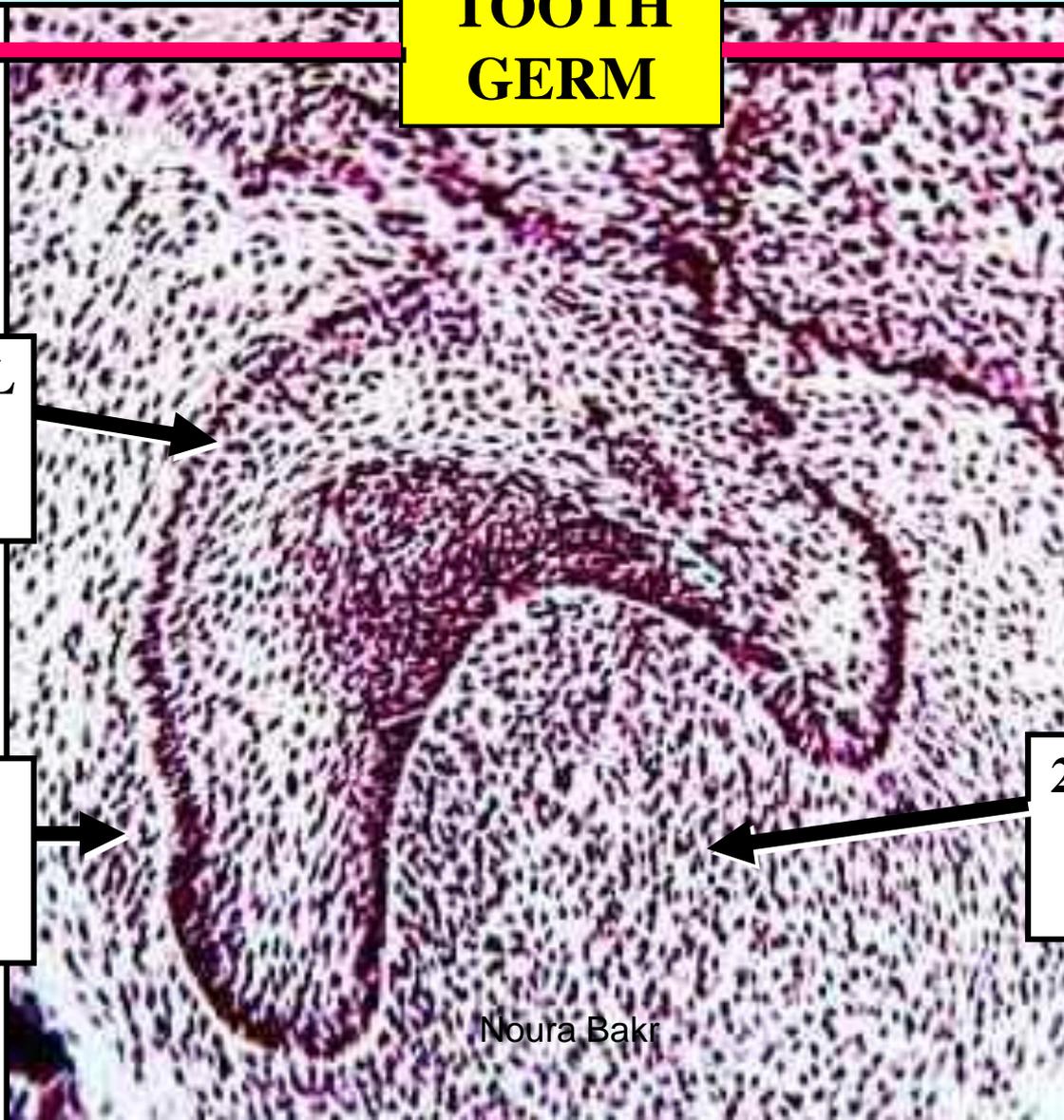
CAP STAGE

**TOOTH
GERM**

**1-DENTAL
ORGAN**

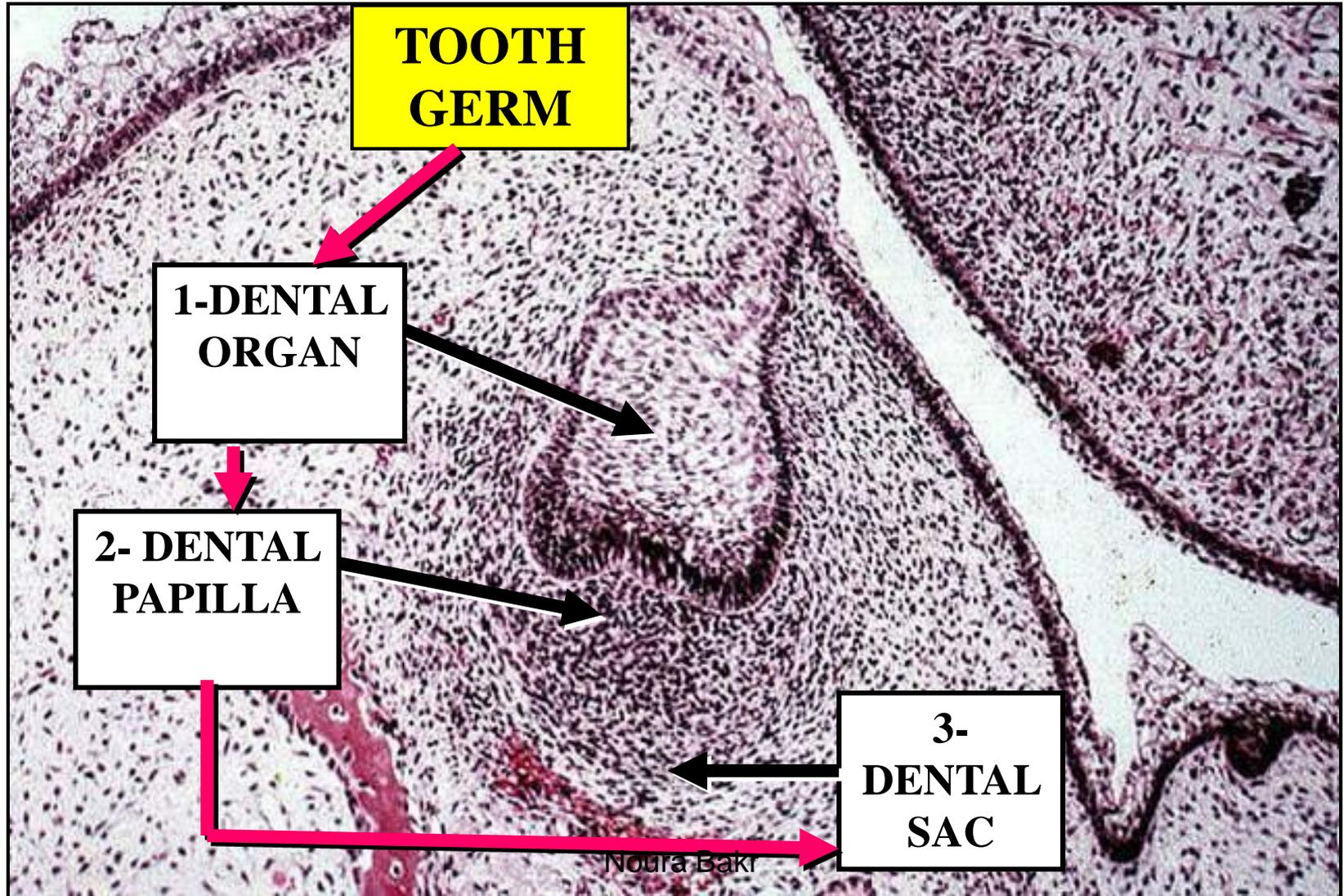
**3-
DENTAL
SAC**

**2- DENTAL
PAPILLA**



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3-CAP STAGE



****In cap stage, the enamel organ shows three different types of cells termed as outer enamel epithelium, inner enamel epithelium and stellate reticulum.**

- **1-The outer enamel epithelium**

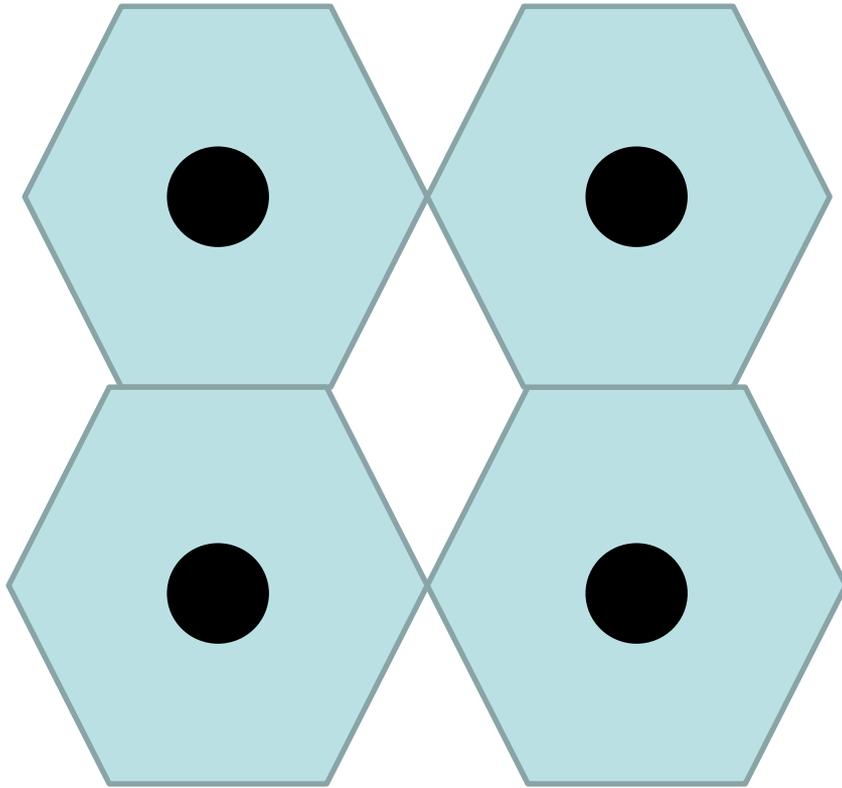
The peripheral cells of enamel organ are cuboidal, lined the convexity of the cap and are called outer enamel epithelium.

- **2- The inner enamel epithelium:**

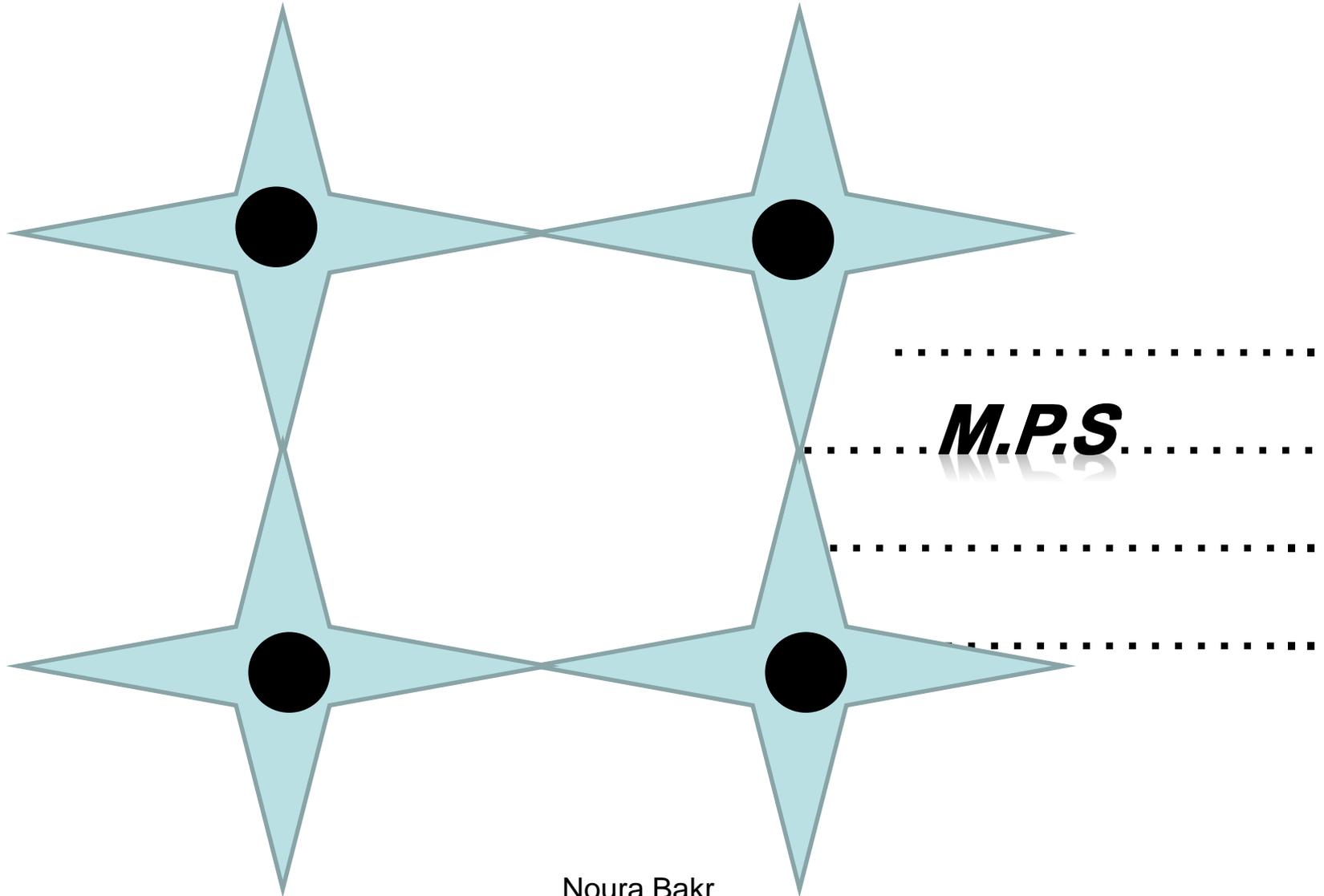
The cells on the concavity of the cap are short columnar and represent the inner enamel epithelium

3-The stellate reticulum

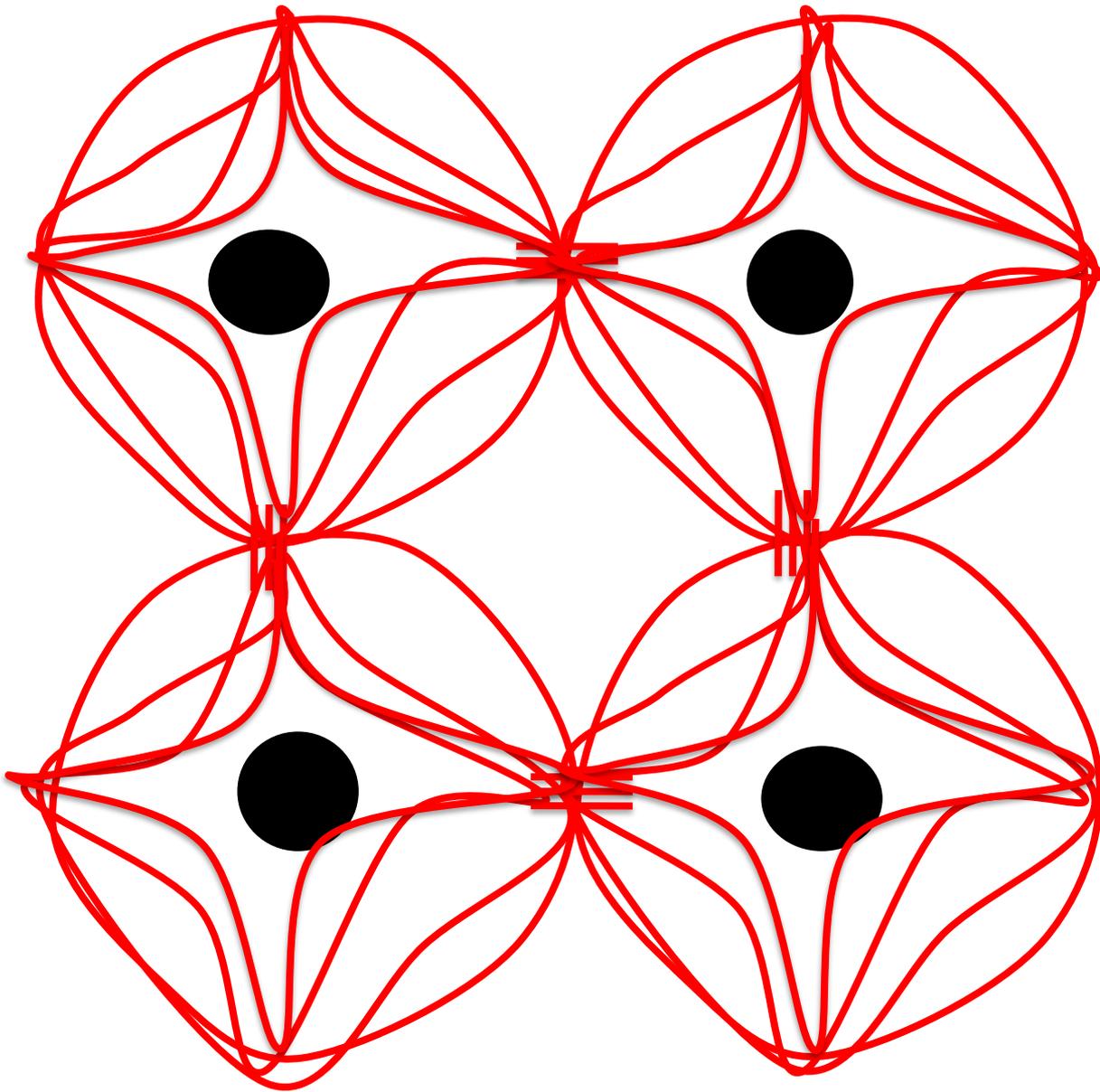
Polygonal cells....change to..



Stellate reticulum cells



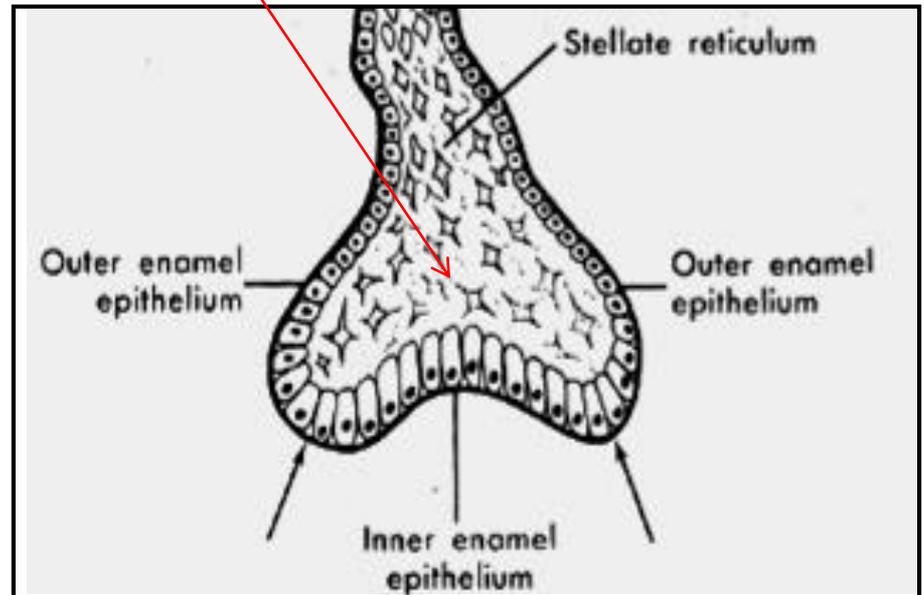
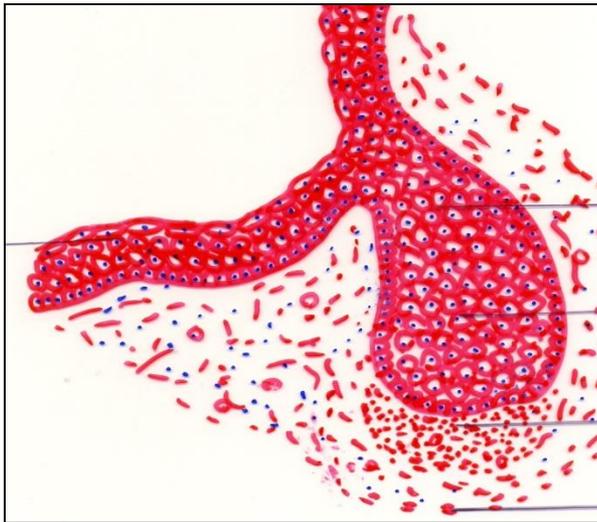
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- The polygonal central cells of enamel organ are termed the stellate reticulum.
- These cells synthesize and secrete glycosaminoglycans(GAG) and GP into the extracellular compartment between them. The glycoaminoglycans are hydrophilic and so pull water into the enamel organ.
- The increasing amount of fluid increases the volume of the extracellular compartment of the enamel organ and the central cells are forced apart.

