Odontogenesis

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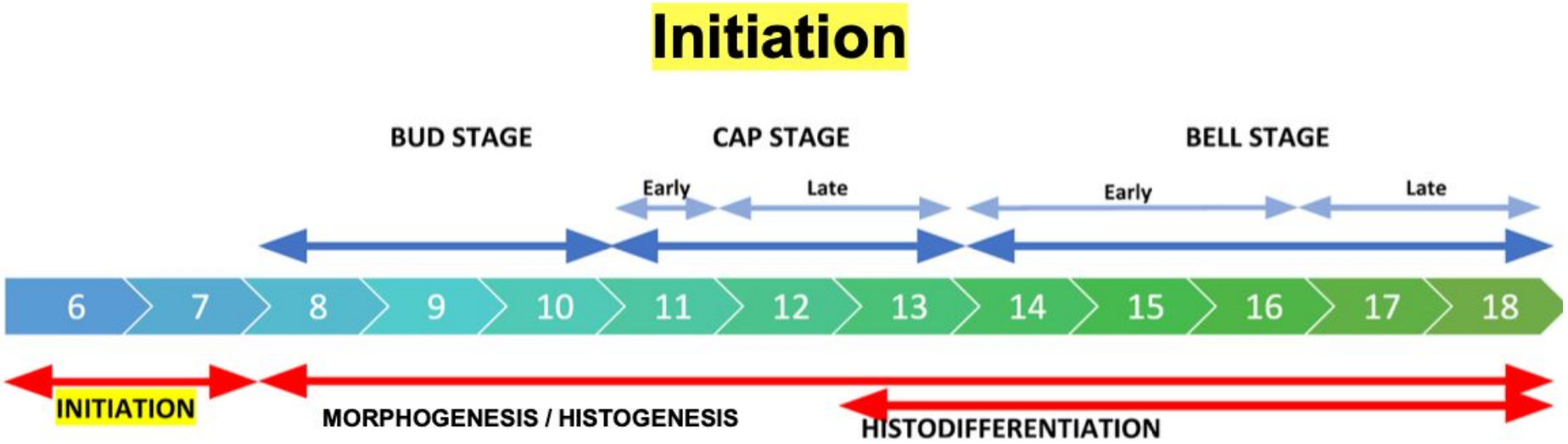
Outline

