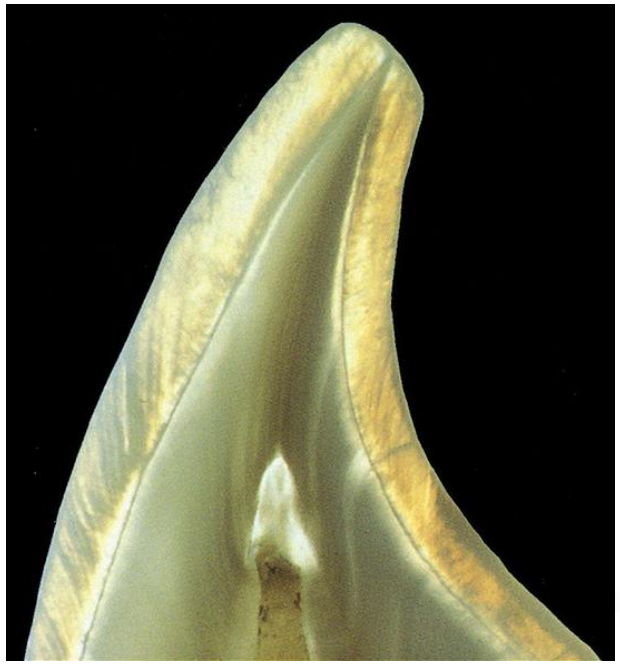
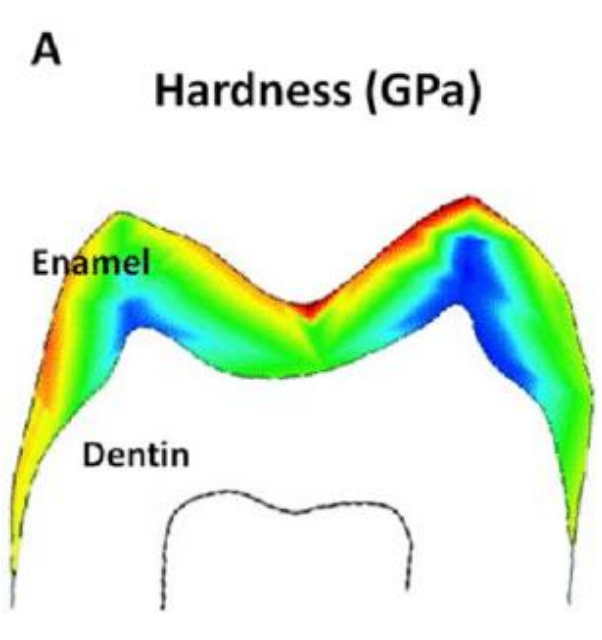
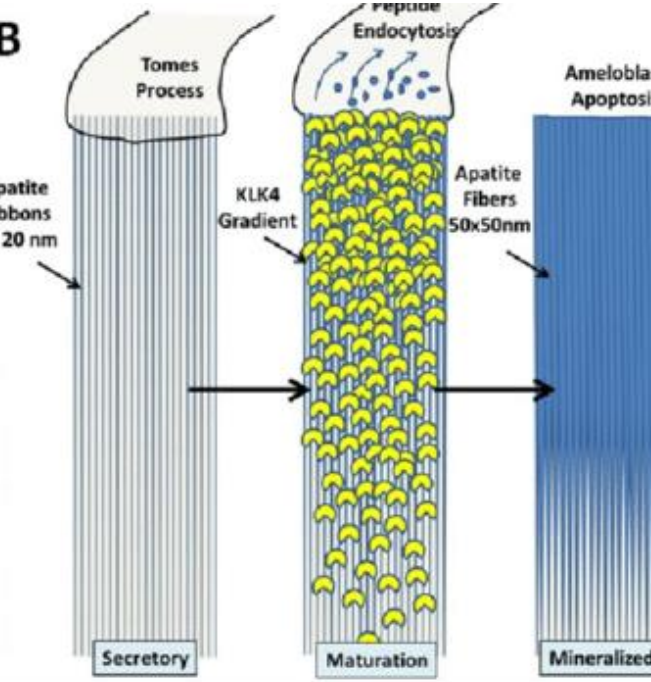
Enamel, cementum

Jan Křivánek

3. 4. 2024







Enamel

(enamelum, enamel, email, substantia adamantina, s. vitrea)

