ORAL HISTOLOGY and EMBRYOLOGY COURSE

ORAL HISTOLOGY AND EMBRYOLOGY COURSES

- Oral Histology and Embryology Practical lectures will be every Monday at 01:30 in Biology and Histology lab.
- Oral Histology and Embryology Theoretical Lectures will be every Monday at 09:00 in Dentistry Hall.
- Lecturer: Dr. Duran Kala
- Lab assistant: Rojan Arif

Exams and Grades:

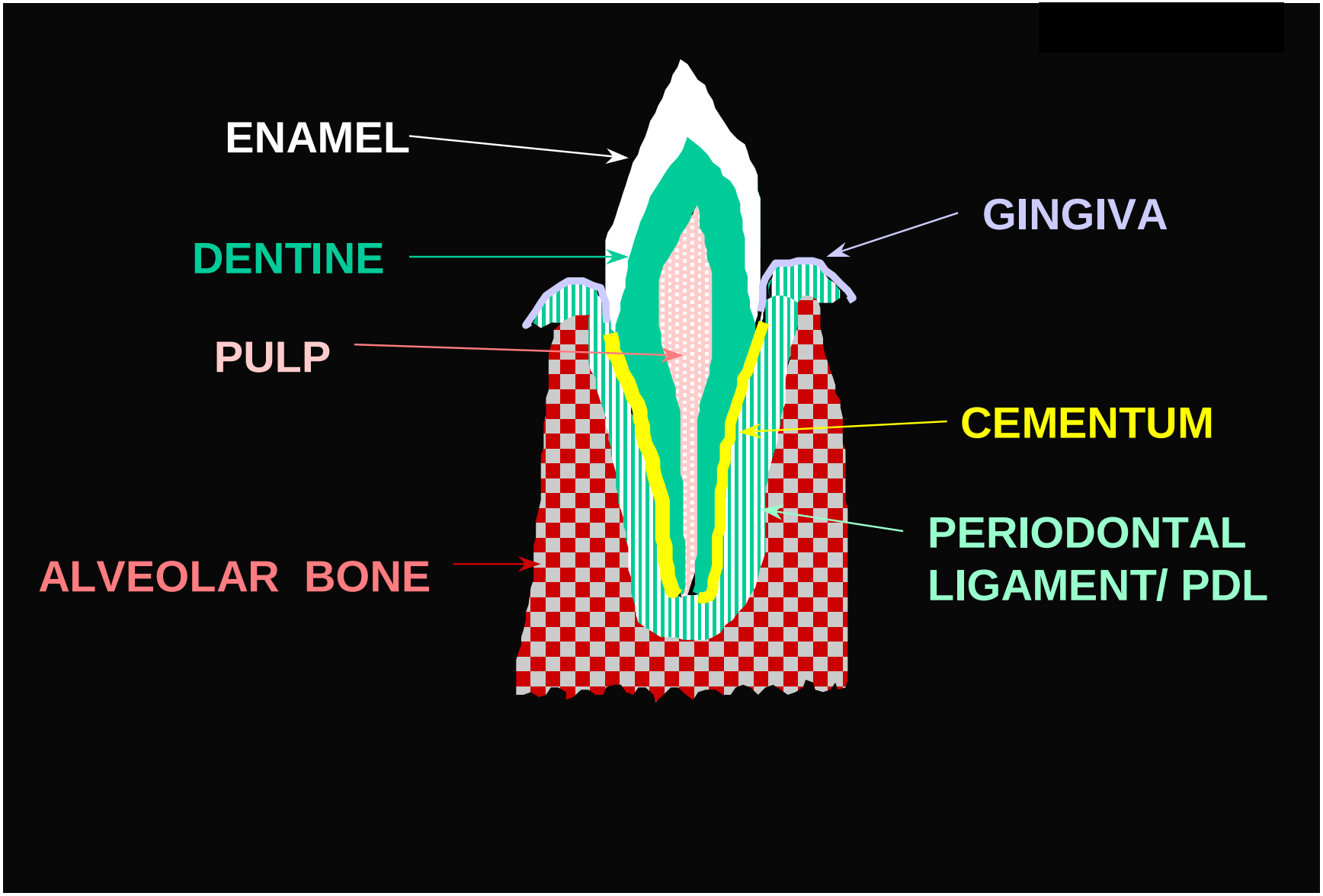
- In Histology and Embryology courses There will be:
- - Midterm practical exams = 10%
- - Lab Manuals = 10 %
- - Theoretical Midterm exams = 30%
- - Final Practical exam = 10%
- - Final Theoretical exam = 40%
- - Total = 100%

CHAPTERS

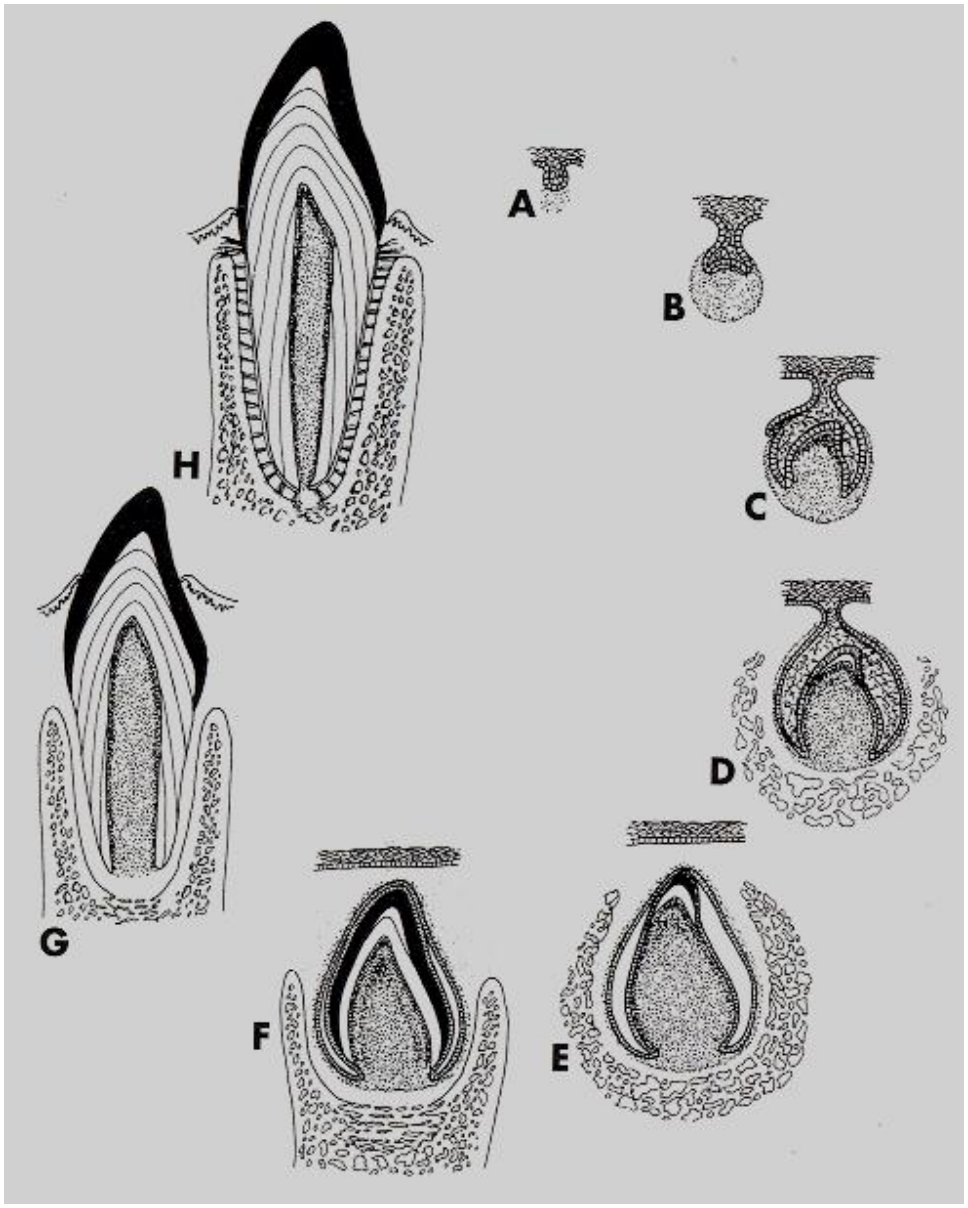
- 1-TOOTH DEVELOPMENT AND GROWTH
- 2-ENAMEL
- 3-DENTIN
- 4-CEMENTUM
- 5-PULP
- 6-PDL
- 7-EMBRYOLOGY
- 8-MANDIBLE
- 9-MAXILLA
- 10-BONE TISSUE TYPES
- 11-ALVEOLAR PROCESS
- 12-ORAL MUCOSA-SALIVARY GLANDS

- Histology is the study of anatomy that deals with the minute structure, composition, and functions of tissues. Oral histology describes in detail the tissues of the teeth, periodontium, and the surrounding oral mucosa.

Tooth and Associated Structures



Tooth Development



A. Bud Stage
B. Cap Stage
C. Bell Stage

D and E. Dentinogenesis and amelogenesis

F. Crown formation

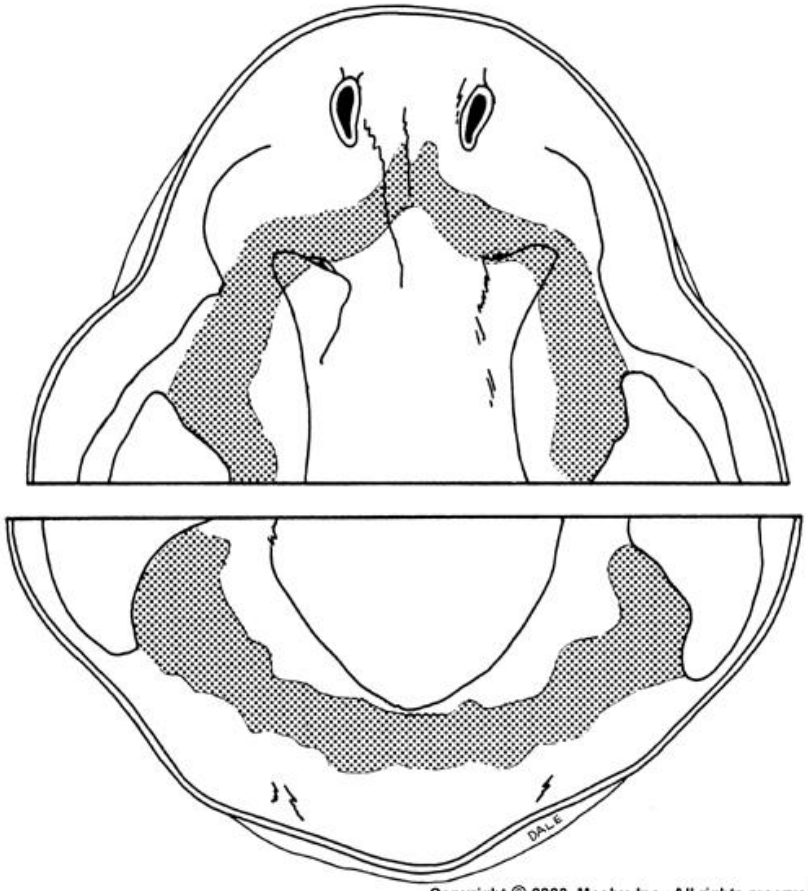
G. Root Formation and eruption

H. Function

Essentials of Oral Histology and Embryology, Ed: James Avery, 2nd edition. 2000.

Initiation of Tooth Development

The initiation of tooth development begins at 37 days of development with formation of a continuous horseshoe-band of thickened epithelium in the location of upper and lower jaws – **Primary Epithelial Band**



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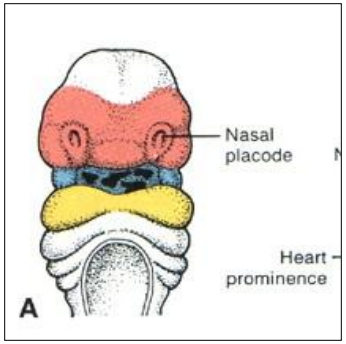
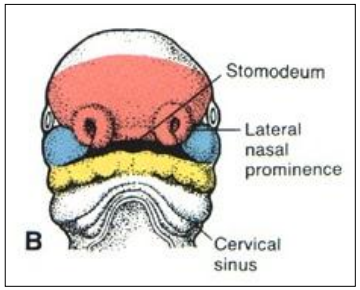
Each band of epithelium will give rise to 2 sub divisions:

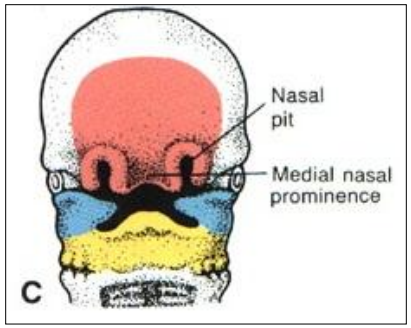
1. Dental lamina and
2. Vestibular lamina Responsible for the formation of the vestibule (the space bordered by the junction of the gingiva and the tissue of the inner cheek)

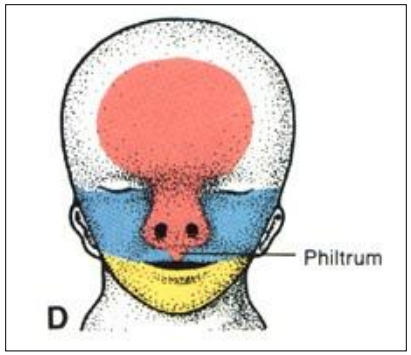
Figure from Ten Cate's Oral Histology, Ed., Antonio Nanci, 6th edition

Front view

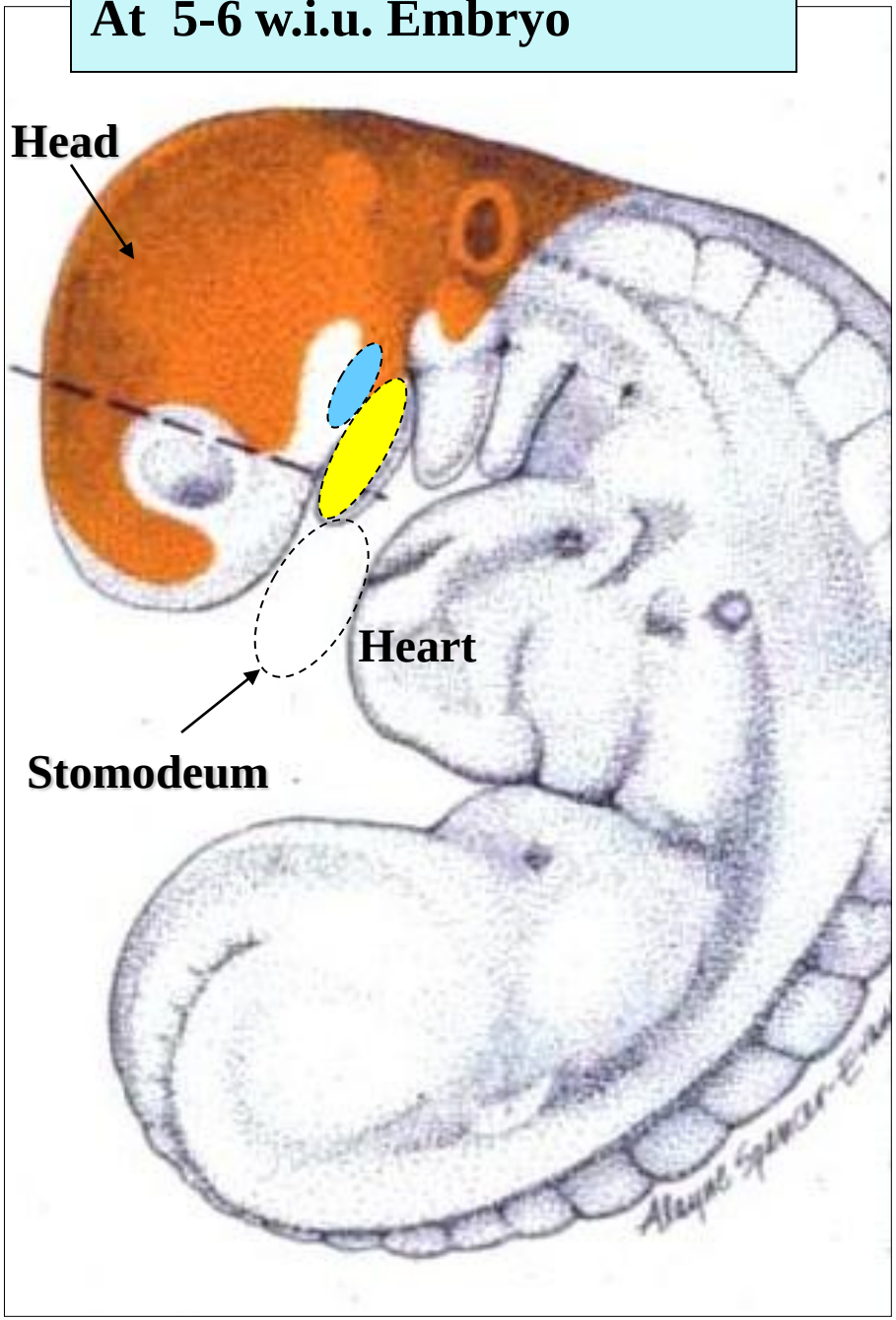




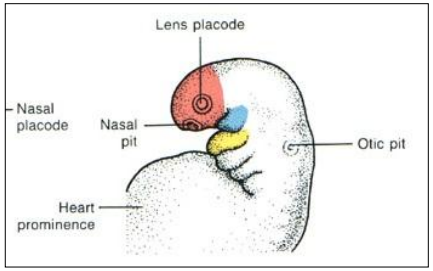


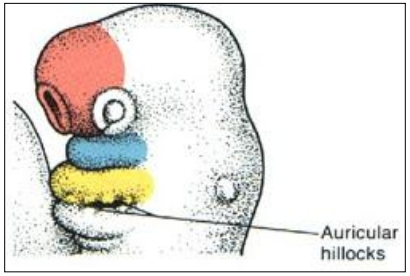


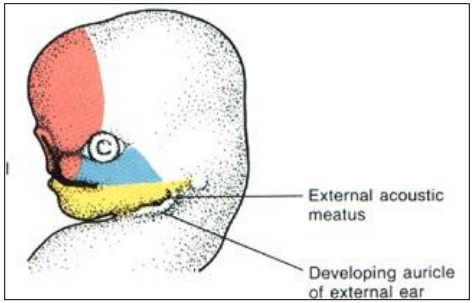
At 5-6 w.i.u. Embryo

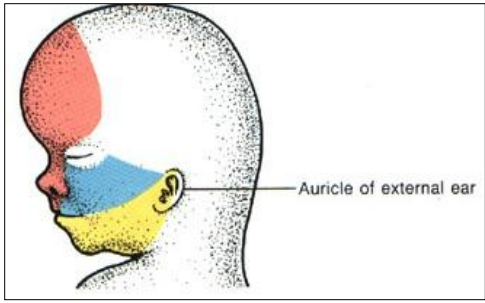


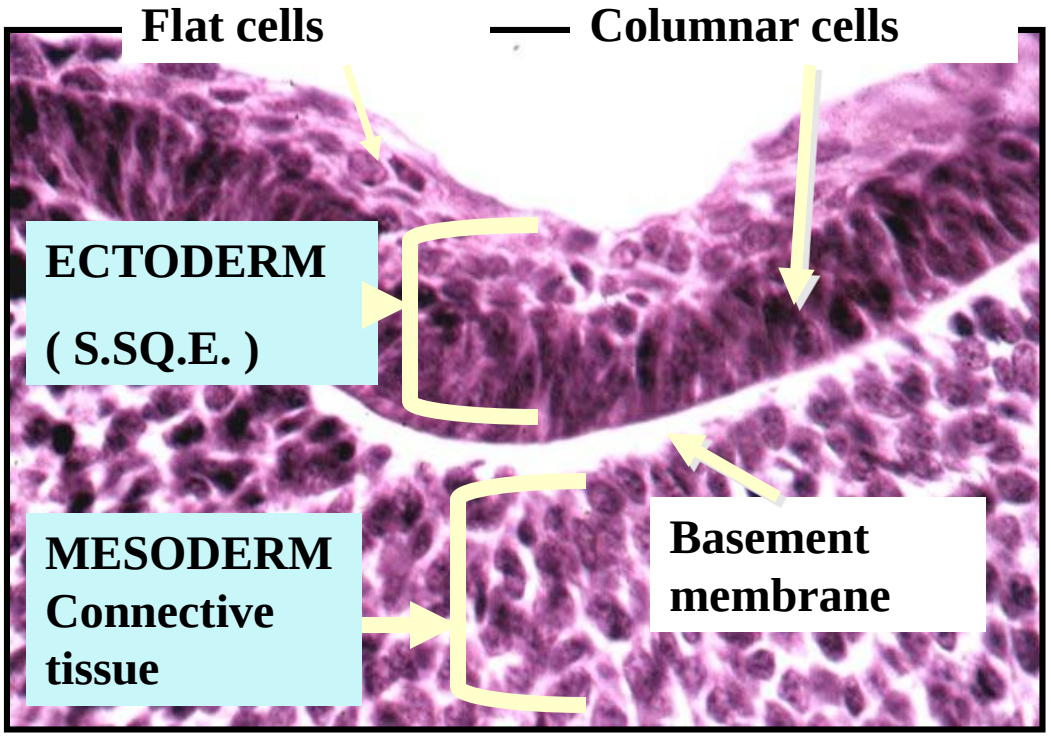
Lateral view

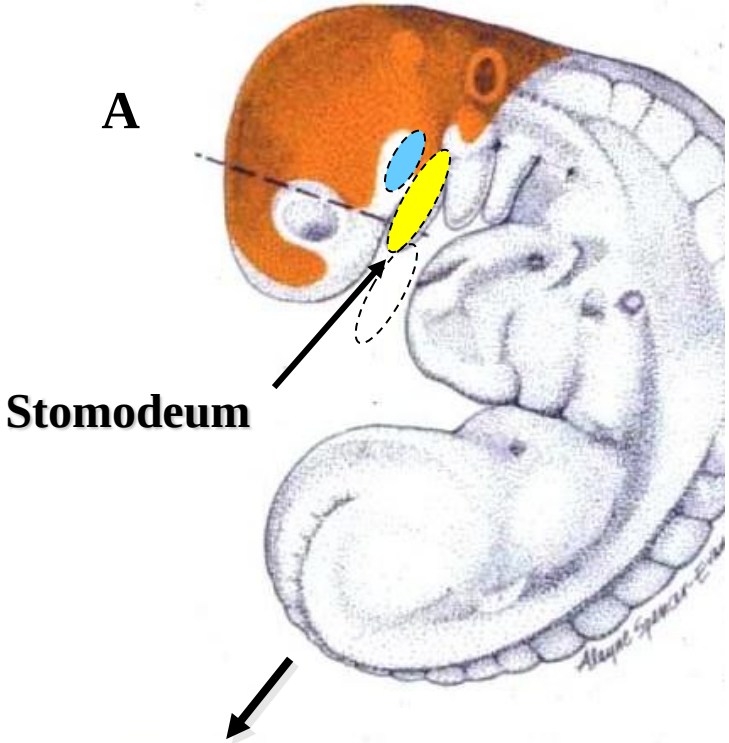


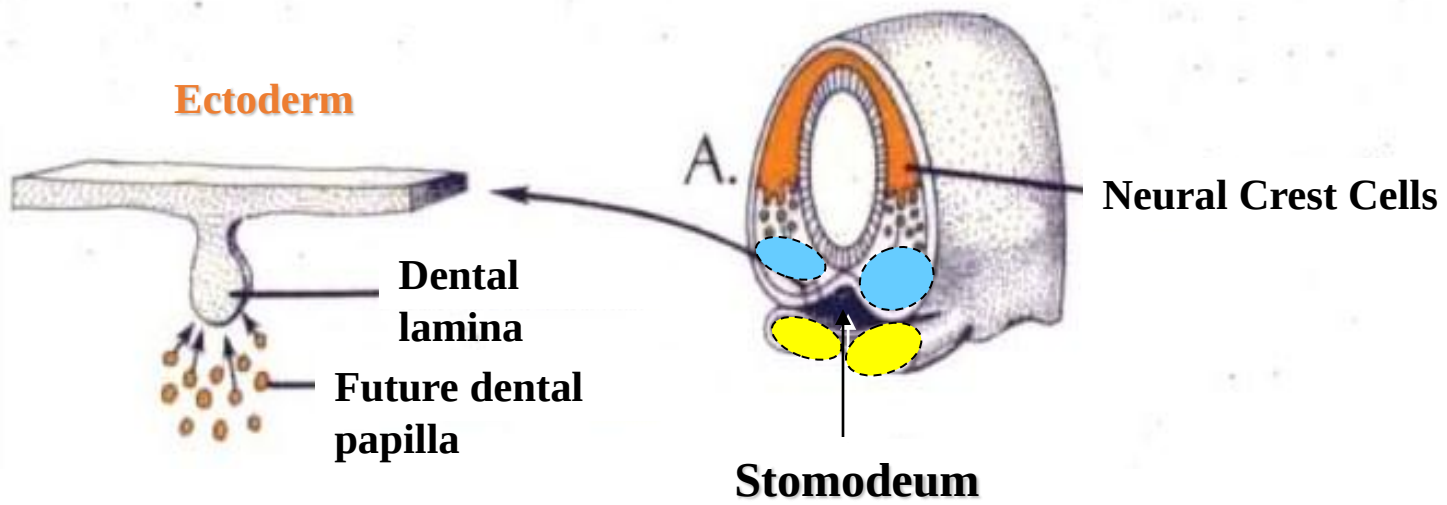


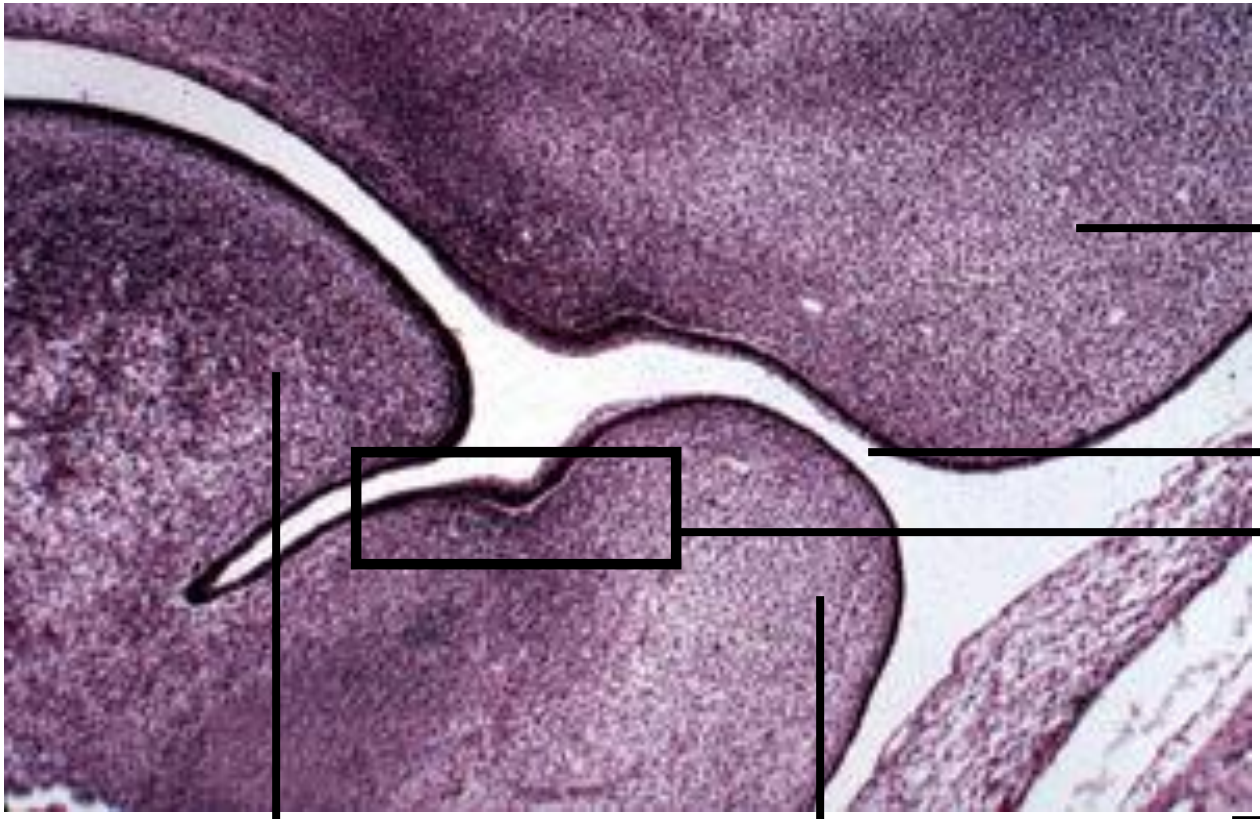





Flat cells
Columnar cells
ECTODERM
(S.SQ.E.)
MESODERM
Connective
tissue
Basement
membrane