Odontogenesis

- Initiation
- Morphogenesis
- Histogenesis
- Amelogenesis
- Dentinogenesis

Tooth Eruption / Dental Age Dental Development Anomalies

Odontogenesis



Initiation

1. Primordial oral cavity - mesenchymal tissue and primitive oral epithelium

<u>Week 6</u>

2. Thickens by proliferation
3. Invagination into underlying mesenchyme

<u>Week 7</u>

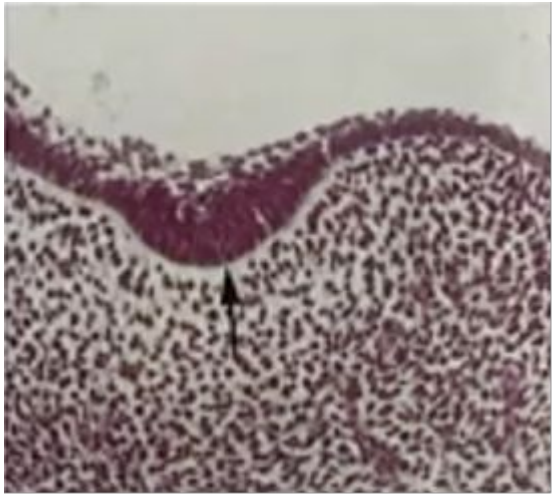
4. Development into two processes

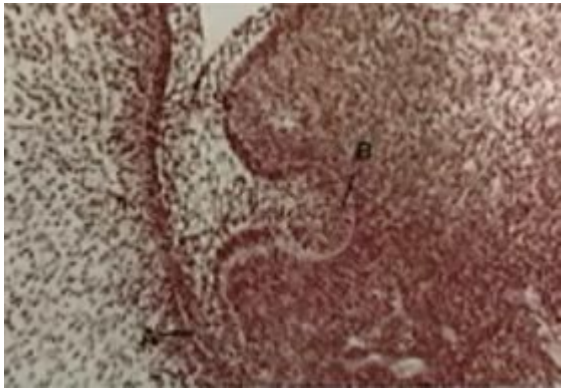
A - Vestibular lamina → vestibule

B - Dental lamina → TG

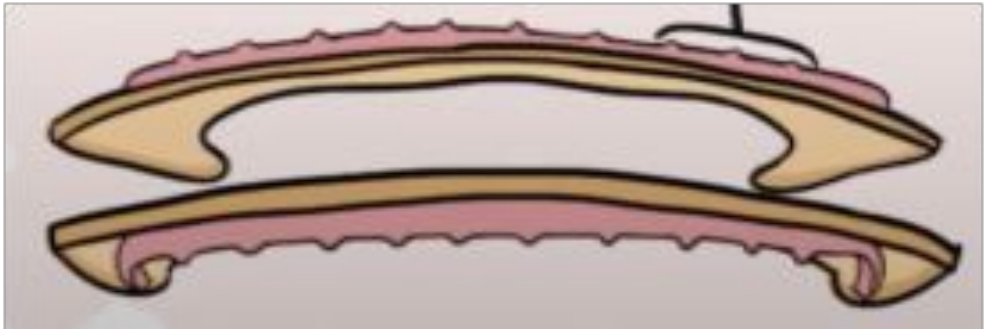
<u>Week 8</u>

5. Enlarging along DL where tooth germs begin developing

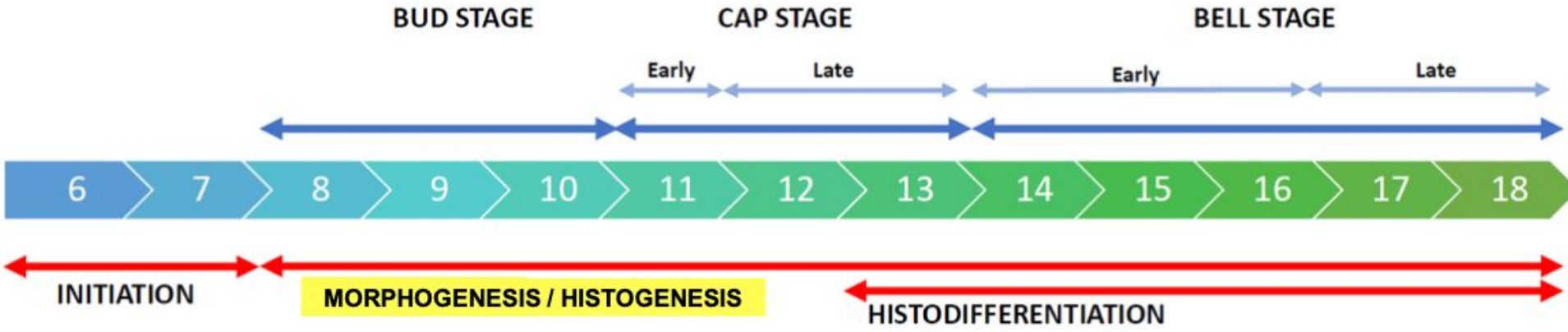





DENTAL LAMINA
VESTIBULAR LAMINA



Morphogenesis / Histogenesis



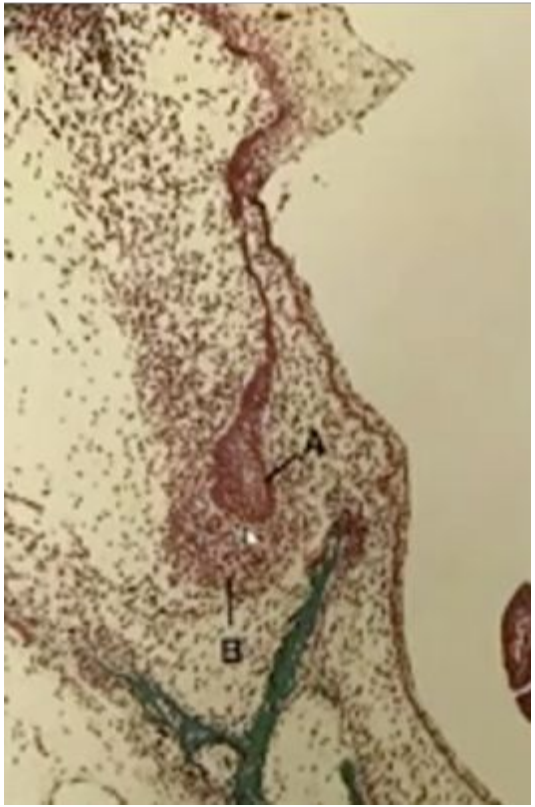
Morphogenesis includes Histogenesis processes; different to Histodifferentiation

- *Morph – Shape changes*
- *Histo – Cellular changes*

Bud Stage

Week 8-10

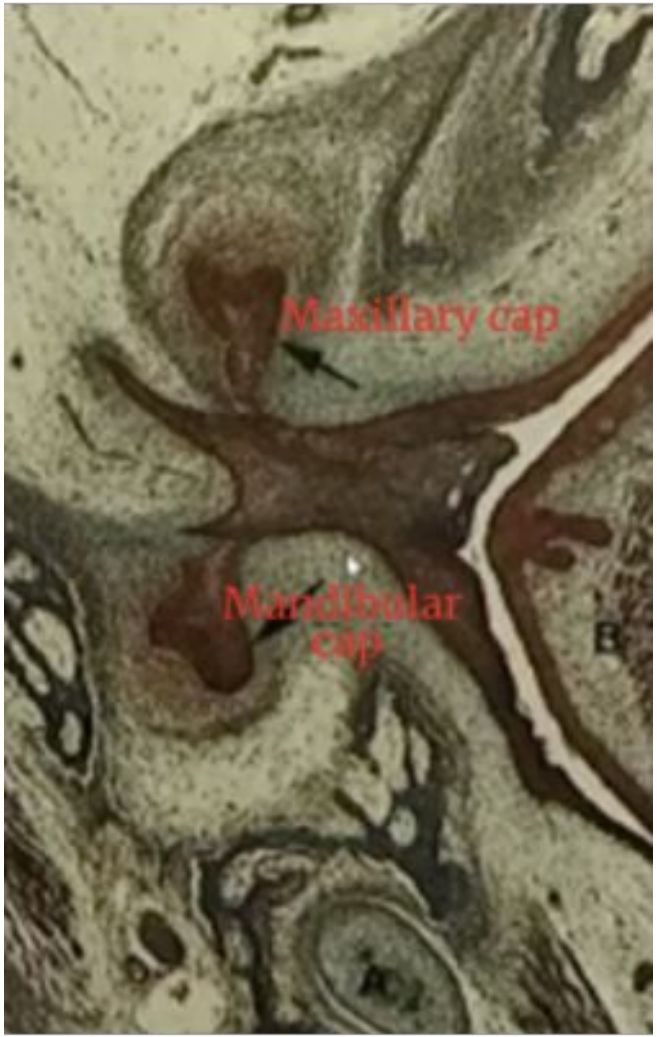
1. Enamel Organ (EO) - enlargement and sac formation from differentiation of DL
2. Surrounded by mesenchymal cells which thicken and condense



Early Cap Stage

Week 11

1. Further differentiation of EO to thicken bud
2. Deeper surface of EO becomes concave to form **cap** shape



Late Cap Stage

Week 12

1. EO - central cells stagnant, stretched but stay connected by desmosomes
2. Peripheral cells of EO differentiate into EEE and IEE