ENAMEL

(enamelum, email, substantia adamantina, s. vitrea, sklovina)

- **Tissue covering tooth crowns**
- **Ectodermal origin**
- **Hardest tissue (fragile) in the vertebrates bodies**
- **Acelular**

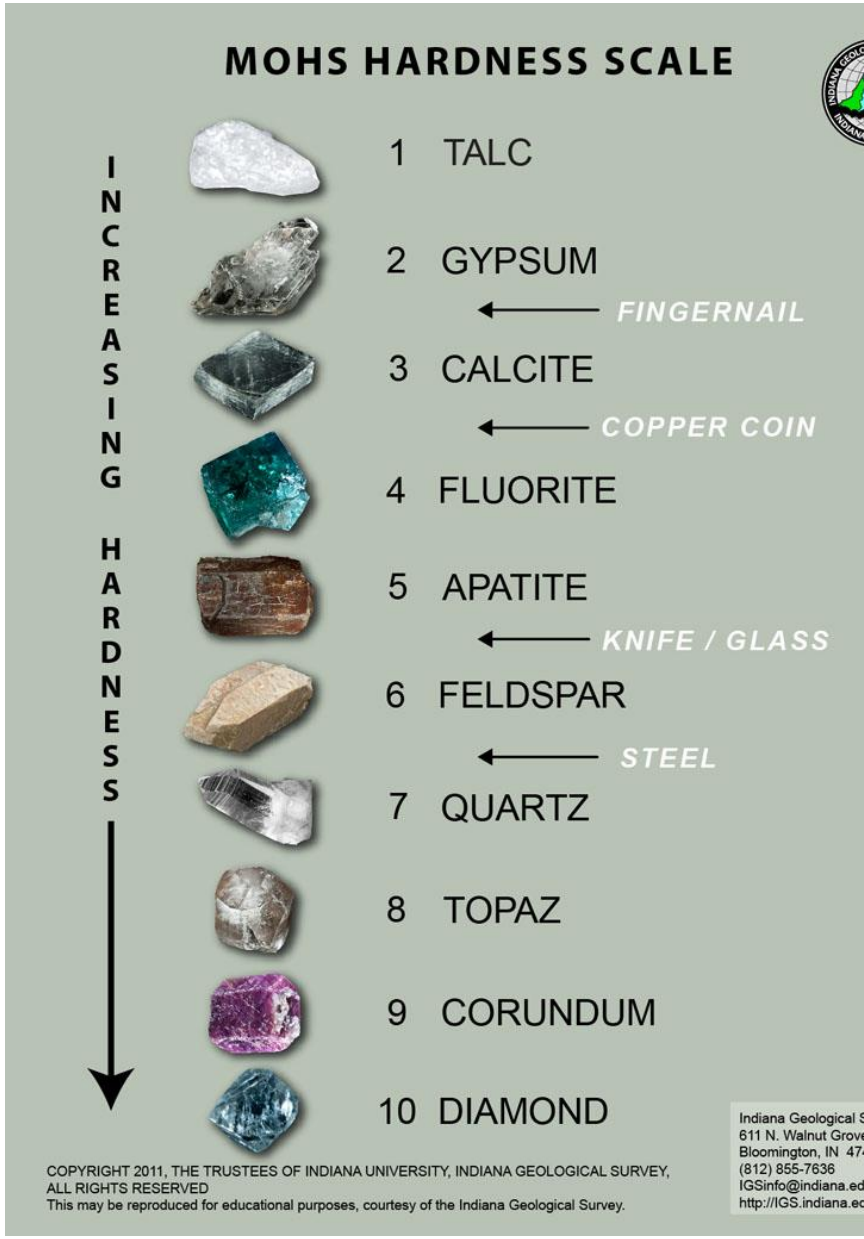
Thickness: Permanent dentition +- 2,5 mm
Primary dentition +- 1,3 mm
Tooth neck +- 0,1 mm

<u>Physical properties</u>

- Refractive index: 1,62; density: 2,9 $g.cm^{-3}$,
- Mohs scale **hardness 5**
- **Translucent**, color – white shades – depends on thickness and mineralization degree
  - Grey-white – occlusion sides
  - White – middle part of crown
  - Yellowish – near the neck (dentin bellow)