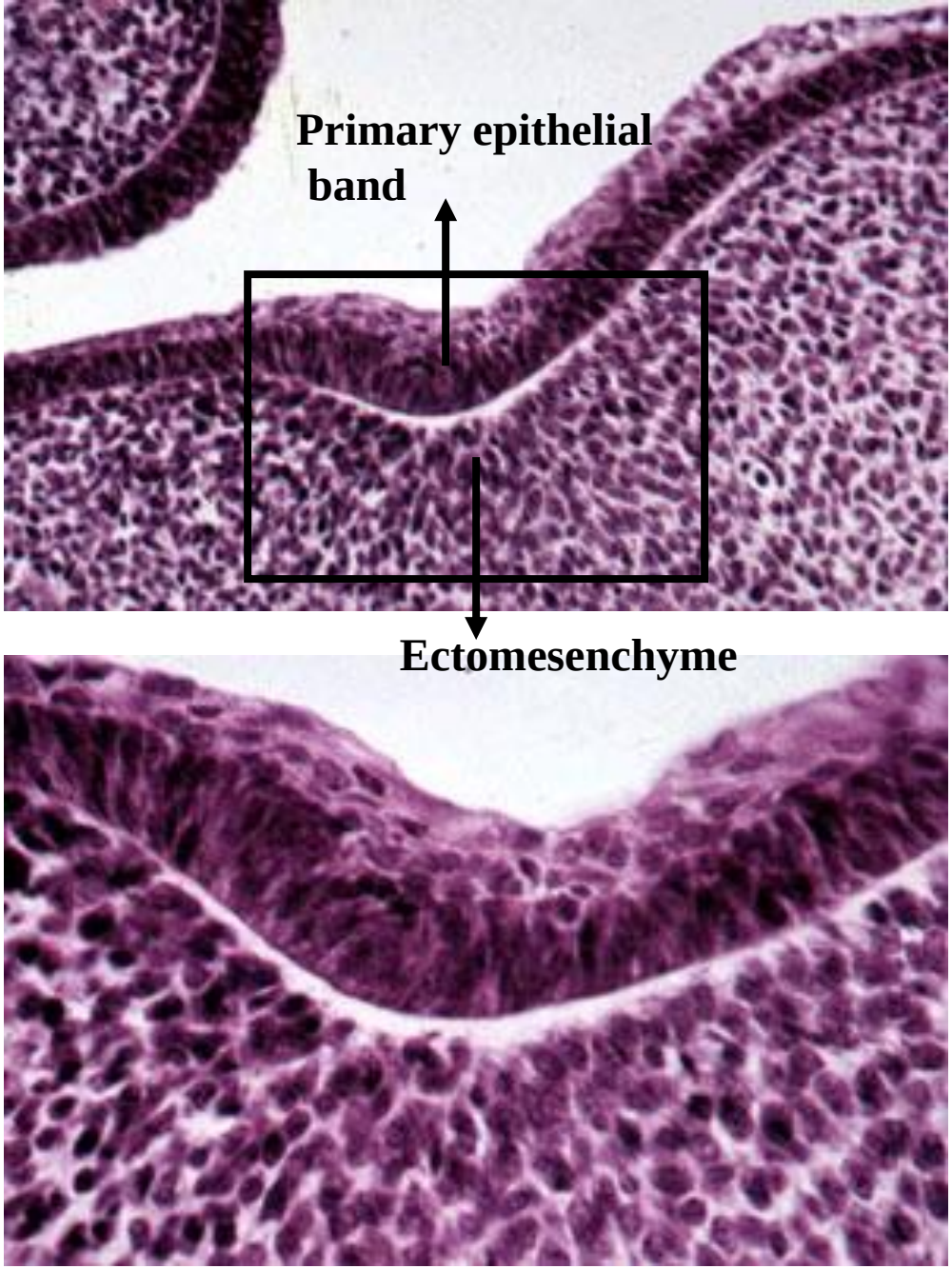

A
Stomodeum


Ectoderm
A.
Neural Crest Cells
Dental
lamina
Future dental
papilla
Stomodeum



http://www.usc.edu/hsc/dental/ohisto/

Dental Lamina



Figures from: http://www.usc.edu/hsc/dental/ohisto/

- Dental lamina appears as a thickening of the oral epithelium adjacent to condensation of ectomesenchyme
- 20 areas of enlargement or knobs appear, which will form tooth buds for the 20 primary teeth
- Not all will appear at the same time. The first to develop are those of the anterior mandible region
- At this early stage the tooth buds have already determined their crown morphology
- Successional lamina: lamina from which permanent teeth develop
- The dental lamina begins to function at 6^{th} prenatal week and continues to 15^{th} year of birth (3^{rd} molar)

Vestibular Lamina

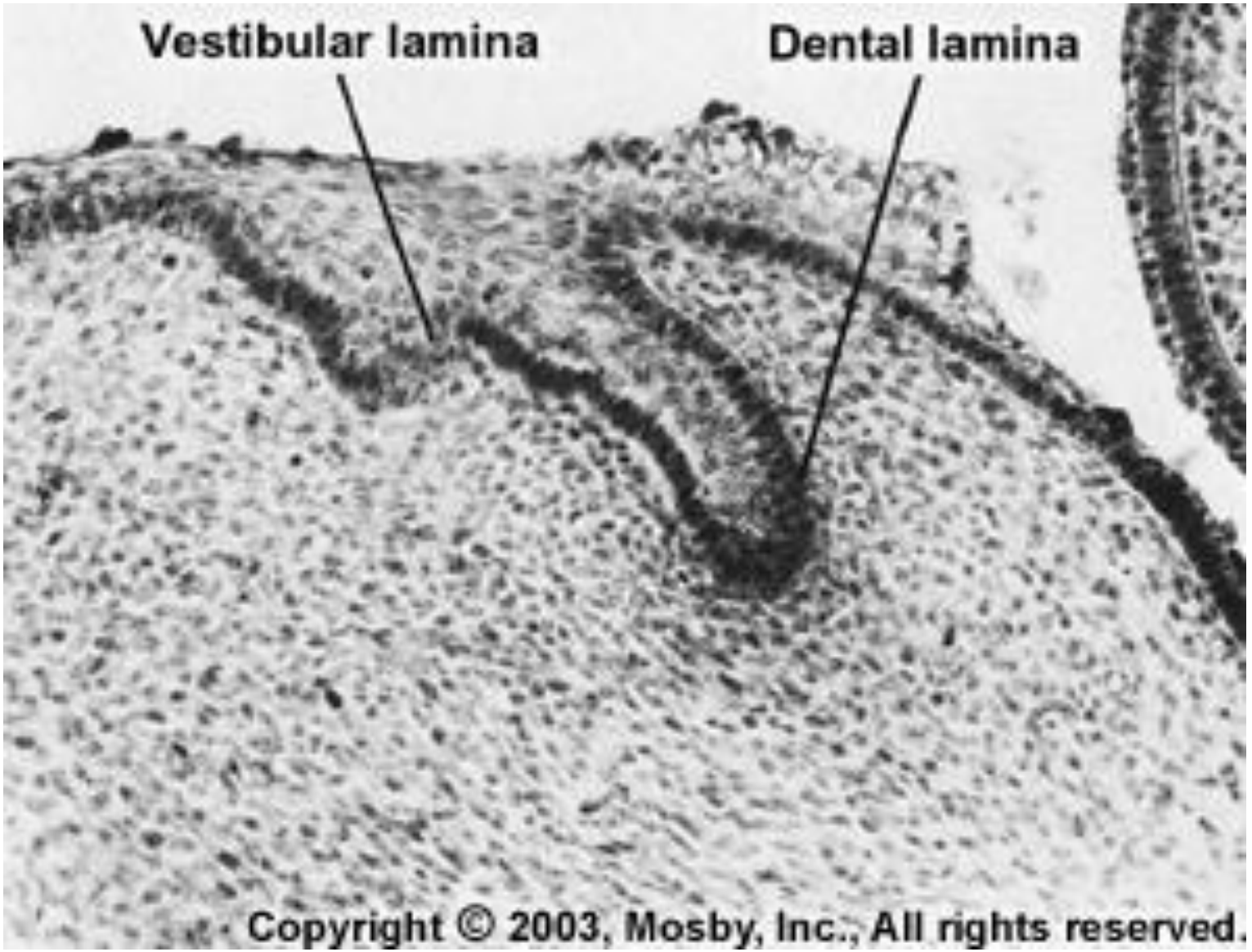


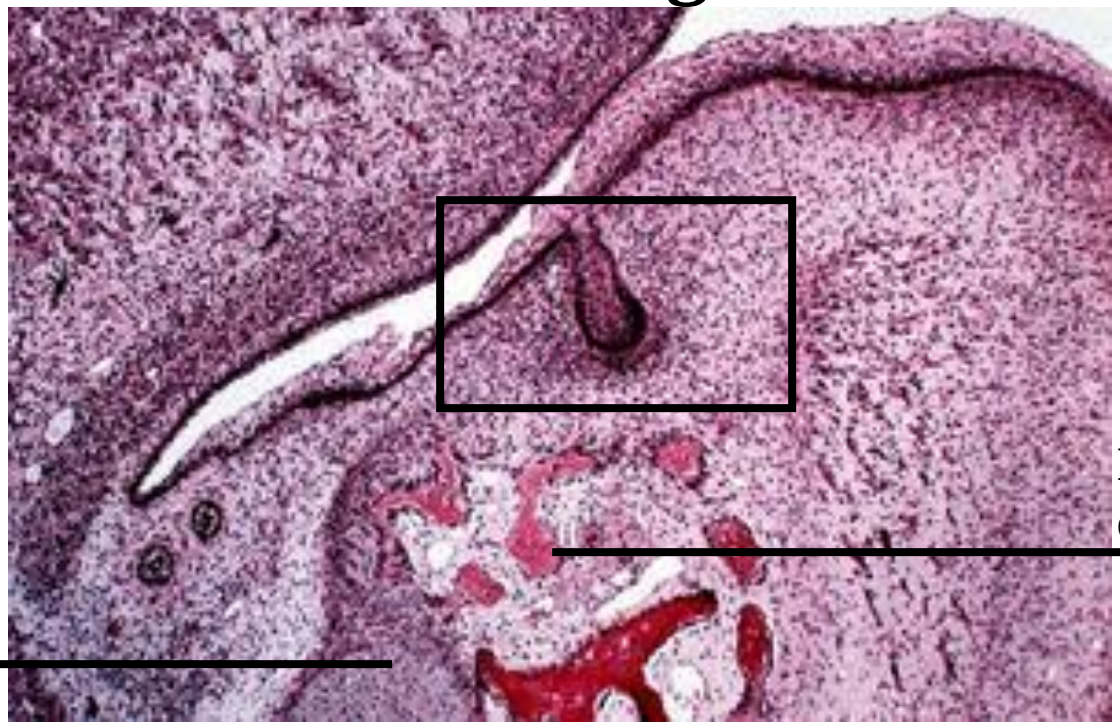
Figure from Ten Cate's Oral Histology, Ed., Antonio Nanci, 6th edition

Ectomesenchyme (ek´tōmez´ nkīm),
n a mass of tissue consisting of neurocrest cells present in the early formation of an embryo. It eventually forms the hard and soft tissues of the neck and cranium.

Tooth development is a continuous process, however can be divided into 3 stages:

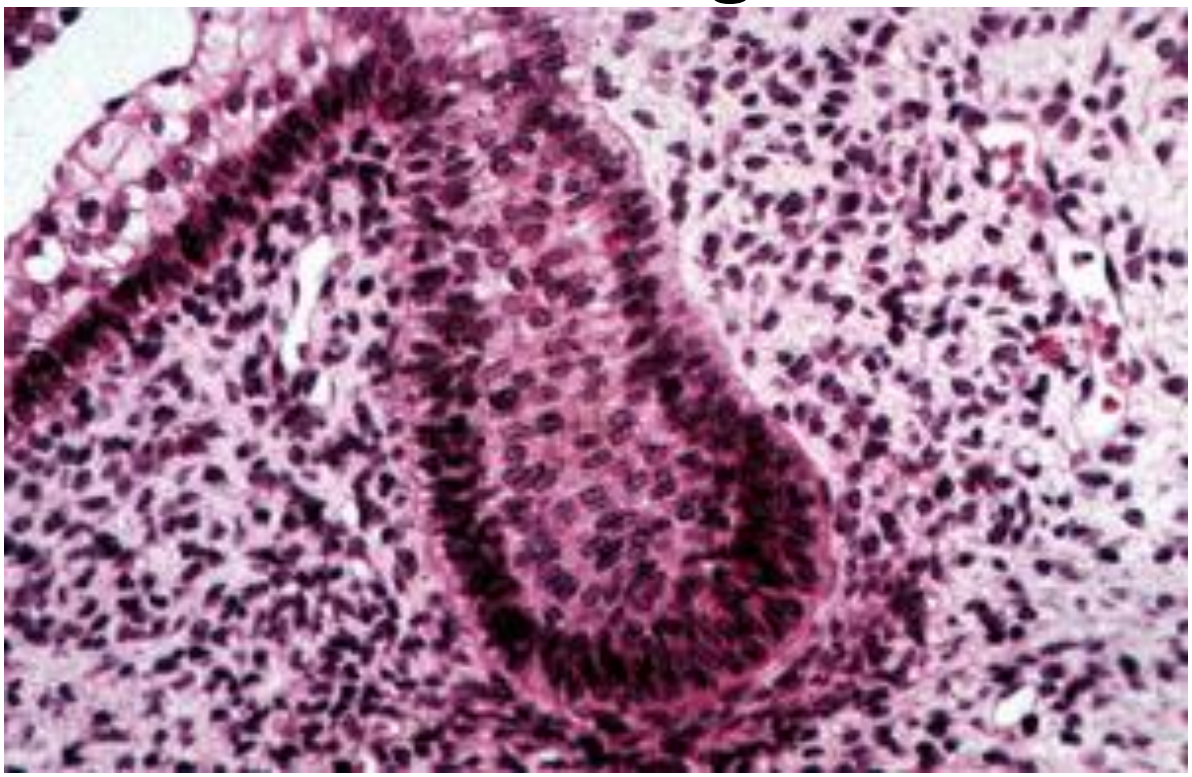
1. **Bud Stage**
2. **Cap Stage**
3. **Bell Stage**

1. Bud Stage



• **Bud stage is characterized by rounded, localized growth of epithelium surrounded by proliferating(reproducing rapidly) mesenchymal cells which are packed closely beneath and around the epithelial buds**

1. Bud Stage

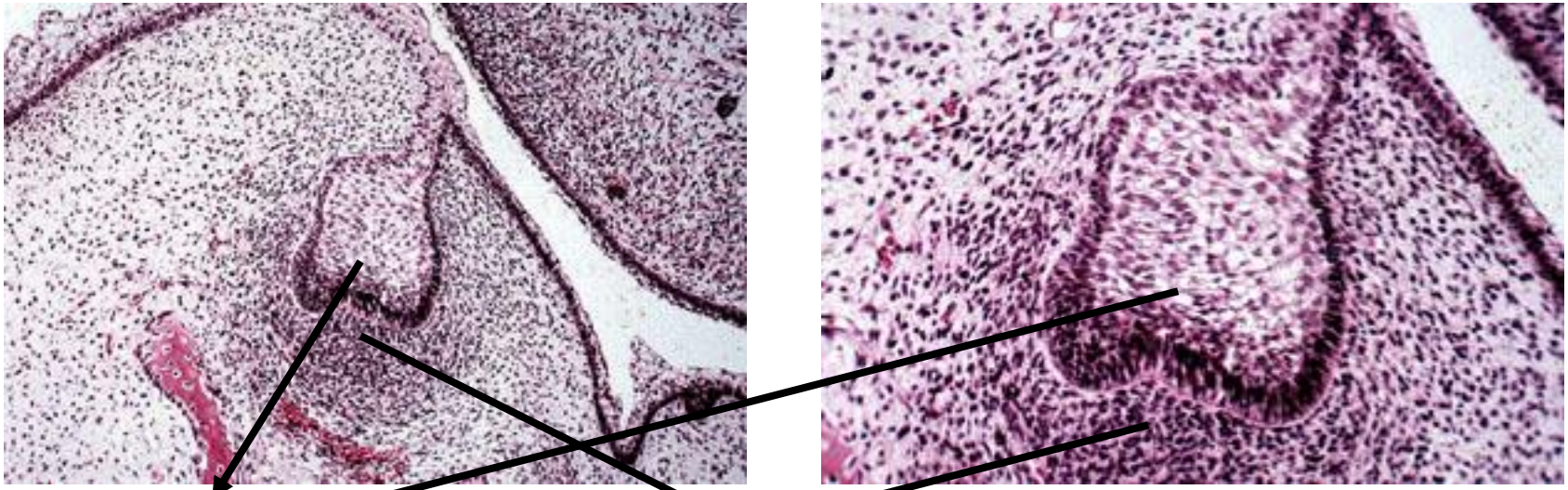


In the bud stage, the enamel organ consists of peripherally located low columnar cells and centrally located polygonal cells

http://www.usc.edu/hsc/dental/ohisto/

2. Cap Stage

2. Cap Stage



Enamel Organ

Dental Papilla

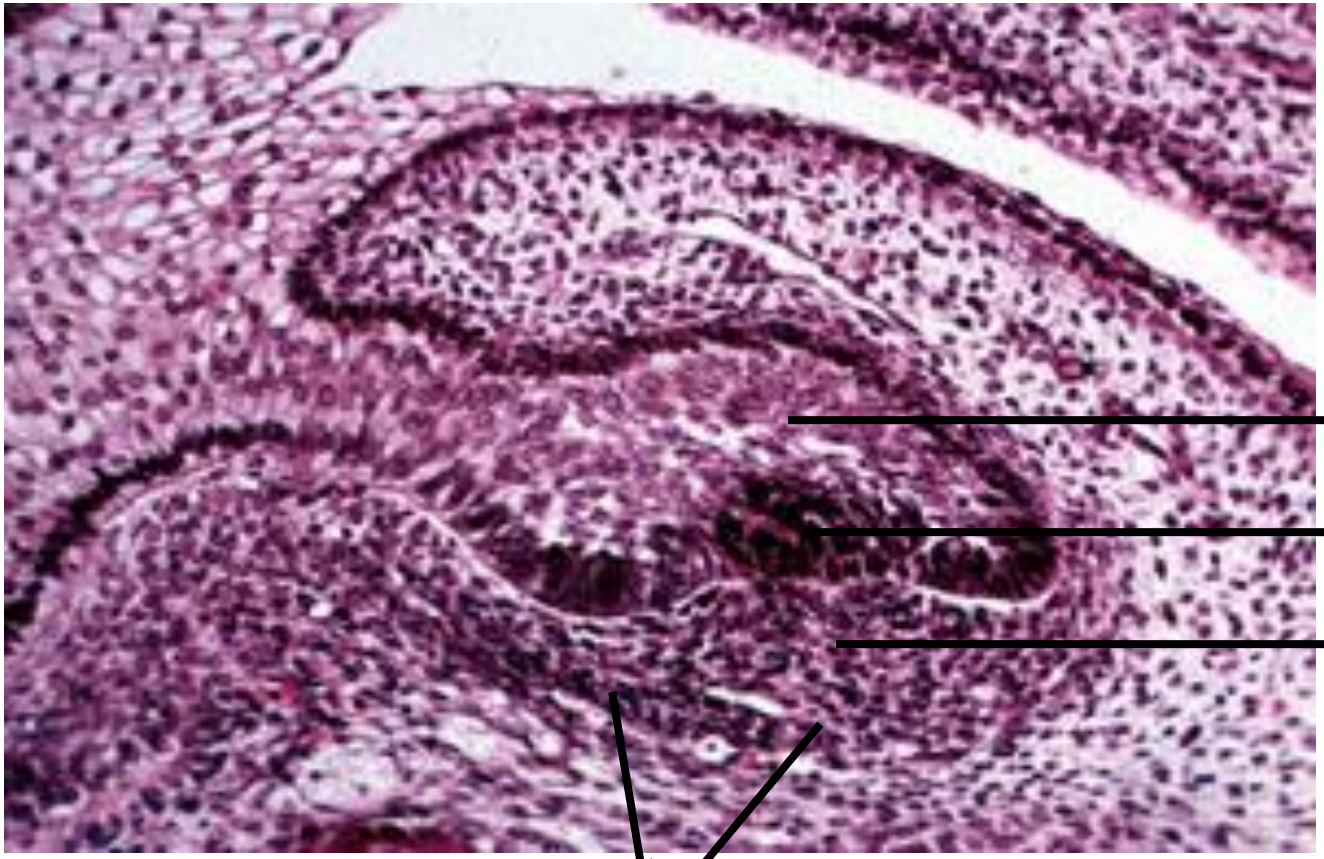
http://www.usc.edu/hsc/dental/ohisto/

Condensation of the ectomesenchyme immediately subjacent to the tooth bud caused by lack of extracellular matrix secretion by the cells thus preventing separation. Histodifferentiation begins at the end of cap stage.

Epithelial outgrowth called <u>Enamel Organ</u> because it will eventually form the enamel

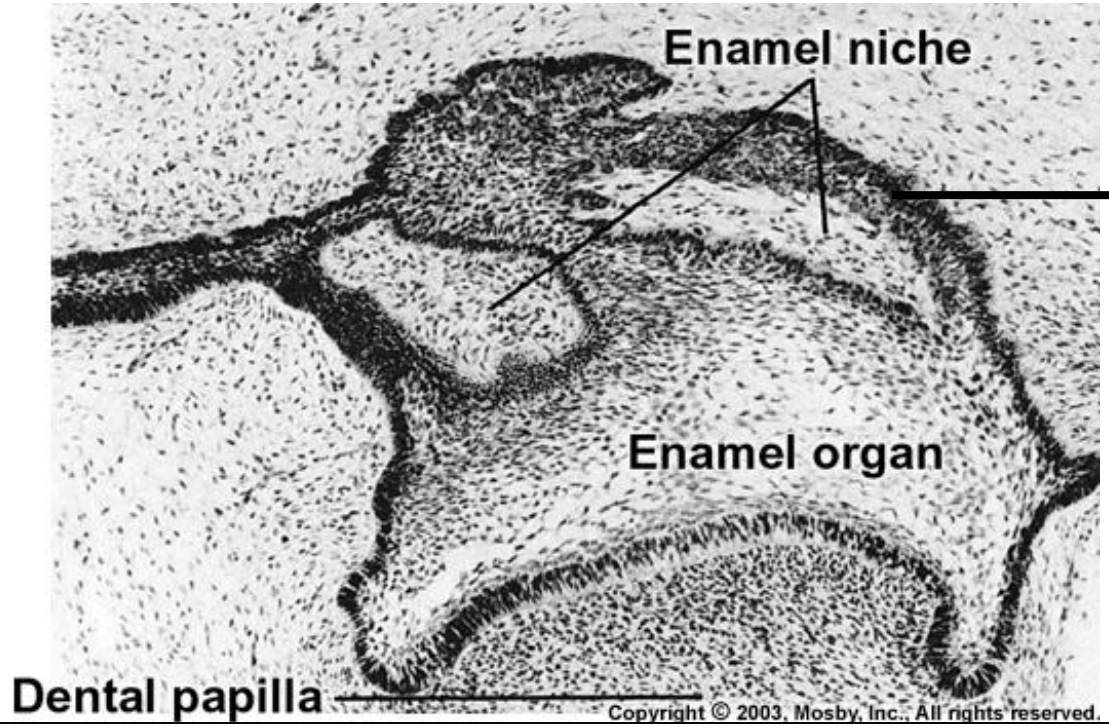
<u>Dental Papilla:</u> Ball of condensed ectomesenchymal cells (it will form dentin and pulp). The peripheral cells adjacent to the inner dental epithelium will enlarge and later differentiate into odontoblasts

2. Cap Stage



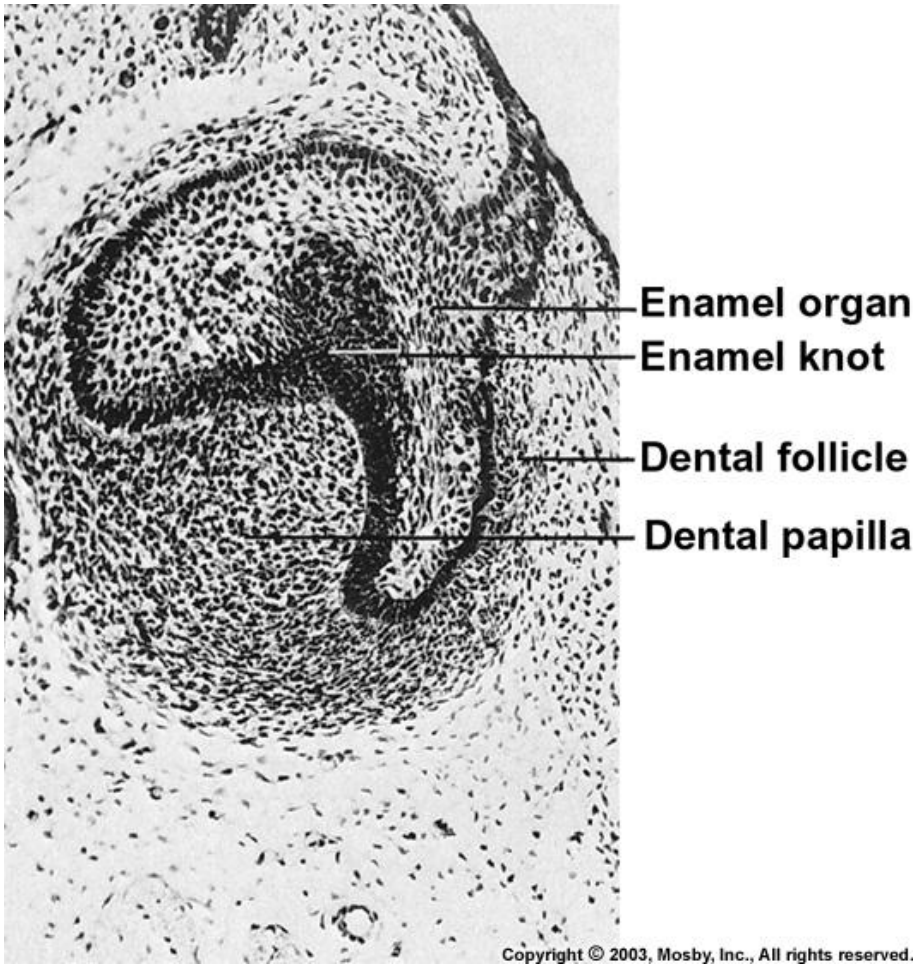
<u>Dental follicle or dental sac</u> is the condensed ectomesenchymal tissue surrounding the enamel organ and dental papilla. This gives rise to cementum and the periodontal ligament (support structures for tooth)