A - stellate reticulum

B - EEE

C - IEE

D - Dental papilla

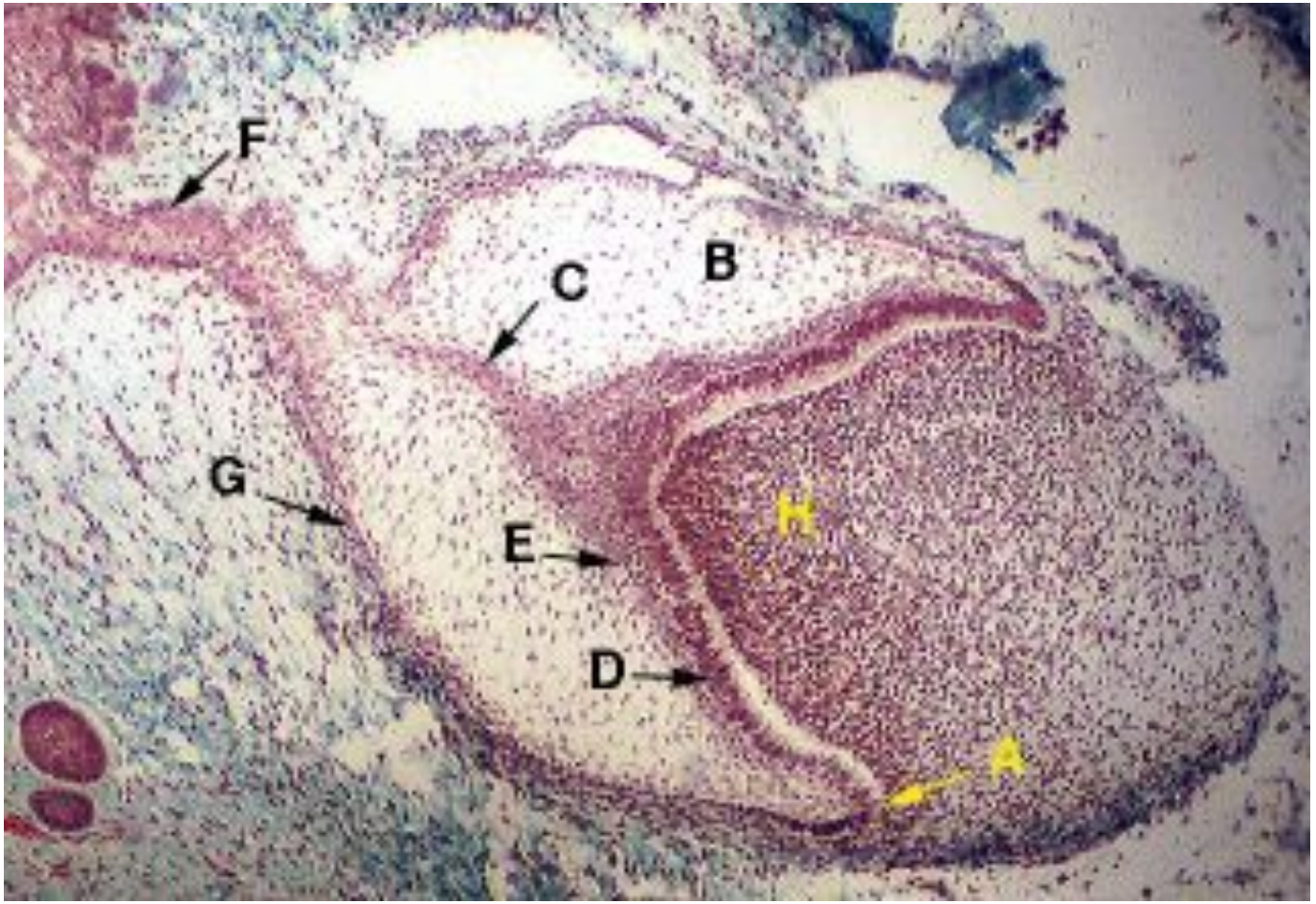
Week 13

3. Configuration of primary tooth germs established

Early Bell Stage

Week 14

1. Disintegration of DL makes TG discrete entity
2. Cap lengthens into bell by intense differentiation of IEE
3. IEE shape roughly resembles occlusal pattern of tooth crown
4. Future outline of roots derived from cervical loop


F
C
B
G
H
E
D
A

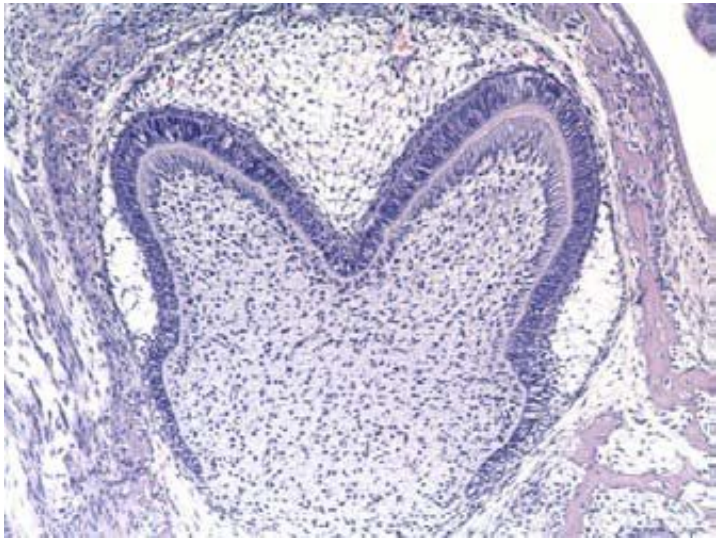
Late Bell stage

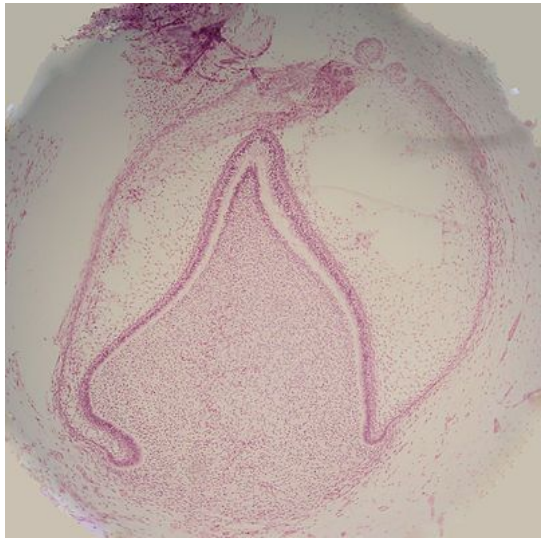
Week 17

1. Lingual downgrowth of EEE → 1-5s
2. Posterior extension of EEE → 6-8s

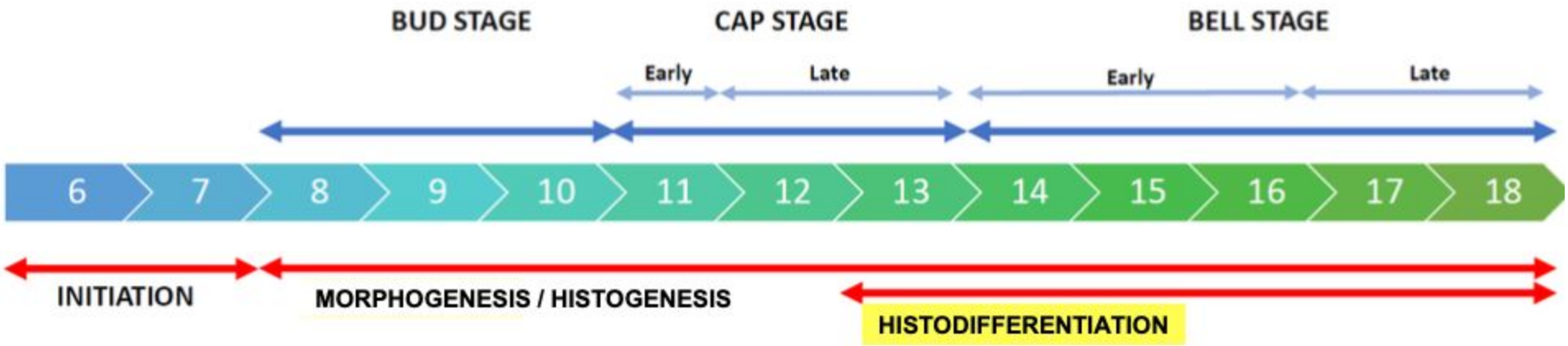
Week 18

1. Commence enamel and dentine deposition (amelogenesis, dentogenesis)





Histodifferentiation



- Amelogenesis
- Dentinogenesis

Amelogenesis

1). Pre-Secretory Stage

2). Secretory

3). Transition

4). Maturation

5). Post-Maturation

1). Pre-Secretory Stage

Reciprocal Induction (Important Concept)

I. IEE Pre differentiate to Ameloblasts that then release growth factors…….

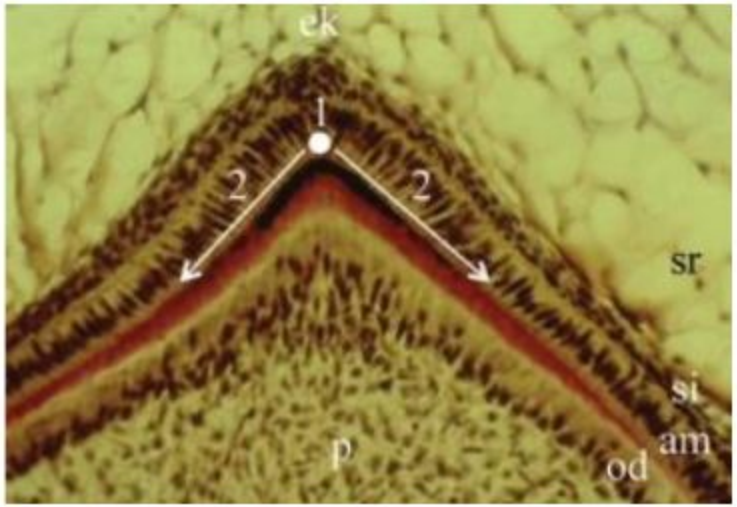
II. Growth factors that traverse basement membrane into contact with adjacent Dental Papilla cells……