High resistence to abrasion

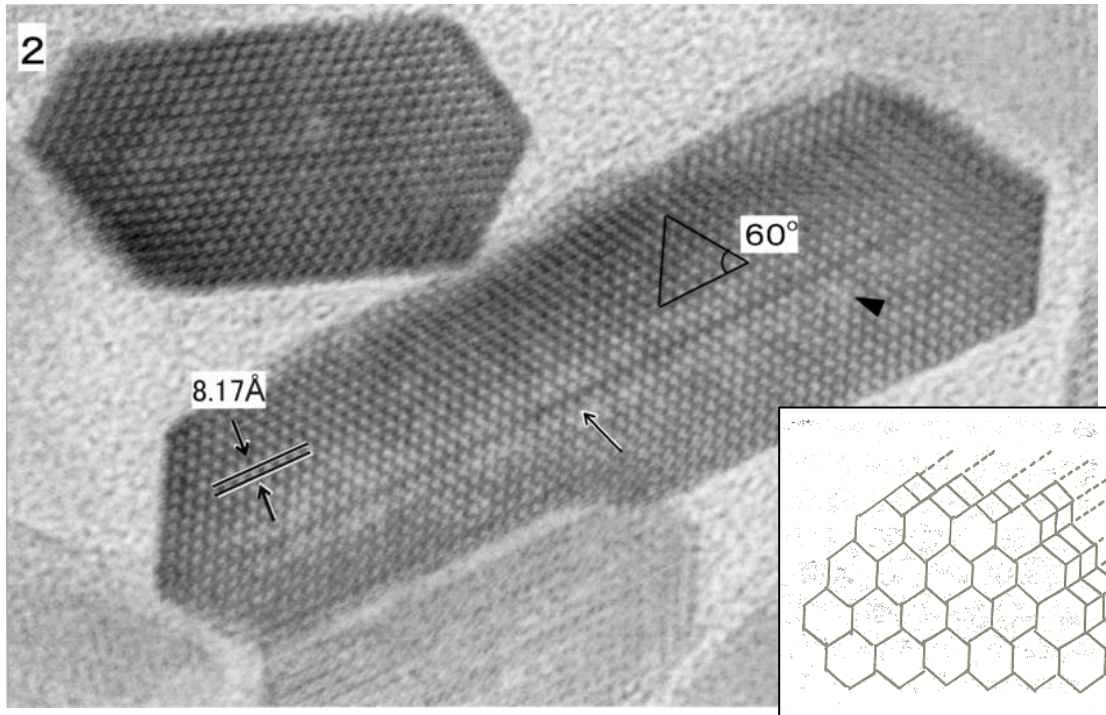
- Denser, harder and less porous in the surface (aprismatic)
- Hardness is decreasing towards DEJ (dentino-enamel junction) and from top of crown towards the neck