Because the stellate reticulum cells retain connections with each other through their desmosomal contacts, these polygonal cells stellate reticulum become **star shaped**



Transitory structures:

Earlier during tooth development two transitory structures may be seen named as the enamel knot and enamel cord.

Enamel knot

-Enamel knot are clusters of non dividing epithelial cells appears in **cap stage** and bulge into the dental papilla, at the centre of the enamel organ.

-The enamel knot disappears in the **bell stage** by apoptosis.

-The enamel knot represents **an organization center which control cuspal morphogenesis.**

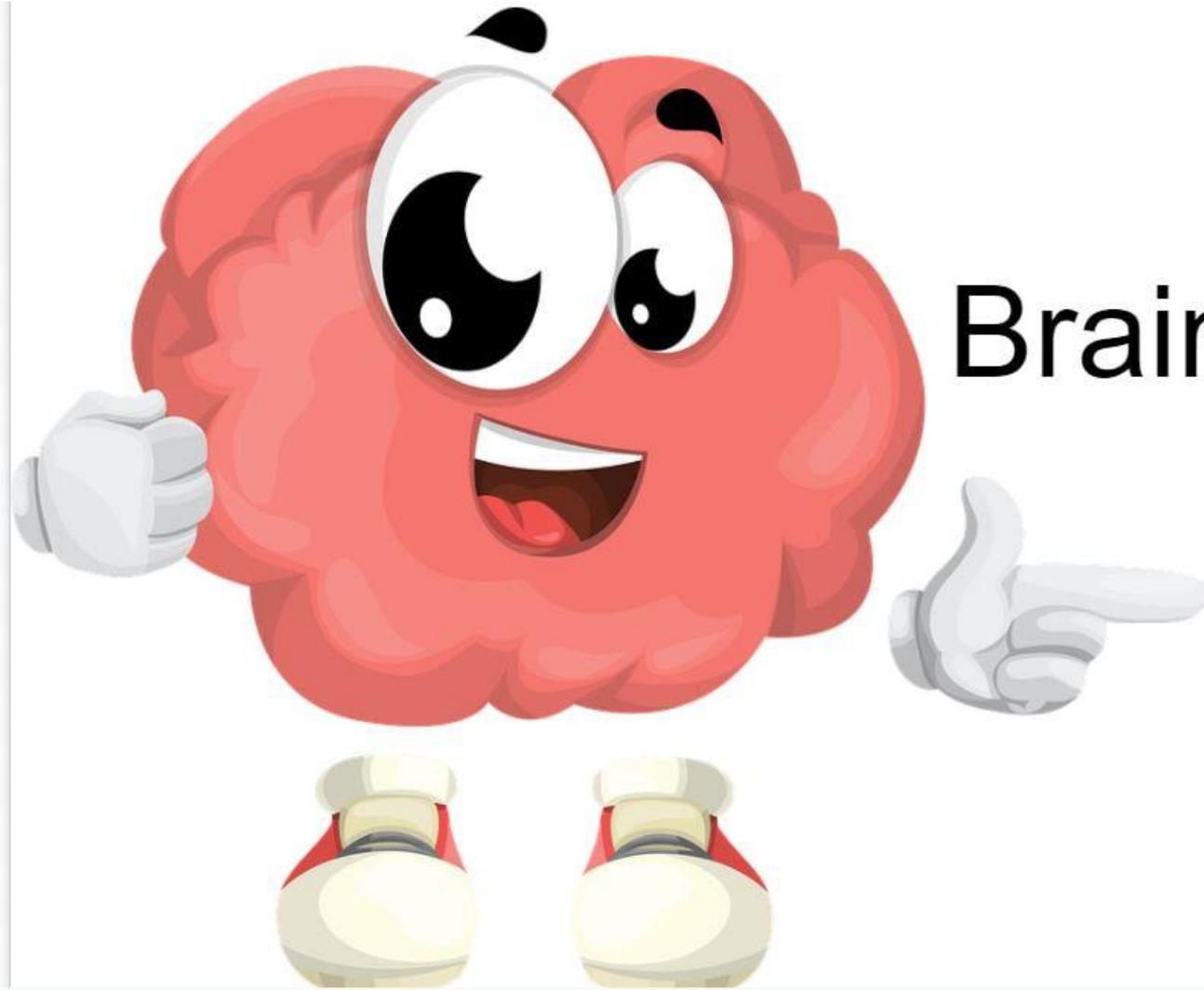
enamel cord may be :-

1- Involved in the process by which the cap stage is transformed into the bell stage (**act as a mechanical tie**)

Or 2- that it is a **focus for the origin of stellate reticulum cells.**

Enamel cord

- The enamel cord is a strand of cells seen at the early bell stage extending from the stratum intermedium to the outer enamel epithelium.
- When it completely divides the stellate reticulum into two parts, it is termed the enamel septum.
- It has been suggested that the enamel cord may be :-
 - 1- Involved in the process by which the cap stage is transformed into the bell stage (act as a mechanical tie)
 - Or 2- that it is a focus for the origin of stellate reticulum cells.



Brain Breaks

1- Enamel organ gives rise to, dental papilla gives rise to & and dental sac gives rise to,&

2- The bud, cap and bell stage of the developing tooth are based on growth of the:

A. Stellate reticulum

B. Dental papilla

C. Enamel organ

D. Dental sac

3- The formation of the dental lamina is initiated by:

A. Forebrain

B. Rathke's Pouch

C. Neural Crest Cells

D. Odontoblast

4- The primary epithelial band divide buccally to:

a) Vestibular lamina.

b) Dental lamina proper.

c) Lateral dental lamina.

d) Dental papilla

4. dental lamina for the permanent successors appears as an extension of dental lamina into the ectomesenchyme..... to the developing primary tooth germ.

a) Lingual

b) Labial.

c) Mesial.

d) Distal

- 1- In cap stage the central cells of enamel organ is termed stellate reticulum ()
- 2- The primary epithelial bands divides into two laminae (vestibular & dental laminae) ()
- 3-The dental sac arised from ectomesenchymal tissue ()
- 4- The main dental lamina gives the permenant molars only ()
- 5- The successional dental lamina gives the permenant succedaneous teeth ()
- 6) The enamel organ arised from ectodermal tissue ()
- 7) The lateral dental lamina formed during the cap stage ()

- **What are the functions of stellate reticulum & stratum intermedium?**

The cap shape of the enamel organ change into a bell shape due to continued unequal growth.

During this stage, the connection of the enamel organ to the dental lamina is elongated forming a lateral dental lamina which is located labially to the dental lamina proper.

Early bell stage

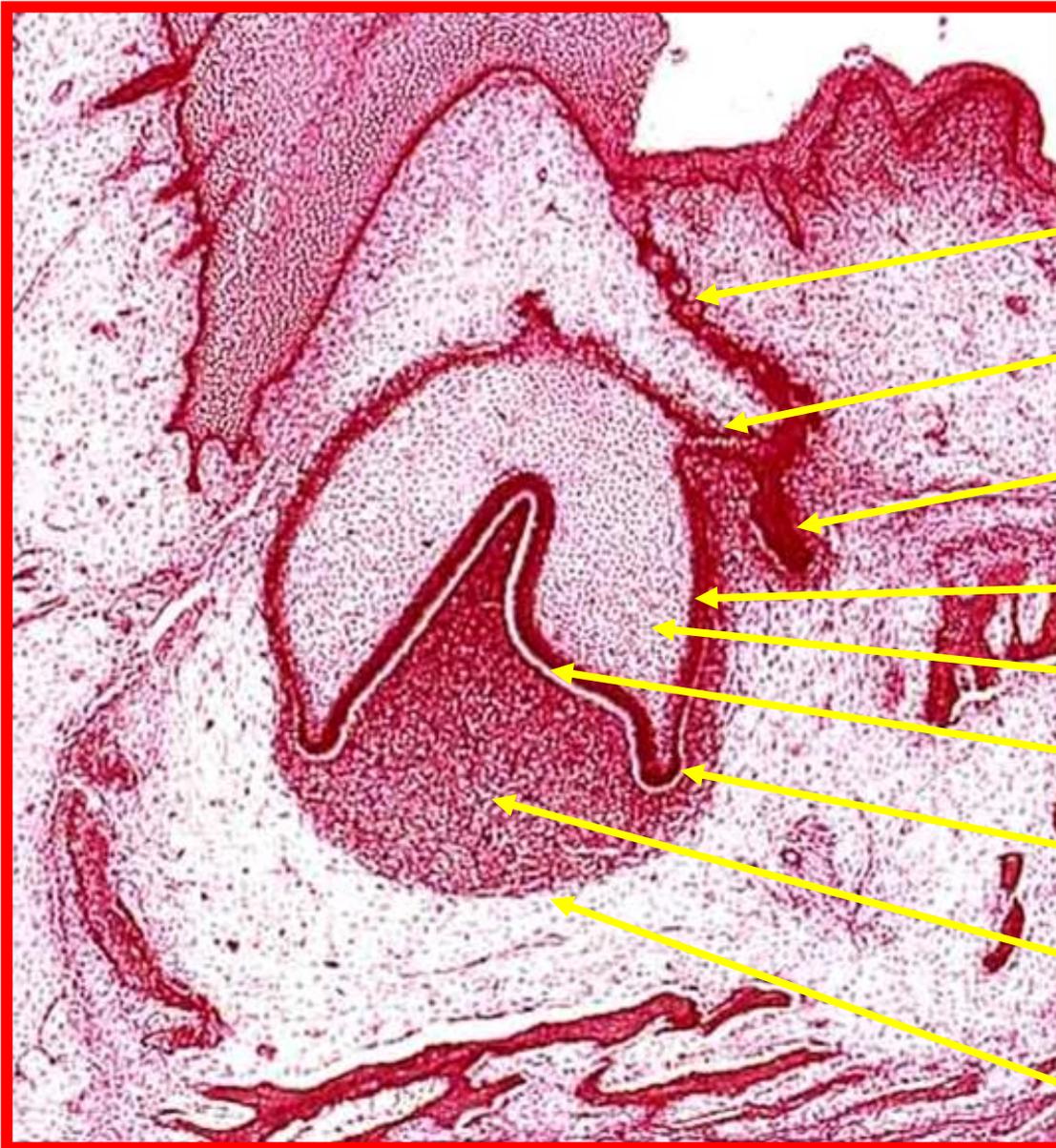


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Early Bell Stage



main dental lamina

lateral dental lamina

successional dental lamina

outer dental epithelium

stellate reticulum

inner dental epithelium

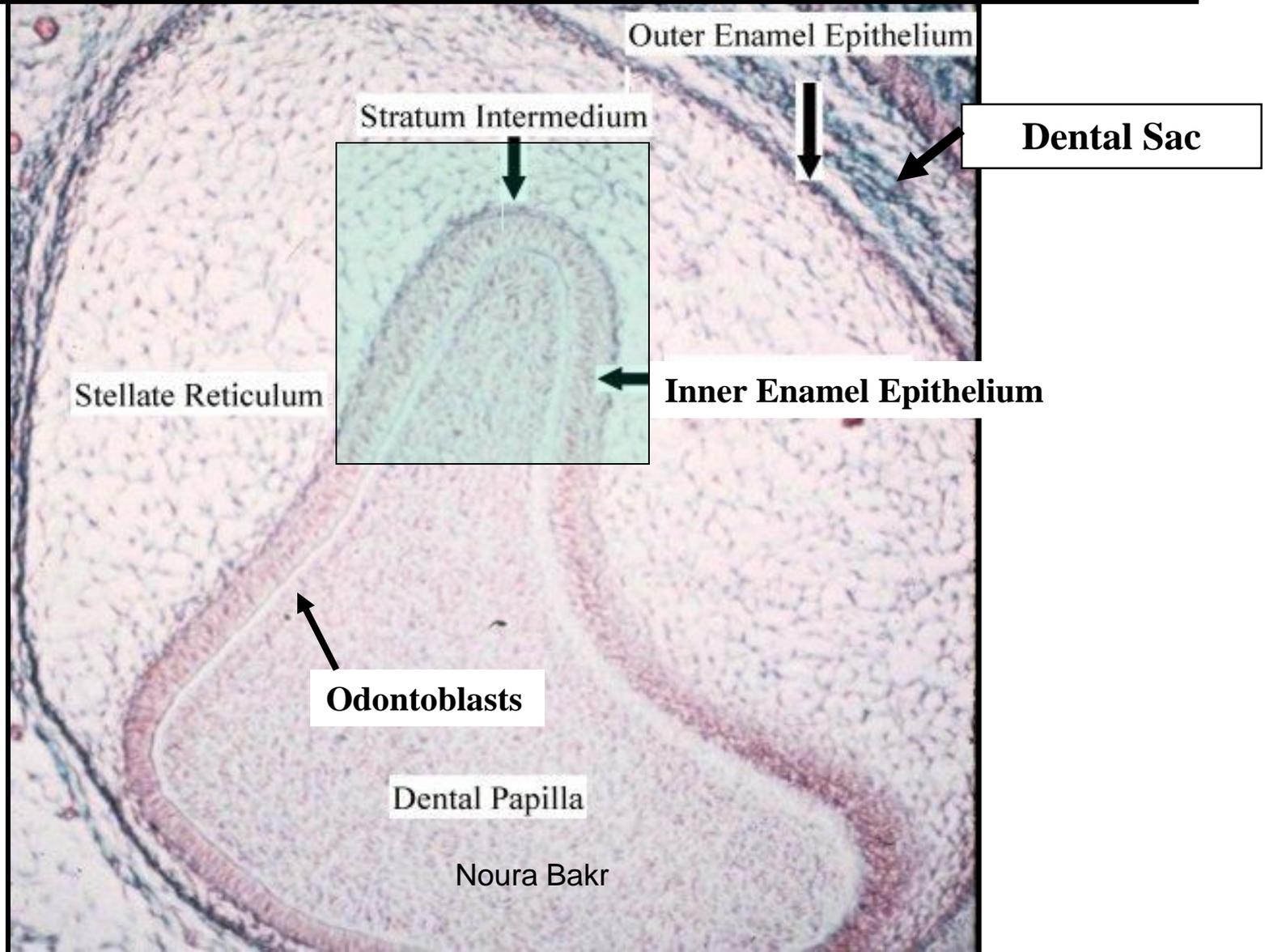
cervical loop

Dental papilla

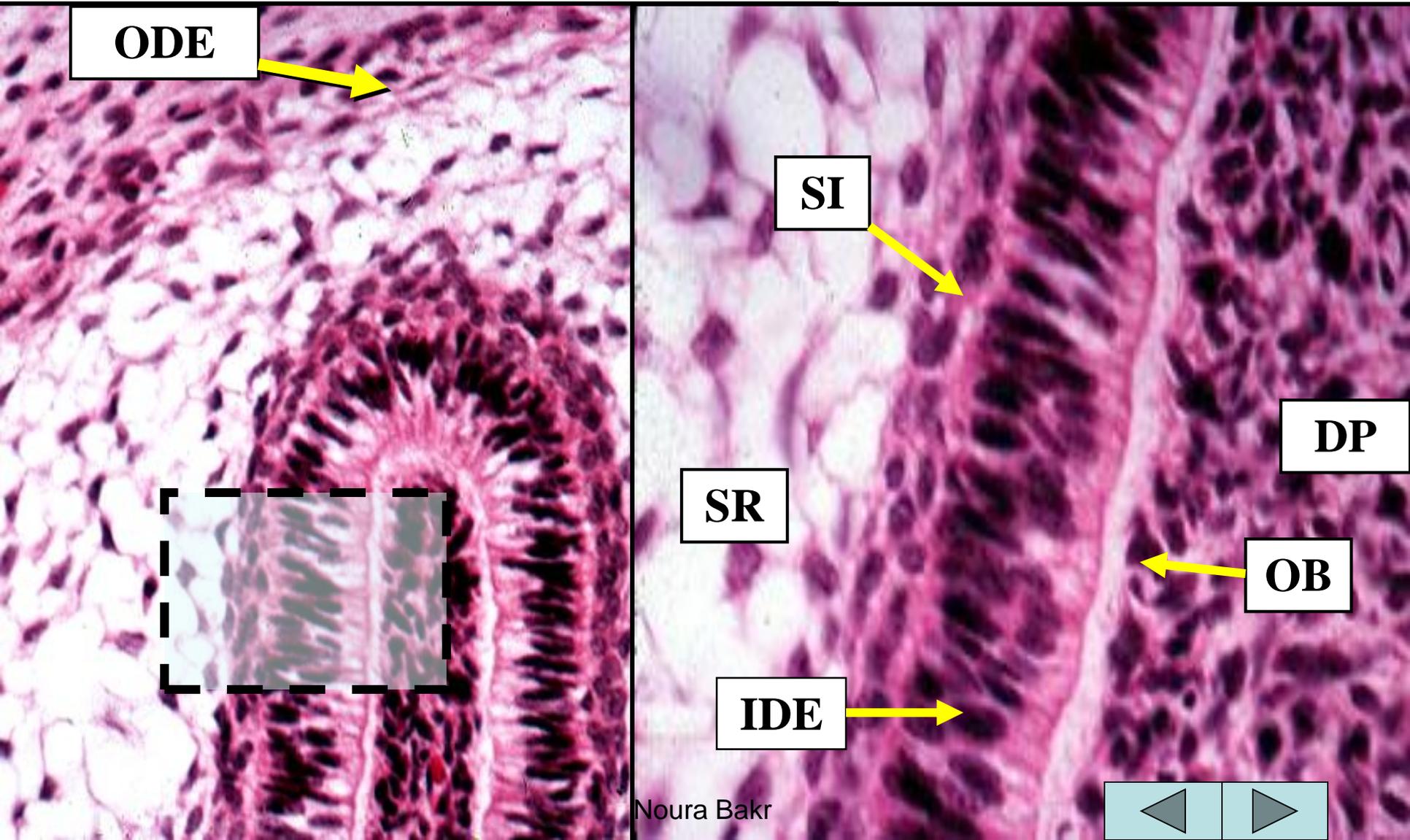
Dental sac "follicle"

4-EARLY BELL STAGE

Histological structure of the tooth germ



In this stage four different types of cells are found within the enamel organ.