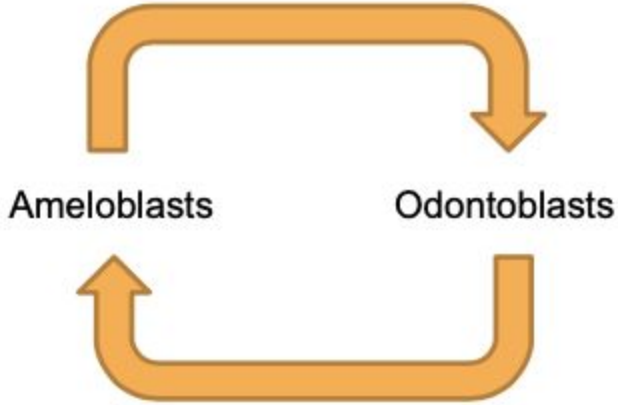
III. Dental Papilla cells differentiate into Odontoblasts which then secrete dentine matrix while…..

IV. Ameloblast degrade basement membrane until they come into contact with dentine matrix which…….

V. Induce Ameloblasts to produce enamel matrix!

Progresses from future cusp tip / incisal edge to root





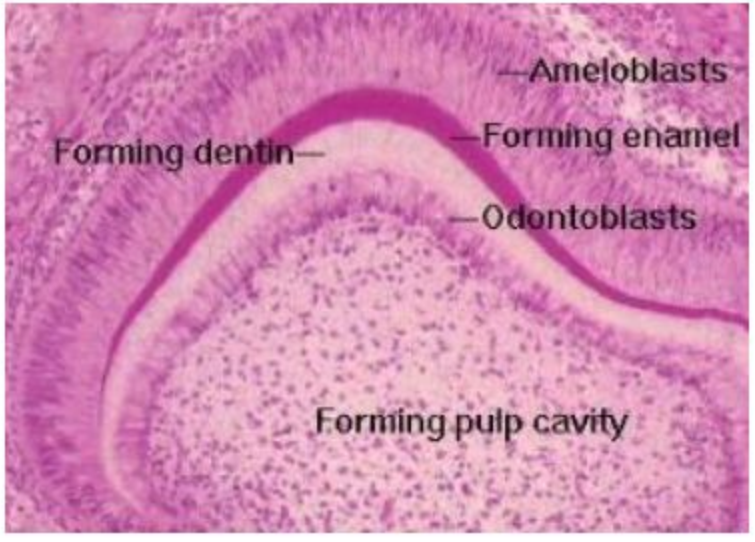
2). Secretory

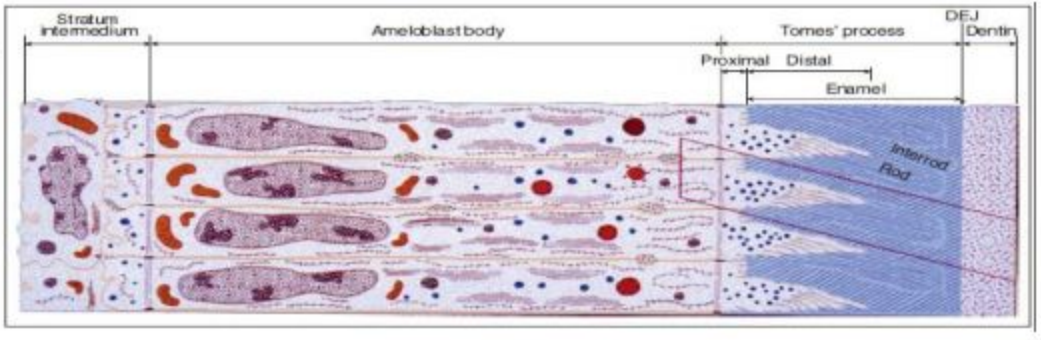
Ameloblasts form secretory tomes processes, move away from produced enamel during formation towards EEE (deposit internal layers first, move away towards outer surface)

Virtually immediate enamel hydroxyapatite crystallisation with low mineralised content

Tomes process retract after full enamel thickness forms

Note: Perikymata (enamel striations) formed through daily incremental enamel deposition





3). Transition

Following enamel matrix secretion and tomes process retraction; approx. 50% Ameloblast population apoptosis

Current high protein content (approx. 25-30% weight)

4). Maturation

Matrix matures: (transition to maturation stage)

- H_2O 65% ⟶ 1-2%
- HA 15% ⟶ 96-98%
- Proteins 20% ⟶ 1-2%

Maturation by Enamel Organ proteases and remaining Ameloblasts moving Ca, PO_4 and CO_3 ions into matrix

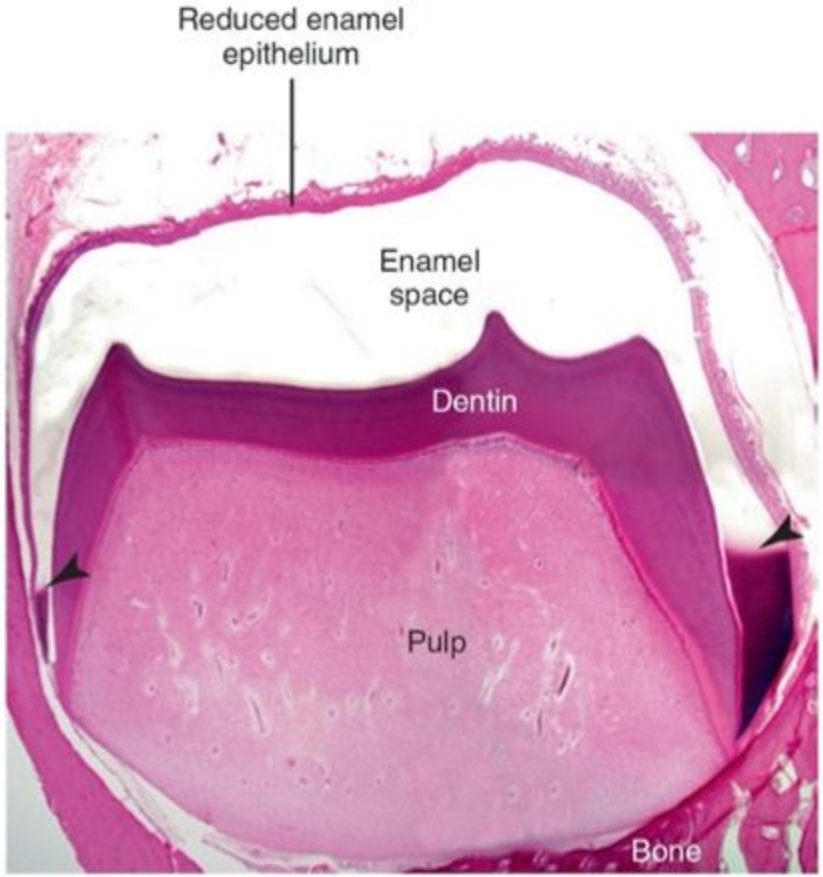
Ions moved in whilst water and degraded proteins removed