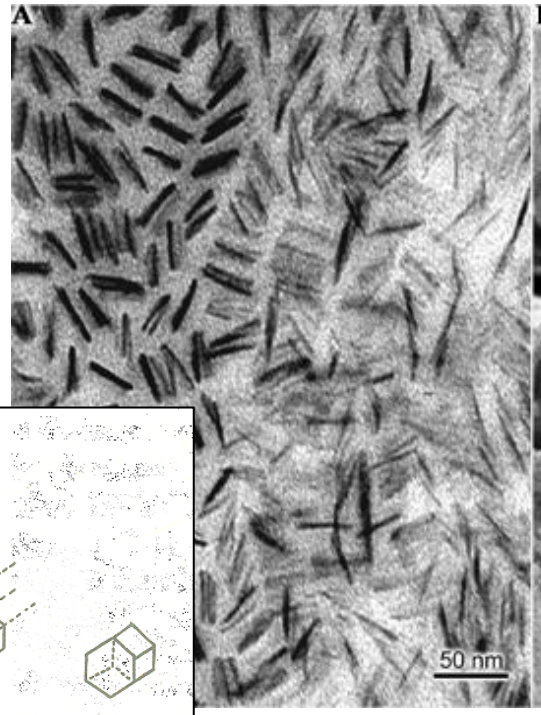


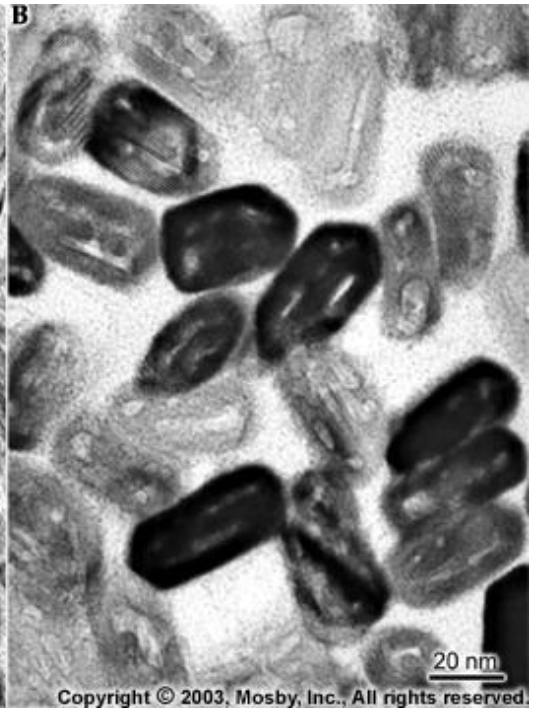
Chemical composition

Inorganic	Water	Organic
96 - 97 %	2 - 3 %	1 %

- Hydroxyapatite building hexagonal crystals
- Fluoroapatite (more on the surface of enamel), it is harder
- Main elements: Calcium, fluoride, magnesium, phosphorus (and others).
- Deposition of other elements (e.g. lead) due to environmental pollution – once depositite, always there.







Chemical composition

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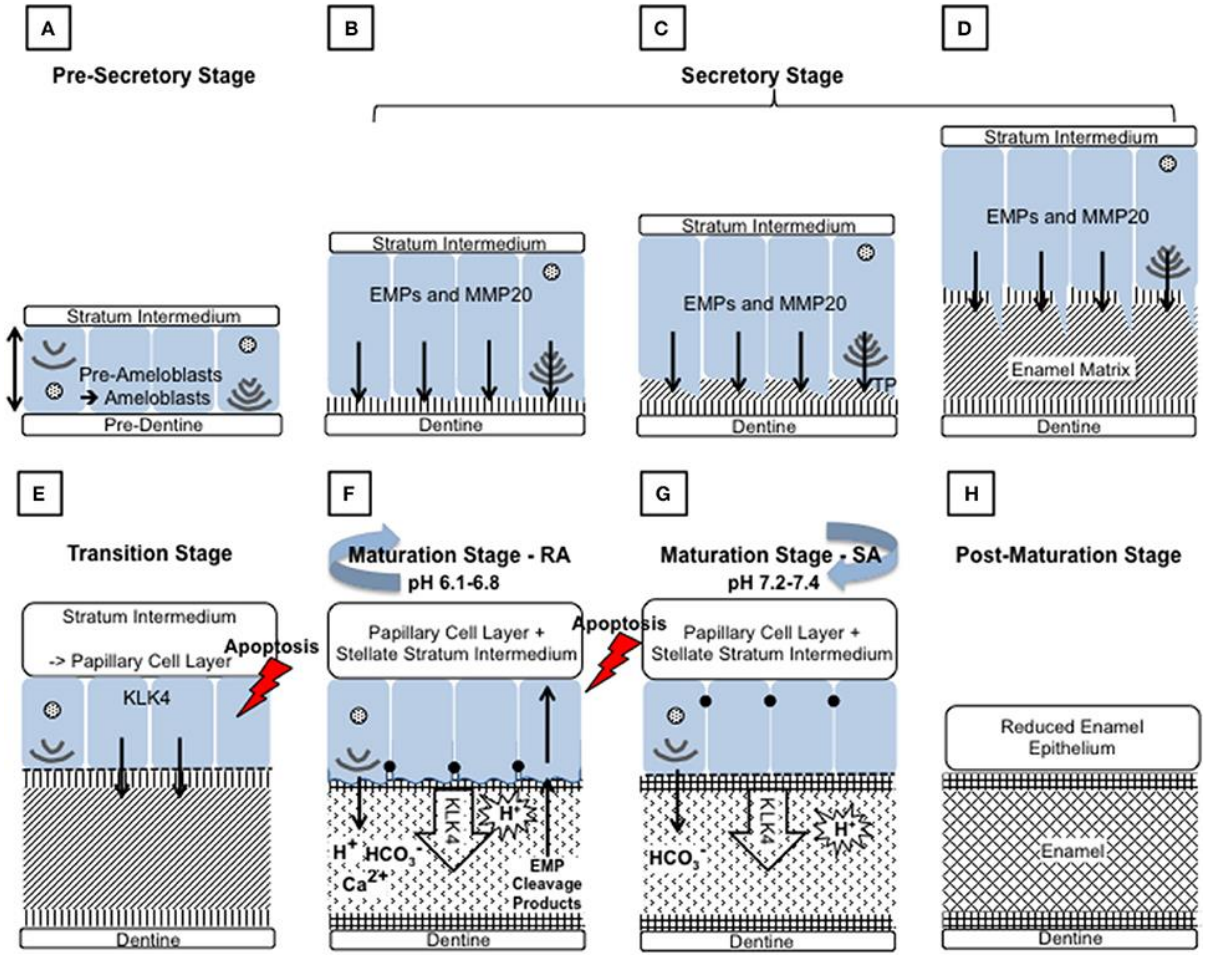
96 - 97 %	2 - 3 %	1 %