1- The outer enamel epithelium:



- -They become low cuboidal in shape
- -These cells are involved in the exchange of substances between the enamel organ and the outer environment

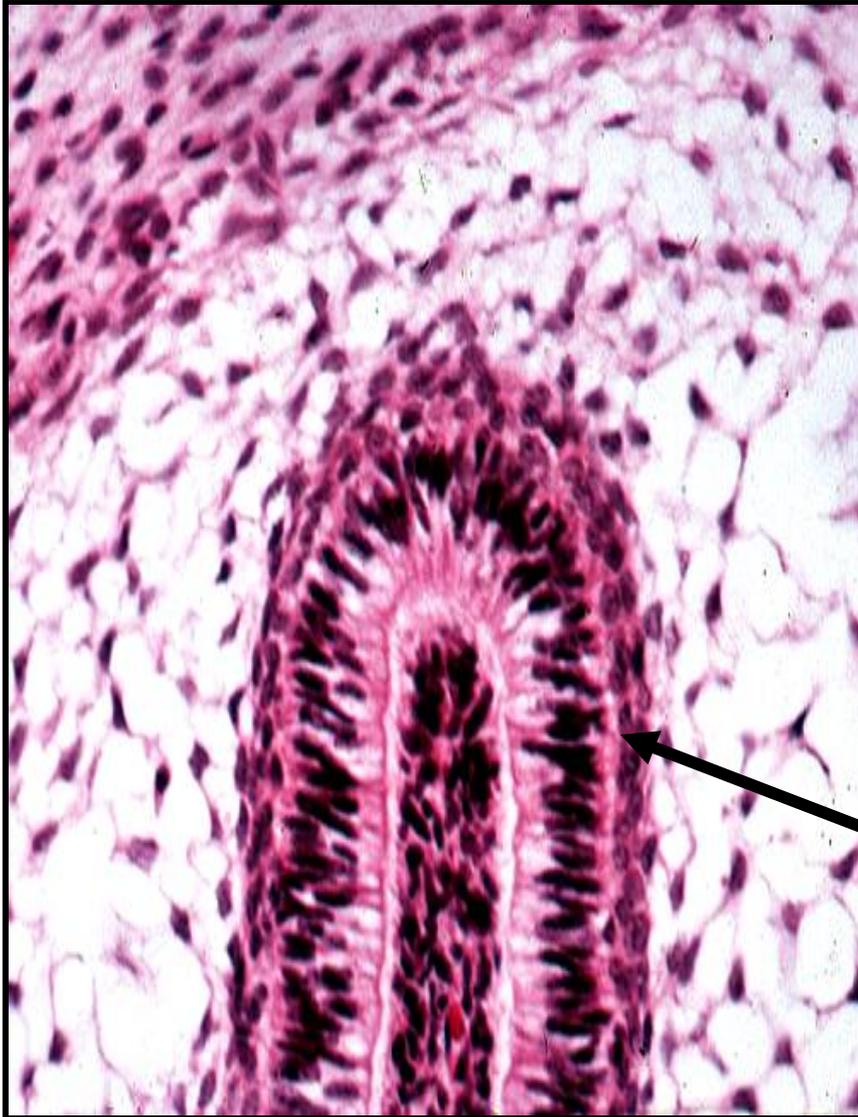
2- The inner enamel epithelium:

- Their arrangement maps out the shape of the crown**
- The cells of the inner enamel epithelium become tall columnar at the site of future incisal edge or cusp development , and they stop division and elongate.**

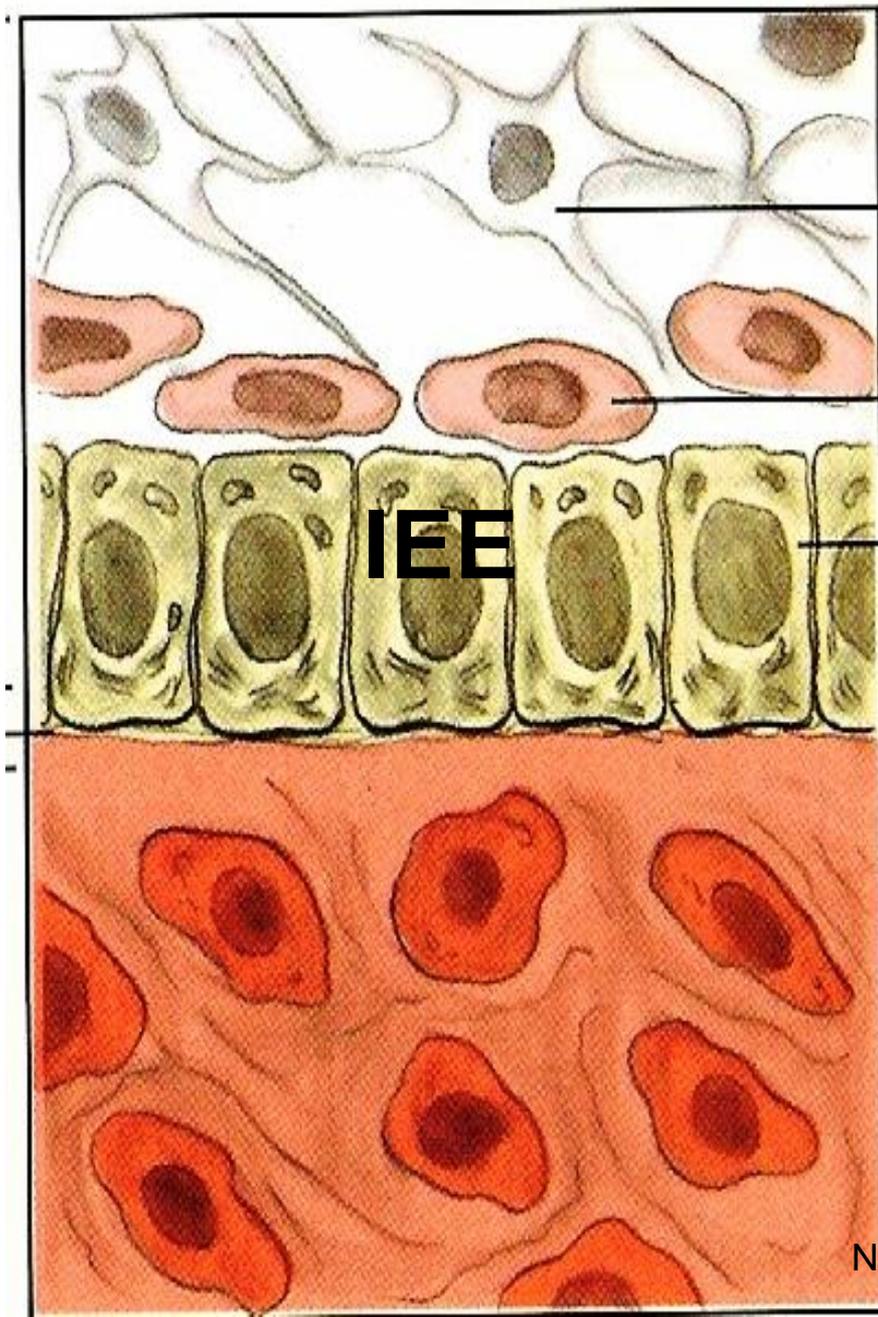
2- Inner enamel epithelium:

- -After formation of predentin, the preameloblasts will be induced to differentiate into ameloblasts, this process is called **Reciprocal induction**
- - The differentiated ameloblasts are tall columnar cells having the power to produce enamel matrix on their side facing the disintegrating basement membrane.
- -When the enamel matrix in contact with the predentin, mineralization of the disintegrating basement membrane now occurs forming the dentino-enamel junction.

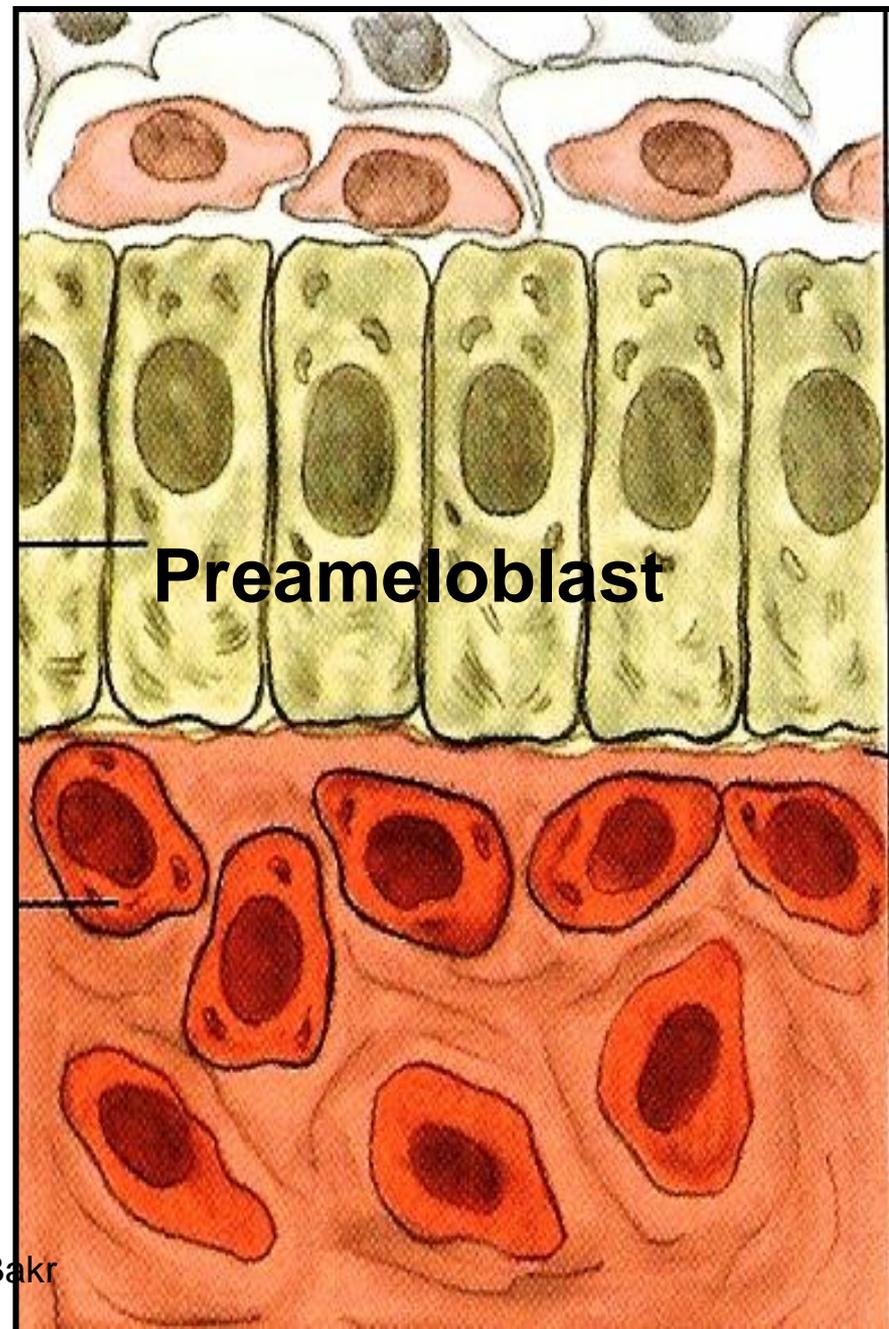
4- The stratum intermedium:



- -This first appears at the bell stage and consists of two or three layers of flattened cells lying over the inner enamel epithelium.
- -They are connected to each other and to the cells of the stellate reticulum and to the inner enamel epithelium by desmosomes.
- -They contain much **alkaline phosphatase enzyme and Ca-Mg ATPase**) needed for enamel mineralization.



IEE



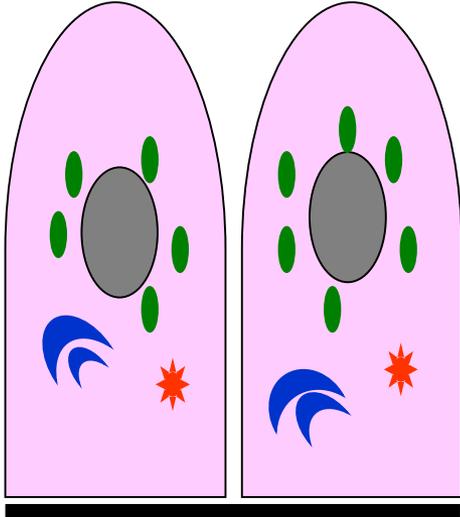
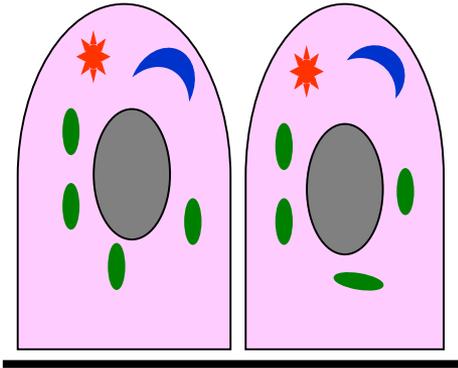
Preameloblast

Induction

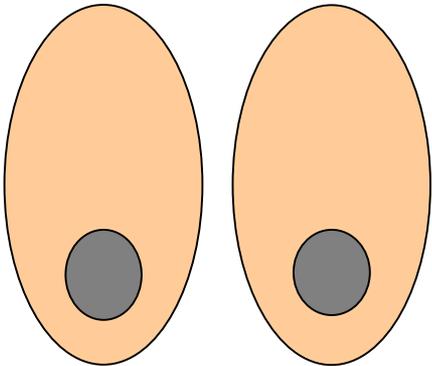
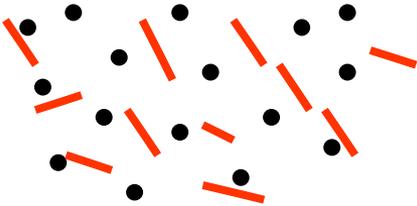
Inner dental epith.

preameloblasts.

Proximal end



Distal end

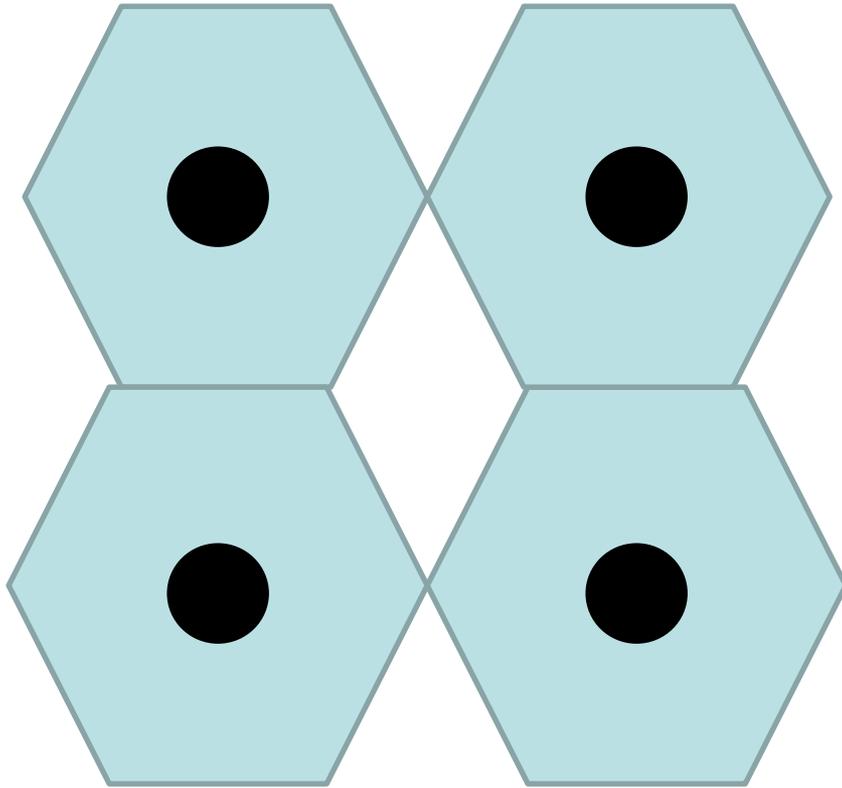


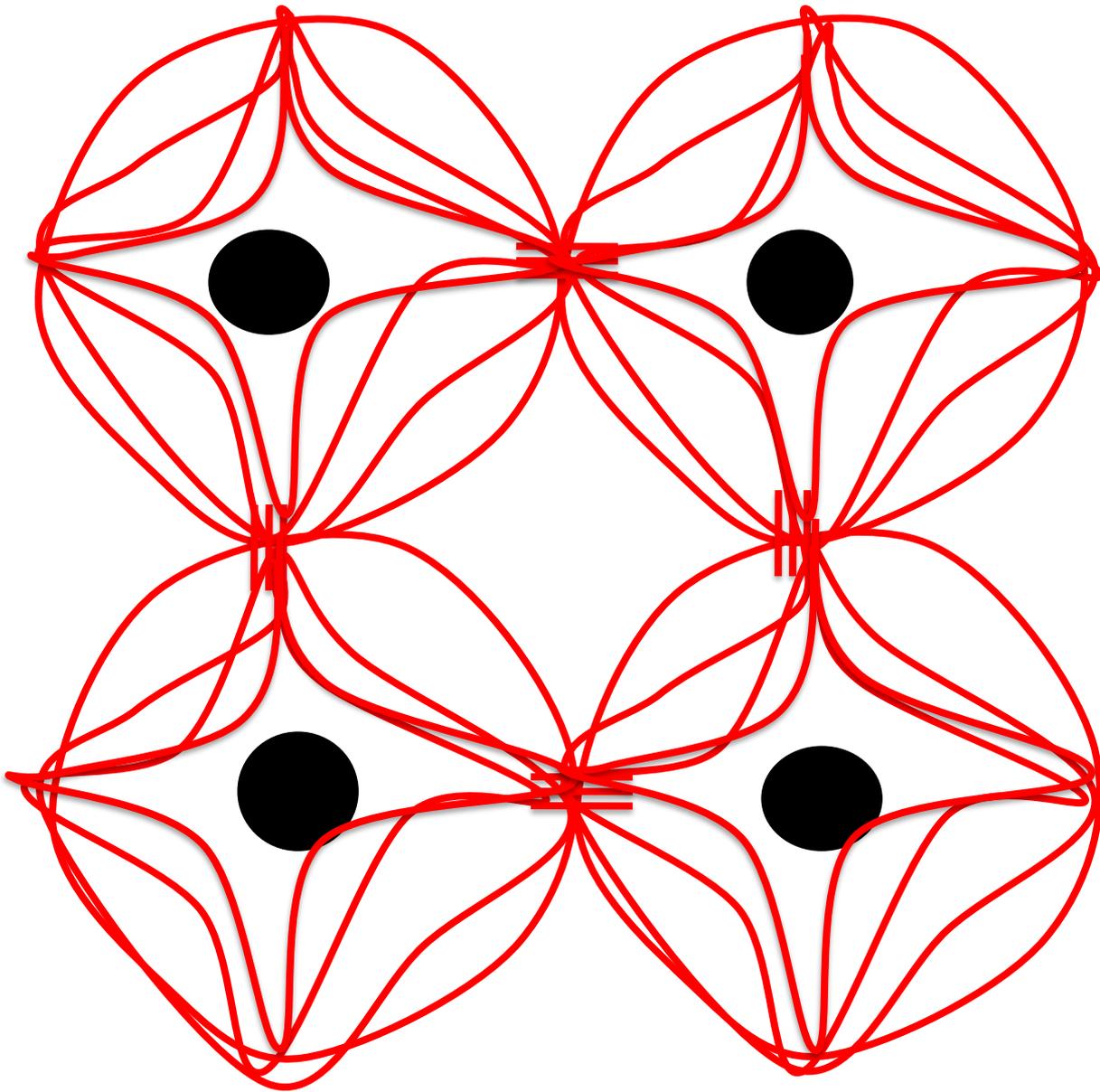
Odontoblasts

-  Centriol
-  Golgi apparatus
-  Mitochondria
-  Nucleus

3-The stellate reticulum

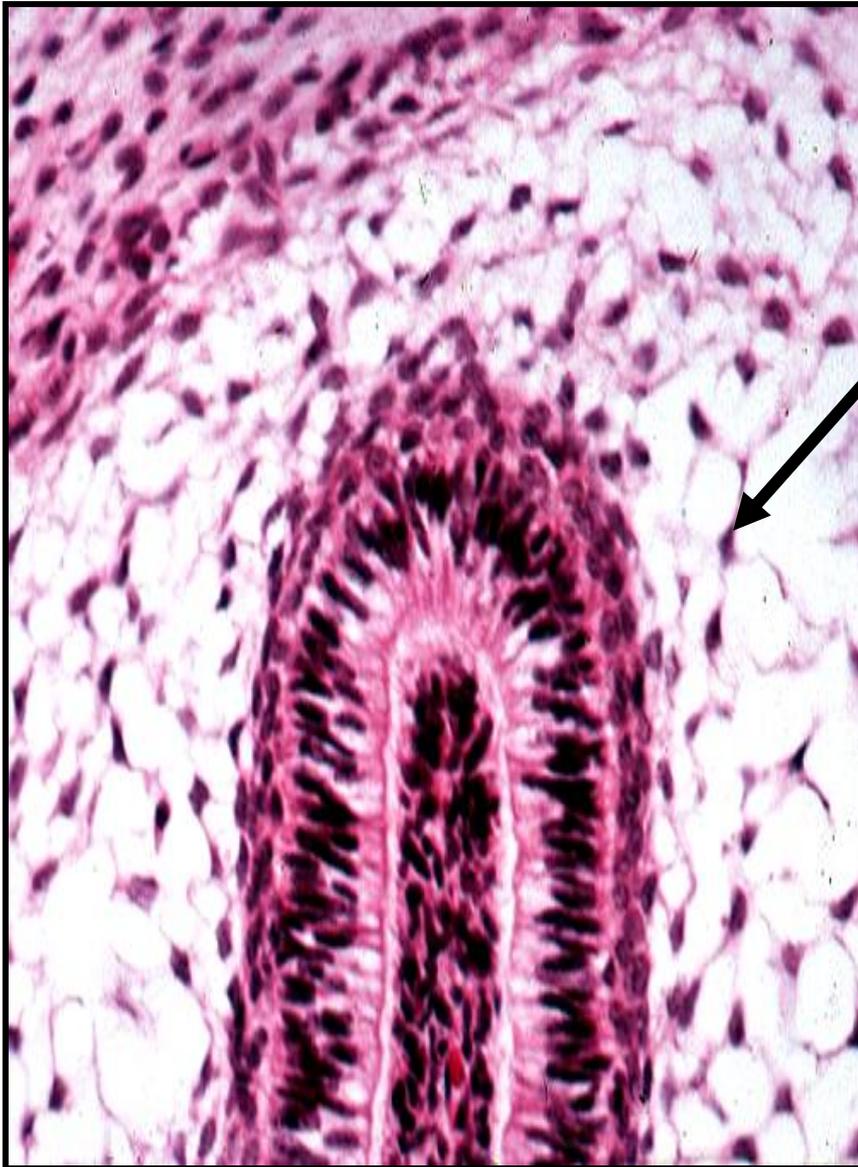
Polygonal cells....change to..