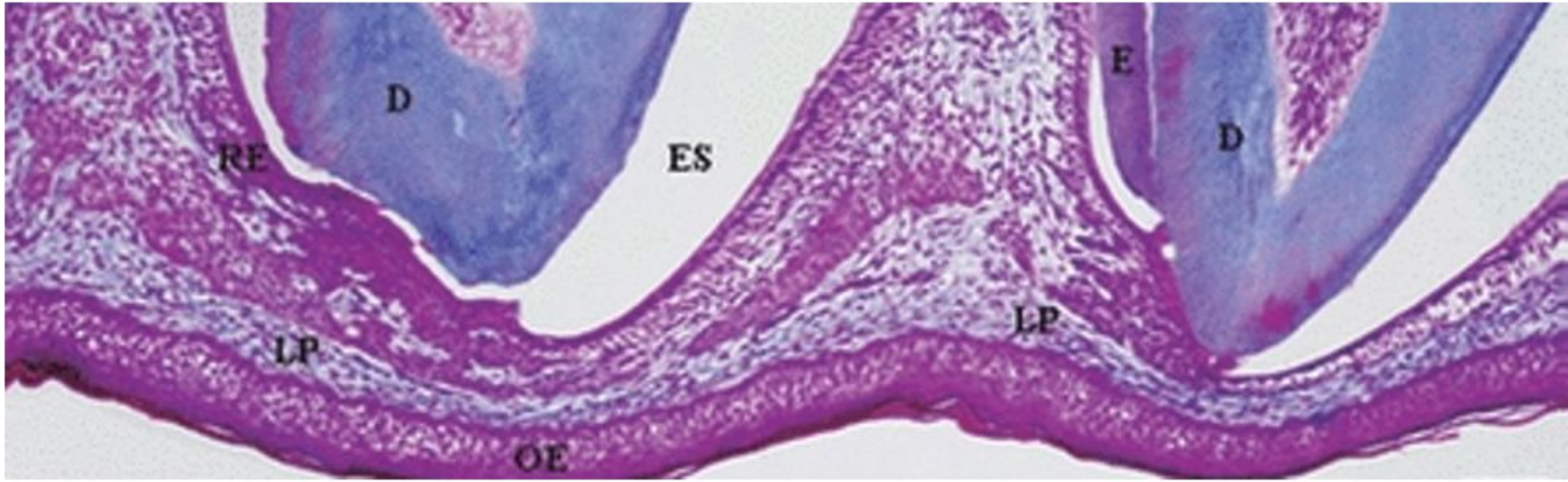
Process thickens enamel prisms from 1.5nm to 25nm diameter

5). Post-Maturation

Remaining Ameloblasts flatten and merge with residual Enamel Organ forming reduced enamel epithelium cover (remains until tooth eruption)

Mineralization post eruption via saliva / oral cavity environment interaction – Fluorapatite!

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Dentinogenesis

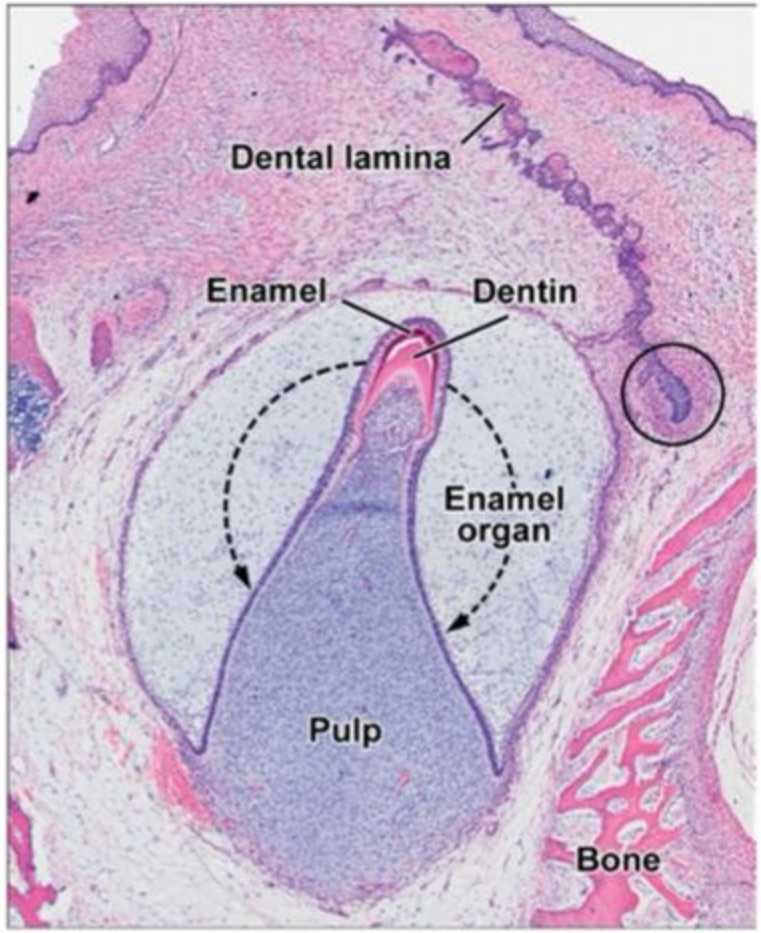
1). Odontoblast Differentiation

2). Matrix Deposition

3). Matrix Mineralisation

4). Peritubular & Secondary Dentine Formation

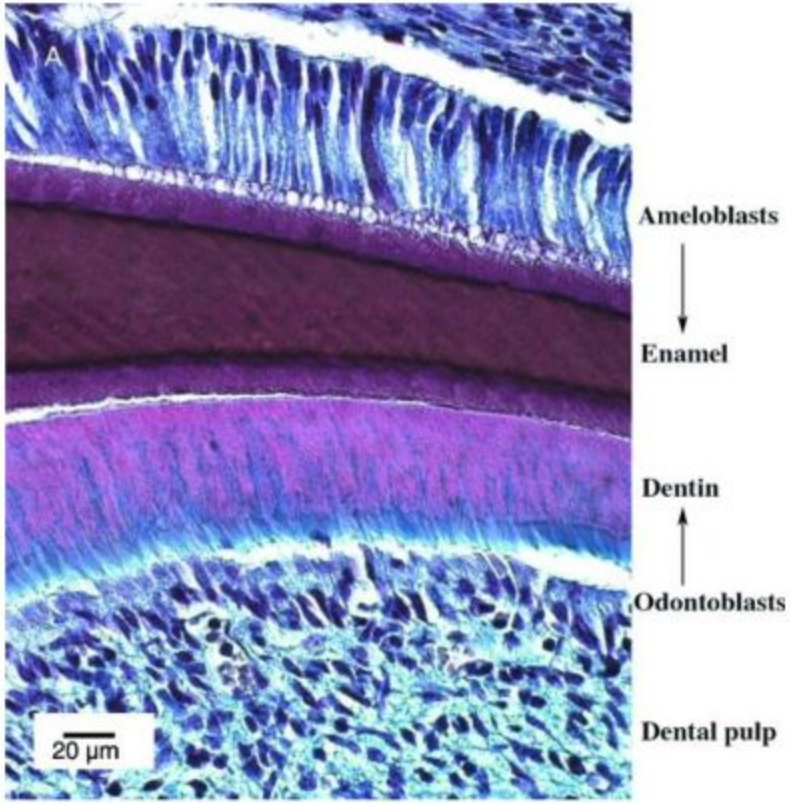
5). Tertiary Dentine Formation



1). Odontoblast Differentiation

Odontoblasts (OD) from Dental Papilla ectomesenchyme cells following Ameloblast growth factor