2. Cap Stage



<u>Lateral Lamina:</u> extension from the dental lamina that is connected to the enamel organ

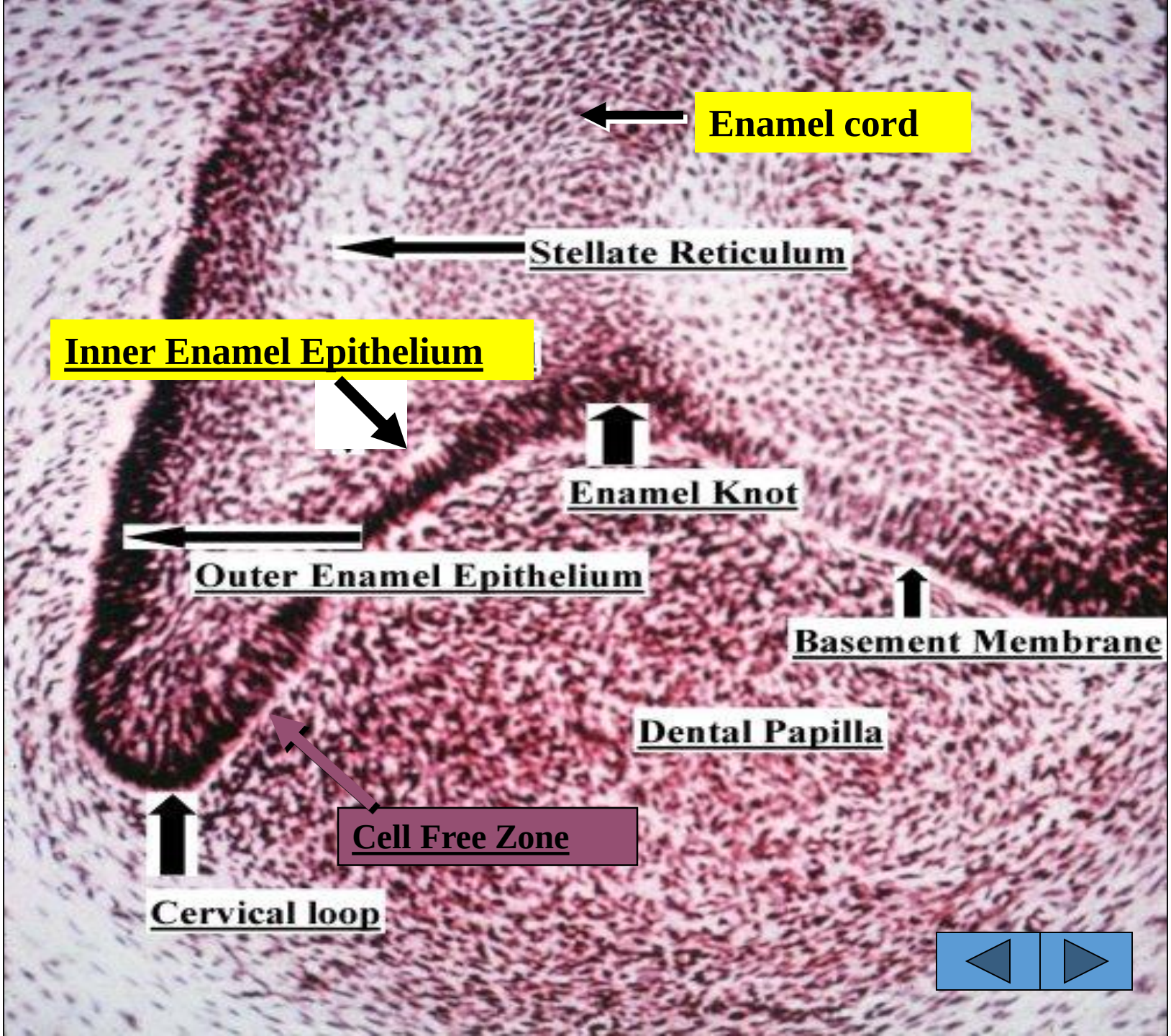
<u>Enamel niche:</u> It is an artifact produced during sectioning of the tissue. It occurs because the enamel organ is a sheet of proliferating cells rather than a single strand and contains a concavity filled with ectomesenchyme



<u>Enamel Knot:</u> Densely packed accumulation of cells projecting from the inner enamel epithelium into dental papilla. Exact role not known, but currently believed to be the organizational center for cusp development (a pointed structure on a cuspid, premolar, or molar).

<u>Dental organ or tooth germ</u> is a term used to constitute the structure that has enamel organ, dental papilla and dental follicle

CA
P
S
TA
GE


Enamel cord
Stellate Reticulum
Inner Enamel Epithelium
Enamel Knot
Outer Enamel Epithelium
Basement Membrane
Dental Papilla
Cell Free Zone
Cervical loop

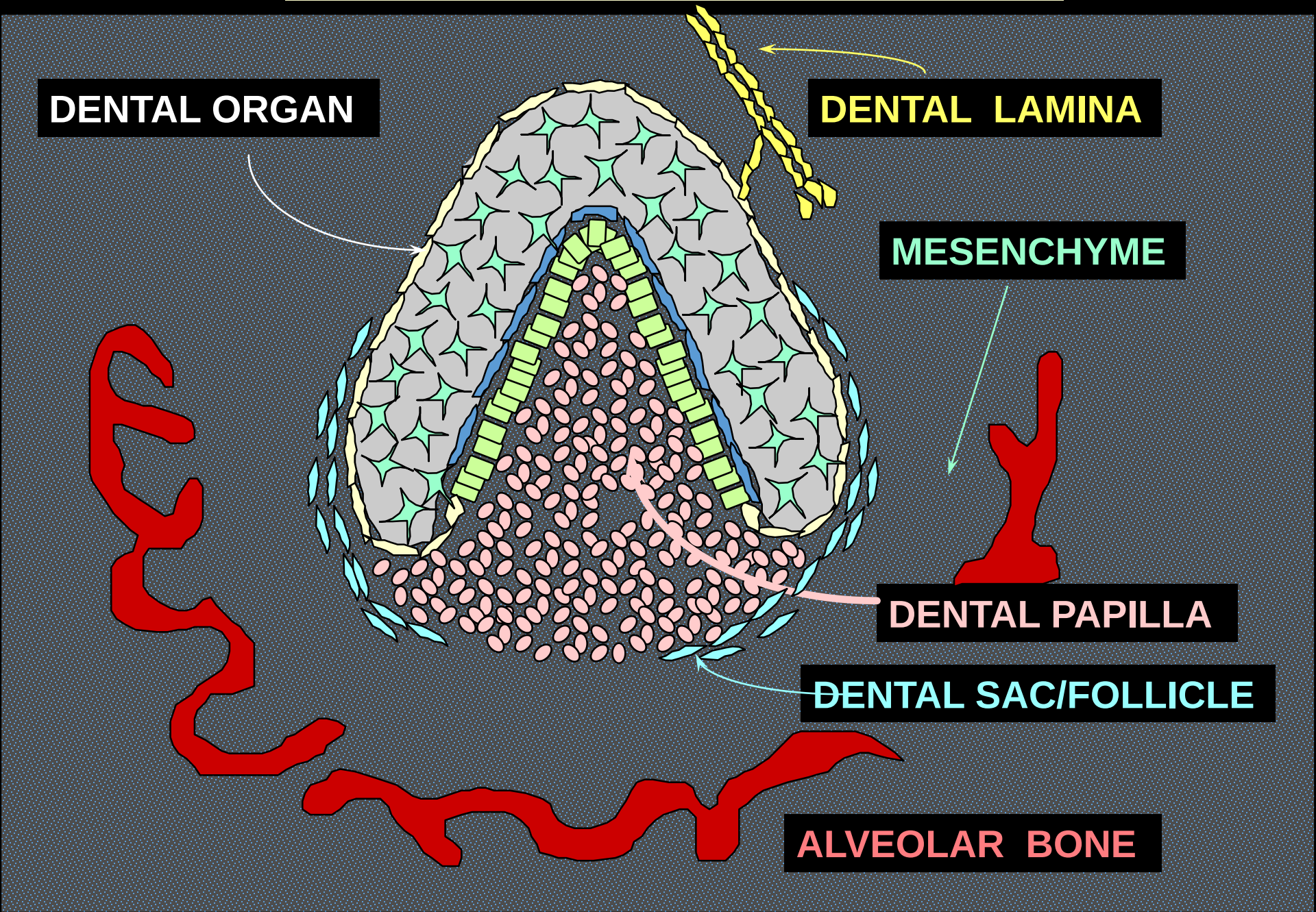
3. Bell Stage

http://www.usc.edu/hsc/dental/ohisto/

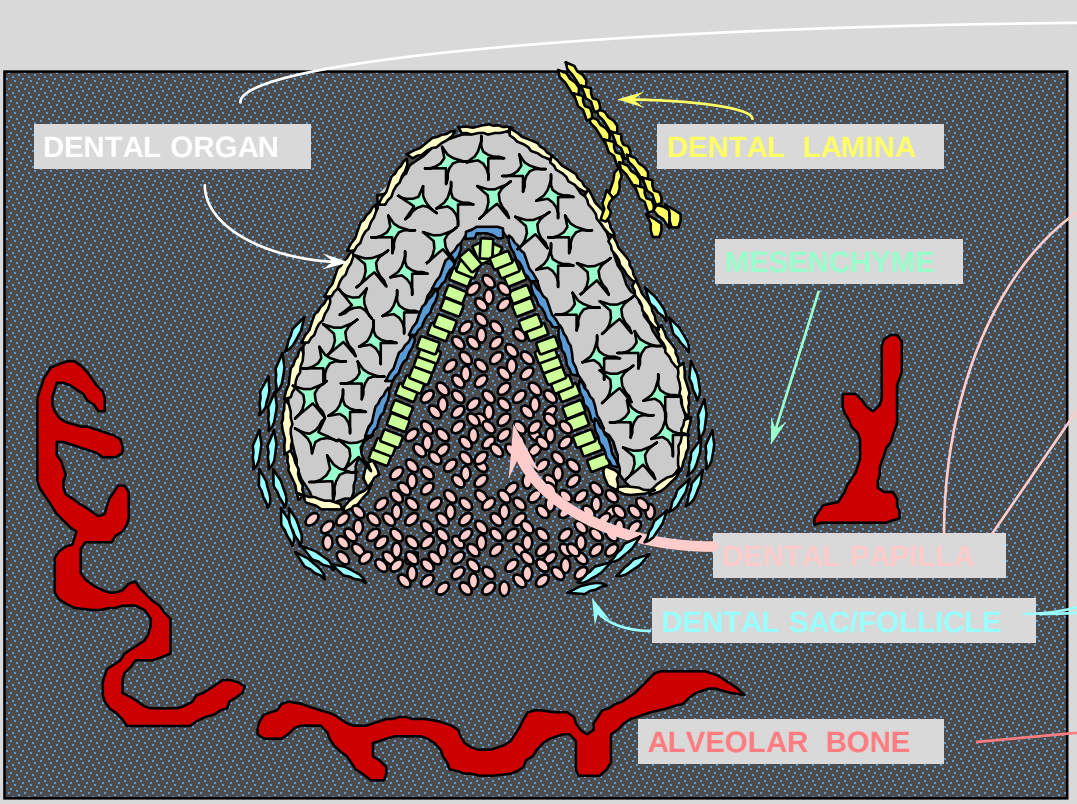
- Continued growth leads to bell stage, where the enamel organ resembles a bell with deepening of the epithelium over the dental papilla

- Continuation of histodifferentiation (ameloblasts and odontoblasts are defined) and beginning of morphodifferentiation (tooth crown assumes its final shape)

TOOTH PRIMORDIUM/GERM



TOOTH TISSUES: Sources



ENAMEL

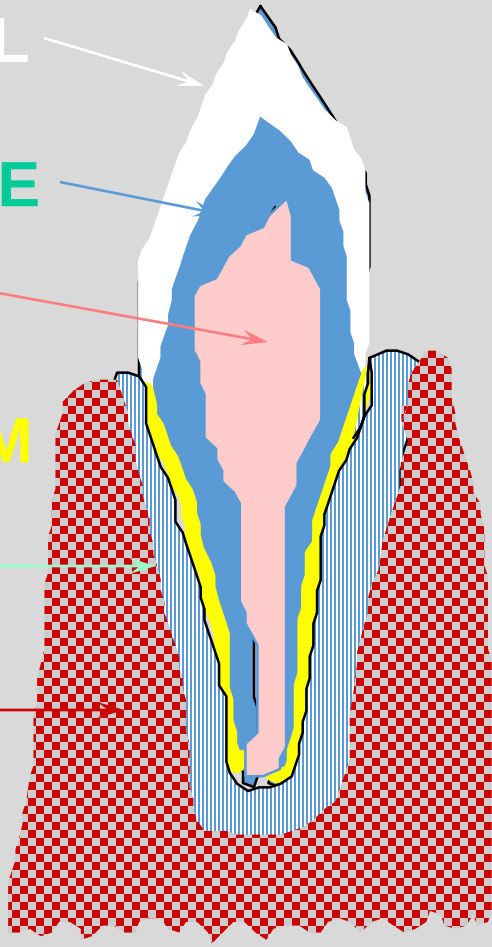
DENTINE

PULP

CEMENTUM

PDL

A BONE



TOOTH TISSUES: Cell Sources

DENTAL LAMINA → TOOTH

DENTAL ORGAN → ENAMEL
Ameloblasts

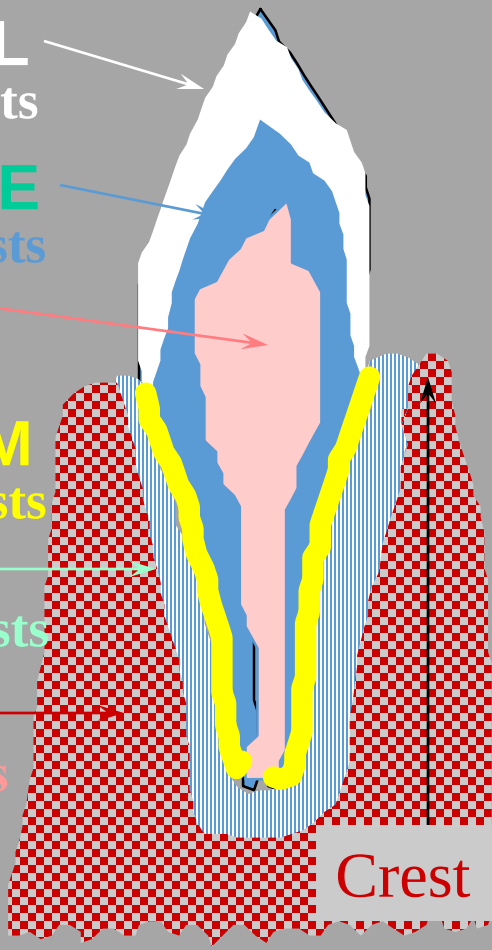
DENTAL PAPILLA → DENTINE
Odontoblasts

DENTAL PAPILLA → PULP
CT cells

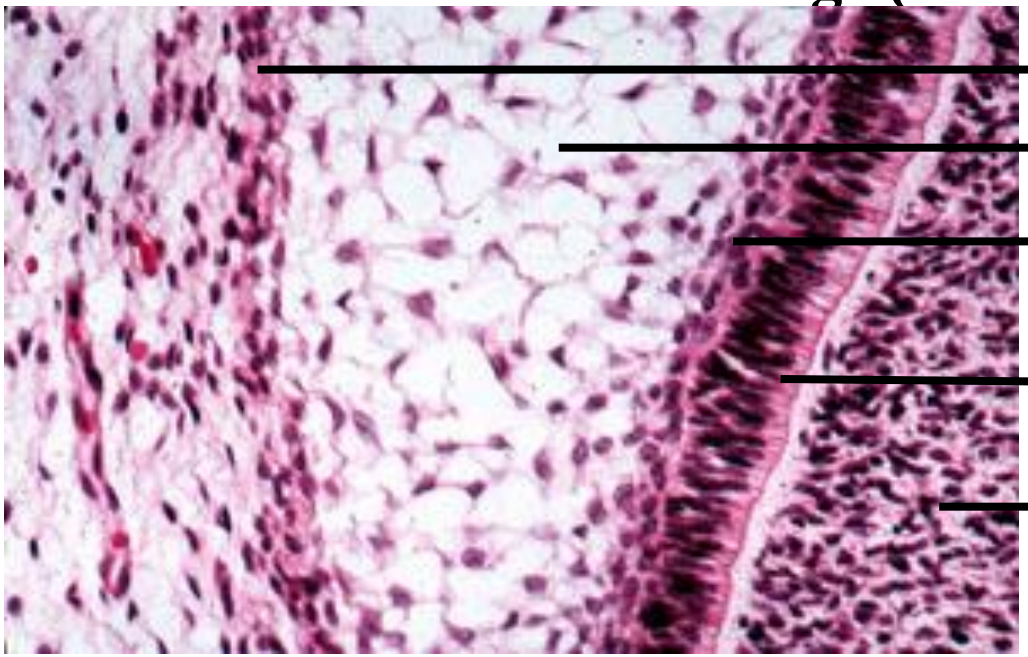
DENTAL SAC/FOLLICLE → CEMENTUM
Cementoblasts

DENTAL SAC/FOLLICLE → PDL
Fibroblasts

ALVEOLAR BONE → A BONE
Osteoblasts & ‘clasts



3. Bell Stage (Early)

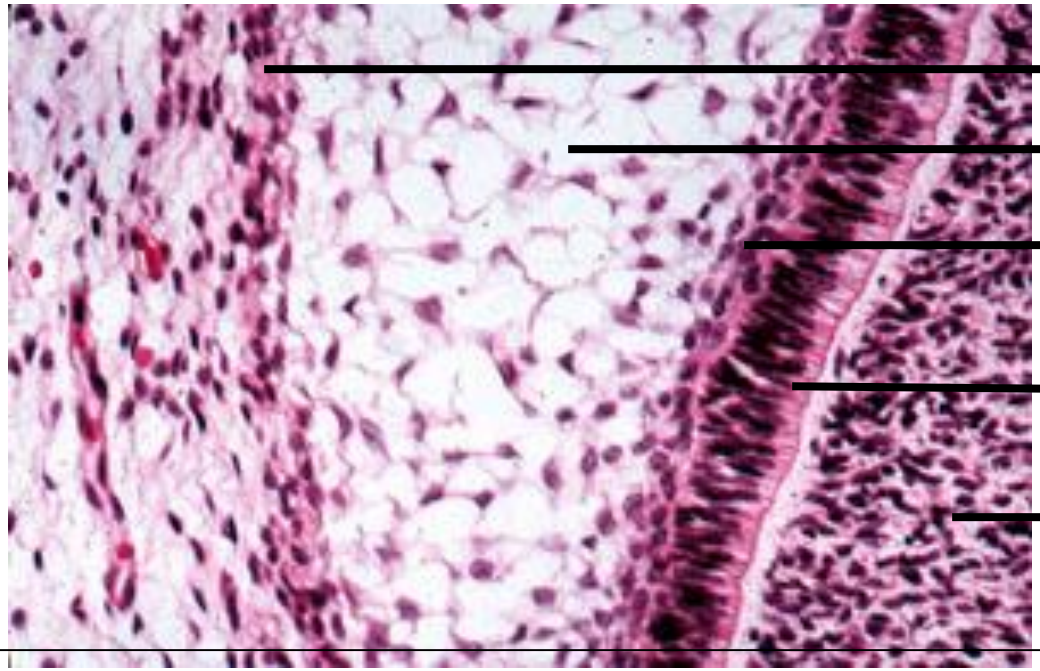


http://www.usc.edu/hsc/dental/ohisto/

Inner dental epithelium: Short columnar cells bordering the dental papilla. These will eventually become ameloblasts that will form the enamel of the tooth crown by differentiating into tall columnar cells. The cells of inner dental epithelium exert an organizing influence on the underlying mesenchymal cells in the dental papilla, which later differentiate into odontoblasts.

Outer dental epithelium: Cuboidal cells that cover the enamel organ. Their function is to organize a network of capillaries that will bring nutrition to the ameloblasts. In preparation to formation of enamel, at the end of bell stage, the formerly smooth surface of the outer dental epithelium is laid in folds.

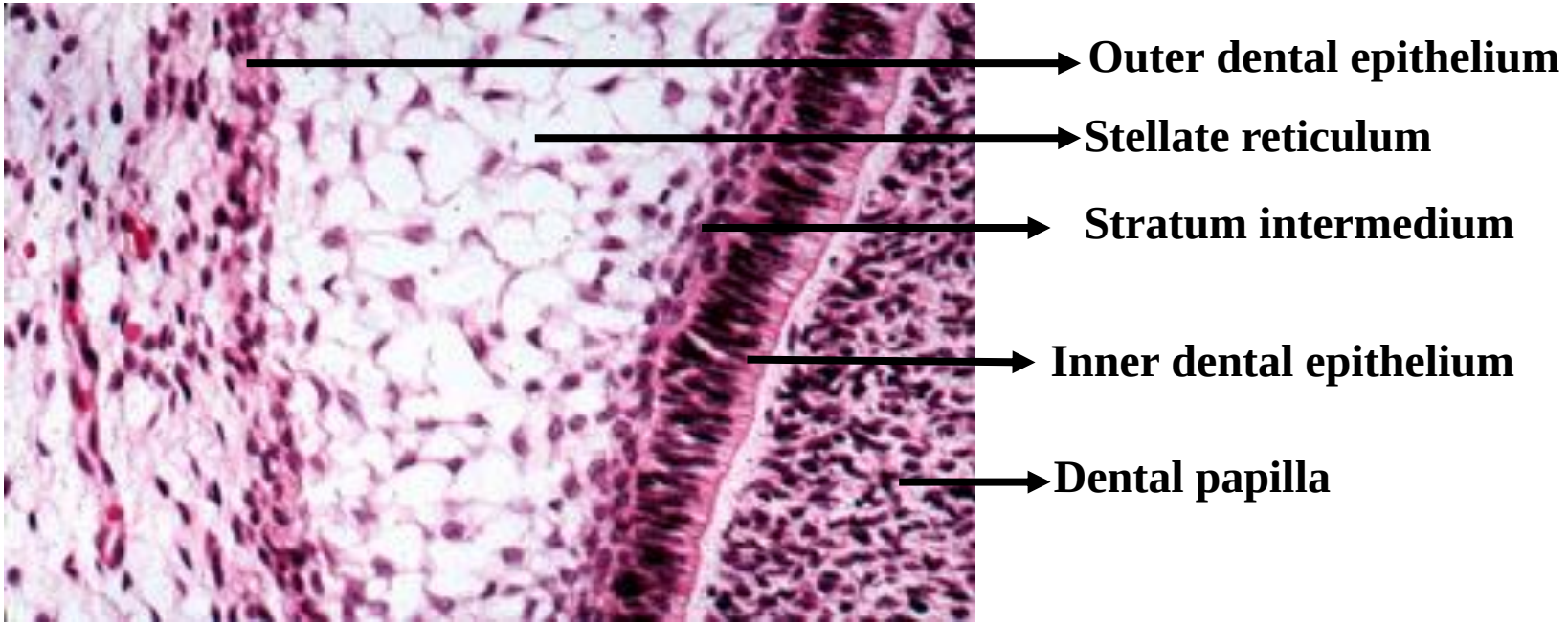
3. Bell Stage (Early)



http://www.usc.edu/hsc/dental/ohisto/

Stellate reticulum: Star-shaped cells with processes, present between the outer and the inner dental epithelium. These cells secrete glycosaminoglycans, which attract water, thereby swelling the cells and pushing them apart. However, they still maintain contact with each other, thus becoming star-shaped. They have a cushion-like consistency that may support and protect the delicate enamel organ. It is absent in the portion that outlines the root portions.

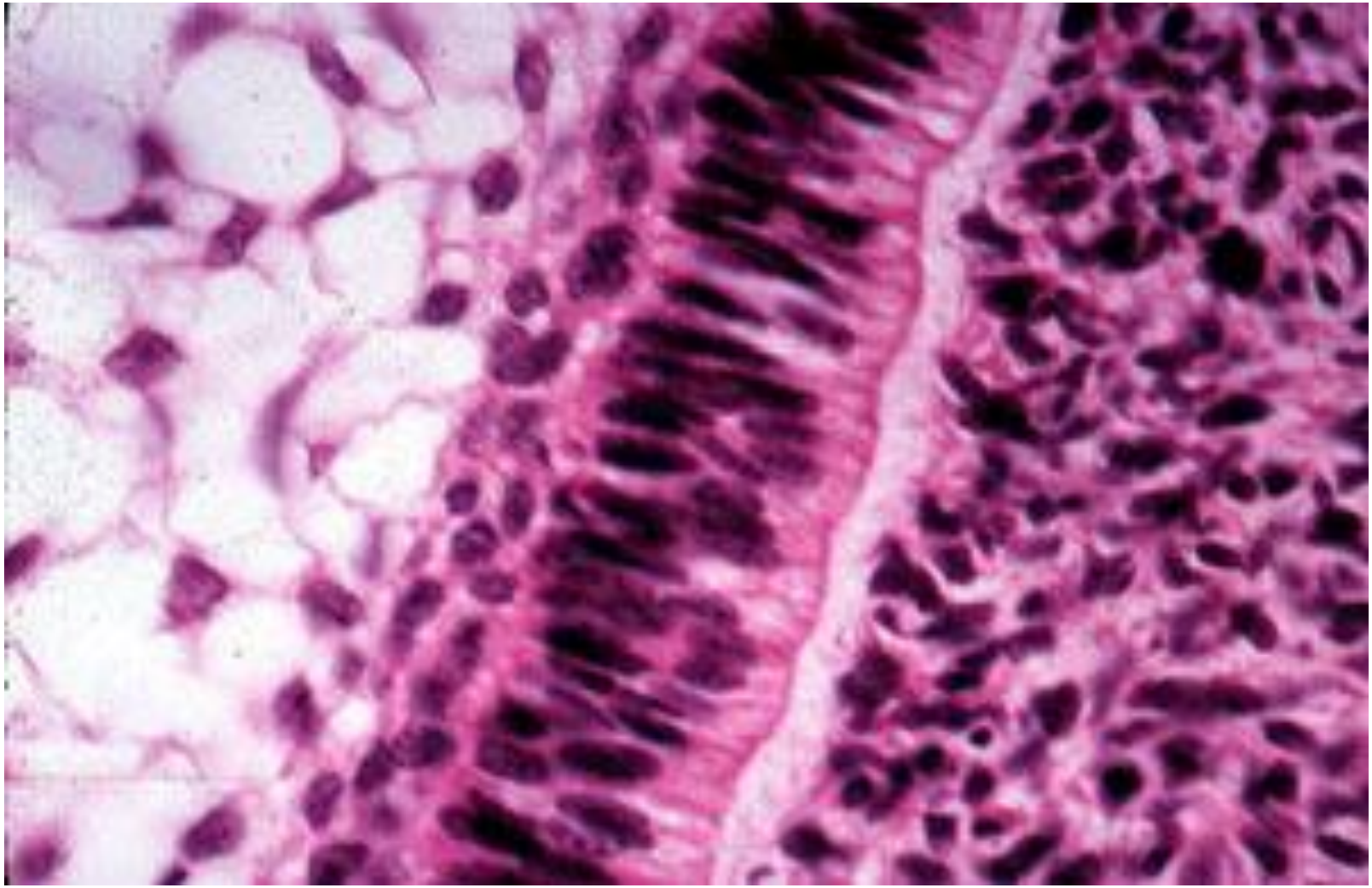
Stratum intermedium: Cell layer between the inner dental epithelium and stellate reticulum which have high alkaline phosphatase activity. They assist inner dental epithelium (ameloblasts) to form enamel.



http://www.usc.edu/hsc/dental/ohisto/

<u>Dental Papilla:</u> Before the inner dental epithelium begins to produce enamel, the peripheral cells of the mesenchymal dental papilla differentiate into odontoblasts under the organizing influence of the epithelium. First, they assume a cuboidal shape and then a columnar form and acquire the specific potential to produce dentin.