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3-The stellate reticulum:



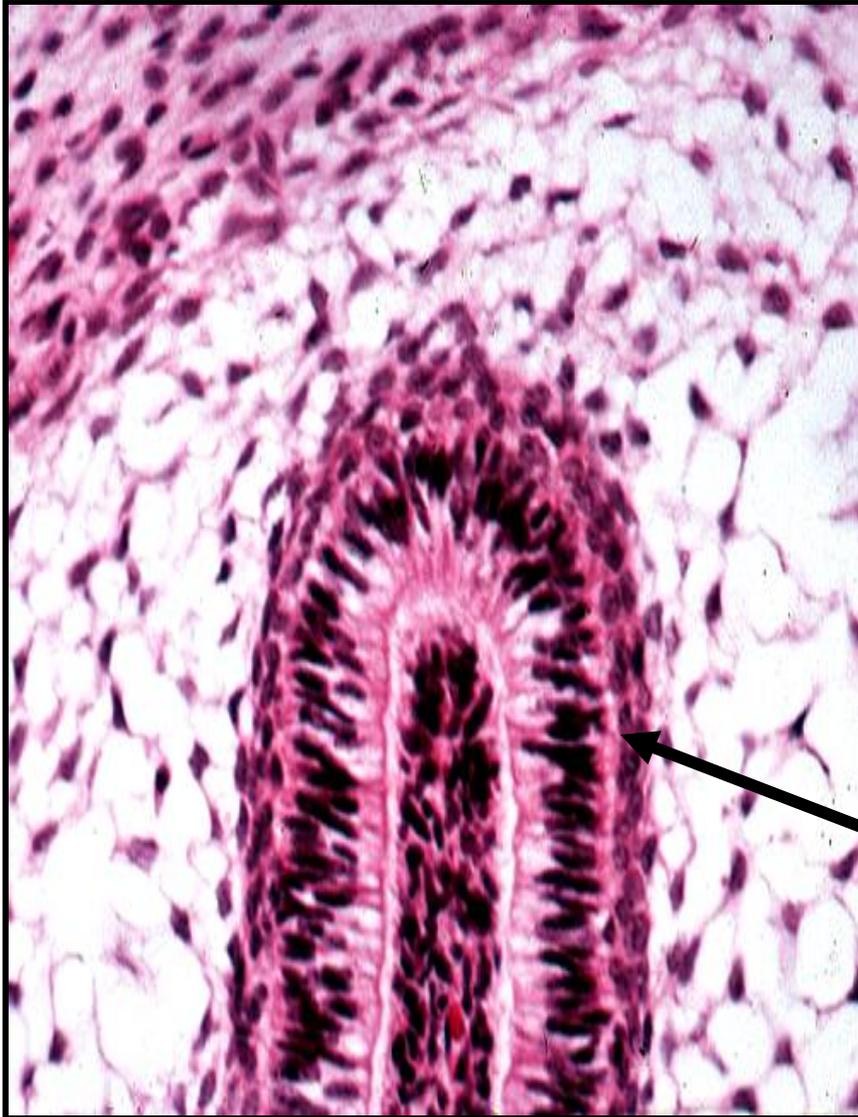
- -This layer is **most fully developed at the bell stages** and their cells expand further apart by increase of the intercellular fluid.

- **Function:**

- 1- Protect the underlying dental tissues against physical disturbance.

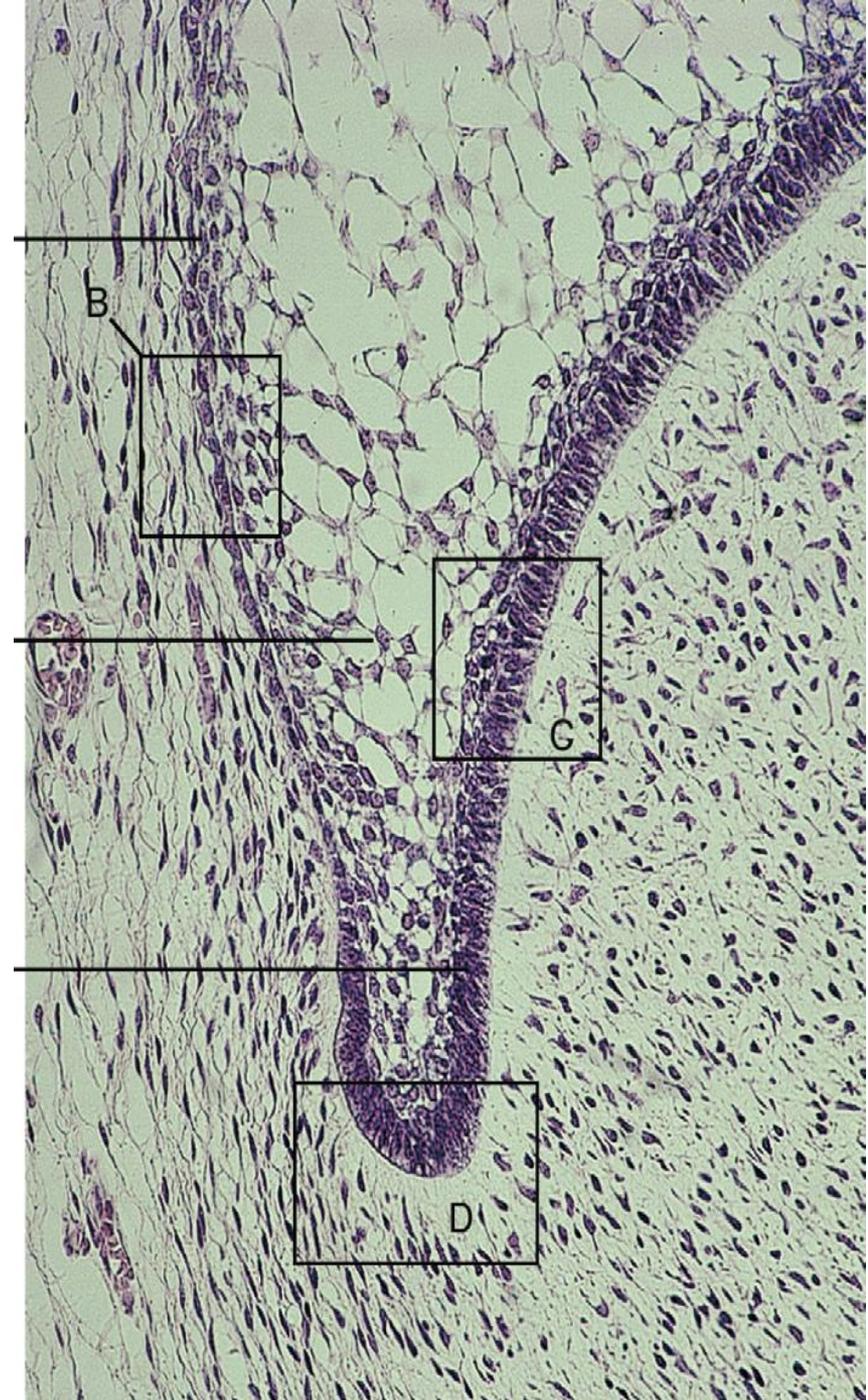
- 2- Maintain tooth shape

4- The stratum intermedium:



- -This first appears at the bell stage and consists of two or three layers of flattened cells lying over the inner enamel epithelium.
- -They are connected to each other and to the cells of the stellate reticulum and to the inner enamel epithelium by desmosomes.
- -They contain much **alkaline phosphatase enzyme (VIP for E mineralization)**

- Cervical loop
- Dental papillae
- Dental sac

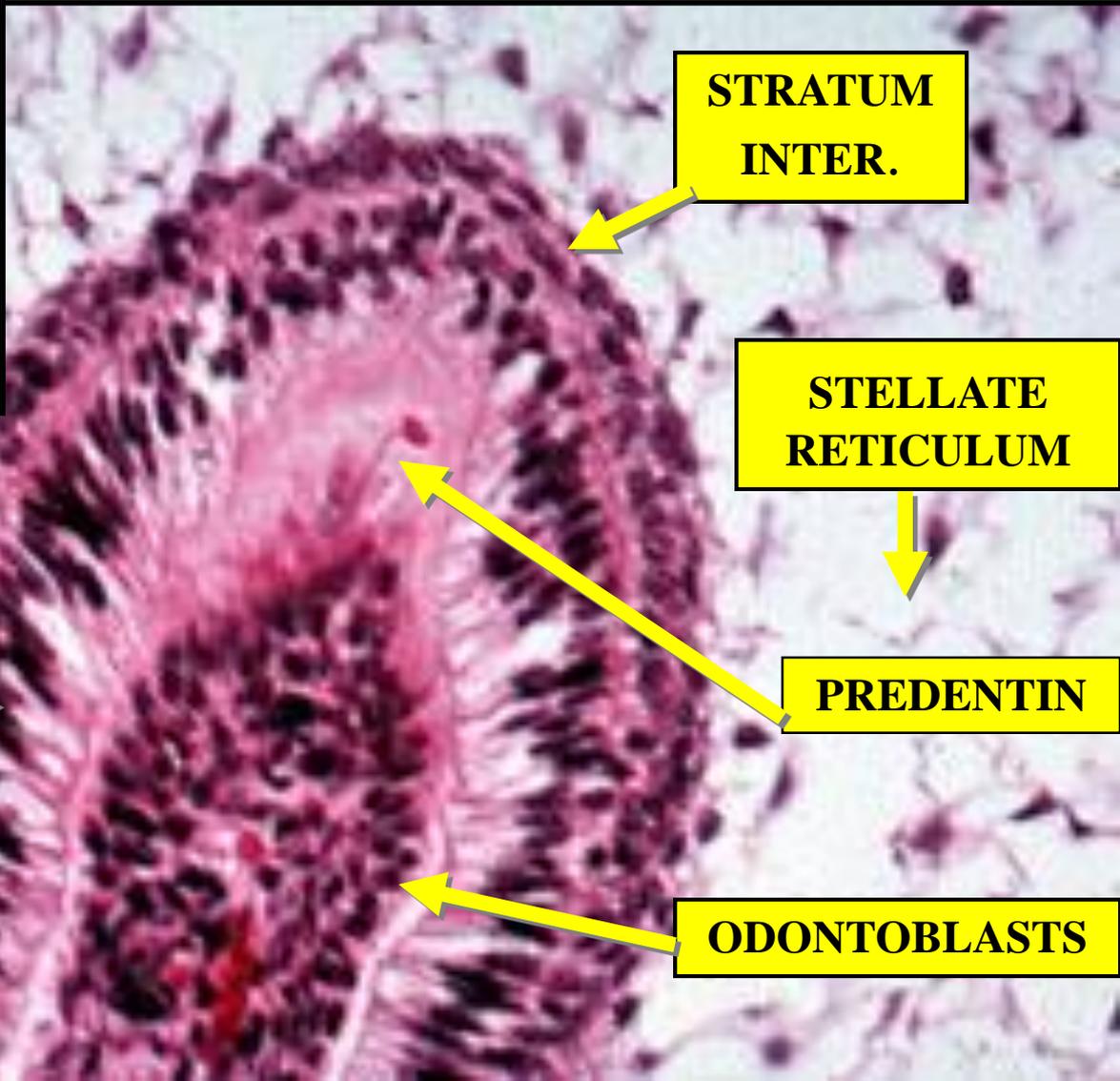
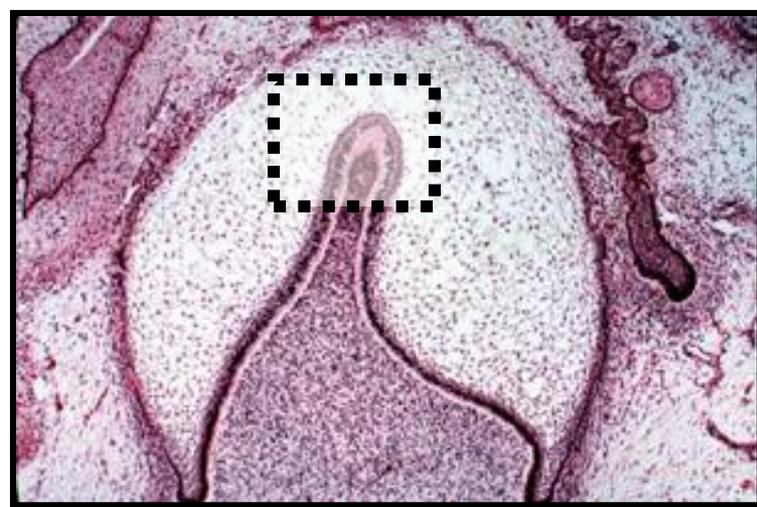


LATE BELL STAGE (Appostion)



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LATE BELL STAGE (Apposition stage)



**INNER
DENT.
EPITH.**

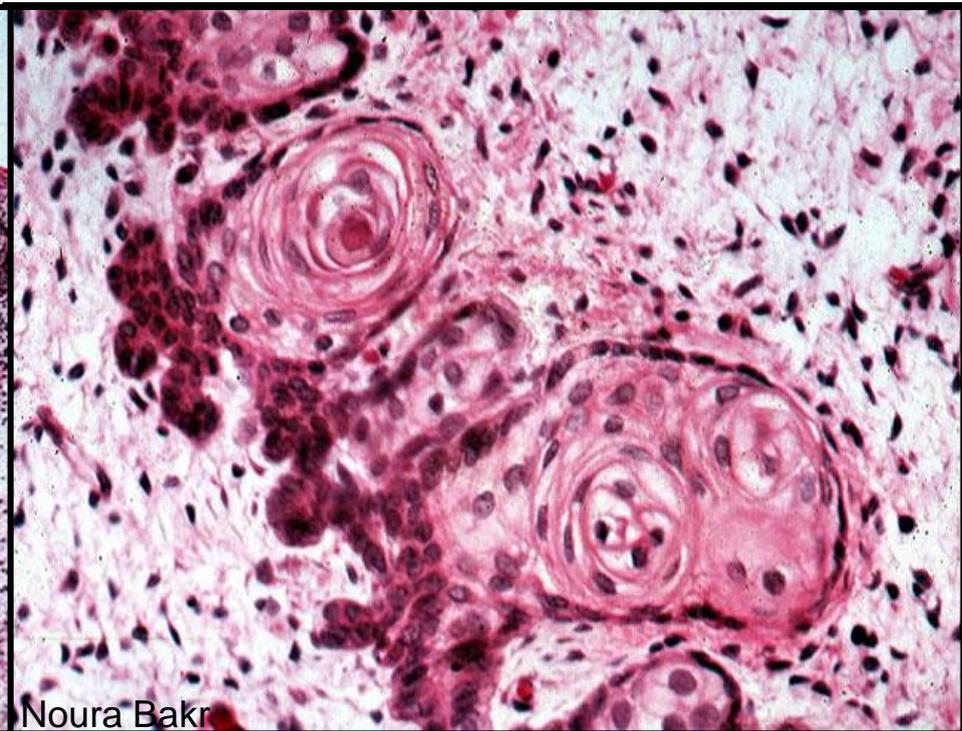
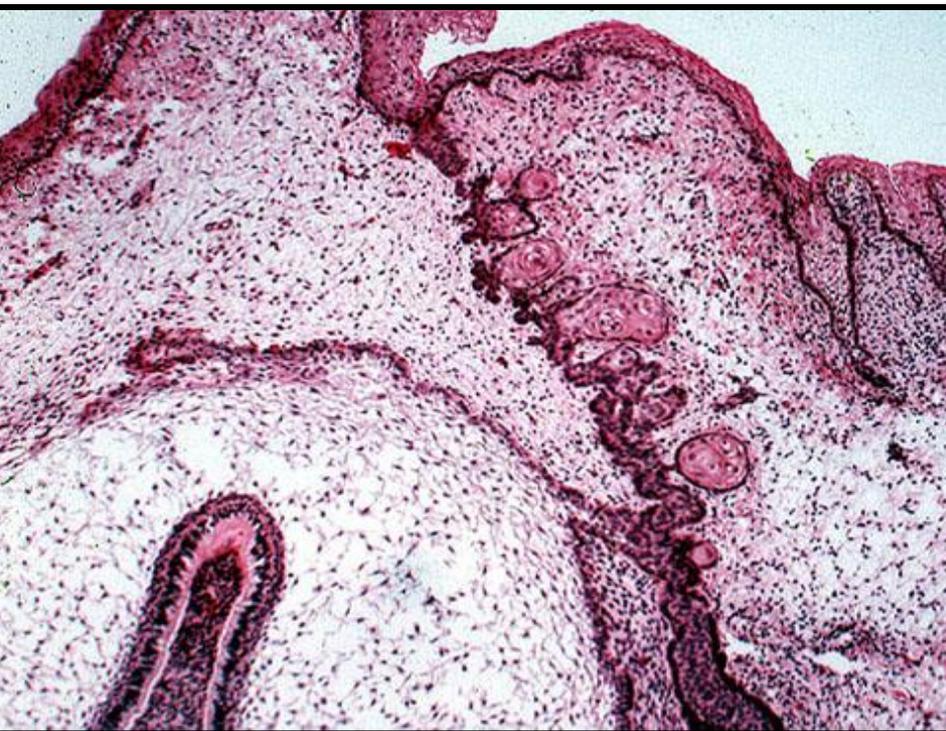
**STRATUM
INTER.**

**STELLATE
RETICULUM**

PREDENTIN

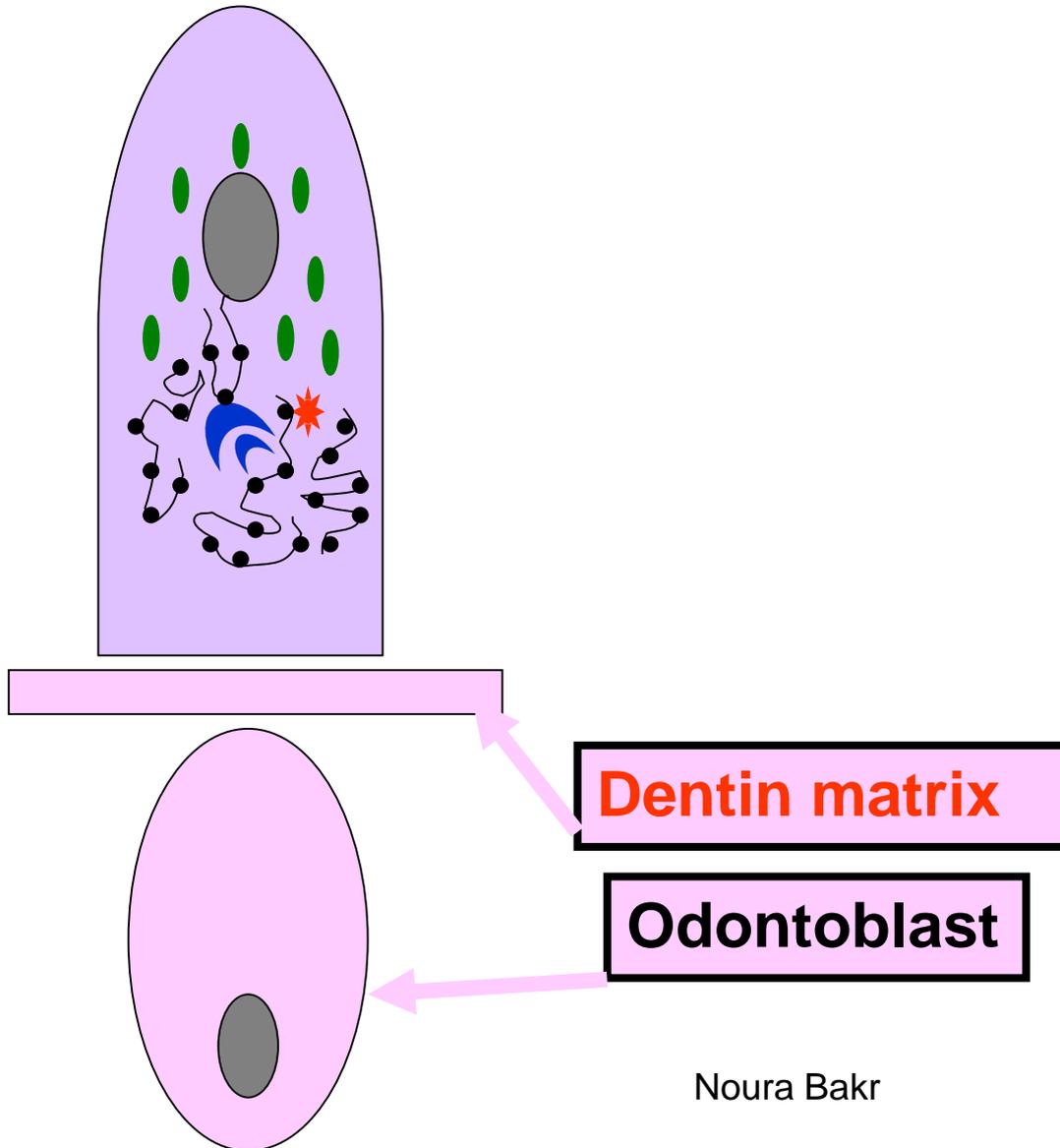
ODONTOBLASTS

During this stage the lateral dental lamina joining the tooth germ to the oral epithelium breaks up into discrete islands of epithelial which normally degenerate but some may persist and are given the name of epithelial pearls (**epithelial rests of Serres**).