Pre-OD develop cellular processes aimed towards IEE (pointing towards Ameloblasts and exterior surface)

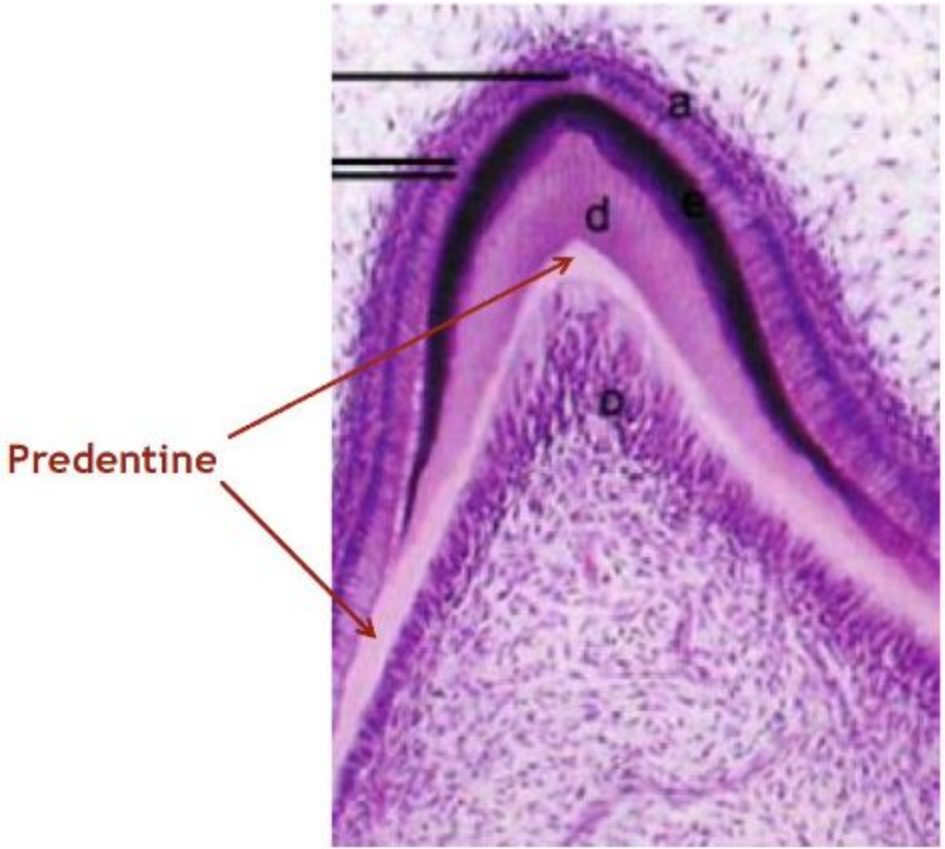


2). Matrix Deposition

Odontoblasts secrete organic matrix (Collagen Type I, III, V and VI & Dentine Phosphoproteins (not exhaustive))

Odontoblasts migrate pulpally away from Ameloblasts

Initial dentine layer does not mineralize immediately, pre-dentine layer!