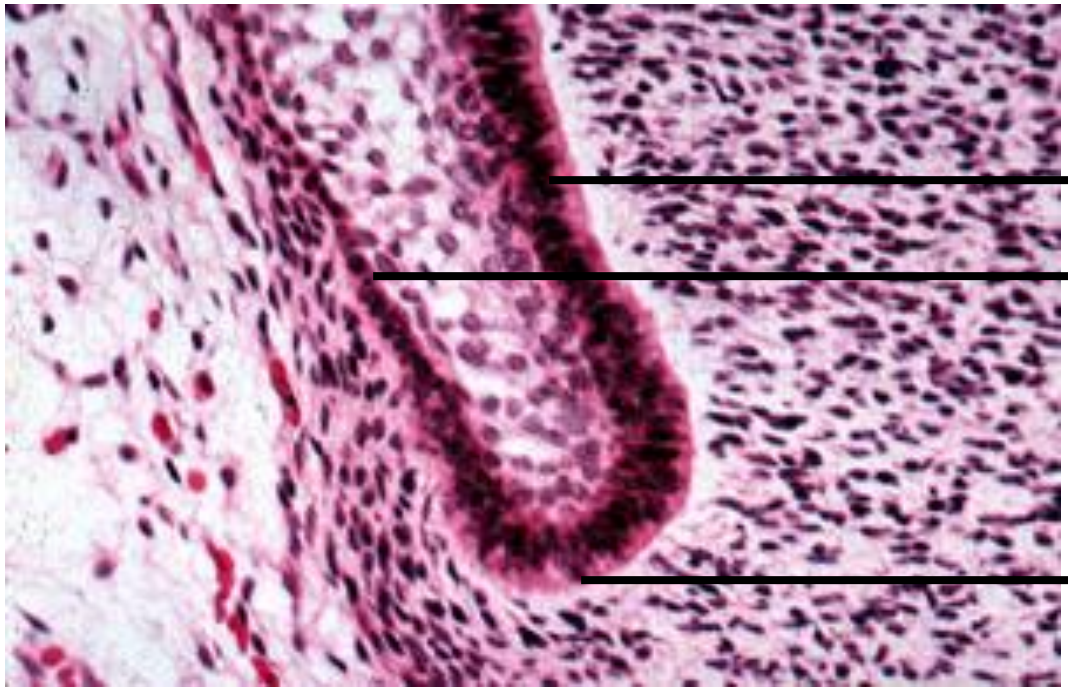
3. Bell Stage



Higher power view

http://www.usc.edu/hsc/dental/ohisto/

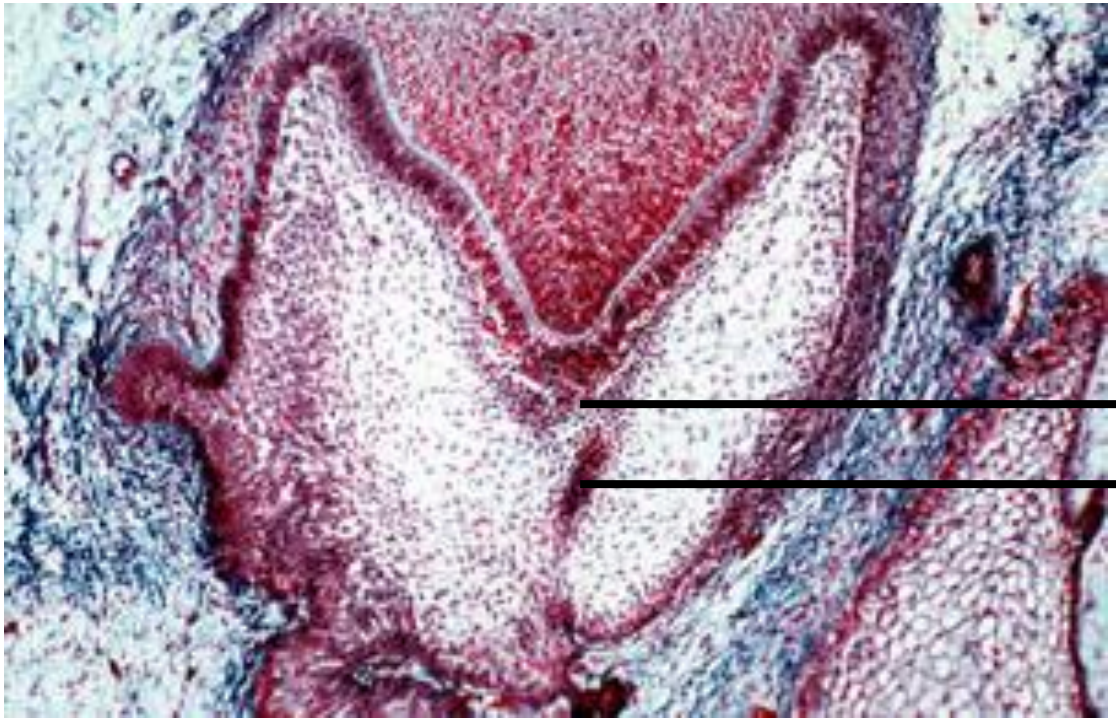
3. Bell Stage



<u>Cervical loop:</u> Area where the inner and the outer dental epithelium meet at the edge of the enamel organ. This point is where the cells will continue to divide until the tooth crown attains its full size and which after crown formation will give rise to the epithelium for root formation. Is also called "Zone of Reflexion".

http://www.usc.edu/hsc/dental/ohisto/

3. Bell Stage

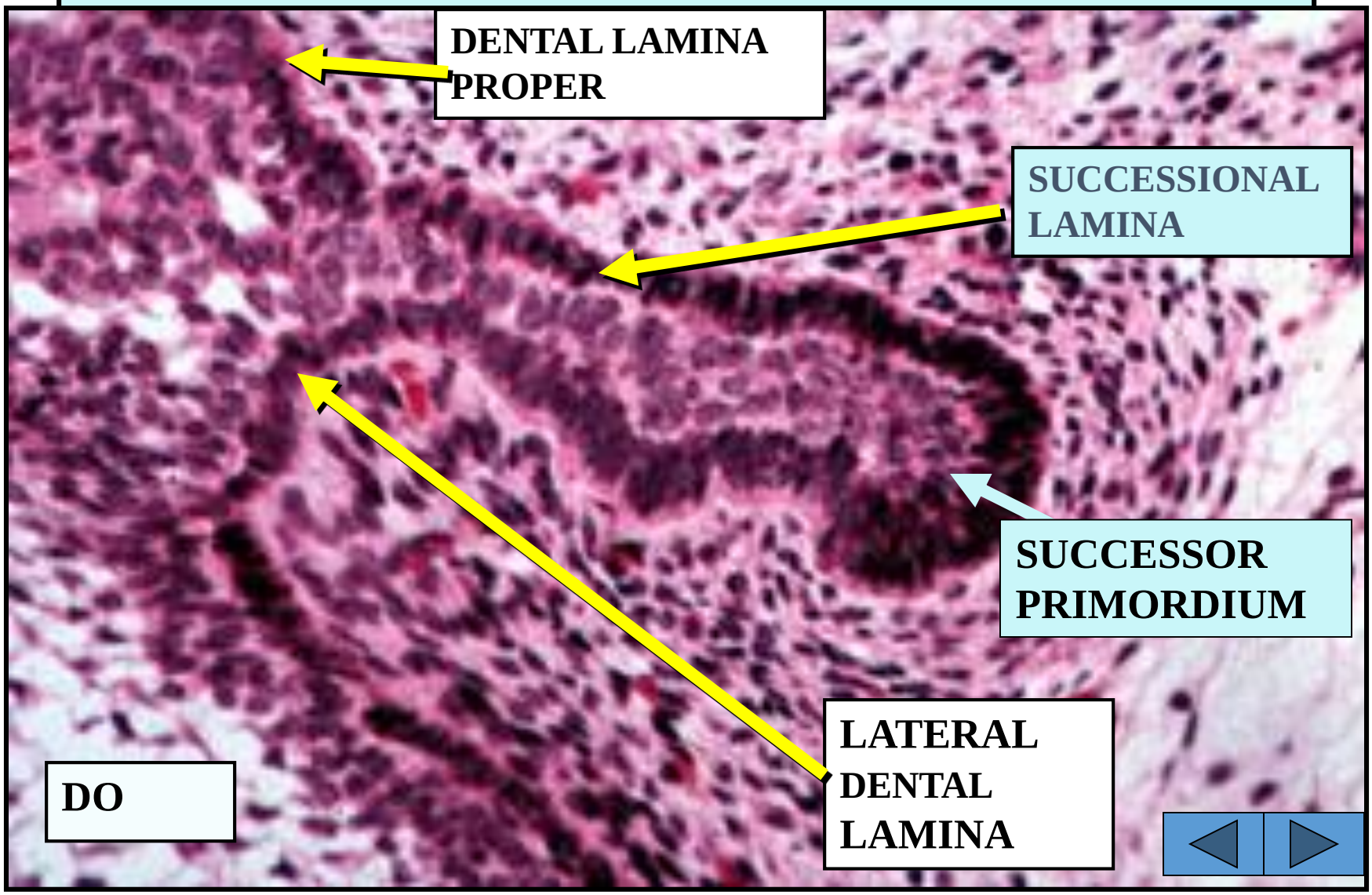


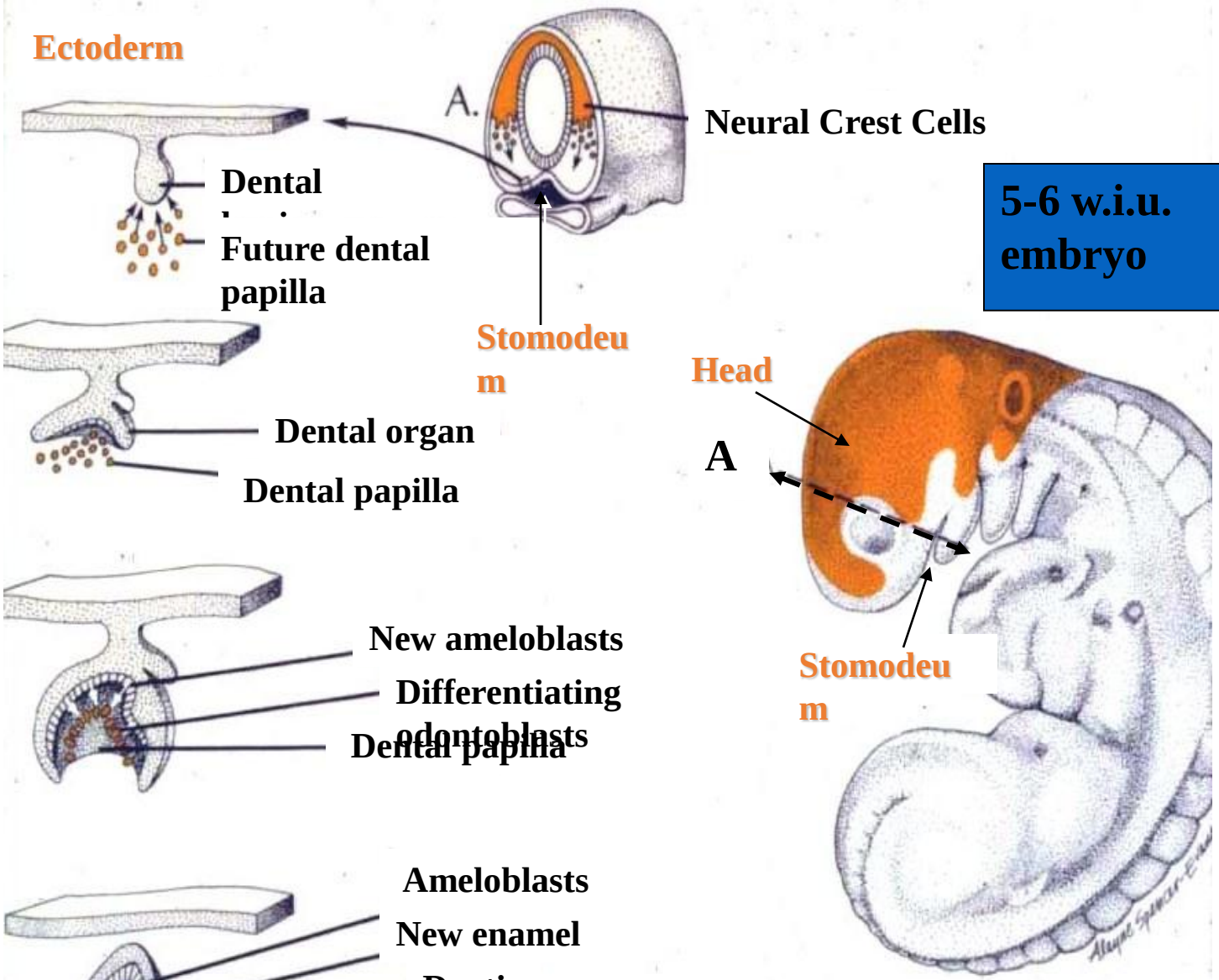
Enamel cord: Pattern of enamel knot that extends between the inner and outer dental epithelium

http://www.usc.edu/hsc/dental/ohisto/

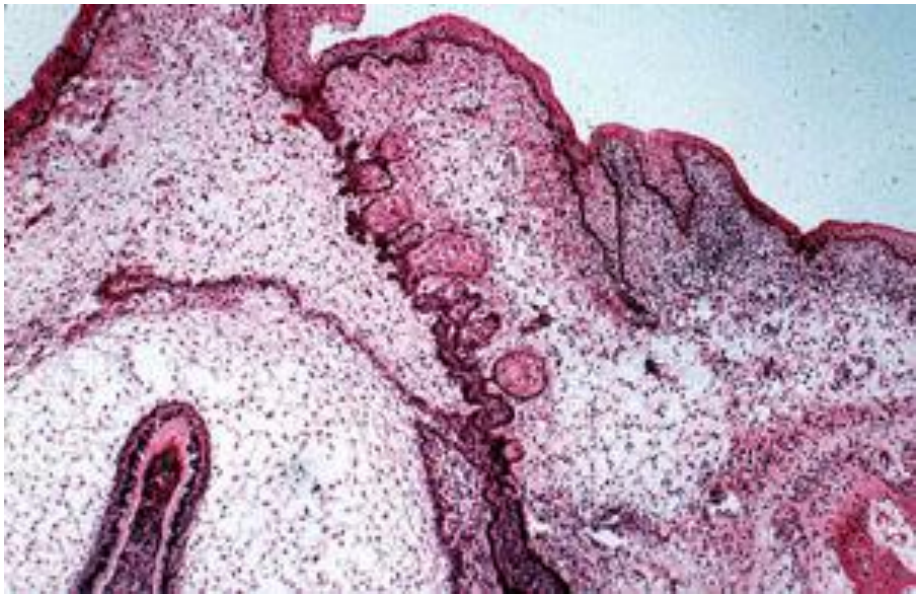
SUCCESSIONAL LAMINA:

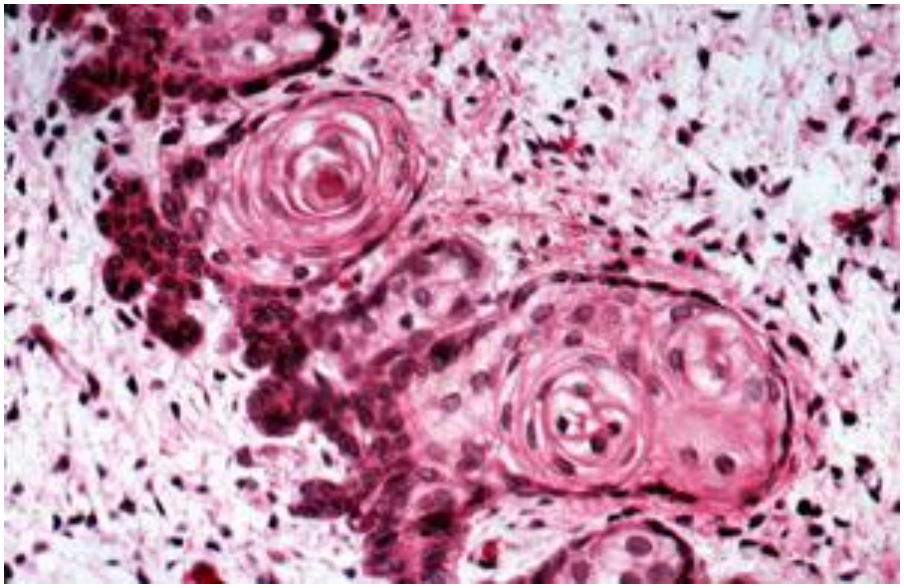
lamina from which permanent teeth develop




Ectoderm
A.
Neural Crest Cells
Dental
Future dental papilla
Stomodeum
5-6 w.i.u. embryo
Dental organ
Dental papilla
Head
A
New ameloblasts
Differentiating odontoblasts
Dental papilla
Stomodeum
Ameloblasts
New enamel
Dentin
Odontoblasts

3. Bell Stage





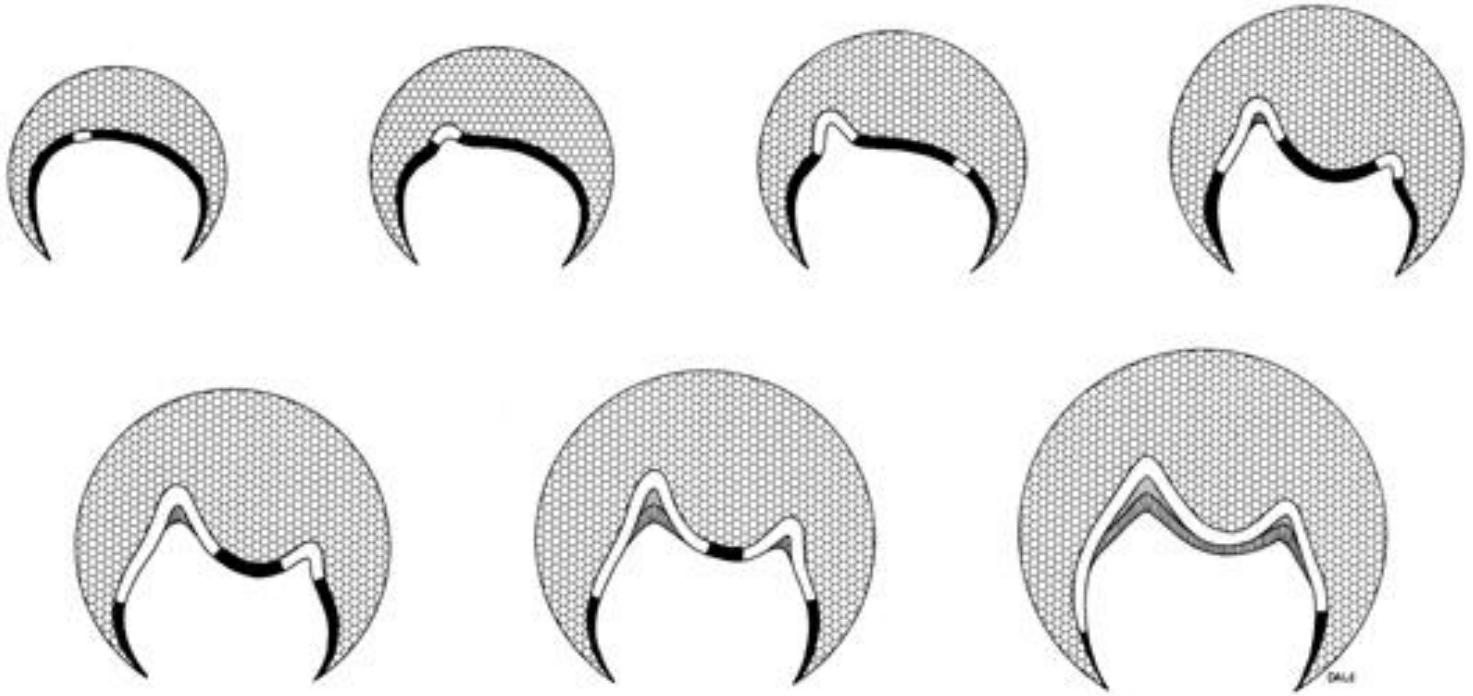
Dental lamina (and the lateral lamina) will disintegrate and loose contact with oral epithelium. Sometimes, these epithelial cells will persist when they are called "epithelial pearls" or "cell rests of Serre"

Clinical significance: Cysts will develop in these (eruption cysts) and prevent eruption, or they may form odontomas (tumors) or may form supernumery teeth

http://www.usc.edu/hsc/dental/ohisto/

Eruption Cyst

Crown Pattern Determination



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Future crown patterning also occurs in the bell stage, by folding of the inner dental epithelium. Cessation(stopping) of mitotic activity within the inner dental epithelium determines the shape of a tooth.

Vascular and Nerve Supply during Tooth Development

Vascular Supply: Clusters of blood vessels in dental follicle and papilla

Clustering of vessels in papilla coincide with position of root formation

Enamel organ is avascular, however vessels seen in close association in the follicle

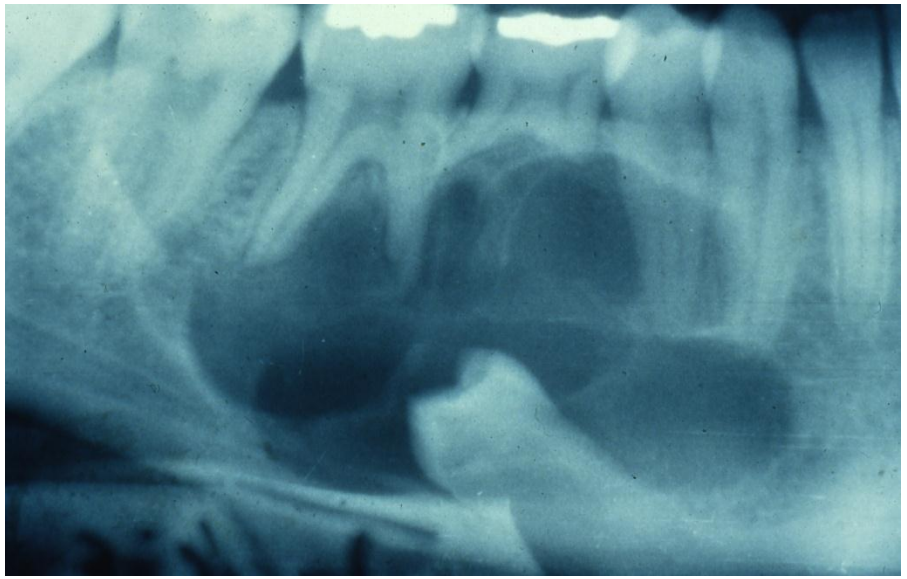
Nerve Supply: Initially noted in the dental follicle during bud to cap stage

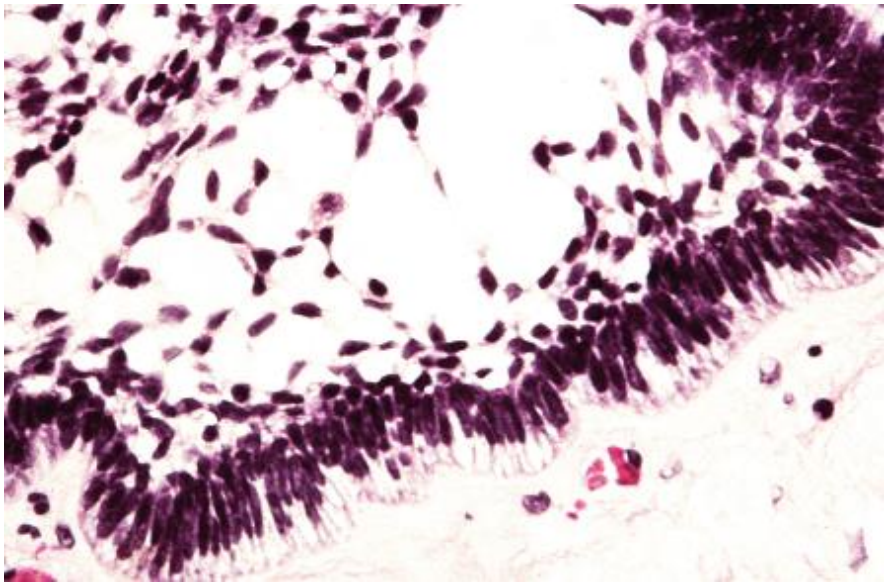
However after start of dentinogenesis, seen in dental papilla

Nerve fibers do not enter enamel organ

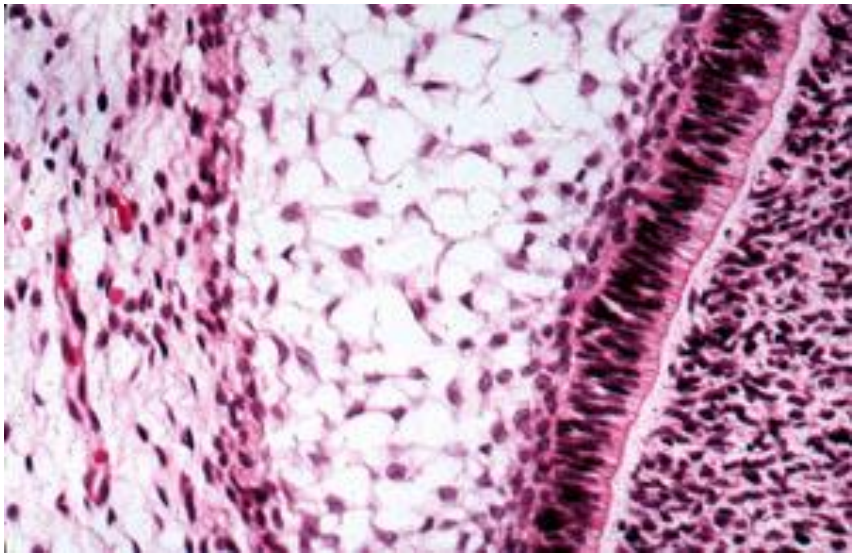
Clinical Correlation. Several odontogenic cysts and tumors can arise from developing tooth structures. Two such conditions are:

1. **Ameloblastoma – which are tumors of odontogenic epithelium that may arise from cell rests of enamel organ or from the developing enamel organ among other things**



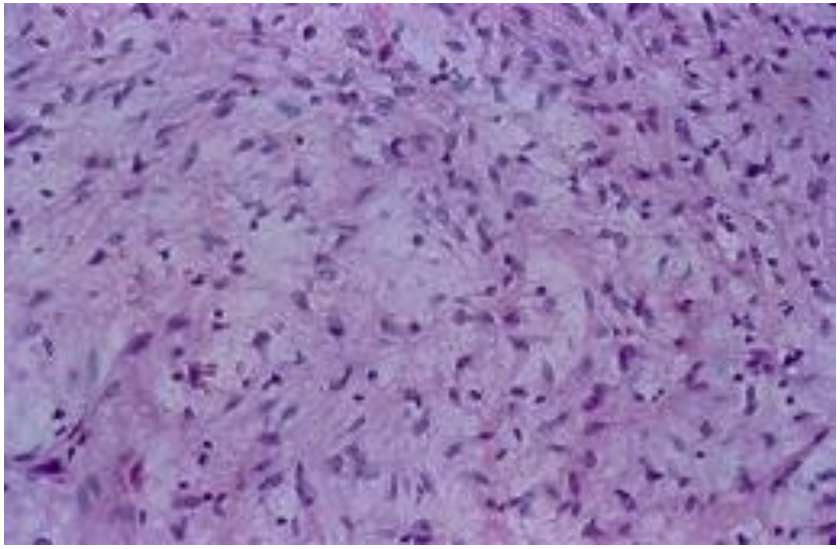


Ameloblastoma

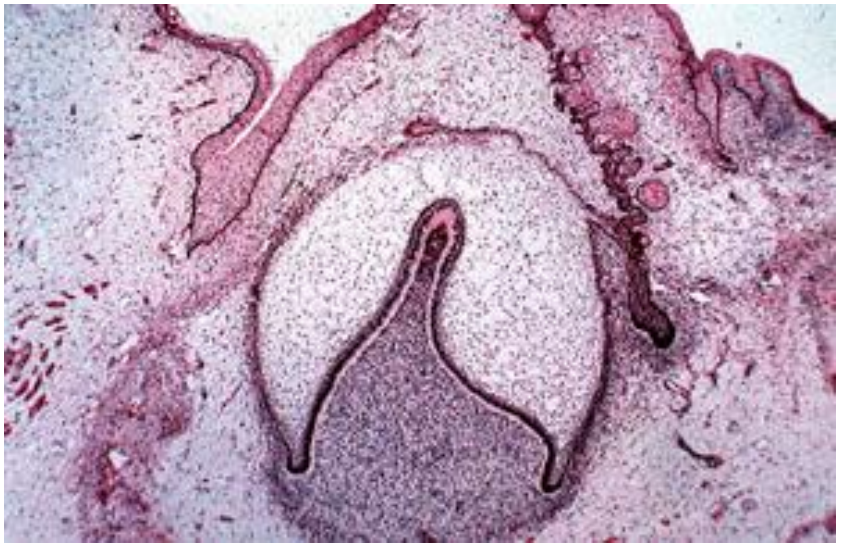


Enamel Organ

Histology resembles enamel organ epithelium with peripheral columnar ameloblast-like cells surrounding loosely arranged stellate-reticulum-like cells



Odontogenic myxoma

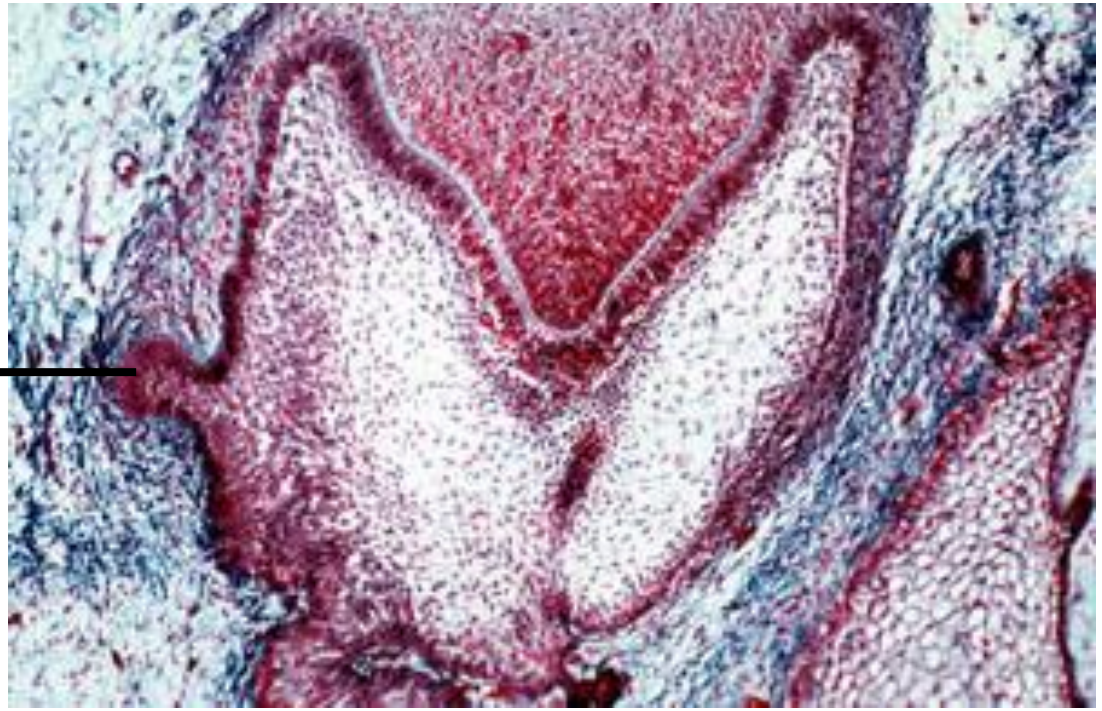


Developing tooth

2. **Odontogenic Myxoma: Tumor of the jaw that arise from odontogenic ectomesenchyme. Histologically, looks similar to mesenchymal portion of a developing tooth (dental papilla).**

Formation of Permanent Dentition

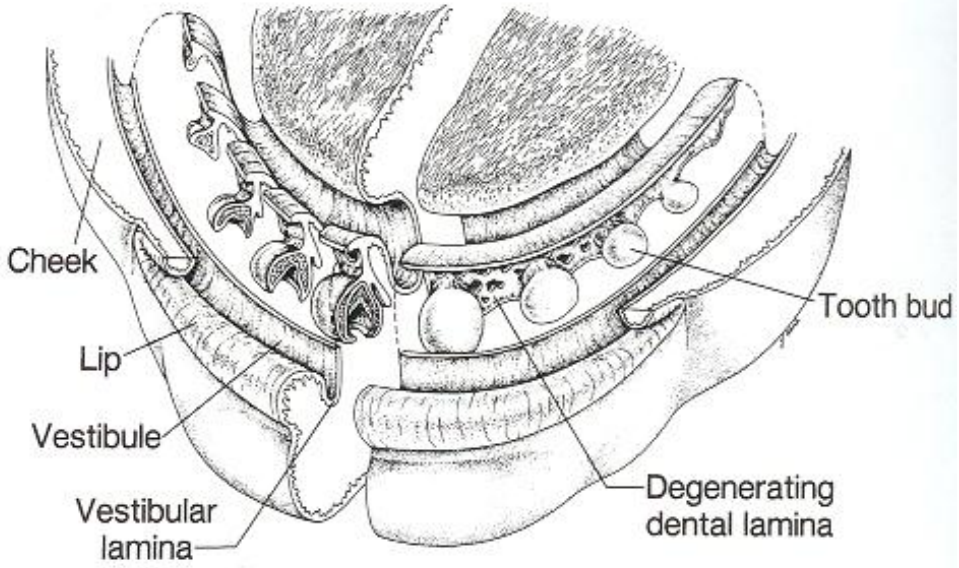
Successional tooth bud

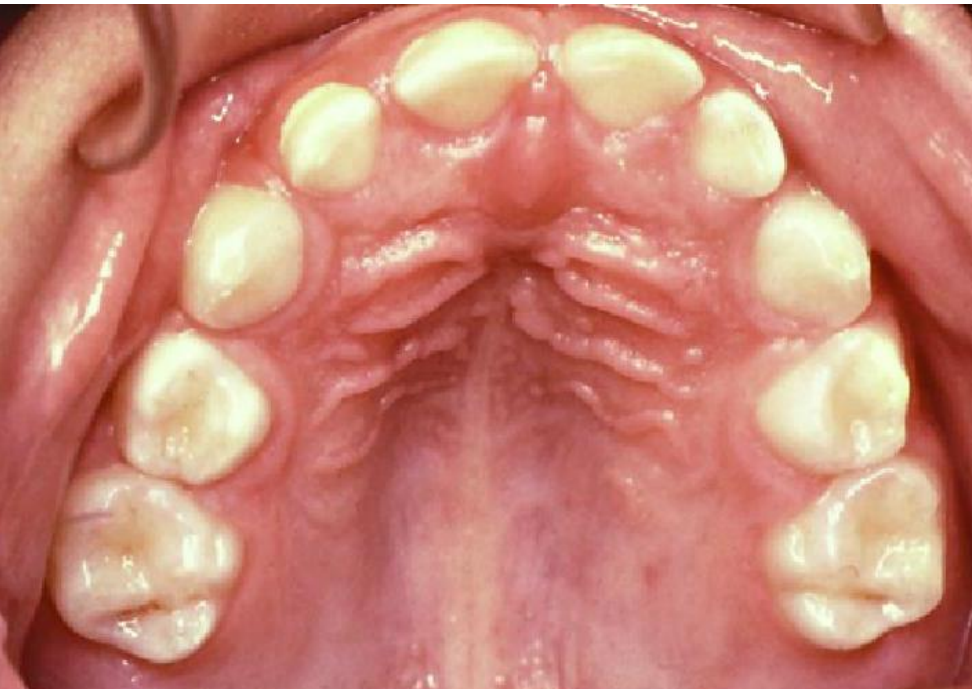


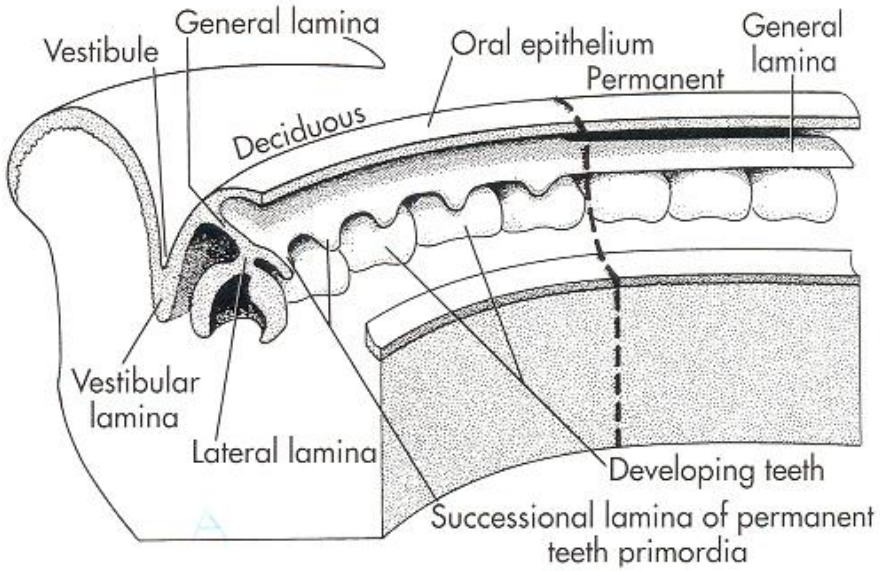
http://www.usc.edu/hsc/dental/ohisto/

The tooth germs that give rise to permanent incisors, canines and premolars form as a result of further proliferative activity within the dental lamina, lingual to the deciduous tooth germ

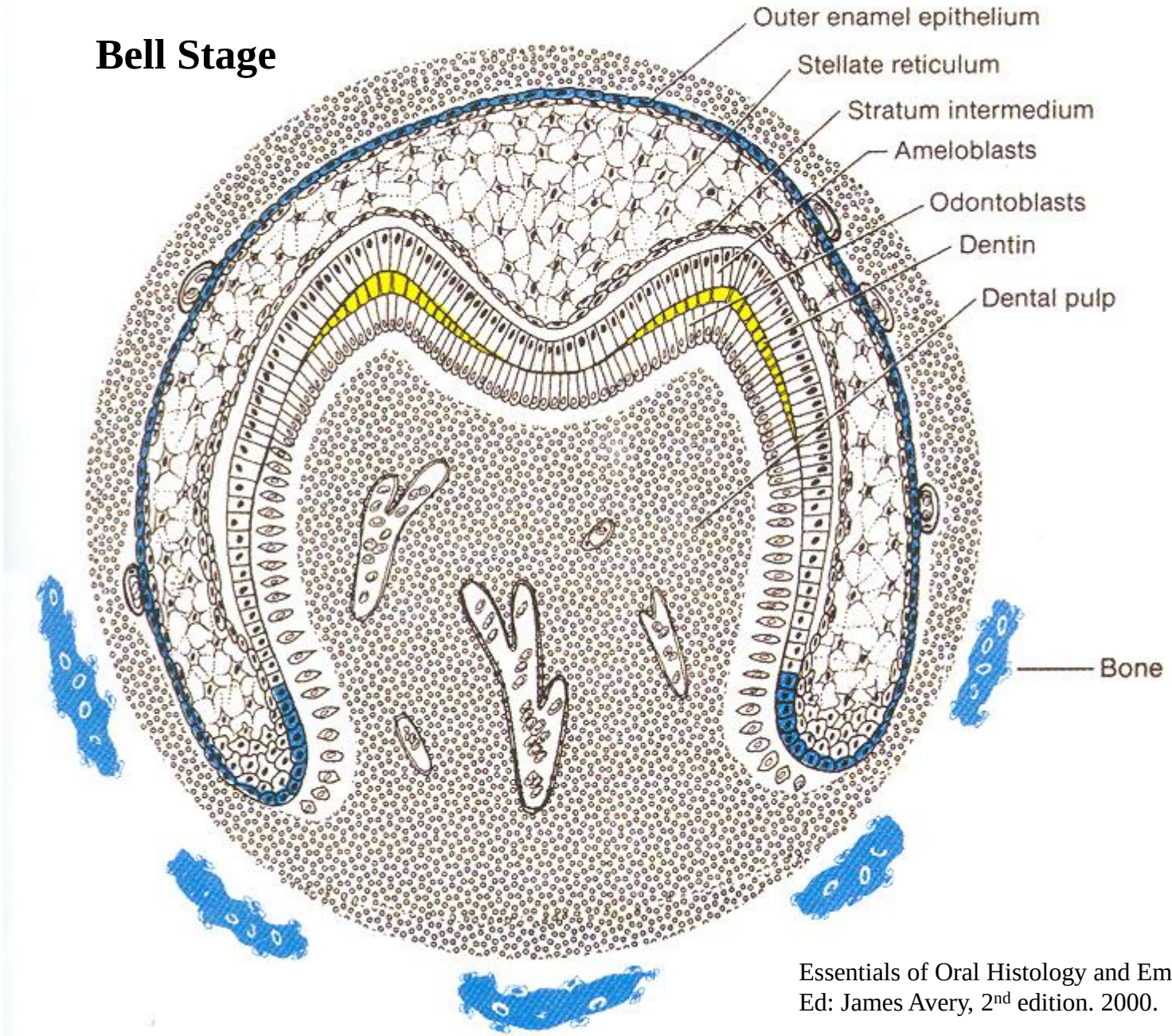
The developing permanent molars have no deciduous predecessor and their tooth germs originate from the dental lamina that extends posteriorly beneath the oral epithelium after the jaws have grown


Cheek
Lip
Vestibule
Vestibular lamina
Tooth bud
Degenerating dental lamina




Vestibule
General lamina
Oral epithelium
Permanent
General lamina
Deciduous
Vestibular lamina
Lateral lamina
Developing teeth
Successional lamina of permanent teeth primordia

Bell Stage



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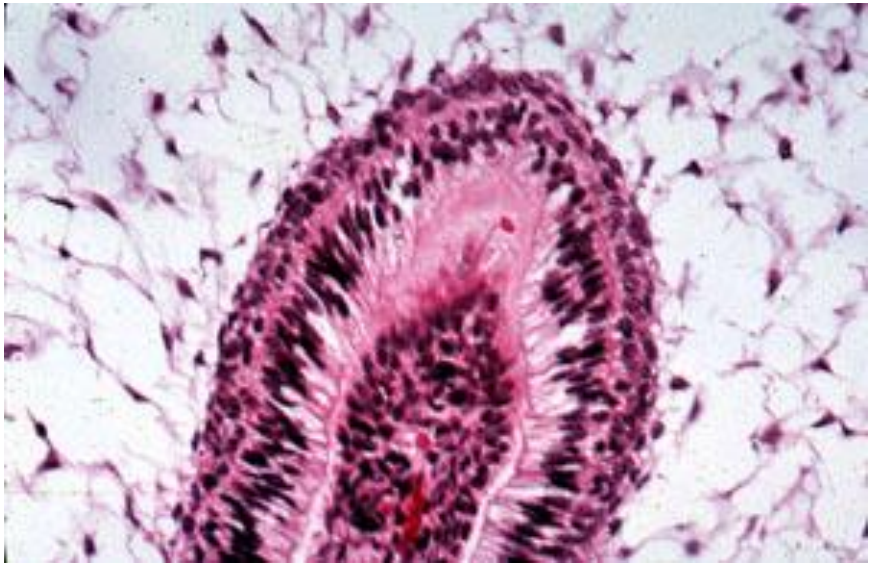
Hard Tissue Formation



http://www.usc.edu/hsc/dental/ohisto/

Deposition of dental hard tissues is called “apposition”

After the crown attains its final shape during cap to early bell stage, the inner dental epithelial cells stop to proliferate, except the cells at the cervical loop

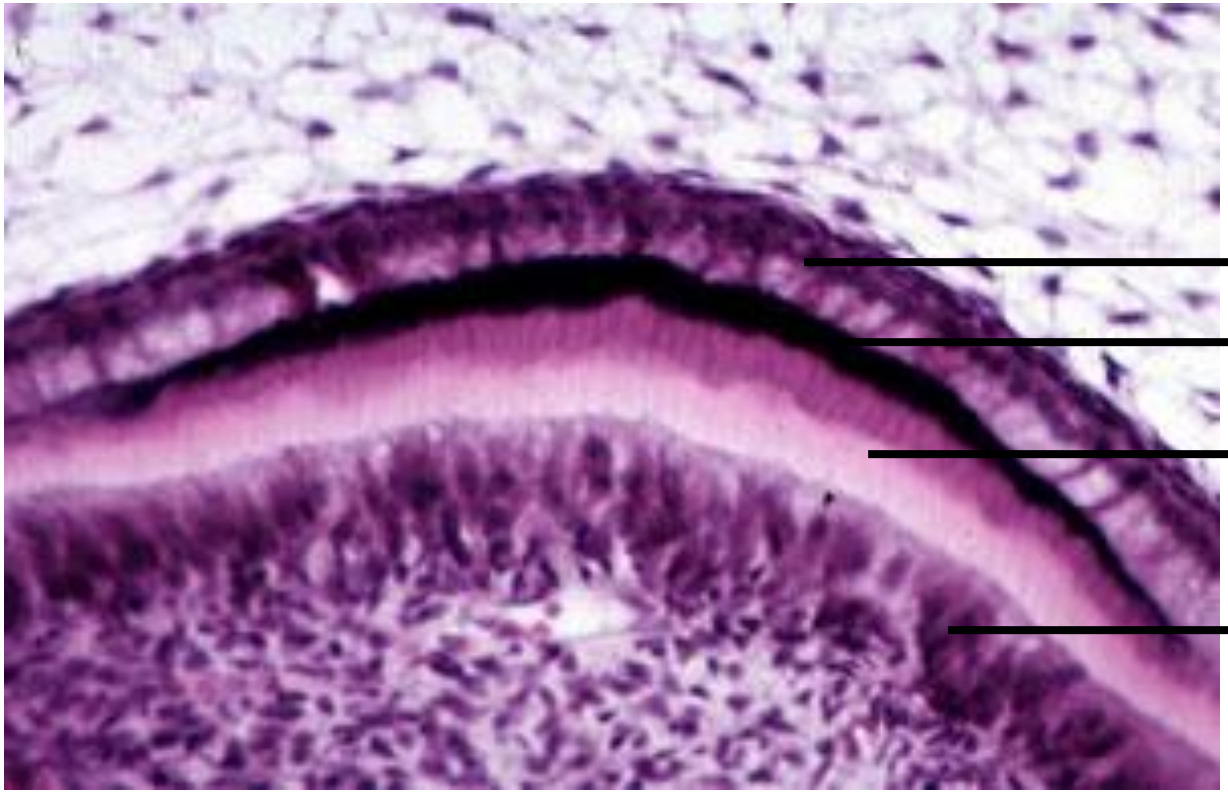
First layer of dentin appears at the cusp tips and progresses cervically, and the columnar cells of the inner dental epithelium become elongated and show reverse polarization, with the nuclei adjacent to stratum intermediate (ameloblasts)

The boundary between the odontoblasts and inner dental epithelium defines the future dentino-enamel junction

For dentinogenesis and amelogenesis to take place normally, the differentiating odontoblasts and ameloblasts will receive signals form each other – “reciprocal induction”

Stages of Apposition

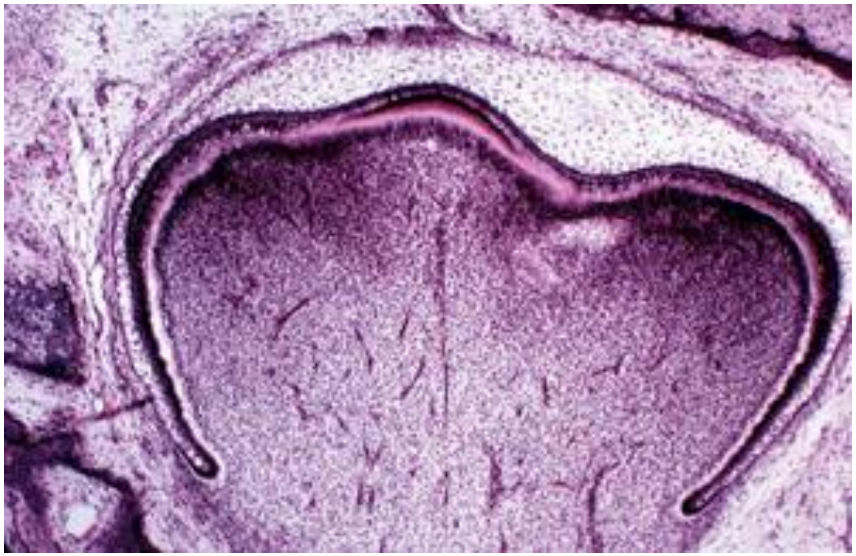
1. Elongation of inner dental epithelium
2. Differentiation of odontoblasts
3. Formation of dentin
4. Formation of enamel

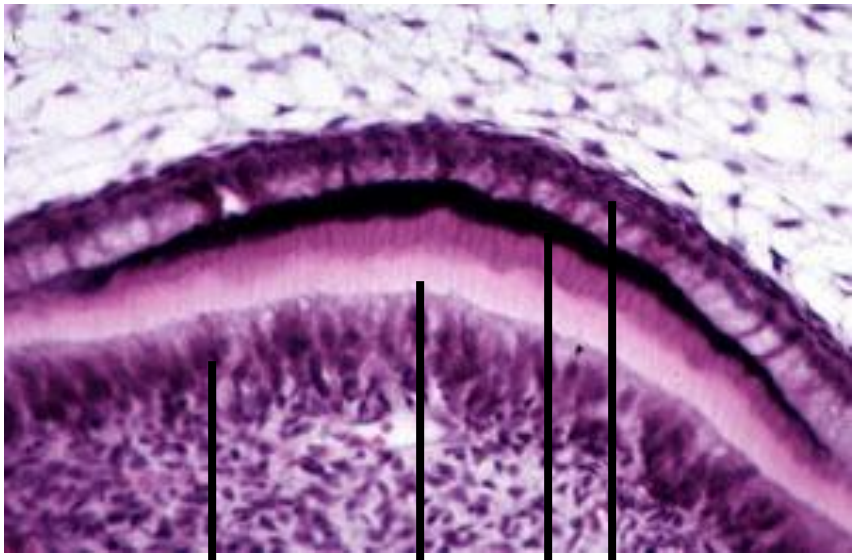


At the same time or soon after the first layer of dentin (mantle dentin) is formed, the inner dental epithelial cells differentiate into ameloblasts and secrete enamel proteins. These proteins further will help in the terminal differentiation of odontoblasts. The ameloblasts will then start laying down organic matrix of enamel against the newly formed dentinal surface. The enamel matrix will mineralize immediately and form the first layer of enamel. The formation of enamel is called amelogenesis.