Late (apposition) stage

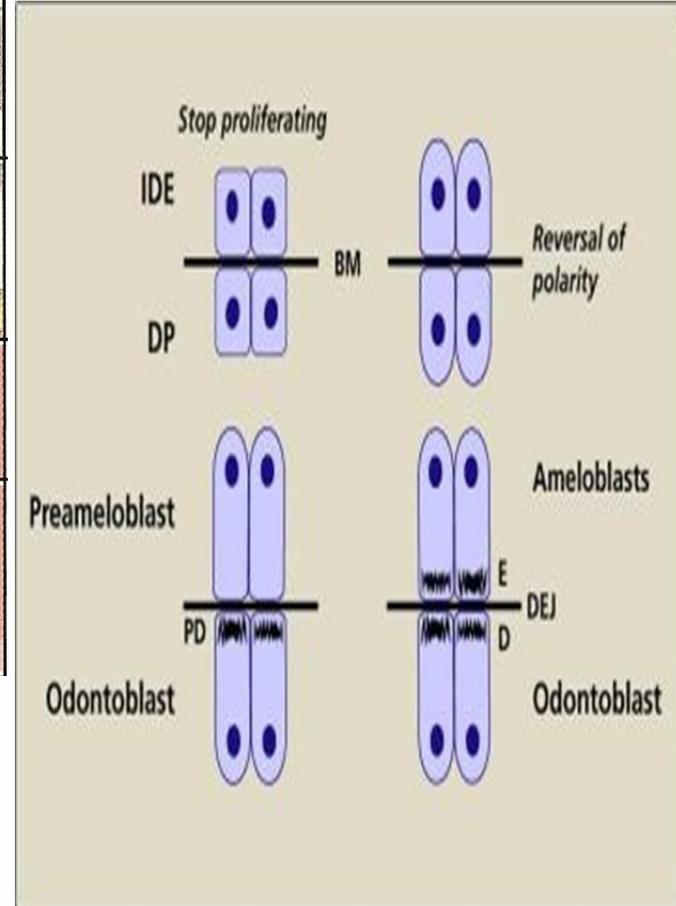
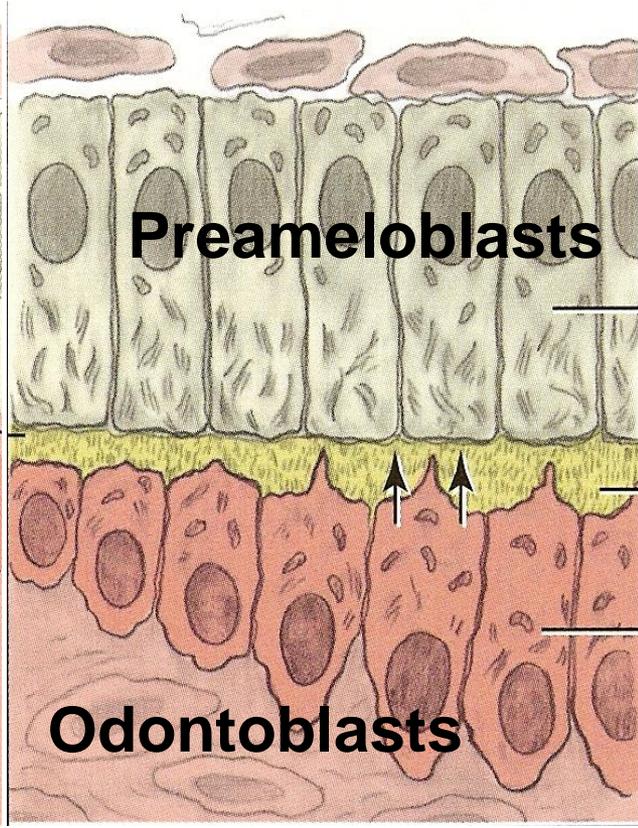
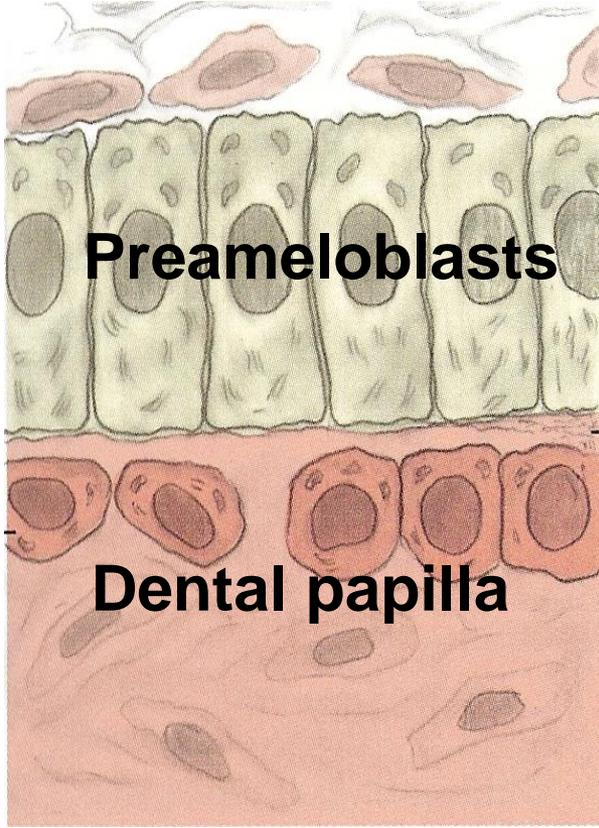
- This final stage of odontogenesis includes apposition of both dentin and enamel
- The odontoblasts start their secretory activity and have laid down the first layer of dentin (predentin) before enamel matrix production begins



Preameloblasts *Induce the outer cell layer of dental papilla.*



Odontoblasts



Preameloblasts

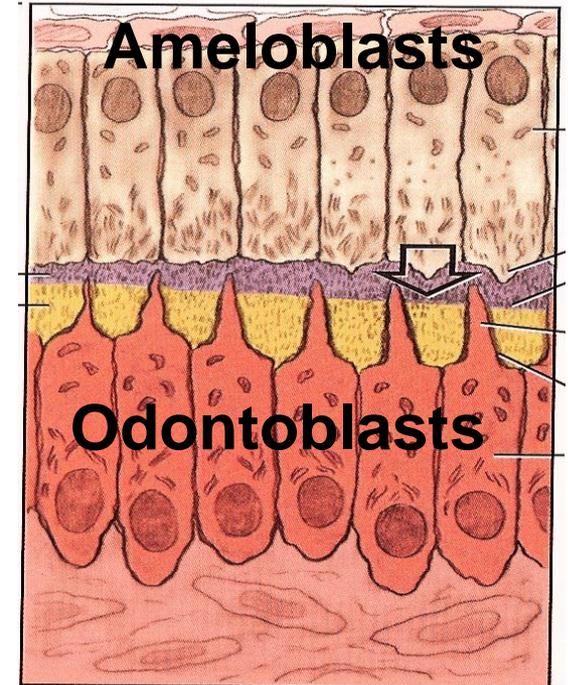
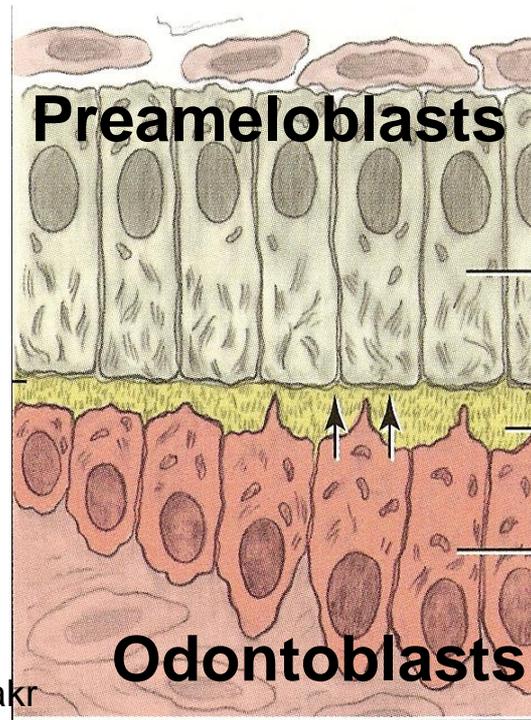
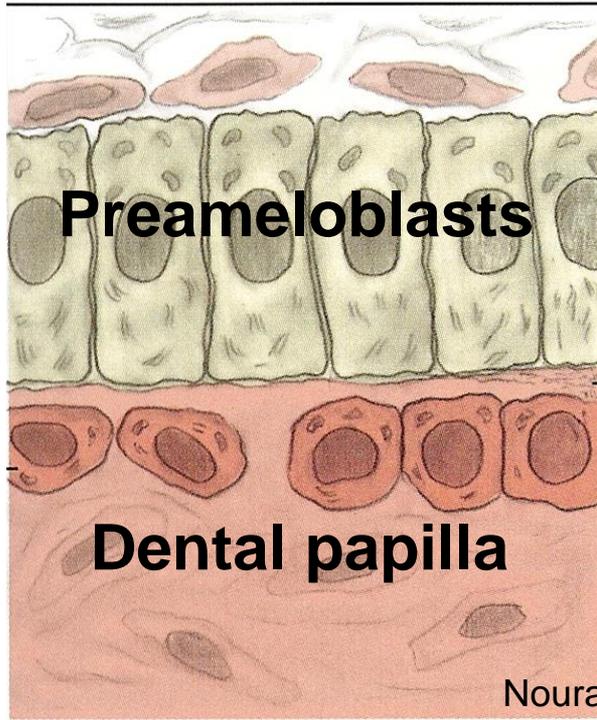
Odontoblasts
(repolarization)

Ameloblasts

Disintegration
of basement
membrane.

Dentin
matrix

Enamel matrix



- During the formation of both dentin and enamel, the surface of the outer enamel epithelium is laid in folds.
- Between these folds the adjacent mesenchyme of the dental sac forms papillae that contain capillary loops providing a rich nutritional supply for metabolic activity of the avascular enamel organ.
- The cells of outer enamel epithelium become flattened and modified to assist in transporting nutrient from the blood vessels to stratum intermedium which in turn transport them to the ameloblasts.
- The cells of stellate reticulum collapse (shrink due to loss of their intercellular fluid) to bring the ameloblasts close to the blood vessels situated outside the outer enamel epithelium.
- So the cells of stellate reticulum are hardly distinguished from those of the stratum intermedium.

Folds Of Outer inner epithelium



Late Bell stage

Noura Bakr

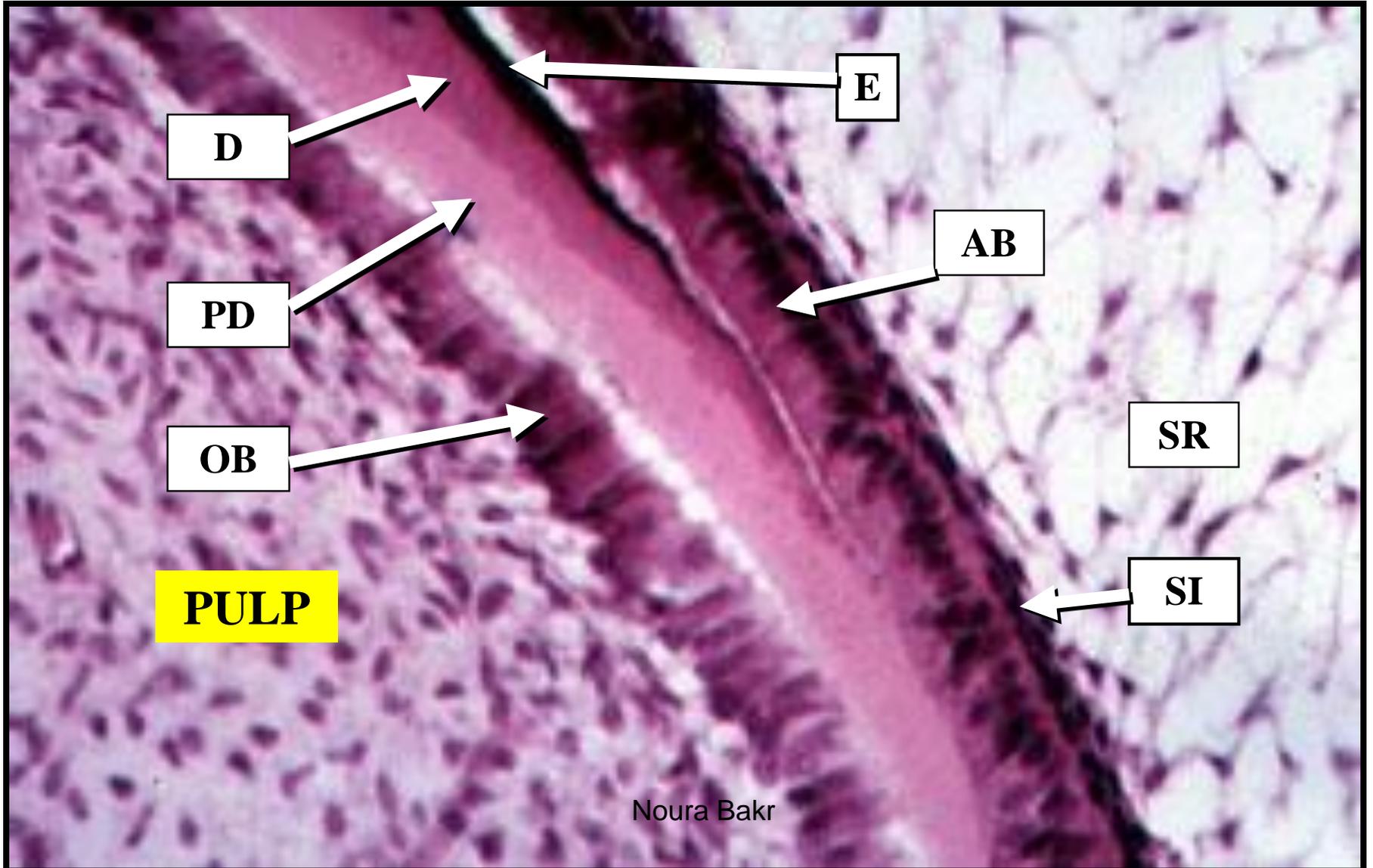
The stellate reticulum

- 1- Protect the underlying dental tissues against physical disturbance.**
- 2- Maintain tooth shape**
- 3- Support the production of enamel**
(The cells of stellate reticulum collapse (shrink) due to loss of their intercellular fluid) to bring the ameloblasts close to the blood vessels situated outside the outer enamel epithelium).

The stratum intermedium

- **1- Synthesis of proteins (alkaline phosphatase, Ca-Mg ATPase)**
- **2- Transport of materials to and from the enamel forming cells (ameloblasts) i.e transfer Ca from blood vessels to ameloblasts.**
- **3- Supporting the production and mineralization of enamel**

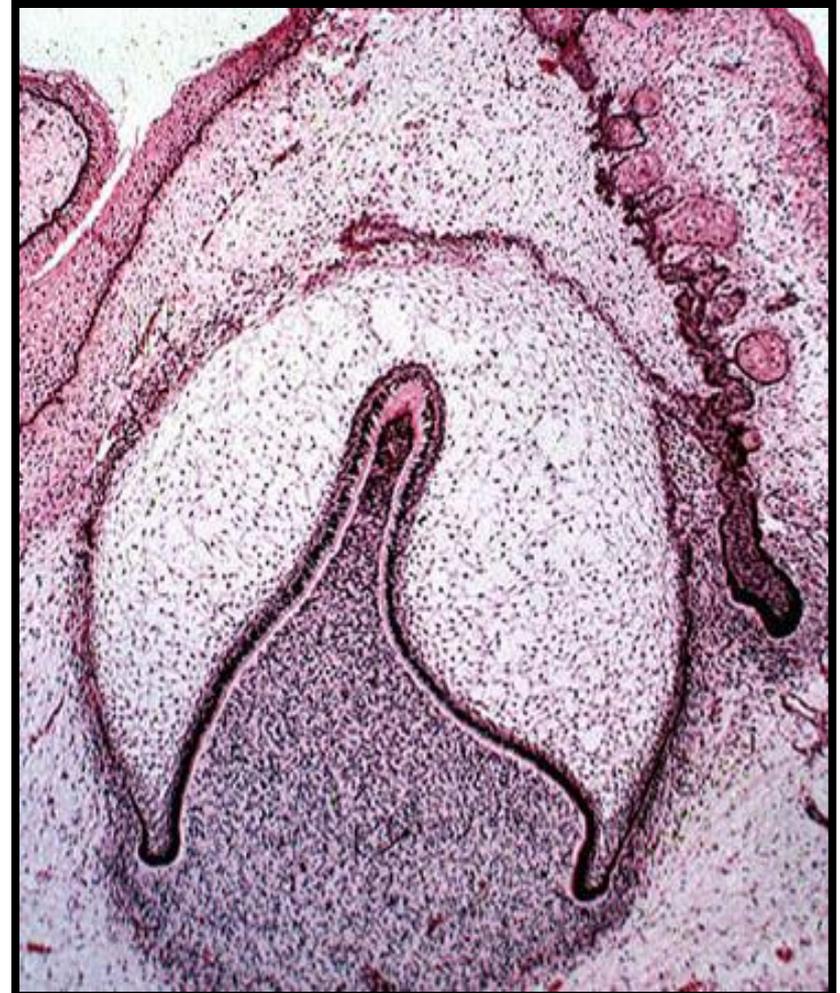
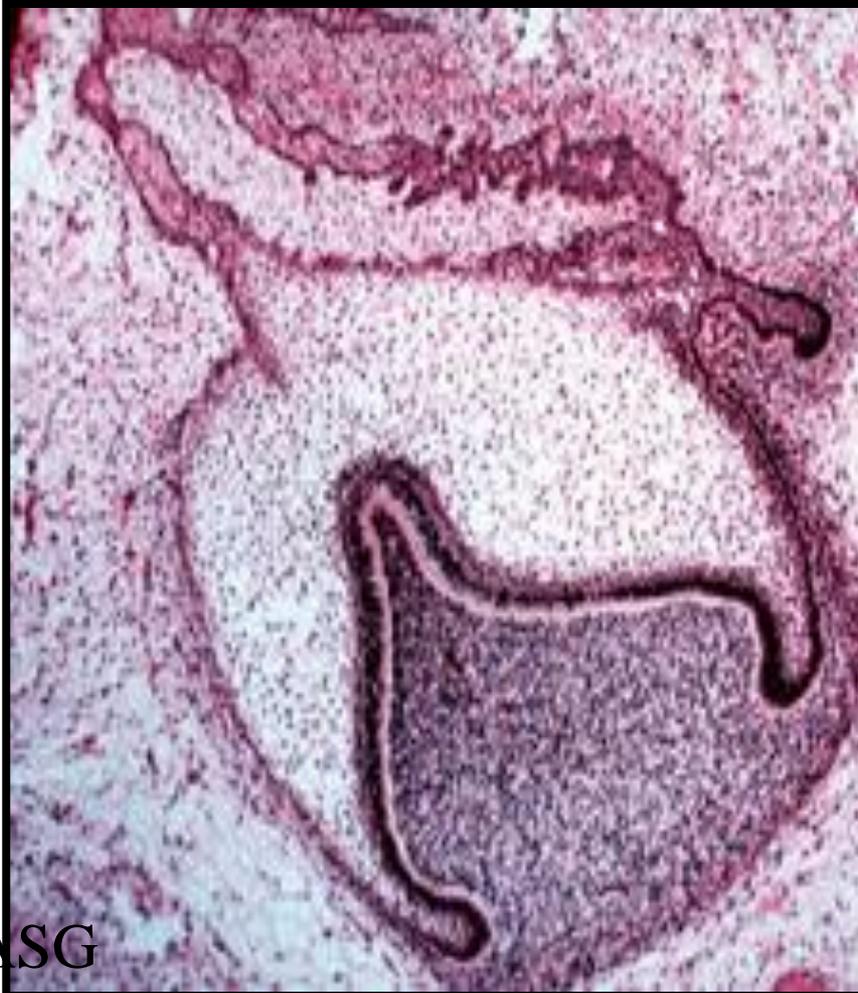
Late Bell Stage



NOTE

EARLY

ADVANCED



ASG

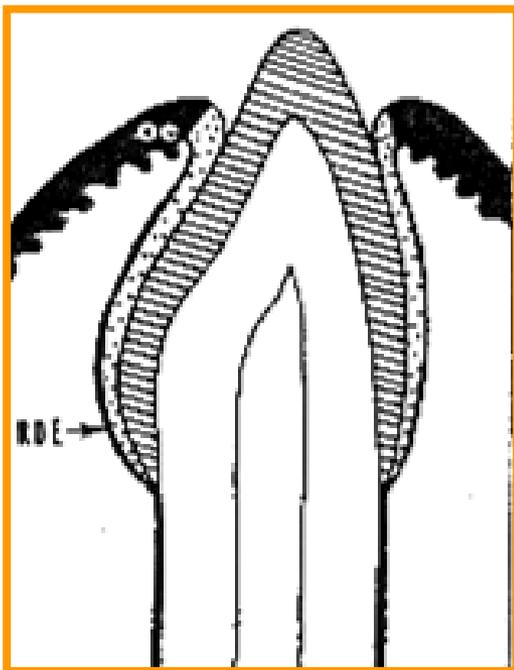
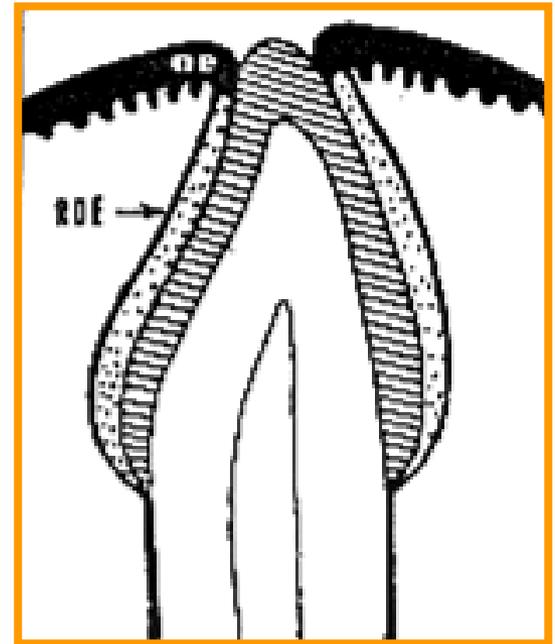
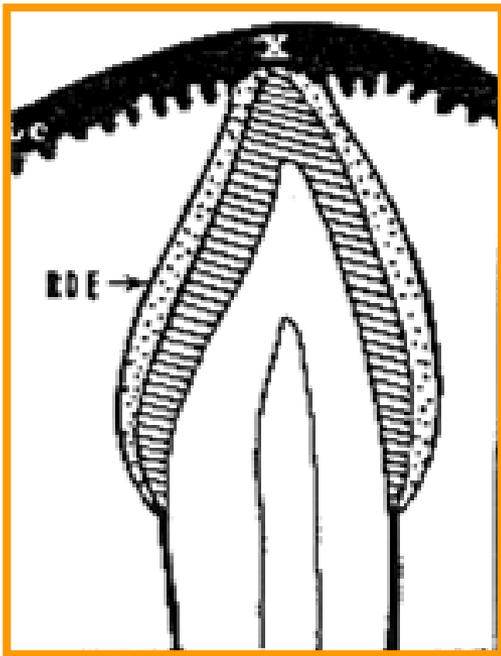
functions of inner dental epithelial cells in tooth development and amelogenesis

1. Establish the crown morphological pattern during the bell stage.
2. Induce adjacent surface cells of the dental papilla to differentiate into coronal odontoblasts. (Induction process)
3. Differentiate into ameloblasts which secrete enamel. (Receprocal induction)

4. Form with the other layers of the dental organ the reduced dental (enamel) epithelium which protects the enamel surface until the tooth erupts.