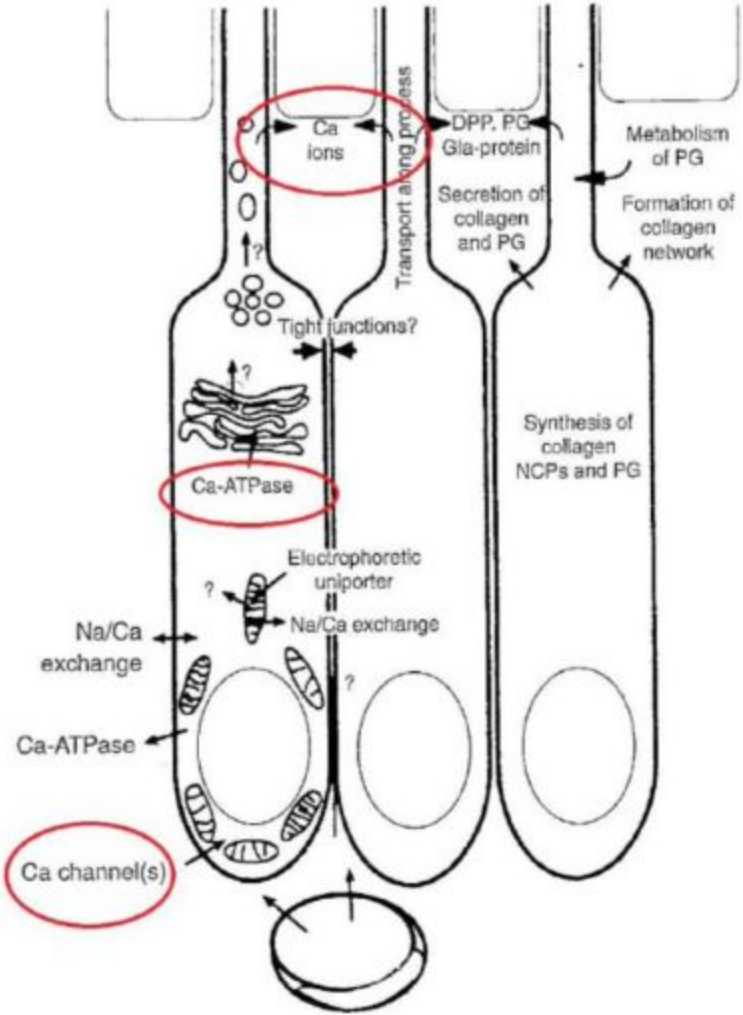


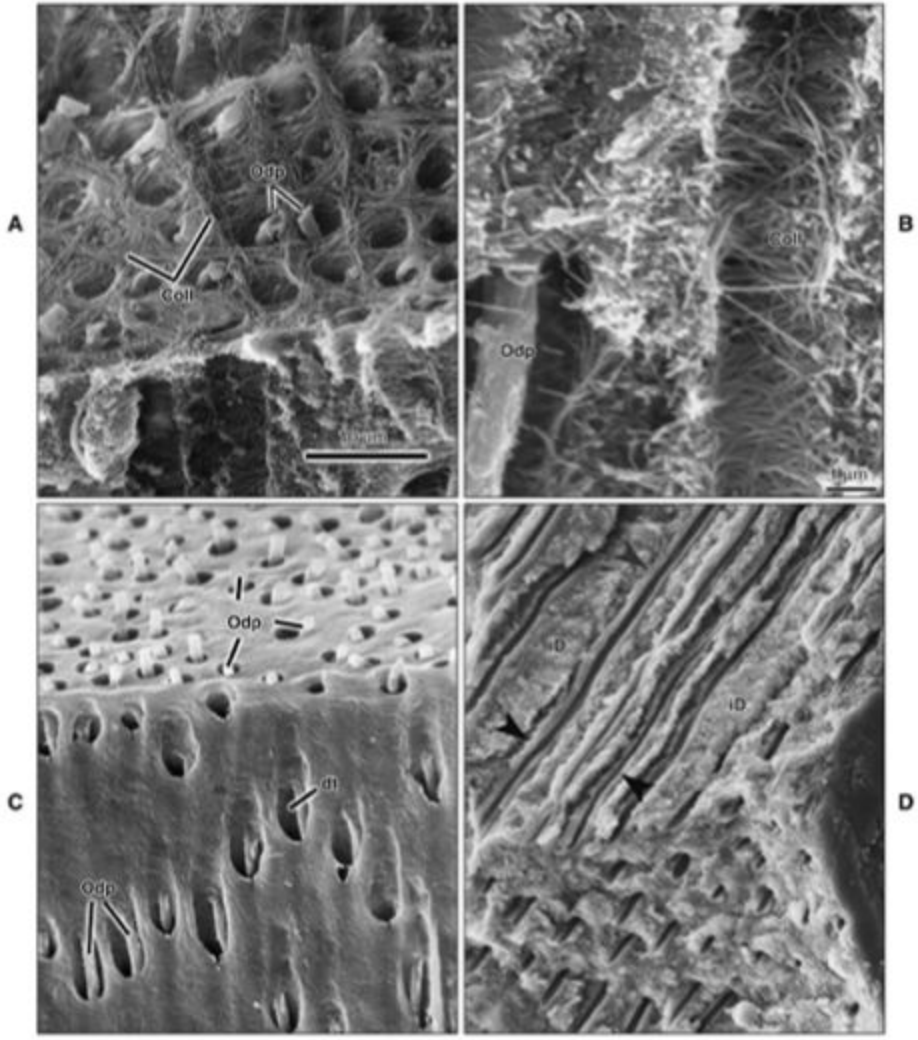
COMPONENTS OF DENTINE MATRIX	
Collagens (Types I, III?, V, VI)	Enamelysin (MMP20)
Proteoglycans	Lipids
Glycoproteins/Sialoproteins	Serum-derived proteins
Dentine Phosphoprotein	Growth factors

3). Matrix Mineralisation

Currently accepted in literature:

- Odontoblasts deliver Ca ions
- Dentine matrix template (scaffold) of collagen type I which is secreted following initial collagen type III material
- Noncollagenous matrix proteins (such as Dentine Phosphoprotein [DPP]) from Odontoblasts regulate subsequent matrix mineralization
- Lags behind initial matrix deposition (compared to enamel which as immediate initial mineralization activity)




A
Odp
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10µm
B
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C
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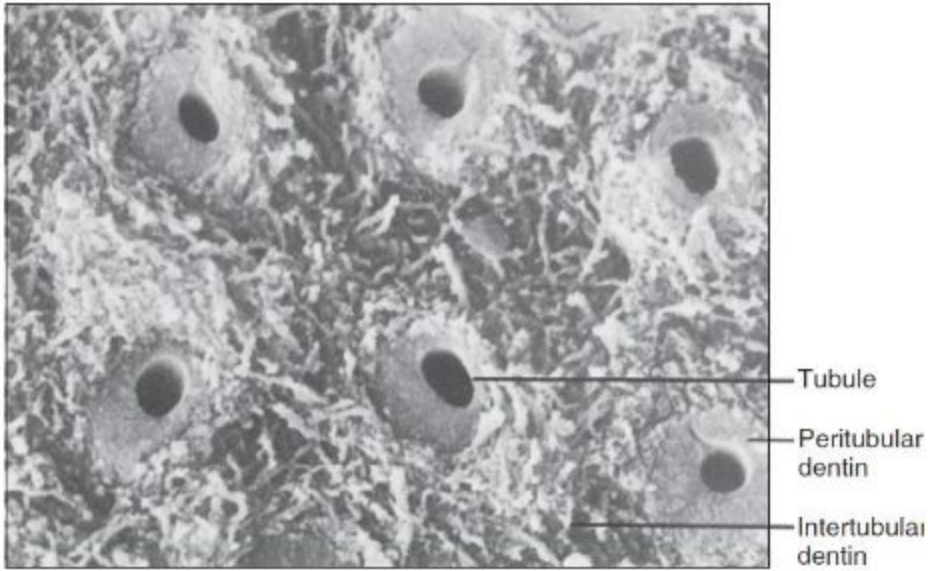
4). Peritubular & Secondary Dentine Formation

Peritubular (Intratubular) Dentine (Bonding implications)

- 5-12% higher mineralisation then intertubular type
- Continually laid down with age (progressive dentinal tubule narrowing – sclerotic dentine)

Secondary (Intertubular) Dentine (Vitality testing implications)

- Continuous dentine deposited pulpally with age (pulp shrinkage)
- As pulp shrinks, Odontoblast population gradually apoptosis



5). Tertiary Dentine Formation

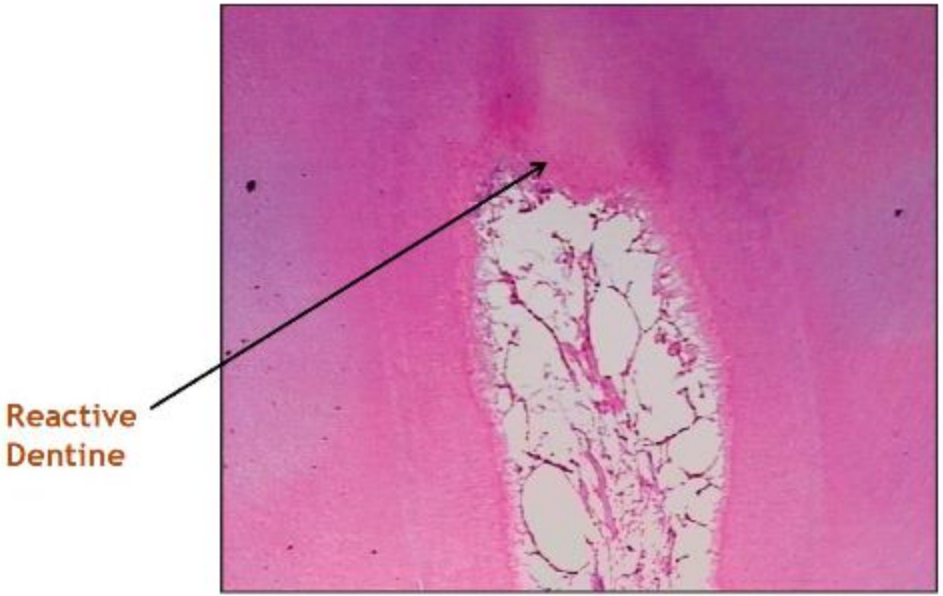
Process occurs post eruption and over lifespan in response to trauma / stimuli (caries, injury, etc)

Reactive / Reactionary Dentine:

- Mild stimuli, Odontoblasts survive, tubular structure remains

Reparative Dentine:

- Severe stimuli kill existing Odontoblasts, newly differentiated odontoblasts form new atubular dentine
- *Newly differentiated odontoblasts do not produce DPP*



Note: Root Dentine

Similar process to coronal dentine with some differences

Lack of adjacent Ameloblasts mean Odontoblast differentiation is stimulated by Hertwig's root sheath (cervical root)