NON-collagenous proteins

a) **Amelogenins**
   - 90 %
   - Main product of ameloblasts secretory stage
   - Spherical polymers, regulation of enamel prisms growth

b) **Non-amelogenins:**
   - Enamelin – Nucleation and direction of growth regulation of crystals
   - Ameloblastin – Adhesive molecule
   - Kalikrein 4 – Protease secreted by ameloblasts in the final sectretory stage
   - Tuftelin – Stabilizes connection to dentin

c) **Proteins with enzymatic activity**
   - Metaloproteases (MMP20) – amelogenin degradation
   - Alkalic phosphatase, phosphomonoesterase and serinprotease 1

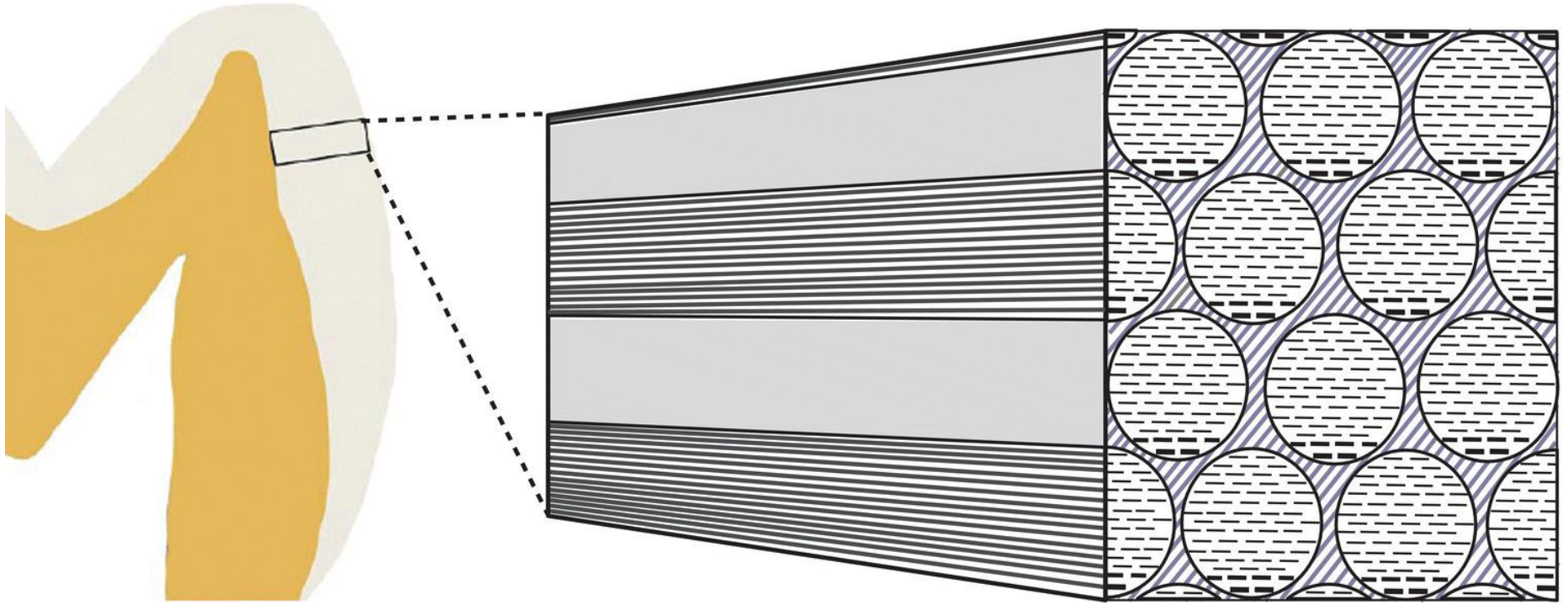


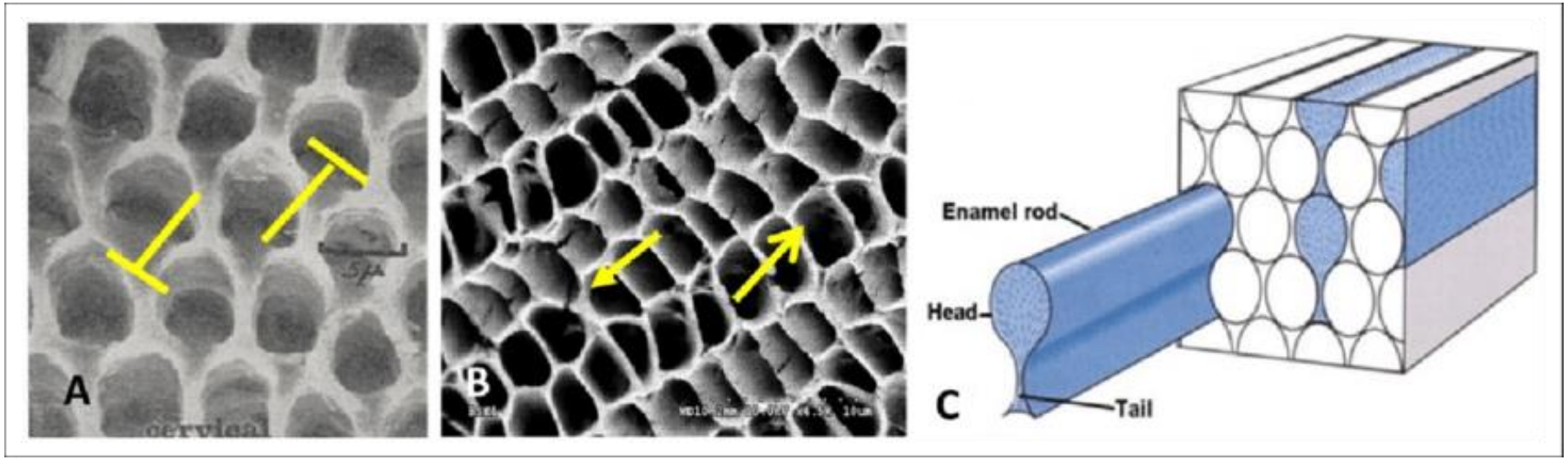
Microscopis structure

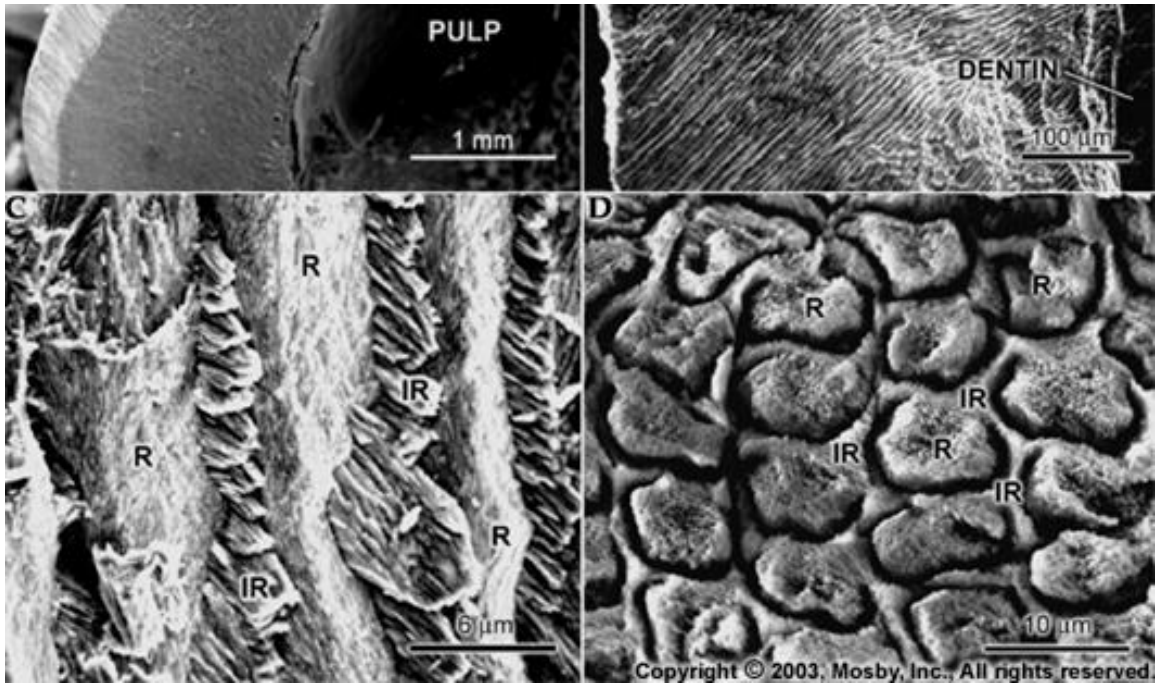
Complicated and species-specific inner structure