5. Share in the **root formation**.

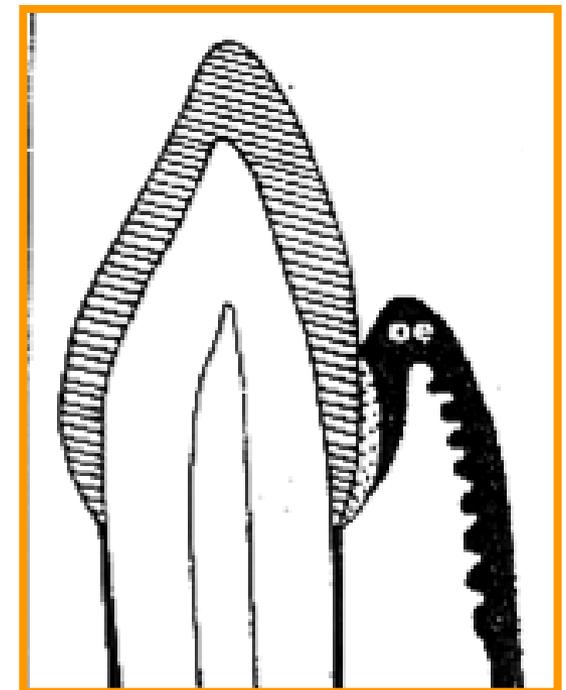
6. Contribute to the formation of the **dentogingival junction** of erupted teeth.



Reduced dental
epithelium



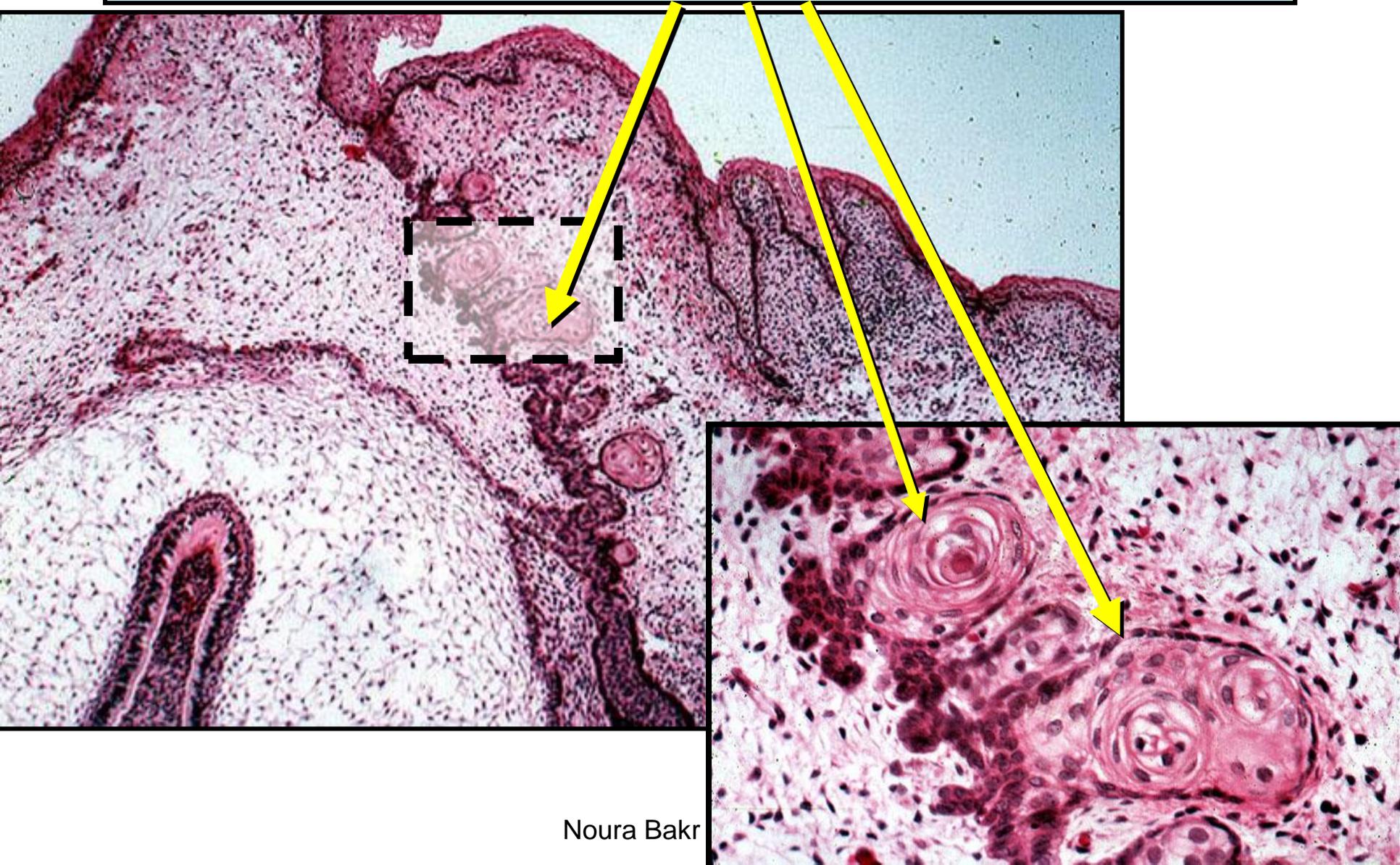
Dentogingival
junction



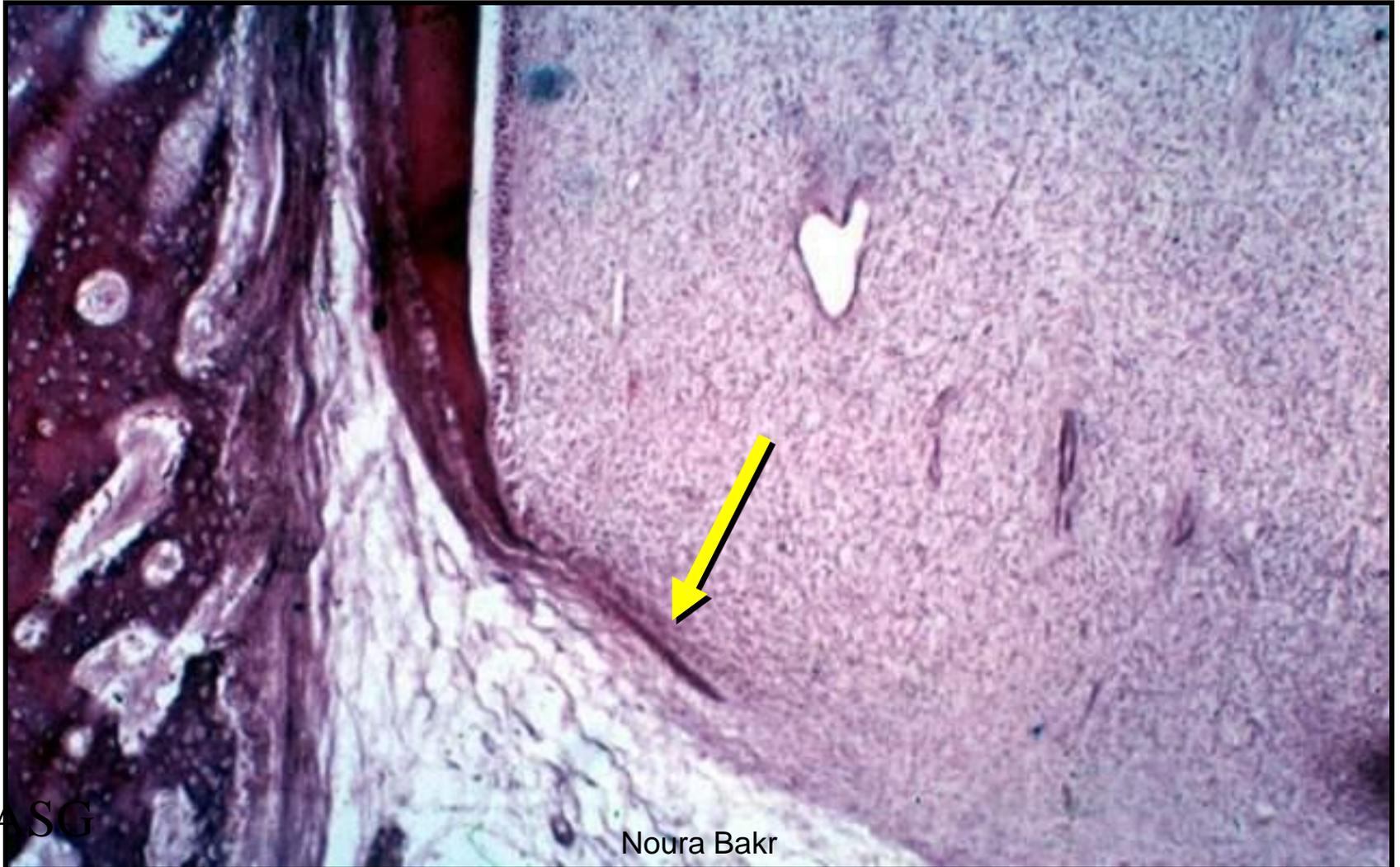
So the functions of stellate reticulum during this stage :-

- **1- Acts as a buffer against physical forces that may distort the underlying preameloblasts arrangement on the basement membrane (the future amelodentinal junction) leading to gross morphologic changed. So it maintains the morphology of the enamel organ as well as tooth shape.**
- **2- It permits a limited flow of nutritional elements from the outlying blood vessels in dental sac to the formative cells (preameloblasts) , so it acts as a store house for the nutritive materials.**

SERRES' PEARLS



Root formation



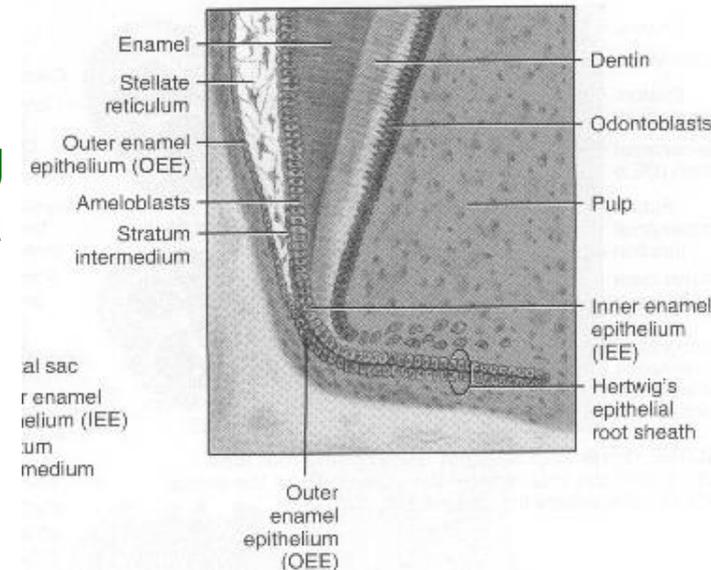
-The cervical loop begins to grow deeper into the surrounding ectomesenchyme of the dental sac, elongating and moving away from the newly completed crown area to enclose more of the dental papilla tissue forming Hertwig's epithelial root sheath (HERS)

At first the epithelial root sheath bends at the future cemento-enamel junction into horizontal plane known as epithelial diaphragm.

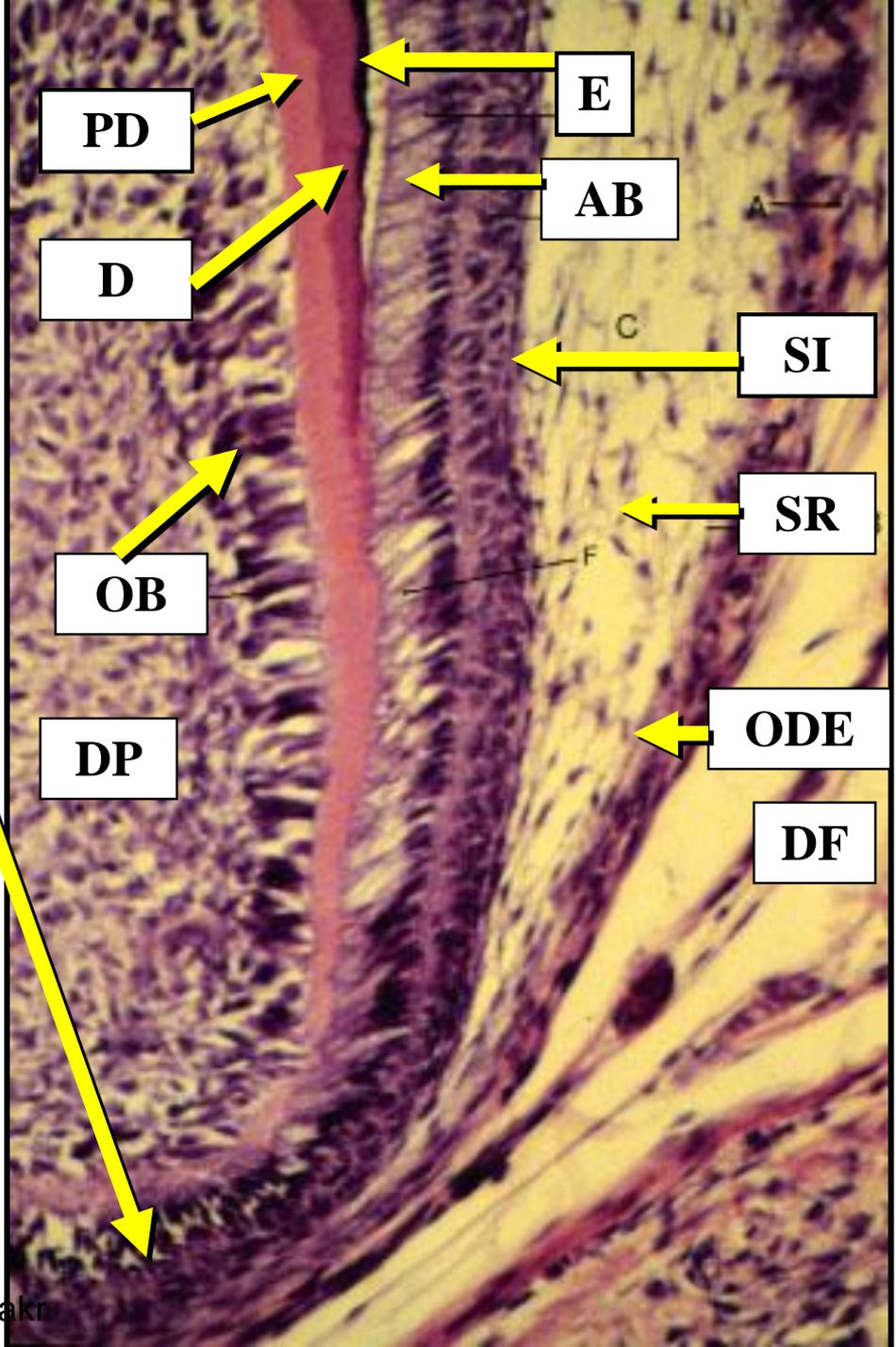
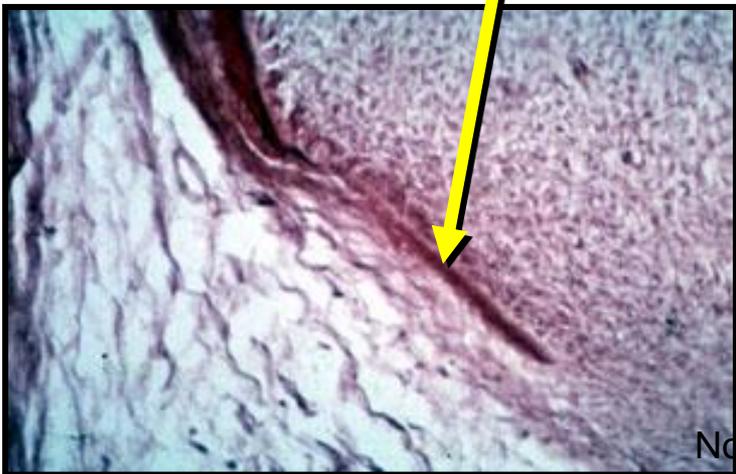
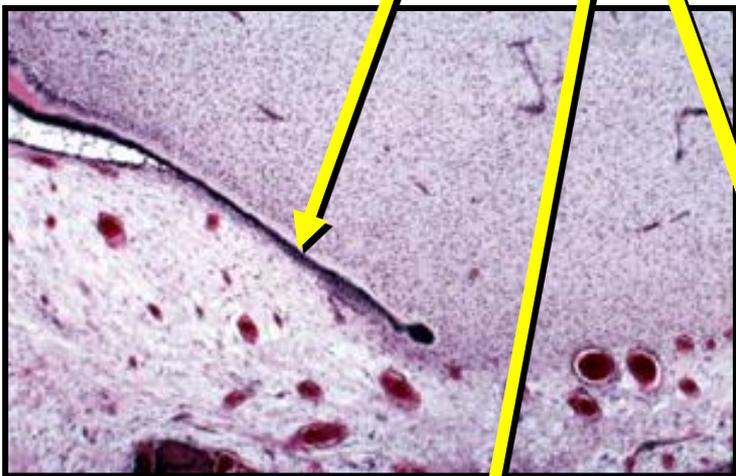
- This diaphragm produces narrowing of the wide cervical opening of the tooth germ.

-The plane of the diaphragm remains relatively fixed during root development and growth.

- The epithelial root sheath of Hertwig proliferates coronally to the diaphragm in a vertical direction.