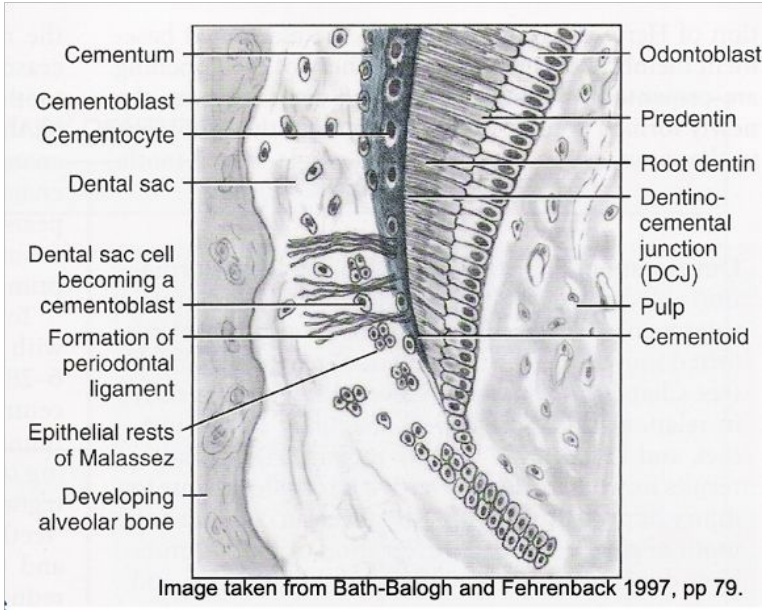


Image taken from Bath-Balogh and Fehrenback 1997, pp 79.

Tooth Eruption / Dental Age

Tooth eruption/dental age

Primary teeth: Calcification pattern A, D, B, C, E

Eruption pattern: A, B, D, C, E

Teeth	A	B	C	D	E
Mx / Md Calcification	Mx before Md	Mx before Md	Md before Mx	Mx before Md	M before Md
Approx. calcification at birth	3/4	1/2	1/3	Cusps unified	Cusps isolated
Approx. age of crown completion	2.5 months	3 months	10 months	6 months	11 months
Approx. age of root completion	18 months	24 months	40 months	30 months	42 months
Approx. eruption age (months)	**Mx:** 10 **Md:** 7	**Mx:** 12 **Md:** 14	**Mx:** 20 **Md:** 20	**Mx:** 16 **Md:** 16	**Mx:** 29 **Md:** 28

Tooth Eruption permanent

Calcification: 6, 1, Mx2, 3, Md 2, 4, 5, 7, 8,

Mx eruption: 6, 1, 2, 4, 3, 5, 7, 8

Md eruption: 6, 1, 2, 3, 4, 5, 7, 8

Crown development takes 4 years
Root development takes 4 years (incisors), 7-8 years for remainder

1st molar: 3 years crown development, 6 years root development
Teeth begin eruption when roots ½- ¾ formed

Root apex closure → full development complete

Teeth	Initial Calcification Time	Eruption Time (years)	
		Mx	Md
1	3 months	**F:** 7 **M:** 7	**F:** 6 **M:** 7
2	Mx: 5 months Md: 1 year	**F:** 8 **M:** 9	**F:** 8 **M:** 8
3	5 months	**F:** 11 **M:** 12	**F:** 10 **M:** 11
4	1 ½ - 2 ½ years	**F:** 11 **M:** 11	**F:** 11 **M:** 11
5	2 ½ - 3 ½ years	**F:** 12 **M:** 12	**F:** 12 **M:** 12
6	Birth	**F:** 7 **M:** 7	**F:** 6 **M:** 7
7	2 ½ - 3 ½ years	**F:** 12 **M:** 13	**F:** 12 **M:** 12
8	7 – 12 years	NA	NA

Calculating Dental age

Pick 3 teeth (partially developed) from an OPG or other radiograph

Dental age = Calcification + (crown development time x amount completed) + Estimate root development x amount completed

For example

17 Crown is fully developed and root ½ developed

Dental age = calcification (2 ½ - 3 ½ yrs) + crown (1x4 years) + root development (0.5 x 7-8) ∴ 10-11 years

Dental Developmental Anomalies

Dental development anomalies

- Tooth Structure Anomalies
- Tooth Number Anomalies
- Tooth Size Anomalies
- Tooth Shape Anomalies

Tooth Structure Anomalies

- Amelogenesis imperfecta
- Dentinogenesis imperfecta
- Molar-incisor hypomineralisation
- Trauma
- Dental fluorosis
- Tetracycline staining

Amelogenesis Imperfecta

- Mutation of genes: AMELX, ENAM or MMP20
- Complex group of hereditary conditions characterized by developmental abnormalities in the enamel structure in the absence of systemic disorders/disease
- Broadly classified into 3 groups:
  - ***Hypoplastic***: abnormal enamel matrix deposition, mineralisation/maturation normal
  - ***Hypomature***: normal enamel matrix deposition, abnormal maturation
  - ***Hypocalcified***: normal enamel matrix deposition, abnormal mineralisation

Clinical presentation of AI

- ***Hypoplastic***:
  - Generalised vs localised
  - Generalised: various pits scattered across tooth structure
  - Localised: usually linear depressions, horizontal rows of pits
- ***Hypomature***:
  - Normal shaped
  - mottled/opaque/yellow/brown discolouration
  - Soft & may detach from underlying dentine
- ***Hypocalcified***:
  - Weak & discoloured enamel
  - Rapidly lost of structure during function due to lack of minerals

Hypomatured

Hypocalcified/hypomineralised

Hypoplastic

Dentinogenesis Imperfecta

- Hereditary developmental disturbance of the dentine formation in the absence of systemic disorders
- Mutation of the DSPP gene
- May occur concurrently with osteogenesis imperfecta

Clinical appearance: DI

- Translucent or opalescent hue to the teeth with brown to blue discoloration
- Bulbous crown with cervical narrowing in radiographs. Roots are thin & can lose pulpal space

Molar-incisor hypomineralisation

- Presence of defect on 1 or more 1st molars or permanent central incisors
- Chalky white, softer & porous enamel
- Incisors quite commonly affected: central incisors & 1st molars start developing embryologically at the same time

Tooth Number Anomalies

- Hypodontia
  - Agenesis of 1-6 teeth
  - Oligodontia: agenesis of >6 teeth
  - Anodontia: agenesis of whole dentition
  - 8s, Md 5s, Mx 2s common
- Hyperdontia
  - Supernumeries
  - Mostly in permanent dentition
  - Mesiodens are common

Tooth Size Anomalies

- Microdontia
  - Smaller than usual
  - Not relating to jaw size
  - Mostly affecting isolated teeth & associating with hypodontia
- Macrodontia
  - Larger than usual
  - Isolated usually to the 1s & 3s

Tooth Shape Anomalies

- Gemination/fusion
  - “Double tooth” (for both)
  - Gemination: Single enlarged or joined teeth, tooth count: normal (counted as 1)
  - Fusion: single enlarged tooth due to 2 joined teeth. Tooth count: missing tooth
- Dens Evaginatus
  - Accessory cusp: central tubercle.
  - Cusp like elevation in the central fossa, usually contains pulpal tissue
- Dens invaginatus
  - Tooth in tooth; very rare
- Hypercementosis
  - Excessive cementum
- Taurodontism
  - Enlarged pulp chamber
  - Usually with systemic disease

Dens Evaginatus