http://www.usc.edu/hsc/dental/ohisto/

Apposition



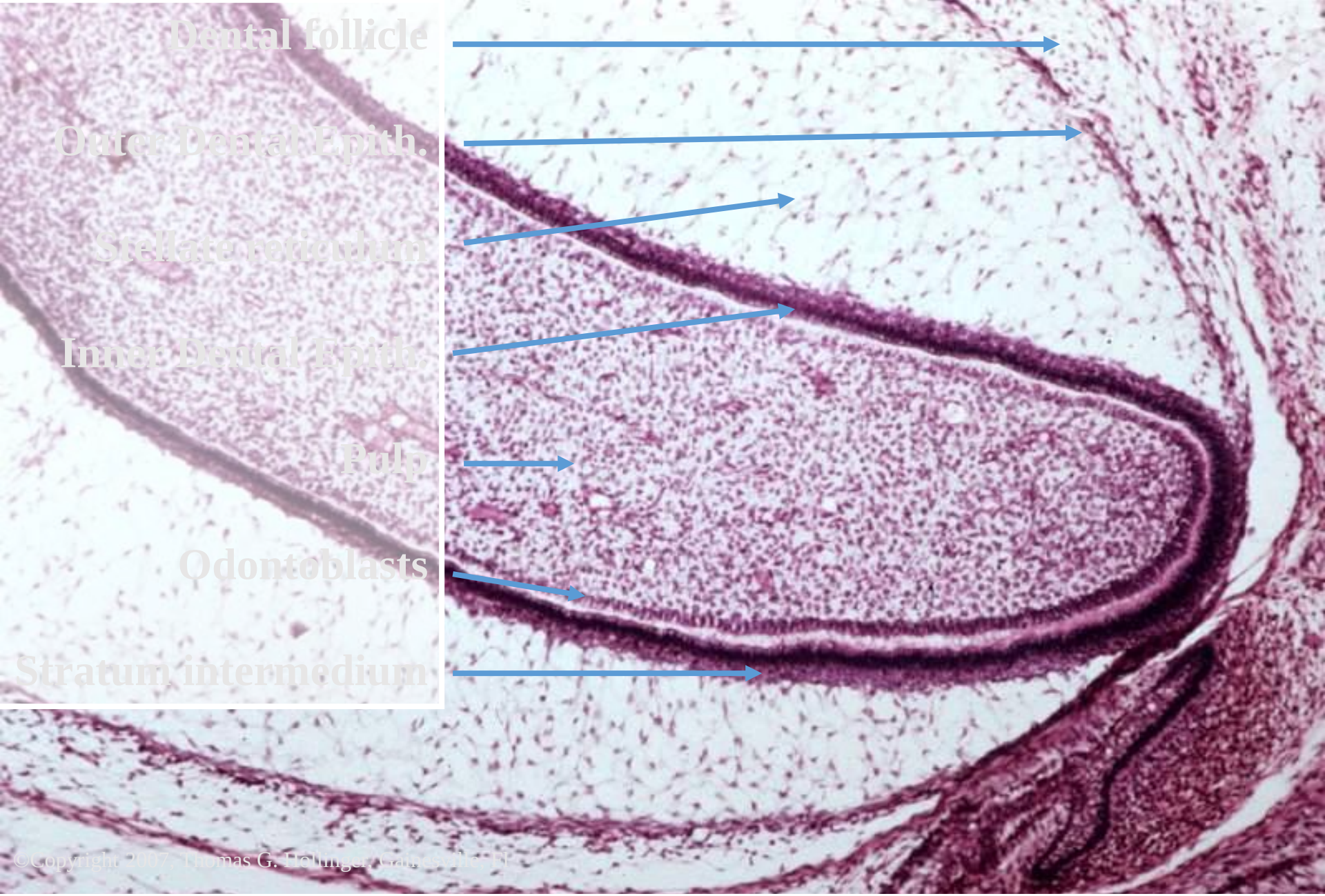


At the same time when the inner dental epithelium is differentiating, the undifferentiated ectomesenchymal cells increase rapidly in size and ultimately differentiate into odontoblasts

Differentiation of odontoblasts from ectomesenchymal cells are induced by influence from the inner dental epithelium

Experiments have shown that if there is no inner dental epithelium, there is no dentin formed

http://www.usc.edu/hsc/dental/ohisto/



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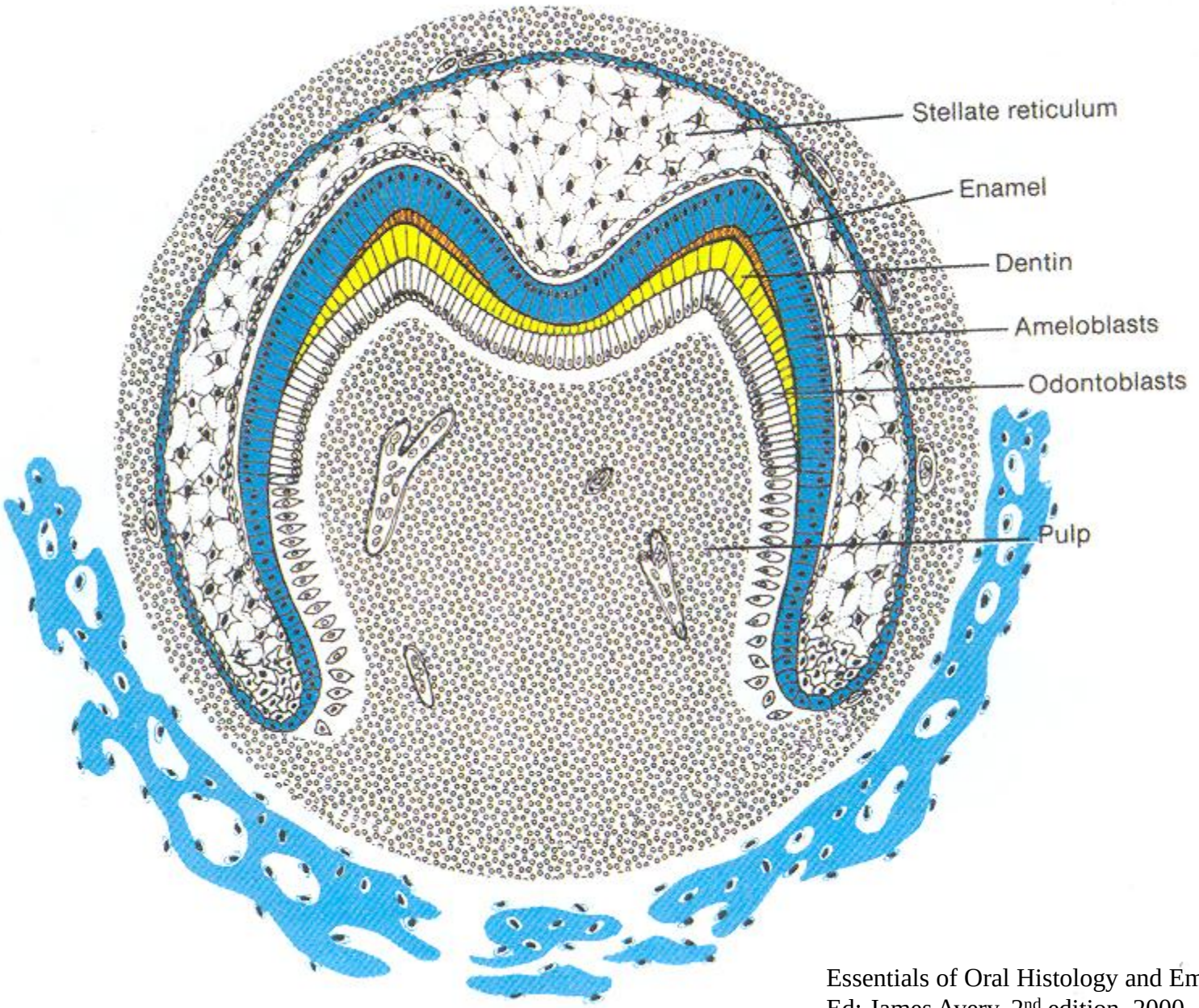
Structures at Appositional Stage



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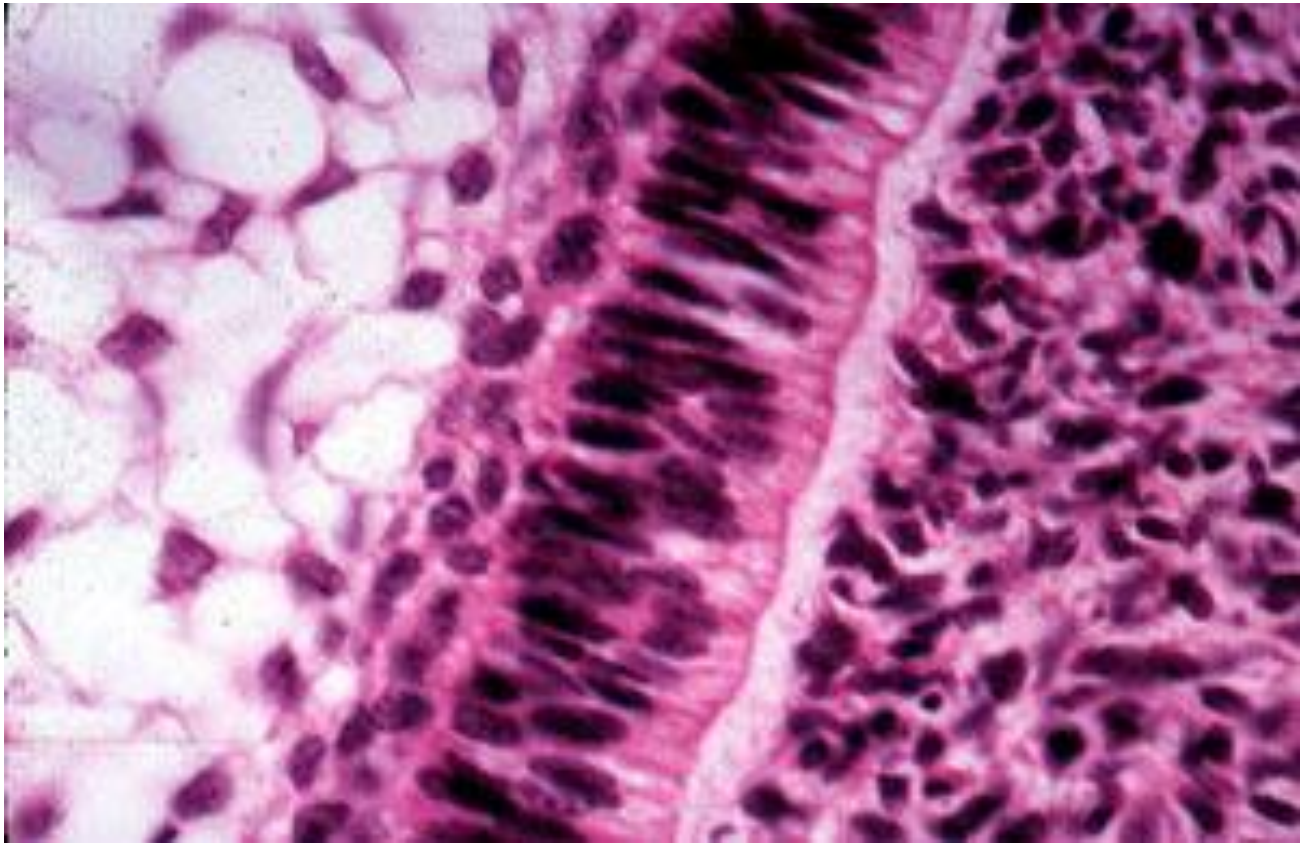
Dentinogenesis

Dentin is formed by odontoblasts that differentiate from ectomesenchymal cells of dental papilla with influence from the inner dental epithelium

Differentiation of odontoblasts is mediated by expression of signaling molecules and growth factors in the inner dental epithelial cells



http://www.usc.edu/hsc/dental/ohisto/

Odontoblasts are highly polarized with the nuclei away from inner dental epith.

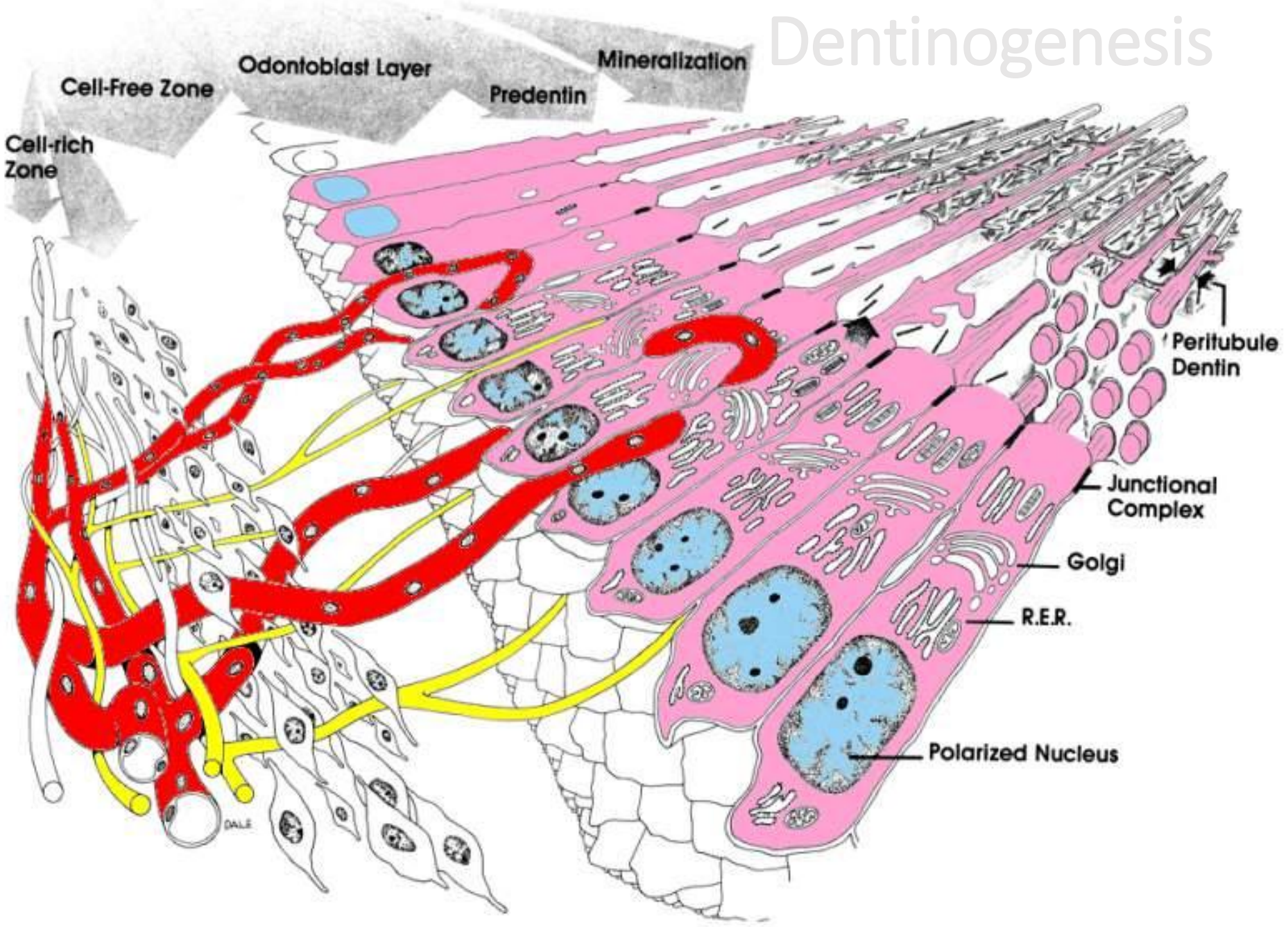
Following differentiation of odontoblasts, first layer of dentin is produced, characterized by appearance of large-diameter type III collagen fibrils (0.1 to 0.2 μm in dia) called *von Korff's fibers*, followed by type I collagen fibers – MANTLE DENTINE

At the same time as initial dentin deposition, the odontoblasts will develop stubby Processes (short and thick extensions) at the side close to the inner dental epithelium which extend into forming extracellular matrix

As the odontoblasts move pulpward, the *odontoblast process (Tomes´ fiber)* will elongate and become active in dentine matrix formation

It is initially called predentin and following mineralization is called dentin

Dentinogenesis



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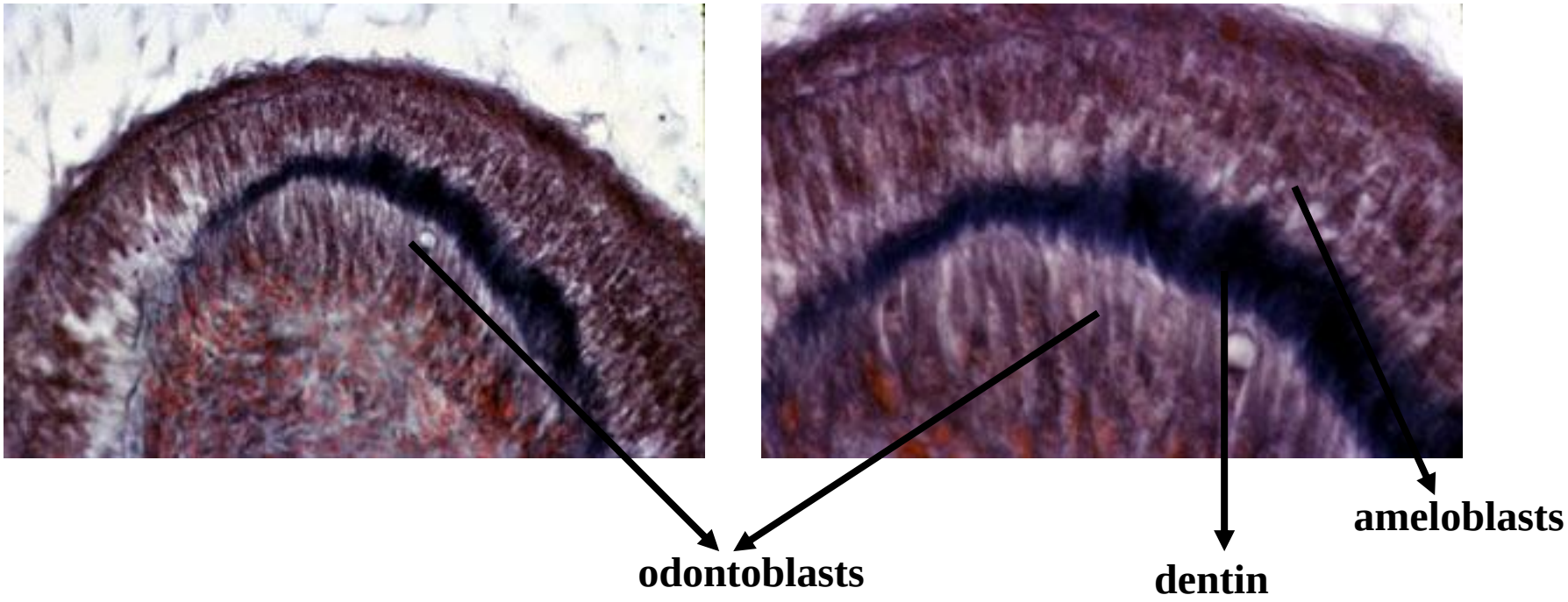
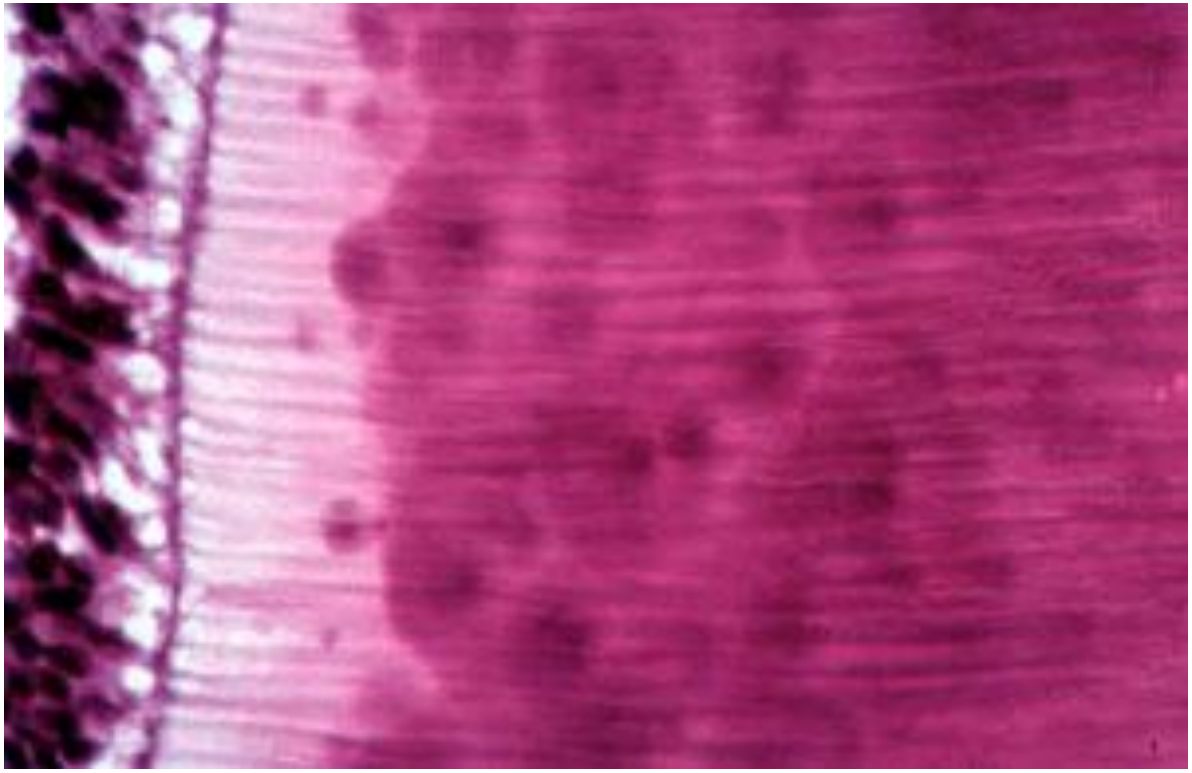
The odontoblasts as they differentiate will start elaborating organic matrix of dentin, which will mineralize. As the organic matrix of dentin is deposited, the odontoblasts move towards the center of the dental papilla, leaving behind cytoplasmic extensions which will soon be surrounded by dentin. Therefore, a tubular structure of dentin is formed.



http://www.usc.edu/hsc/dental/ohisto/



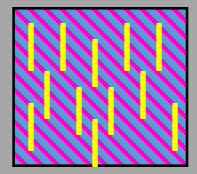
Odontoblasts with cytoplasmic processes forming dentinal tubules

2 steps of dentinogenesis:

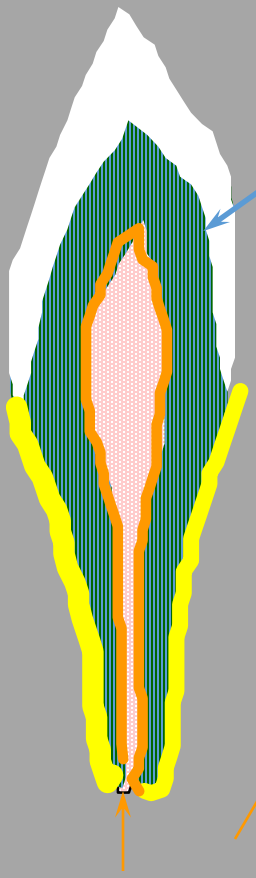
1. **Formation of collagen matrix**
2. **Deposition of calcium and phosphate (hydroxyapatite) crystals in the matrix**