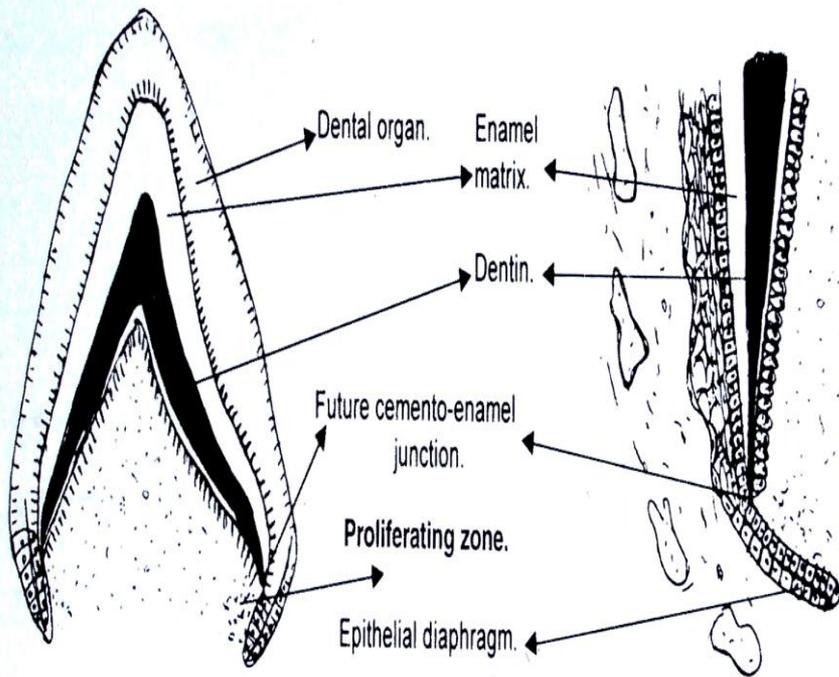


CERVICAL LOOP



SINGLE ROOT FORMATION

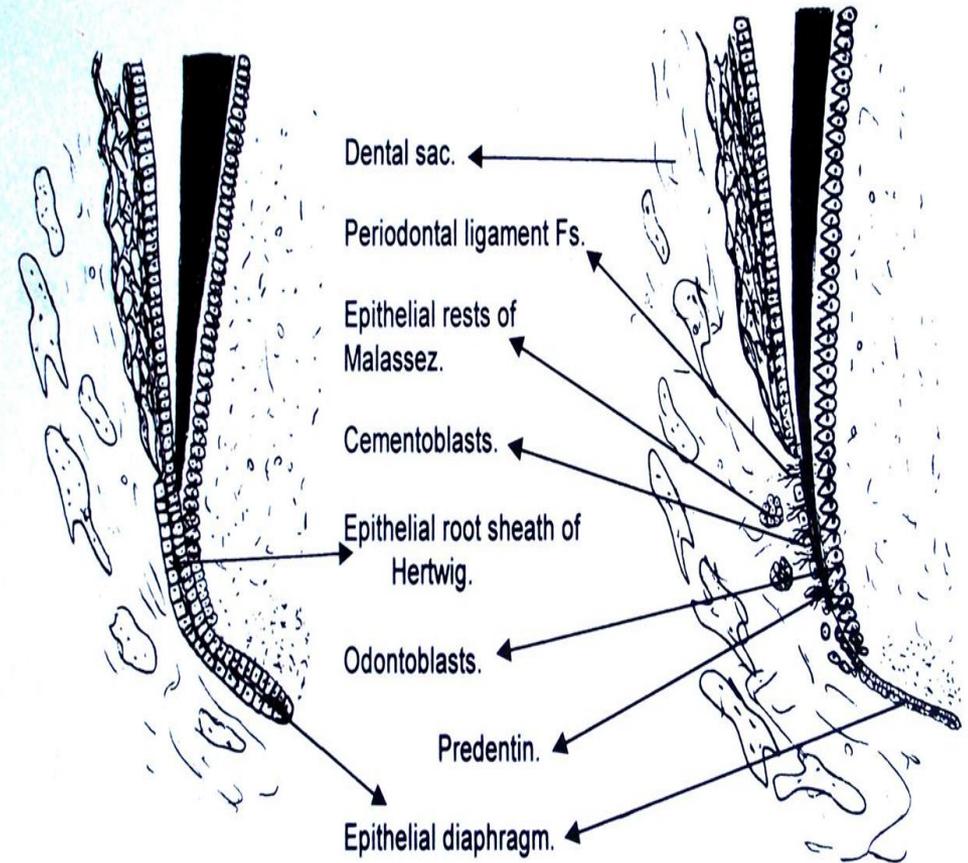
Stages of root formation.



(A)

(B)

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(C)

(D)

◆ Root formation

Elongation of cervical loop
(without st.reticulum or
st.intermedium)



Formation of
epithelial root sheath of Hertwig



odontoblast differentiation



beginning of
of root dentin formation



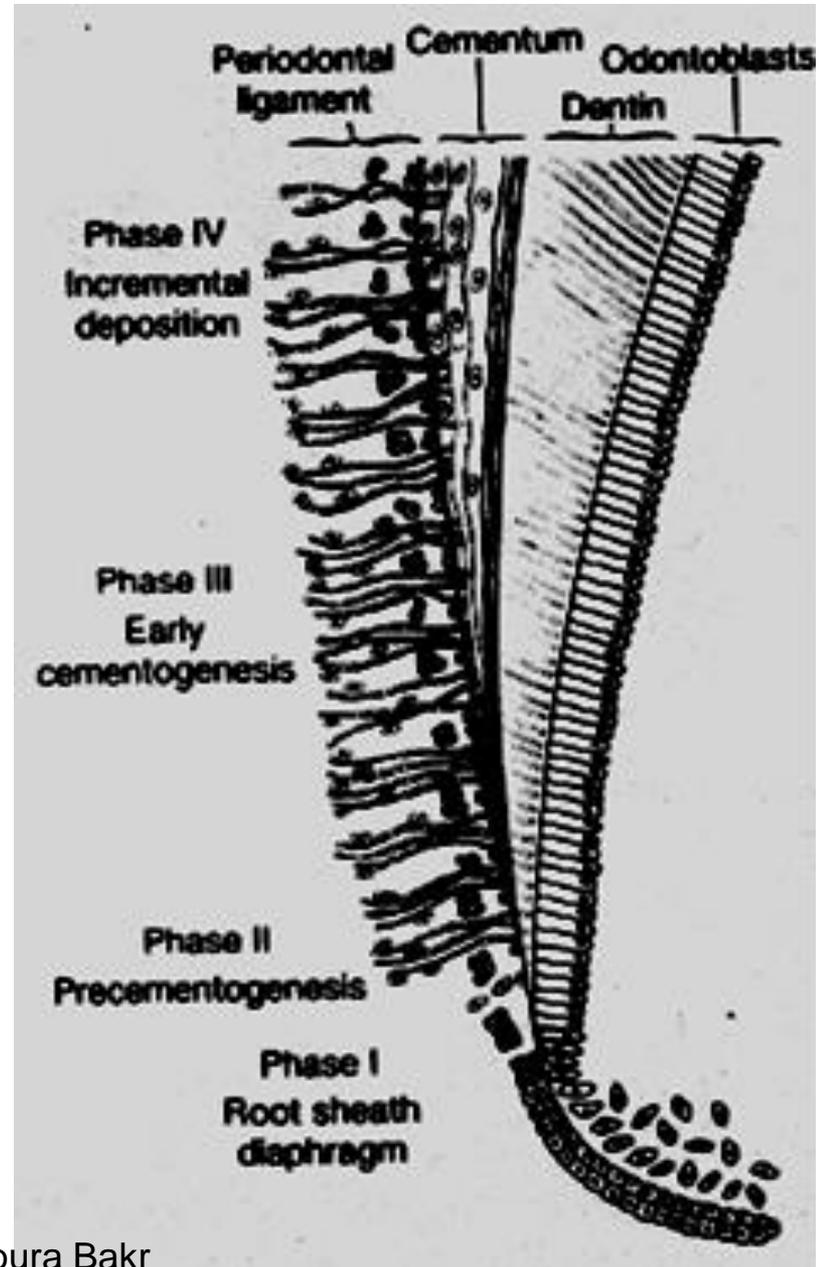
Breakdown & migration
of root sheath cells



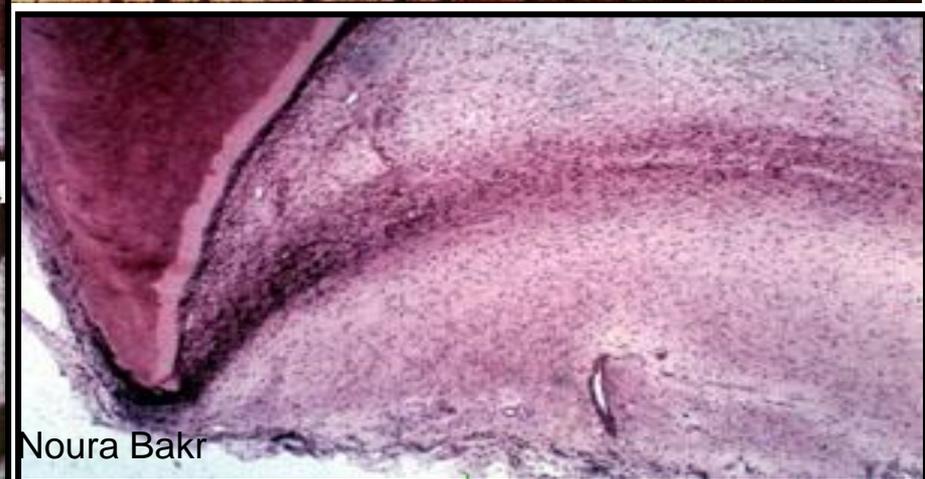
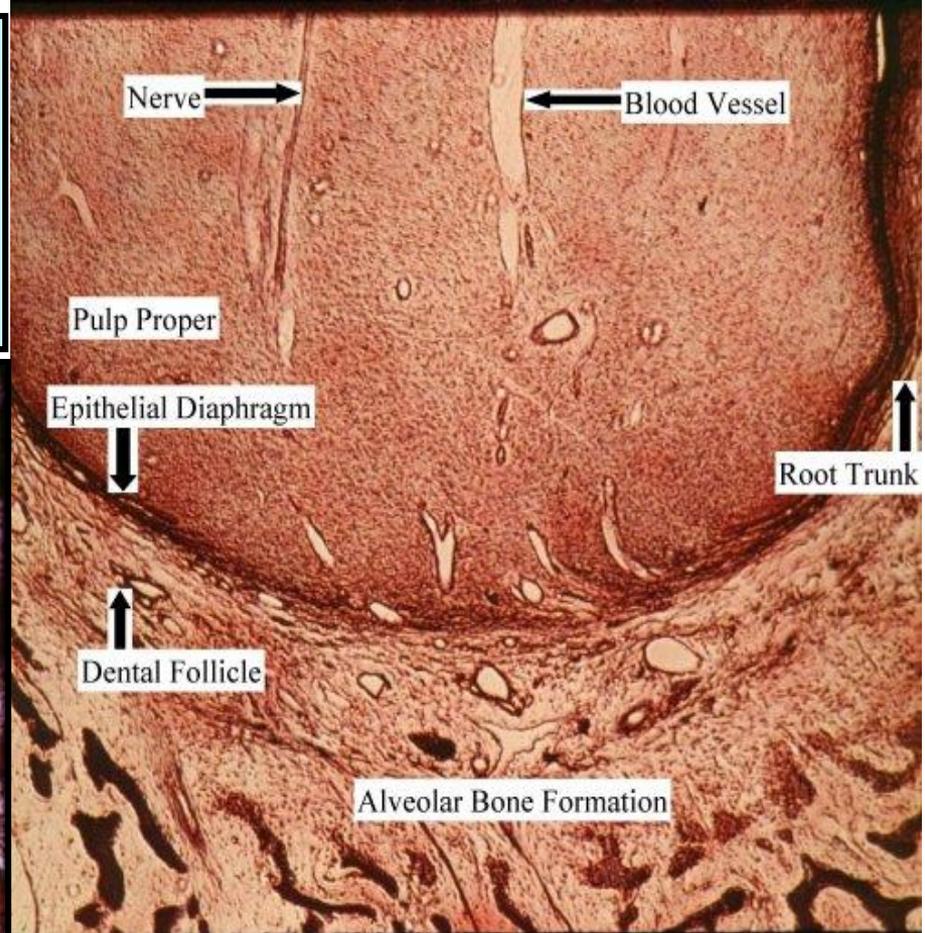
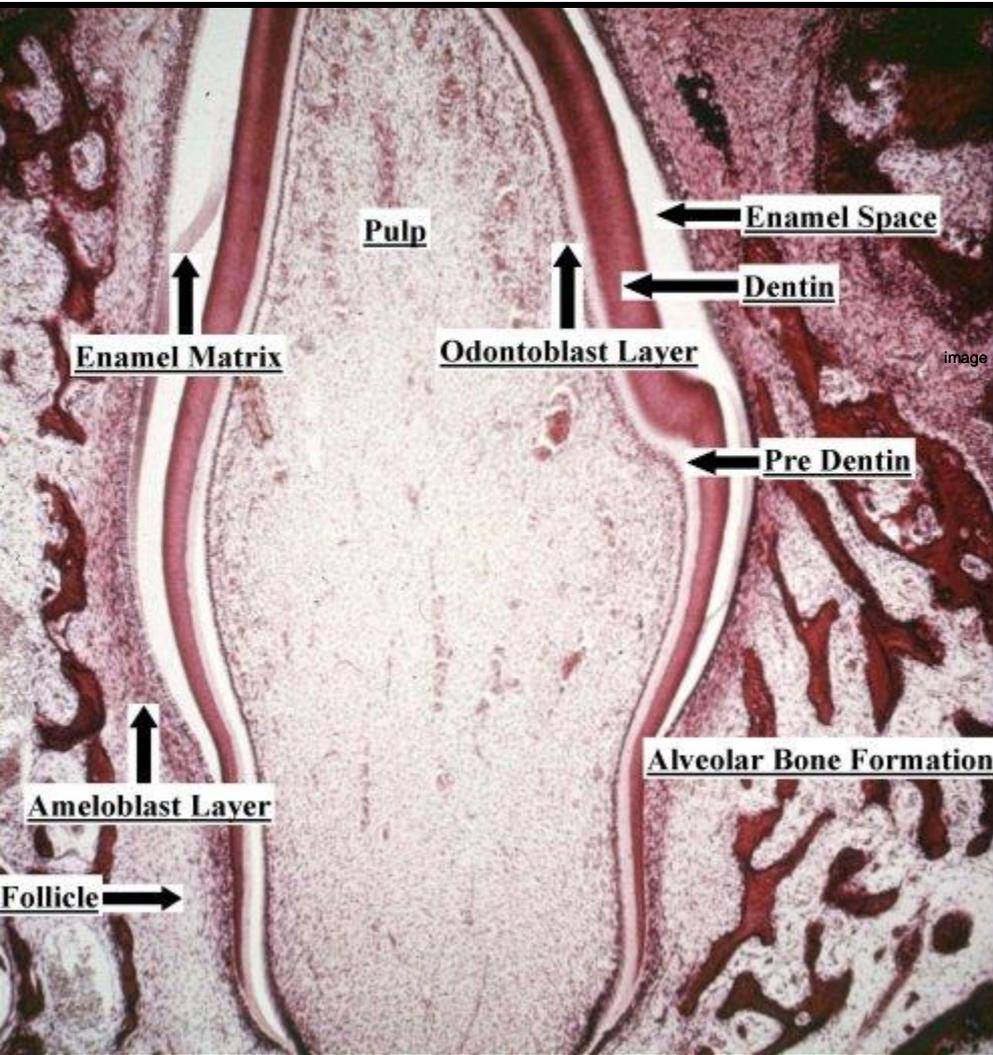
Differentiation of cementoblasts
from dental sac cells



Formation of cementum
on the surface of root dentin



SINGLE ROOT FORMATION



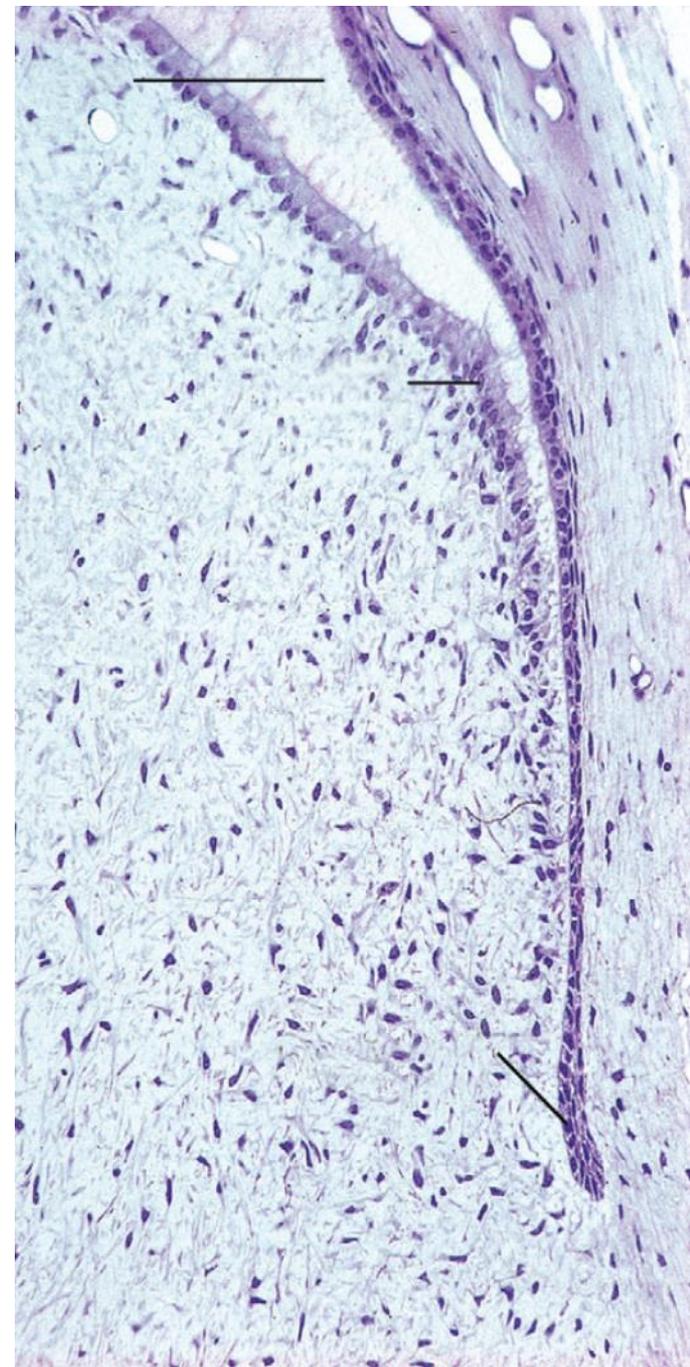
The single rooted tooth:

When the enamel and dentine formation reached the future cementoenamel junction.

The cervical loop (the inner & outer enamel epithelia without the stellate reticulum and stratum intermedium) begins to grow deeper into the surrounding ectomesenchyme of the dental sac, elongating and forming Hertwig's epithelial root sheath (HERS)

At the first (HERS) bends at the future cementoenamel junction into horizontal plane known as epithelial diaphragm. (produces narrowing of the wide cervical opening of the tooth germ).

The plane of the diaphragm remains relatively fixed during the root development. The epithelial sheath of Hertwig proliferates coronally to the diaphragm in a vertical direction.



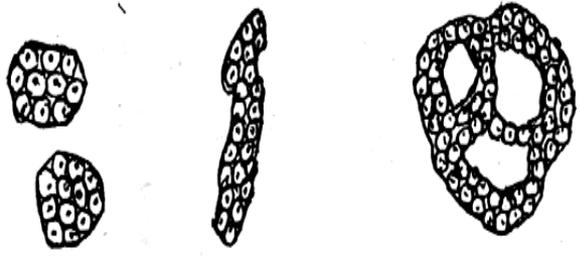
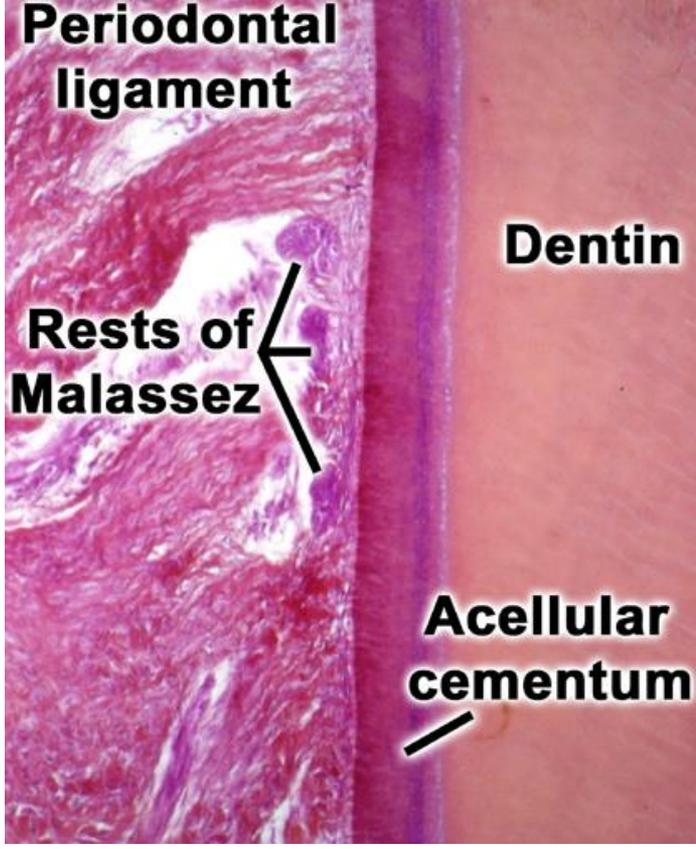
The cells of the inner enamel epithelium forming the sheath of Hertwig induce the undifferentiated mesenchymal cells of the dental papilla to differentiate into odontoblasts.