Enamel prisms (prisms and interprismatic substance), +-1 µm wide

Direction: from DEJ up to the surface, approx. 8,5 milions (incisivi)




A
cervical
B
C
Enamel rod
Head
Tail


PULP
1 mm
DENTIN
100 µm
C
R
IR
R
R
IR
6 µm
D
R
R
IR
IR
R
IR
10 µm
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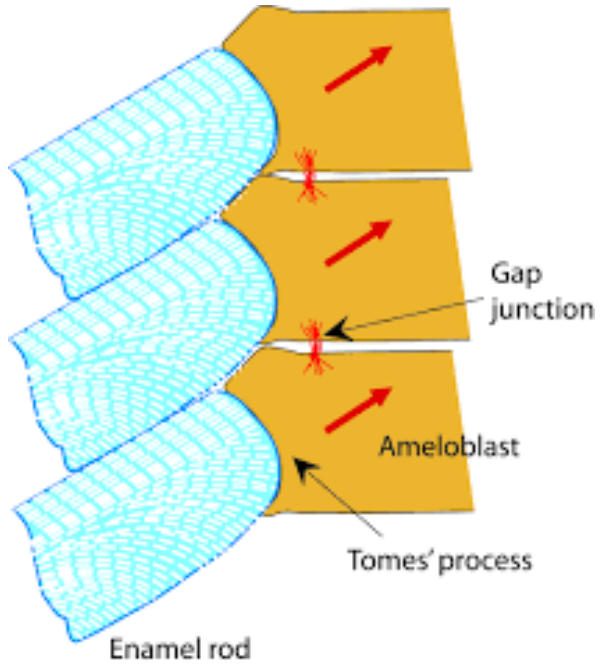
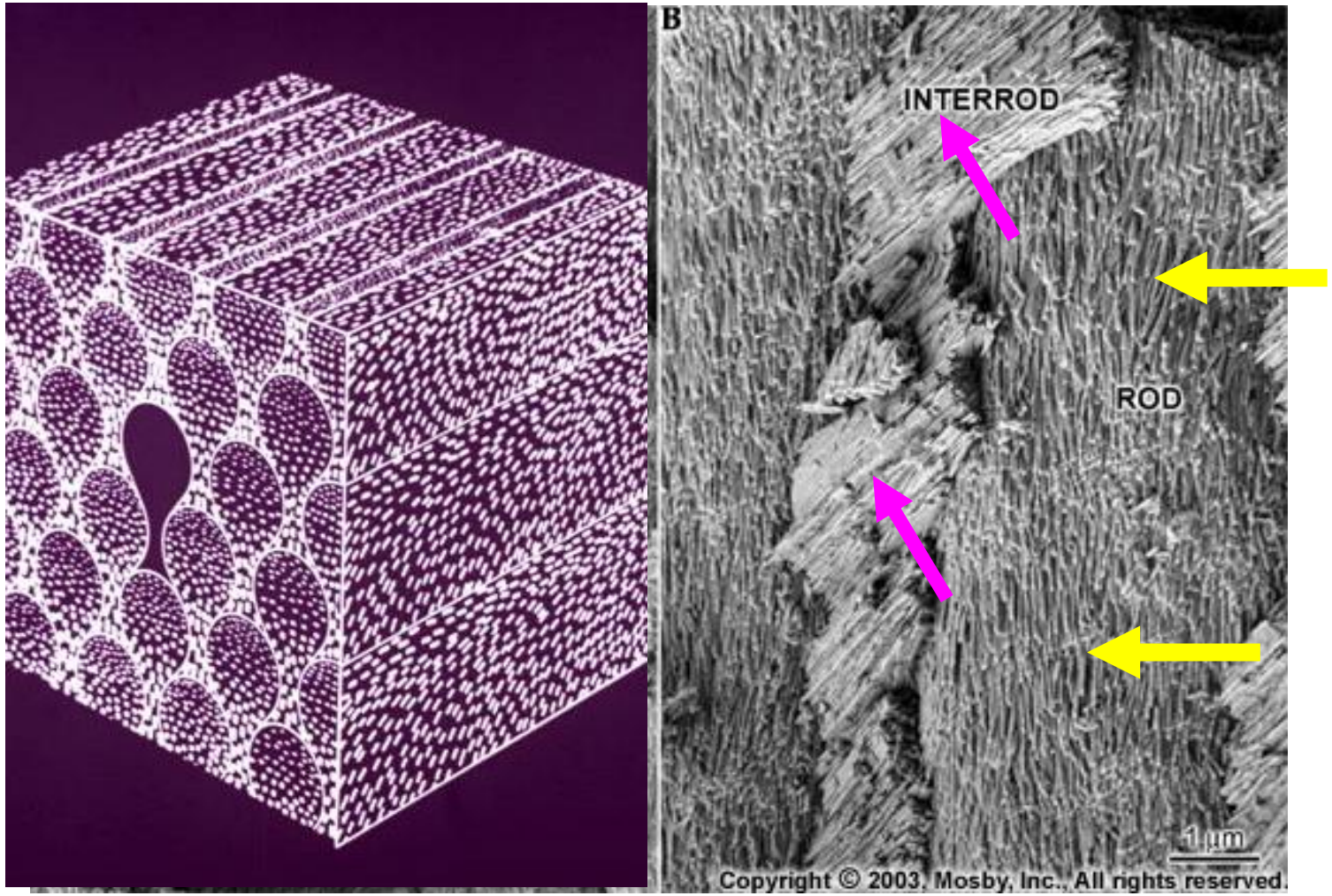