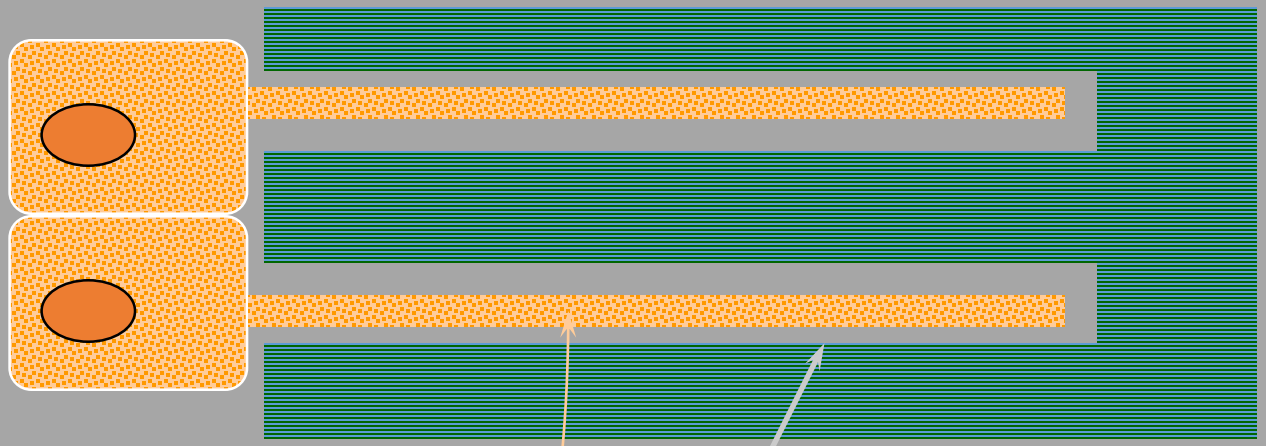
http://www.usc.edu/hsc/dental/ohisto/

DENTIN:Composition



Collagen fibrils matriks, mineral Crystalls, glycoproteins & proteoglycans

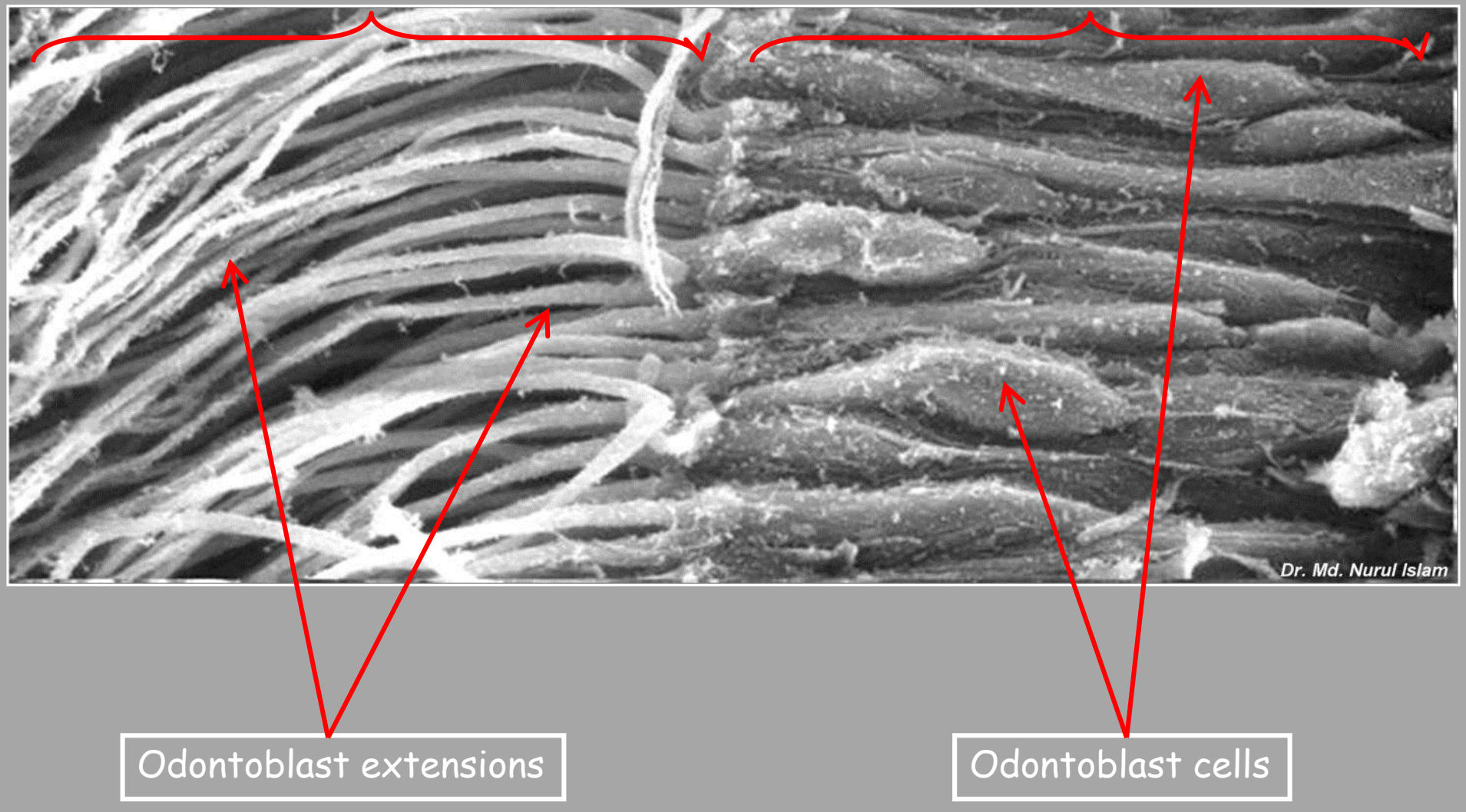


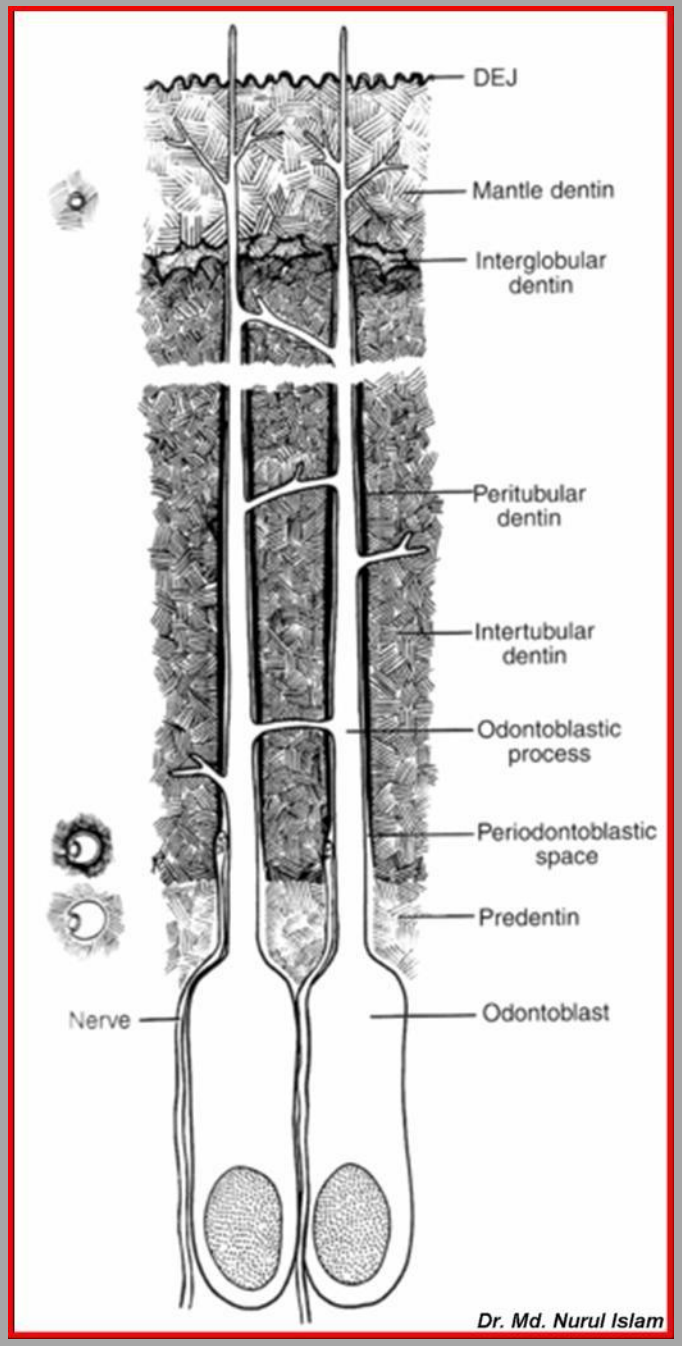


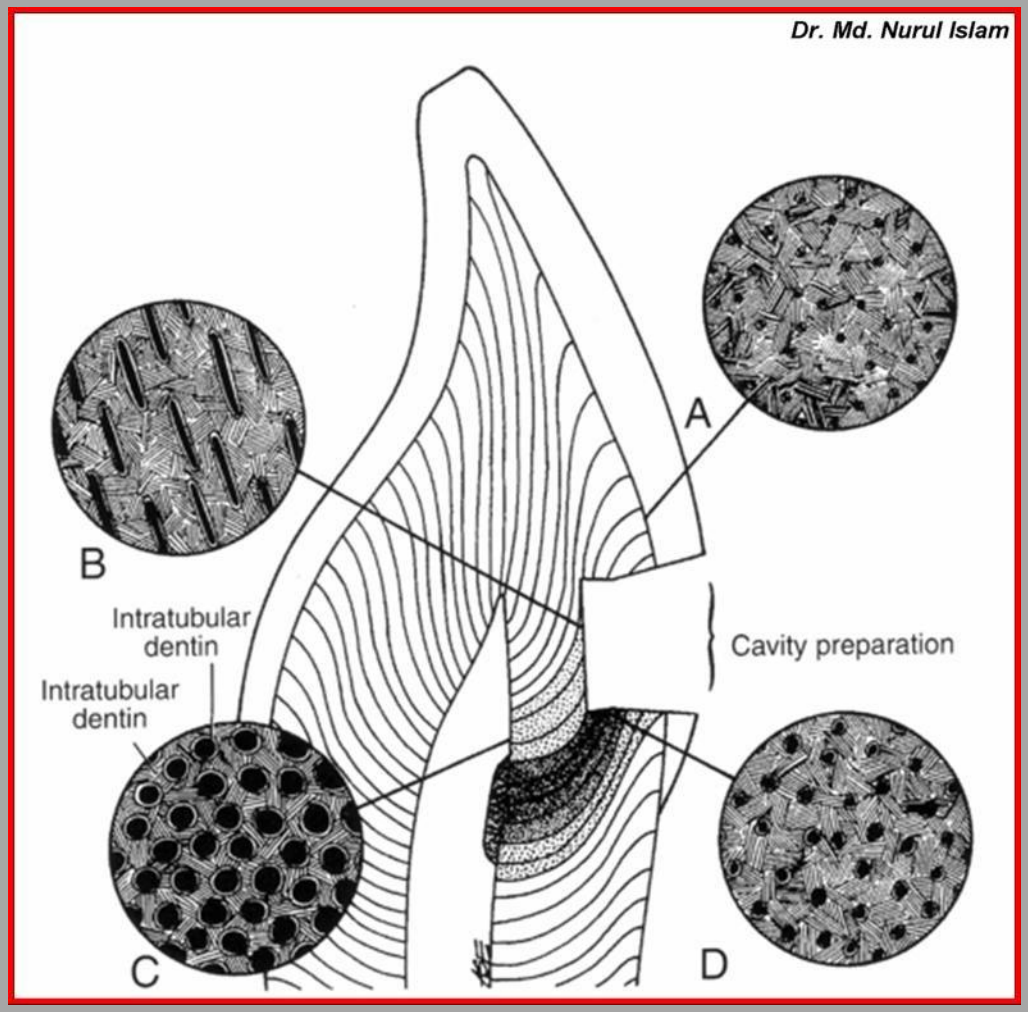
Odontoblast
like squamous epithelium

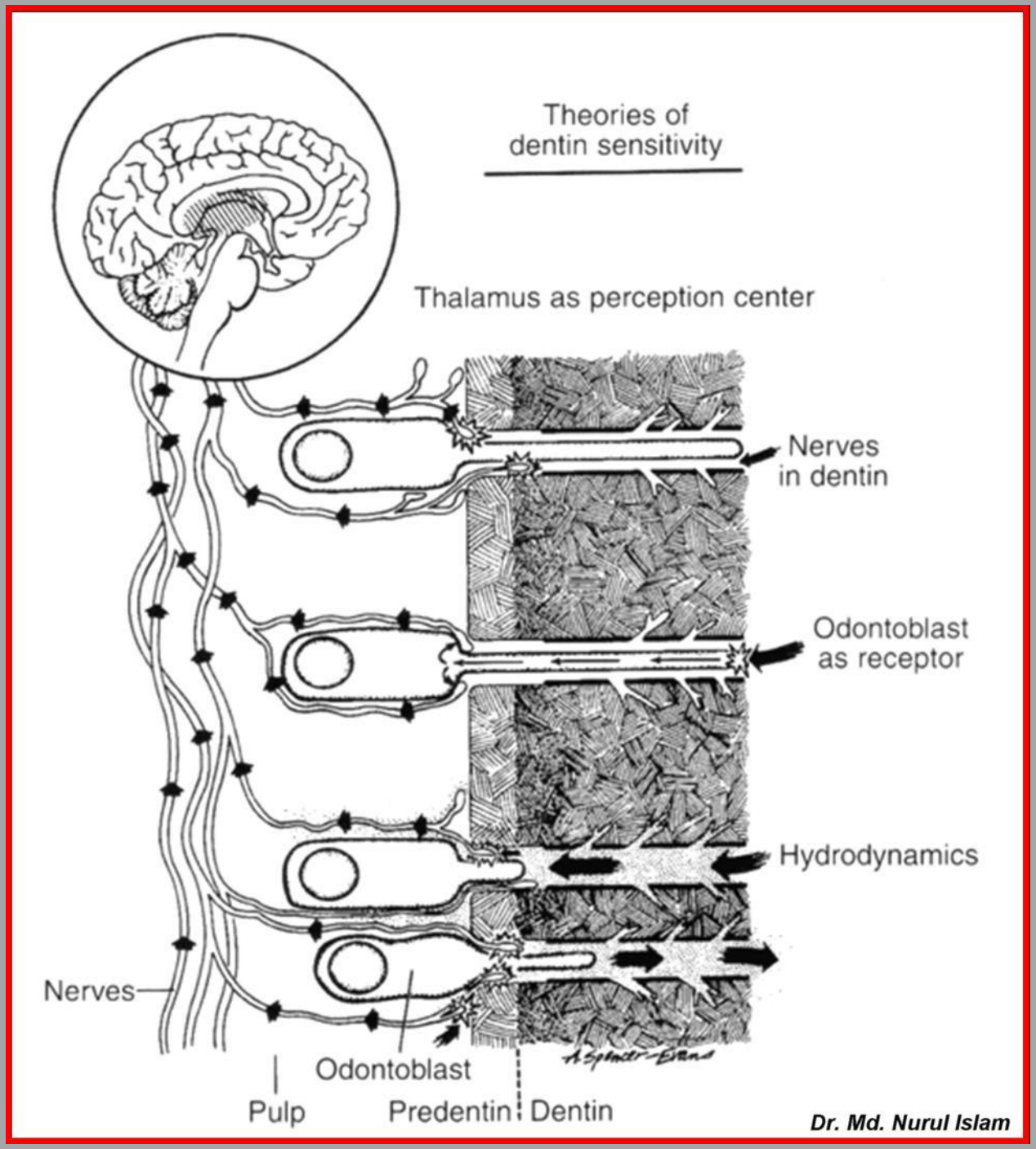
Processes (fibers) of Odontoblast are lining through the dentine tubules but cell bodies are located in pulp region.

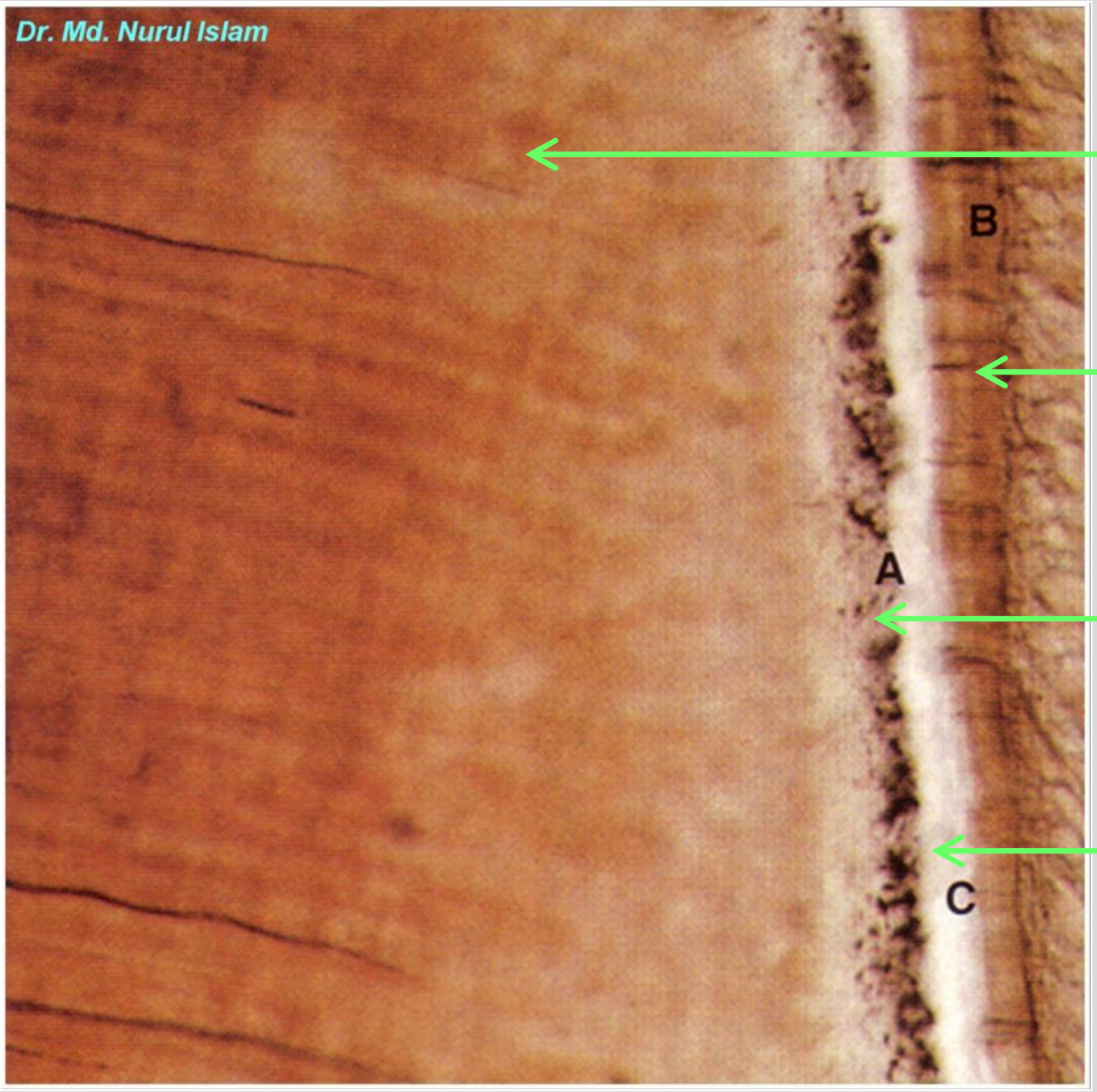
Odontoblasts and process




DEJ
Mantle dentin
Interglobular dentin
Peritubular dentin
Intertubular dentin
Odontoblastic process
Periodontoblastic space
Predentin
Odontoblast
Nerve
Dr. Md. Nurul Islam


Dr. Md. Nurul Islam
A
B
C
D
Intratubular dentin
Intratubular dentin
Cavity preparation


Theories of
dentin sensitivity
Thalamus as perception center
Nerves
in dentin
Odontoblast
as receptor
Hydrodynamics
Nerves
Odontoblast
Pulp
Predentin
Dentin
Dr. Md. Nurul Islam

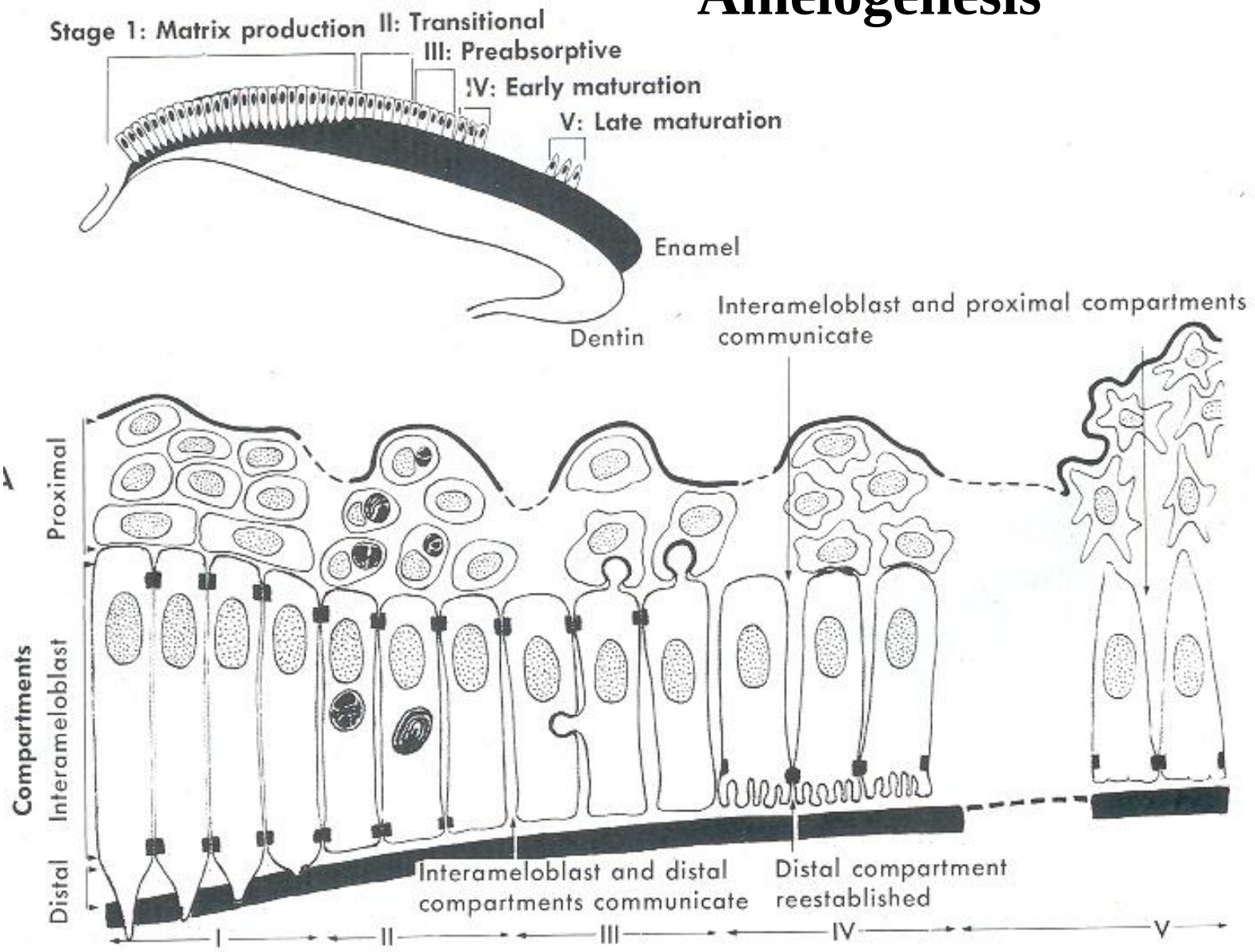

Dr. Md. Nurul Islam
B
A
C
Dentin
Cementum
Granular layer of Tomes
Hyaline layer

Amelogenesis is also a two-step process:

1. **First step produces a partially mineralized matrix (~ 30%)**

2. **Second step involves influx of additional mineral coincident with removal of organic material and water to attain greater than 96% mineral content**

Amelogenesis



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Amelogenesis

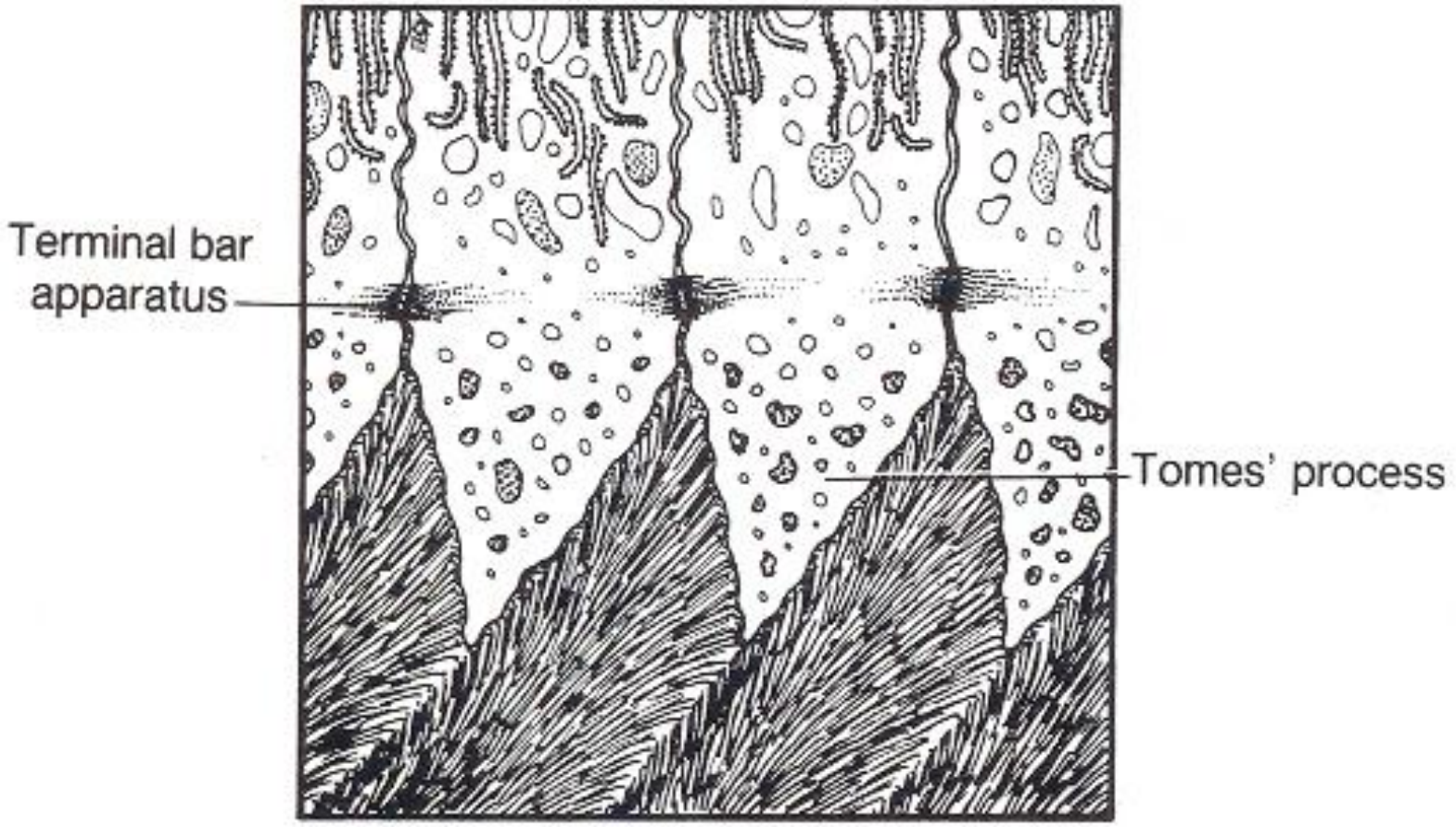
Amelogenesis begins after a few μm of dentin deposition at the dentinoenamel junction

Ameloblasts goes through following functional stages:

1. **Morphogenetic. During this stage the shape of the crown is determined.**

2. **Histodifferentiation. The cells of the inner dental epithelium is differentiating into ameloblasts. The above two stages are the presecretory stages, where the cells differentiate, acquire phenotype, change polarity, develop an extensive protein synthesis machinery, and prepare to secrete an organic matrix of enamel.**

3. **Secretory stage: Ameloblasts elaborate and organize the entire enamel thickness. Short conical processes called Tomes´ processes develop at the apical end of the ameloblasts. The main protein that accumulates is amelogenin.**



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Amelogenesis

4. **<u>Maturation stage:</u> Ameloblasts modulate and transport specific ions required for the concurrent accretion of mineral. At this stage, ameloblast becomes more active in absorption of the organic matrix and water, which allows mineralization to proceed. After the ameloblasts have completed their contributions to the mineralization phase, they secrete an organic cuticle on the surface of the enamel, which is called developmental or primary cuticle**

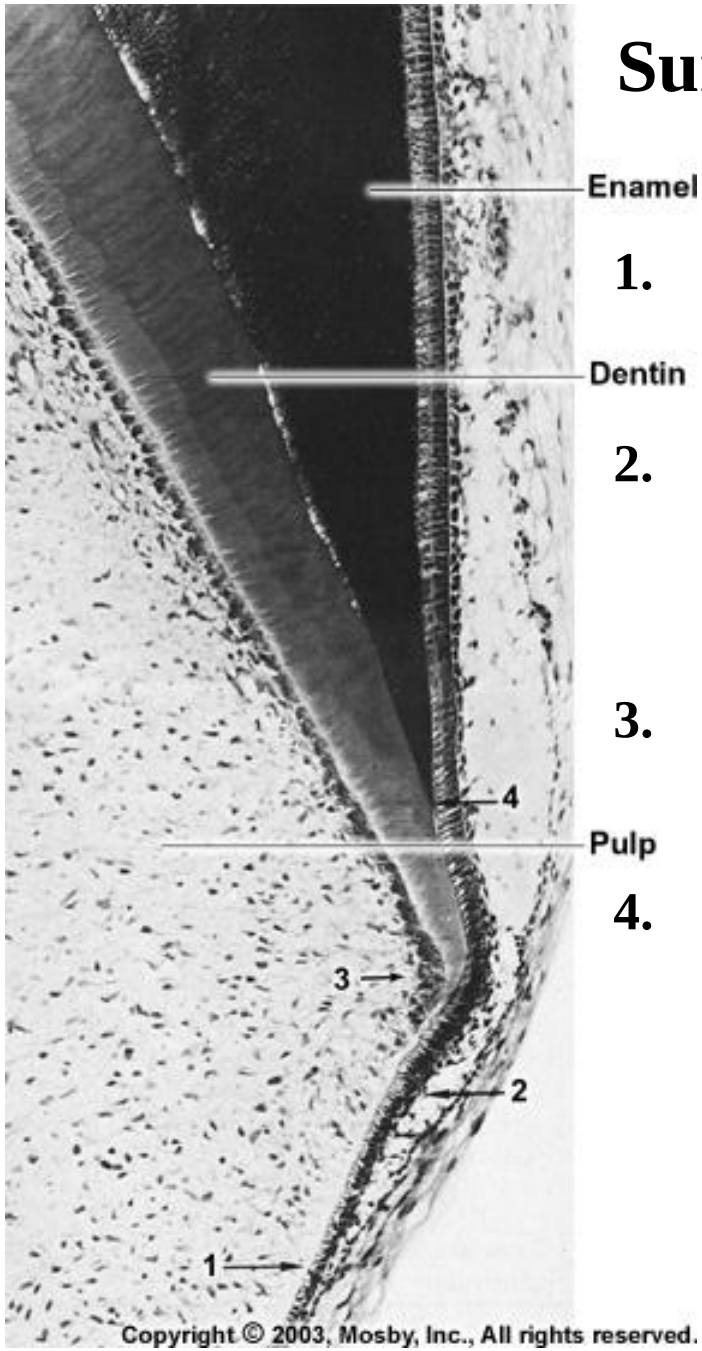
5. **<u>Protection:</u> The ameloblast are shorter and contact the stratum intermedium and outer dental epithelium and fuse to form the reduced dental (enamel) epithelium. The reduced enamel epithelium remains until the tooth erupts. As the tooth erupts and passes through the oral epithelium, the incisal part of the reduced dental epithelium is destroyed but the epithelium present cervically interacts with oral epithelium to become the junctional epithelium**