The function of the root sheath is to mold the shape of the root and initiate dentine formation.

After dentine deposition, the connective tissue of the dental sac proliferates and invades the Hertwig epithelial root sheath dividing it into a network of epithelial strands known as **epithelial rests of Malassez**.

These strands are moved away from the surface of dentine so that the connective tissue cells of dental sac in contact with the outer surface of dentine are differentiated into cementoblasts which deposit cementum on the dentine surface.

The **epithelial rests of Malassez** may undergo degeneration; remnants may persist in the periodontal ligament.



Rosettes. Strand. Network.

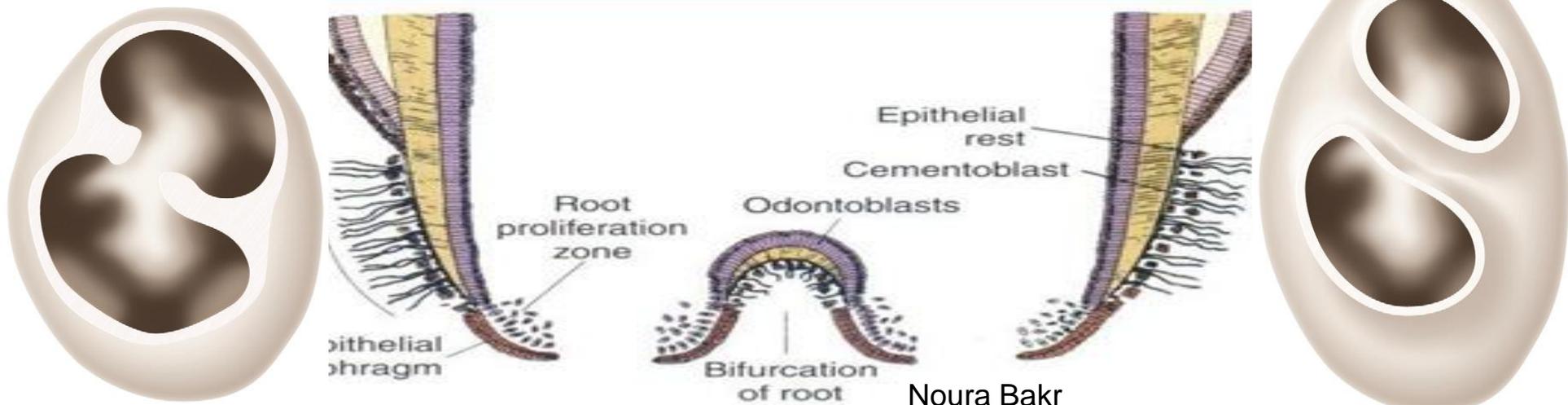
The multirooted teeth:

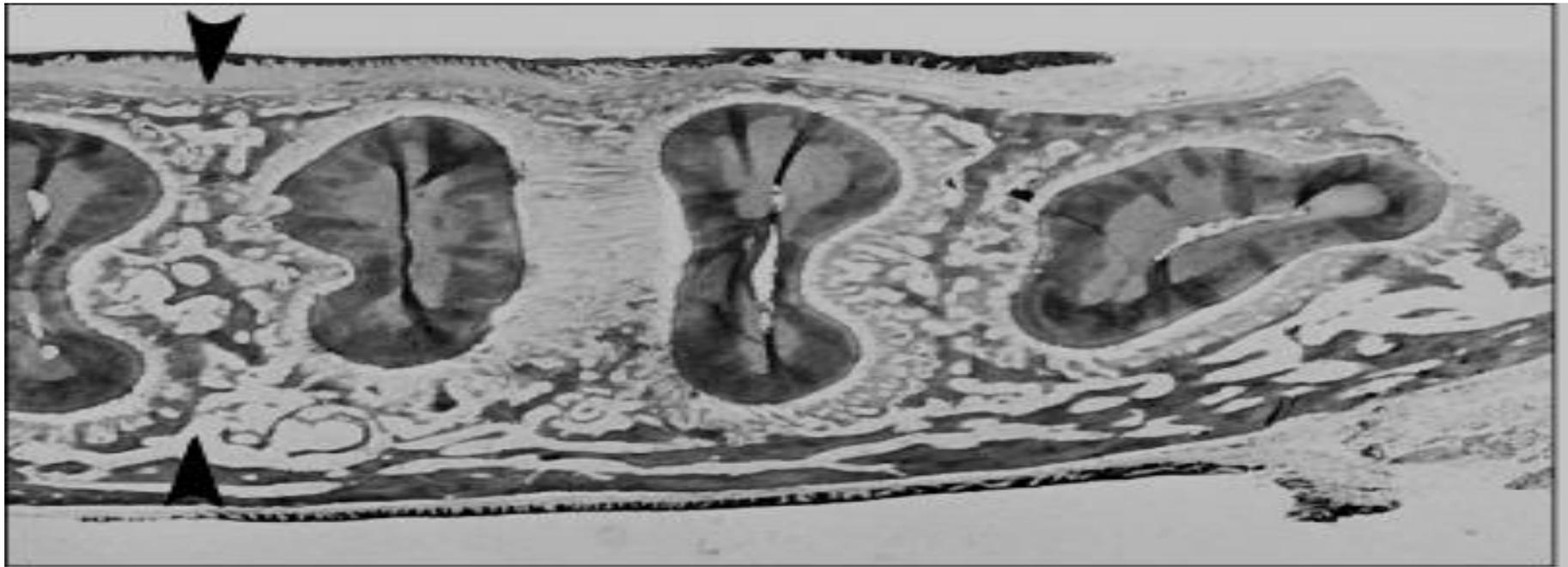
The deciduous and permanent molars and some premolars have more than one root.

* Their roots are formed like the single rooted tooth till it reaches the level of bi-or trifurcation where the epithelial diaphragm proliferates horizontally producing tongue like extensions (2 tongue extensions in case of 2 rooted tooth and 3 in the three rooted tooth).

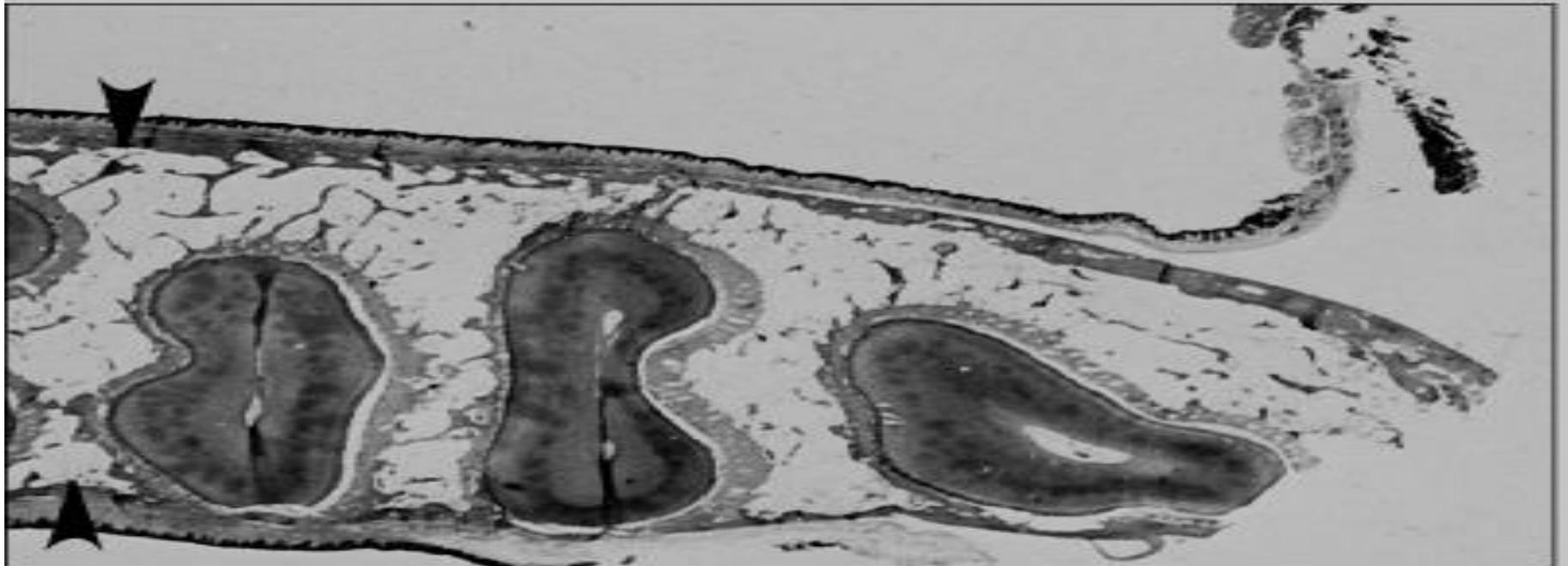
* At the region of future bifurcation of the roots the free ends of these tongue like extensions grow towards each other and fuse dividing the wide opening into 2 or 3 partitions.

Bifurcation root zone in multiple root formation





A



B

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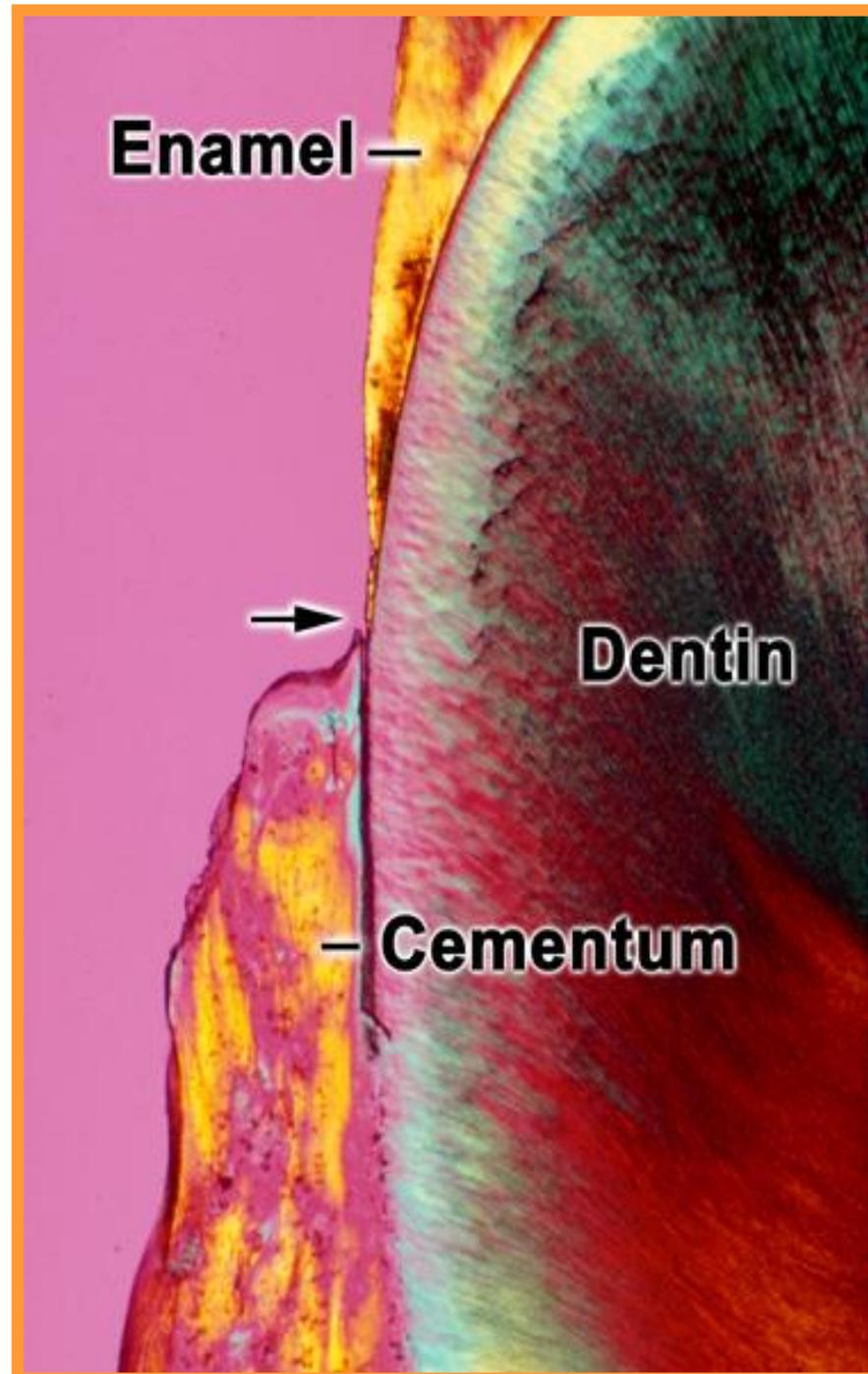
CLINICAL CONSIDERATIONS



Bare dentin

- If the epithelial root sheath of Hertwig is **delayed in its separation** from the dentin, a zone of the root is devoid of cementum.
- In such a case the cemento enamel junction here consists only of a layer of dentin without enamel and cementum. This occurs in about 10% of the teeth.

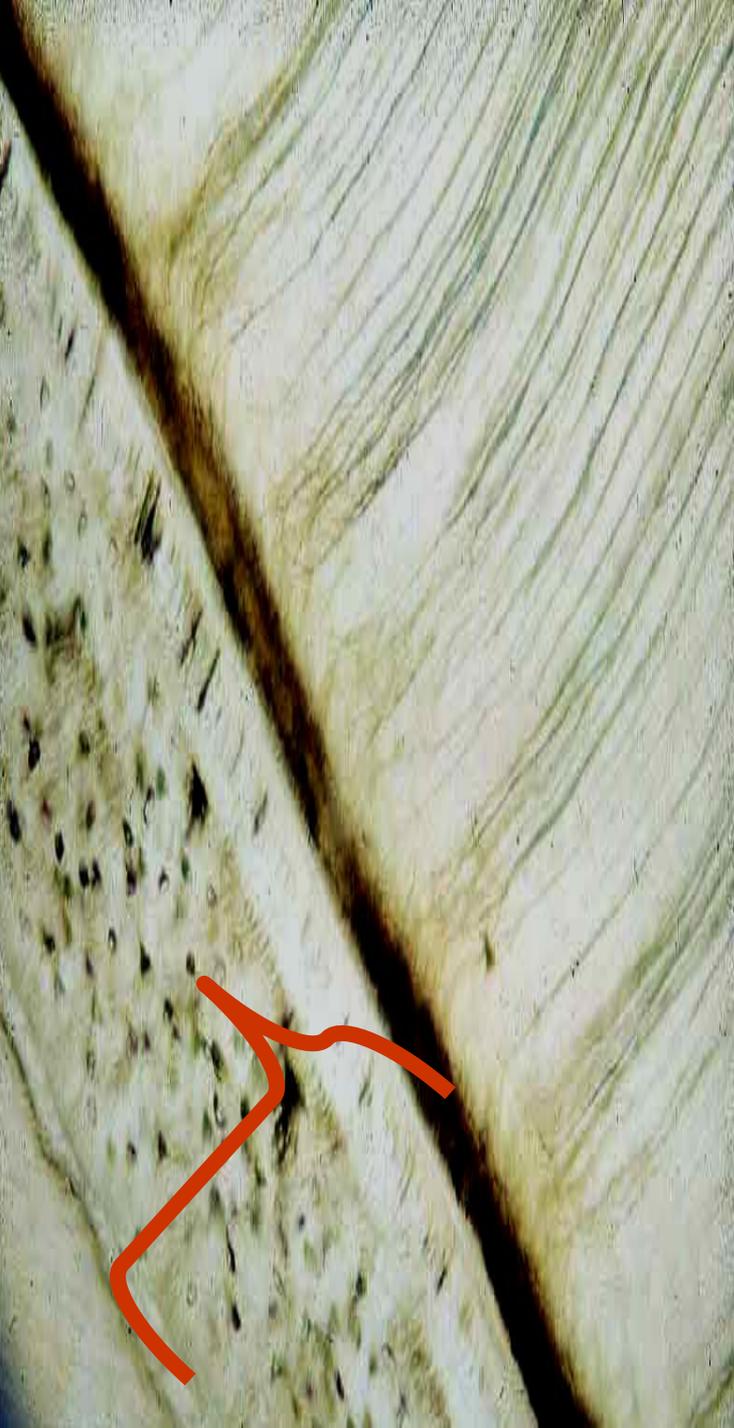
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Intermediate Cementum

If the continuity of the Hertwig's root sheath is broken **after** odontoblastic differentiation and before dentine formation, intermediate cementum is developed.

It occurs at apical 2/3 of premolars and molars roots and rare in incisors and deciduous teeth.



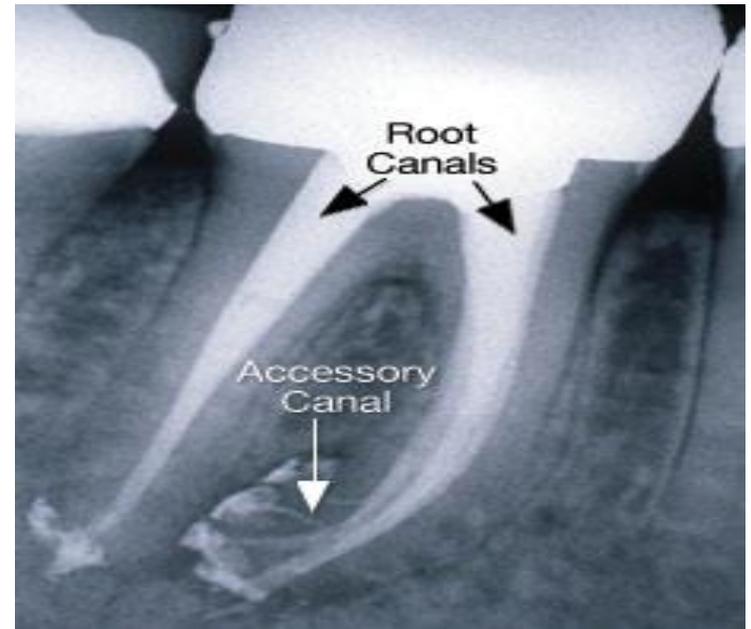
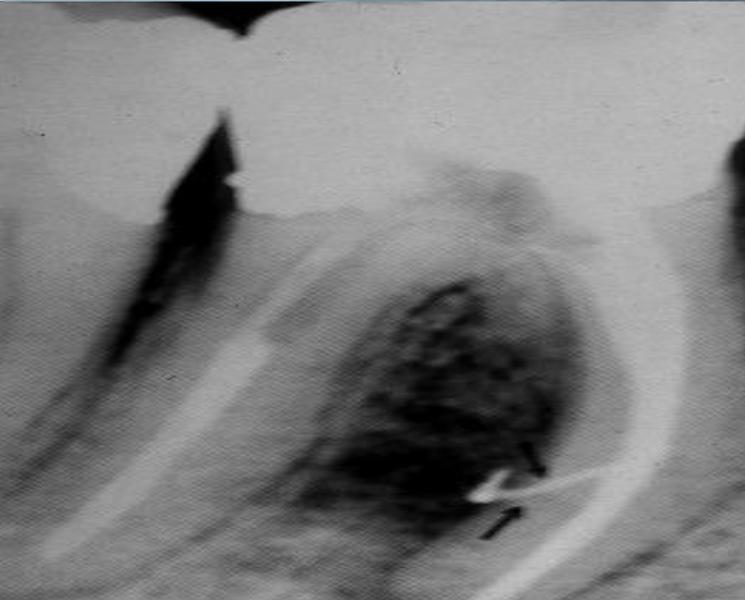
ACCESSORY ROOT CANAL



a) If the continuity of the epithelial root sheath of Hertwig is broken prior to odontoblastic differentiation and dentin formation.

b) The disturbance in the fusion of the tongue like extension of the diaphragm in the pulpal floor.

c) Large blood vessel may disturb the course of the root sheath lead to accessory root canal.



ENAMEL PEARL



If the cells of the epithelial root sheath of Hertwig remain adherent to the dentin surface, they may differentiate into ameloblasts and produce enamel, called enamel pearls.

They appear as small, spherical enamel projections especially at the cemento-enamel junction (CEJ) or in the furcation area in molars.

Stages of Tooth Development

Morphological stages	Histophysiological stages
1- Dental lamina	1- Initiation (D.L & bud stage)
2- Bud stage	2- Proliferation (all stages)
3- Cap stage	3- Histodifferentiation (bell stage)
4- Bell stage: - early bell - late bell	4- Morphodifferentiation (bell stage)
	5- Apposition (Late bell stage)

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- (3) Fu Wang, Guoqing Li, Zhifang Wu, Zhipeng Fan, Min Yang, Tingting Wu, Jinsong Wang, Chunmei Zhang and Songlin Wang, Tracking diphyodont development in miniature pigs in vitro and in vivo , Biology Open, (2019).
- (4) Jennifer Rosowski, Julia Bräunig, Anna-Klara Amler, Frank P. Strietzel, Roland Lauster and Mark Rosowski, Emulating the early phases of human tooth development in vitro, Scientific Reports, (2019).

Thank you

Dr. Noura Bakr

NOURA BAKR