Amelogenesis Imperfecta

Hypomaturation

Hypoplastic

Hypocalcified



Summary of Tooth Development (So Far)

1. **The epithelium is separated from the dental papilla by an acellular zone**

2. **Inner dental epithelial cells are elongated, and the acellular zone is lost by differentiation of odontoblasts**

3. **Odontoblasts retreat toward the center of the pulp, leaving behind dentin**

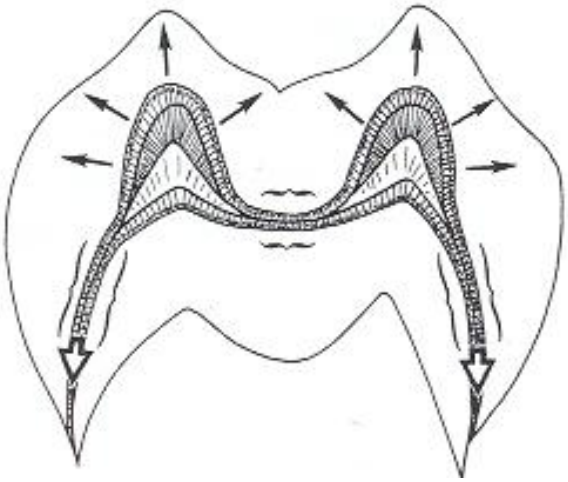
4. **Ameloblasts begin to migrate outward and leave behind formed enamel**

Time Line of Human Tooth Development

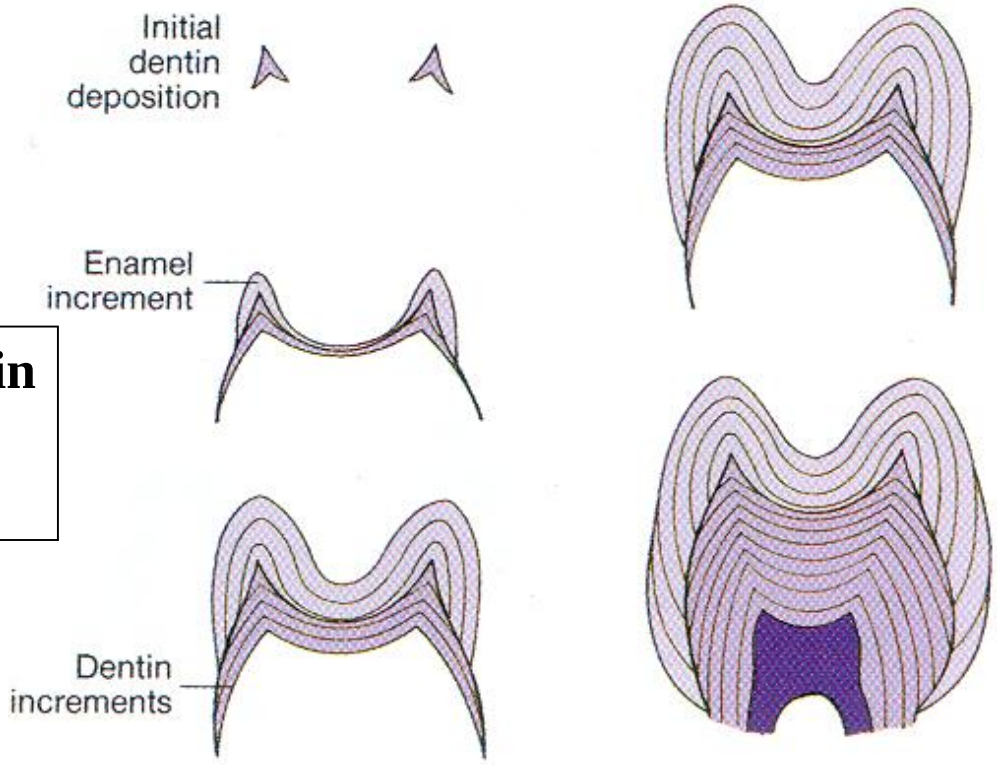
(Table 5-2 in Text book)

Age	Developmental Characteristics
42 to 48 days	Dental lamina formation
55 to 56 days	Bud stage; deciduous incisors; canines and molars
14 weeks	Bell stage for deciduous teeth; bud stage for permanent teeth
18 weeks	Dentin and functional ameloblasts in deciduous teeth
32 weeks	Dentin and functional ameloblasts in permanent first molars

Growth of cusps to predetermined point of completion



Growth areas of developing crown. Growth at cusp tip, intercuspal region, and cervical region



Incremental pattern of dentin and enamel formation from initiation to completion

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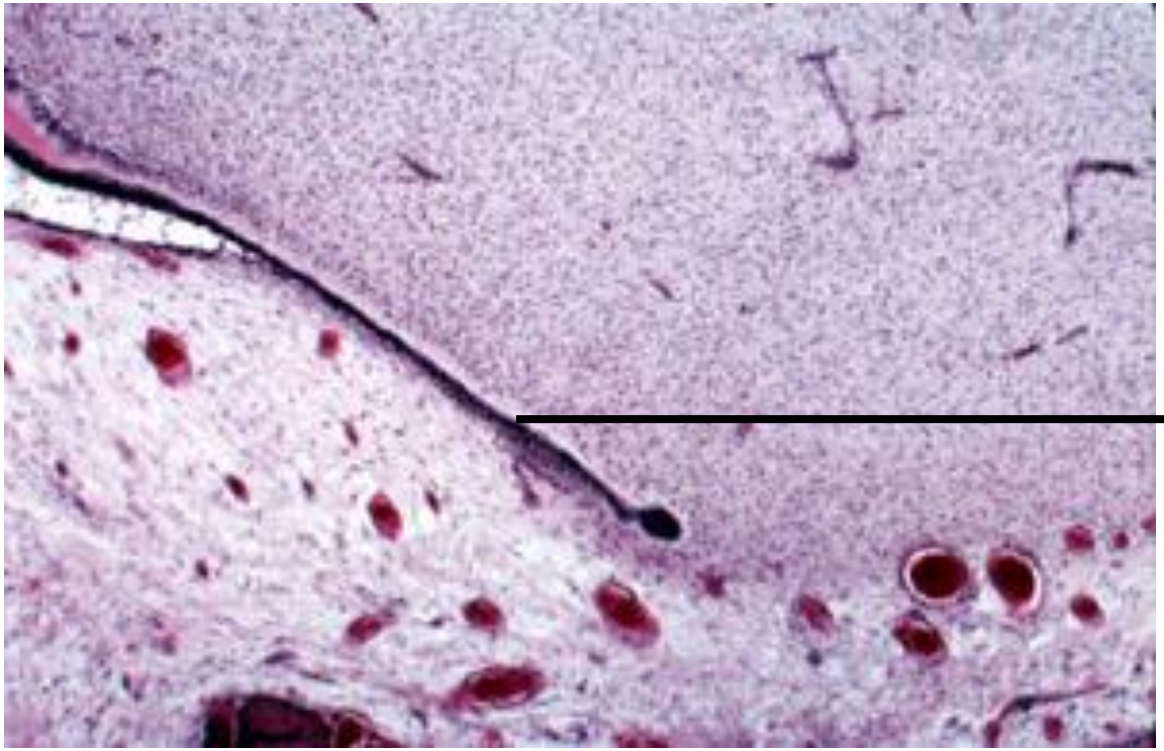
Root Formation



Hertwig's epithelial root sheath

Development of root begins after the enamel and dentin formation has reached the future cementoenamel junction

Epithelial cells of the inner and outer dental epithelium proliferate from the cervical loop of the enamel organ to form the *Hertwig's epithelial root sheath. The root sheath determines if a tooth has single or multiple roots, is short or long, or is curved ir straight*

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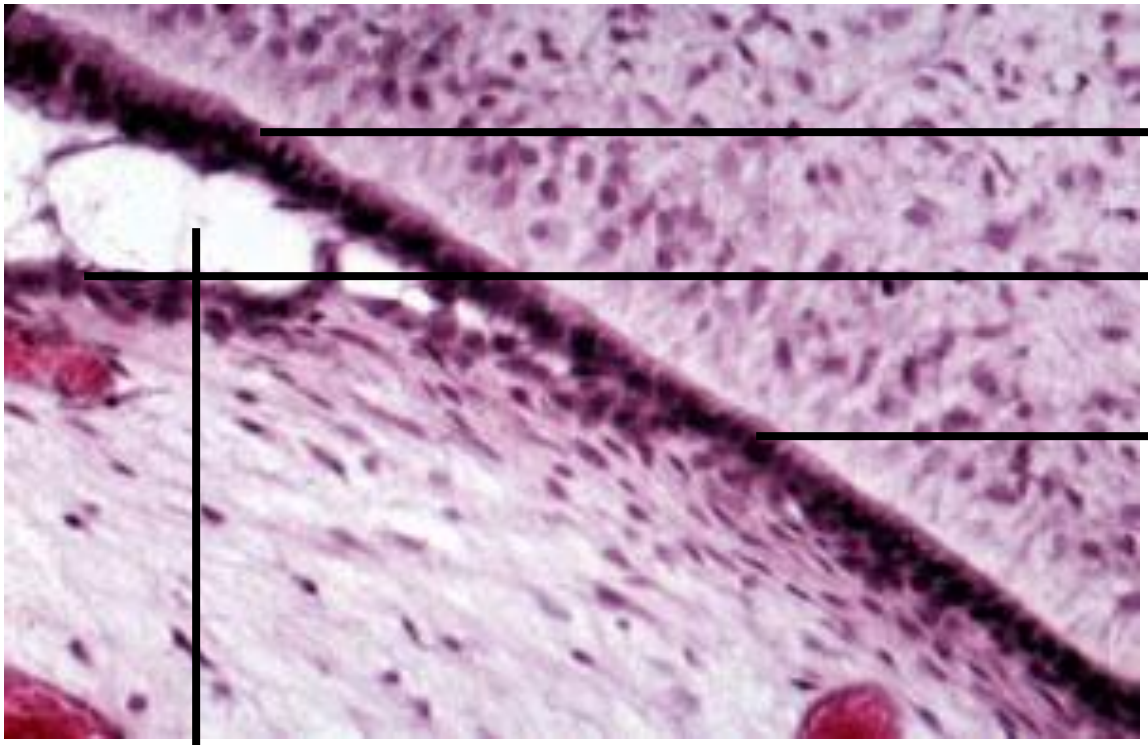

Eventually the root sheath will fragment to form several discrete clusters of epithelial cells known as *epithelial cell rests of malassez. These will persist in adults within the periodontal ligament*

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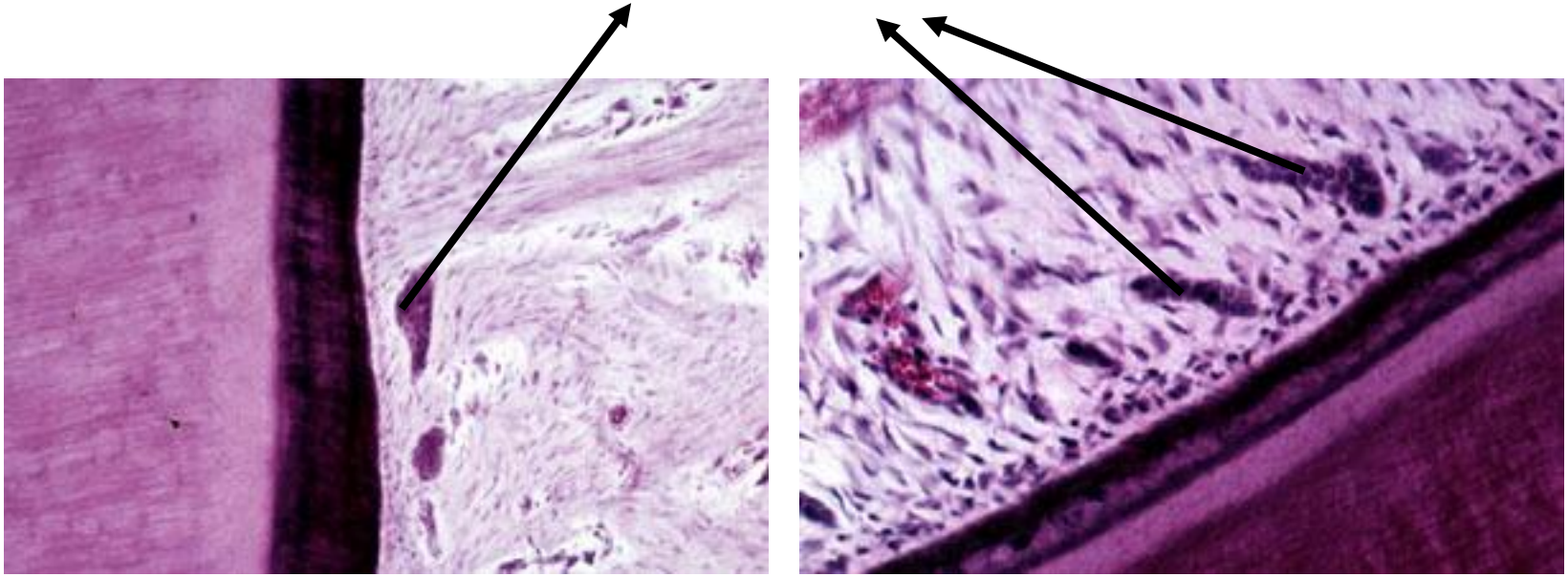
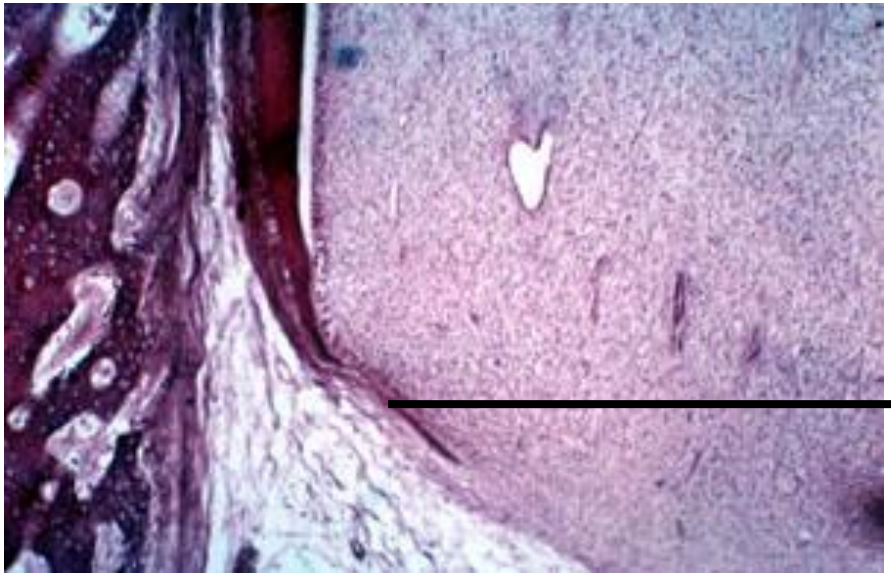
Epithelial Cell Rests of Malassez



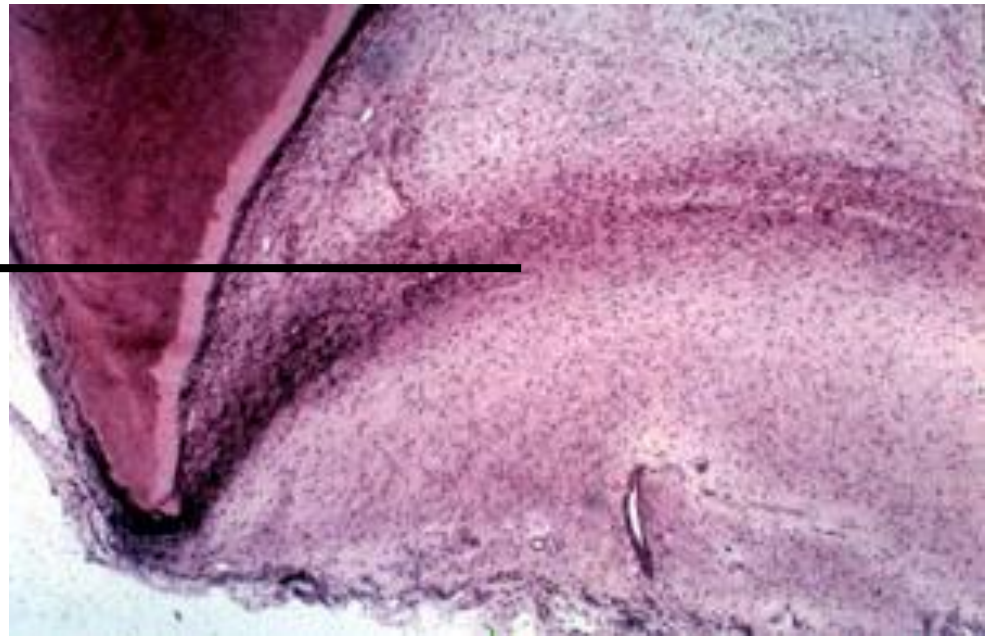
The epithelial rests appear as small clusters of epithelial cells which are located in the periodontal ligament adjacent to the surface of cementum. They are cellular residues of the embryonic structure known as Hertwig's epithelial root sheath.

http://www.usc.edu/hsc/dental/ohisto/



Epithelial diaphragm: the proliferating end of the root sheath bends at a near 45-degree angle. The epithelial diaphragm will encircle the apical opening of the dental pulp during root development

Primary apical formen



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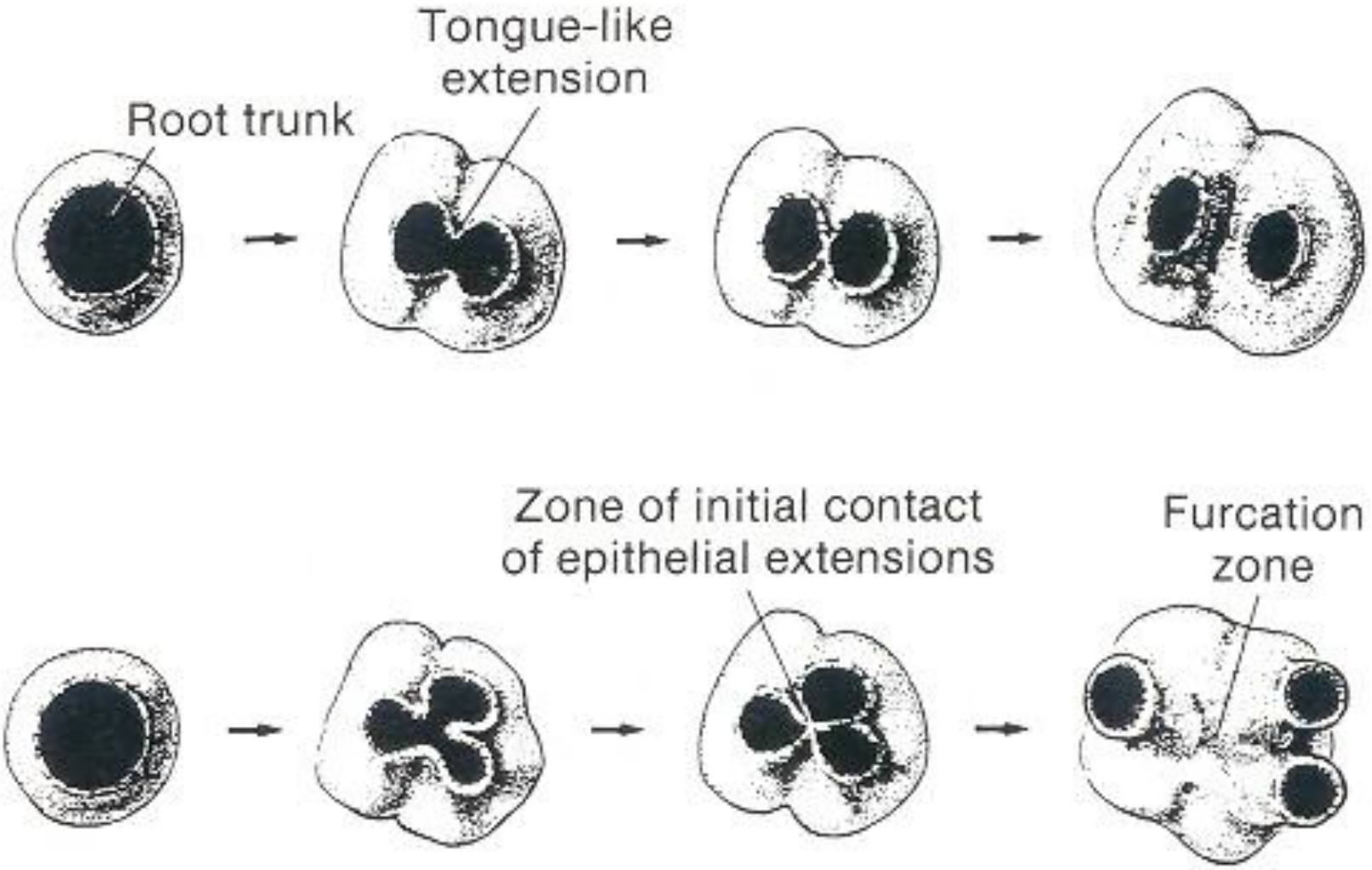

Secondary apical foramen form as a result of two or three tongues of epithelium growing inward toward each other resulting in multirooted teeth

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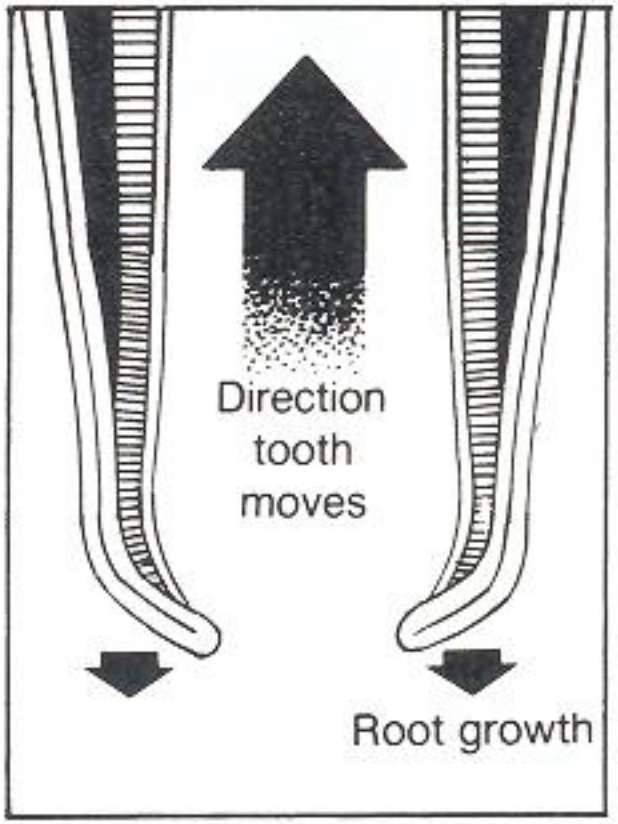
Direction of root growth versus eruptive movement of tooth



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Tooth eruption and Development of supporting structures

Soon after root formation begins, tooth begins to erupt until it reaches its final position

While roots are forming, the supporting structures of tooth also develop – periodontal ligament and cementum

As the root sheath fragments, the dental follicle cells will penetrate between the epithelial cells and lie close to the newly formed root dentin

These cells will differentiate into cementoblasts, which will make cementum

Fibers of the periodontal ligament, which will also form from the cells of the dental follicle will get anchored in the organic matrix of the cementum which will later get mineralized

Figure :Average periods for emergence and exfoliation of primary teeth

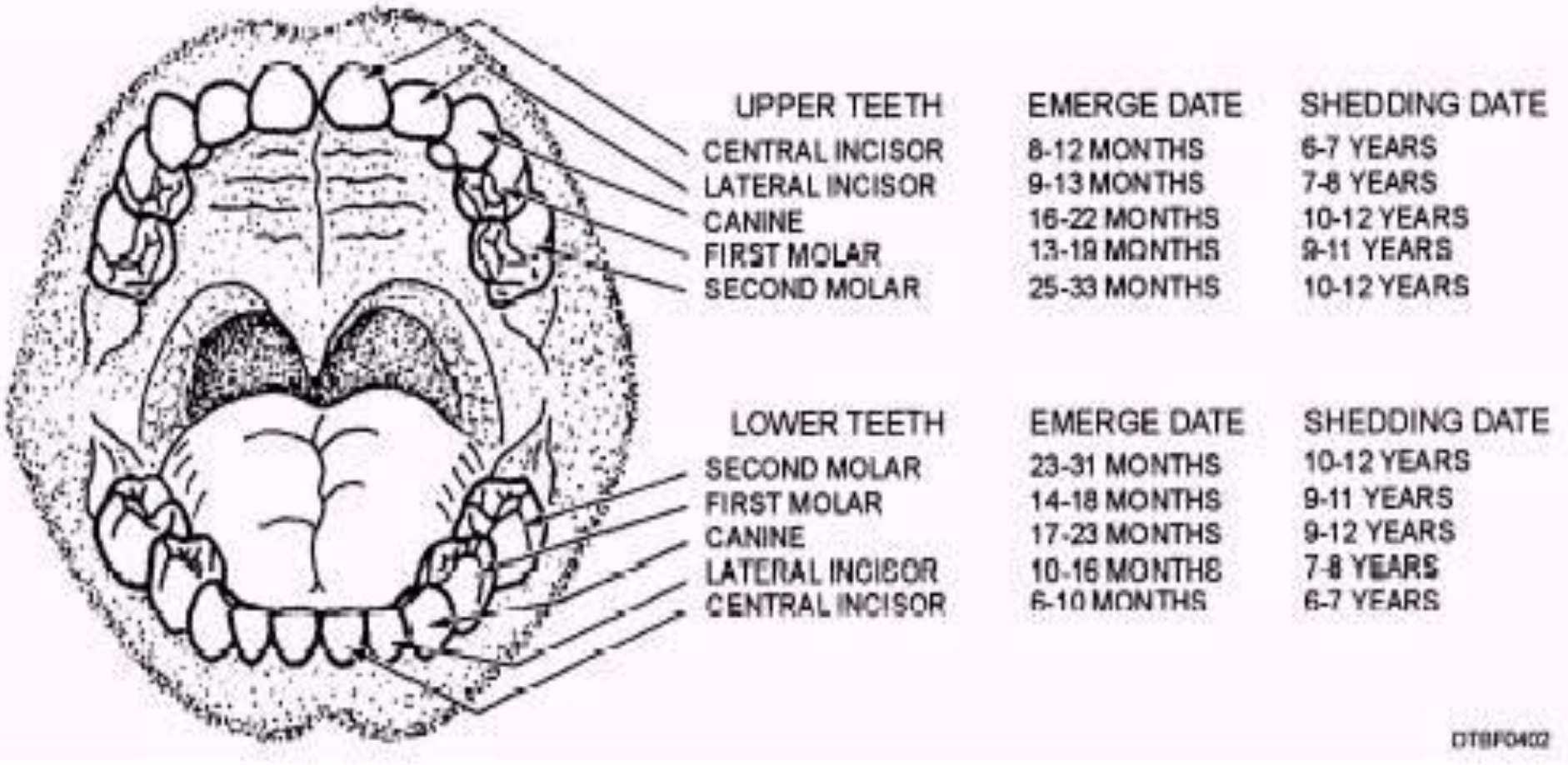

Figure: Average periods of emergence of permanent teeth.