Gap junction
Ameloblast
Tomes' process
Enamel rod

Prisms ultrastructure

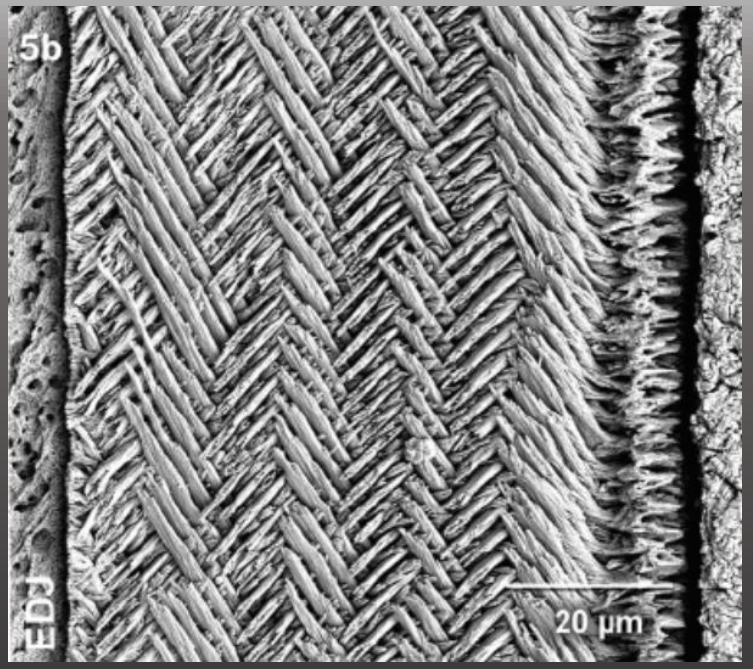
Consists of longitudinal arranged crystals of hydroxyapatite, inserted into proteinous matrix (amelogenins, non-amelogenins)

Interprizmatic substance structure is the same, but crystals are laid down under different angle



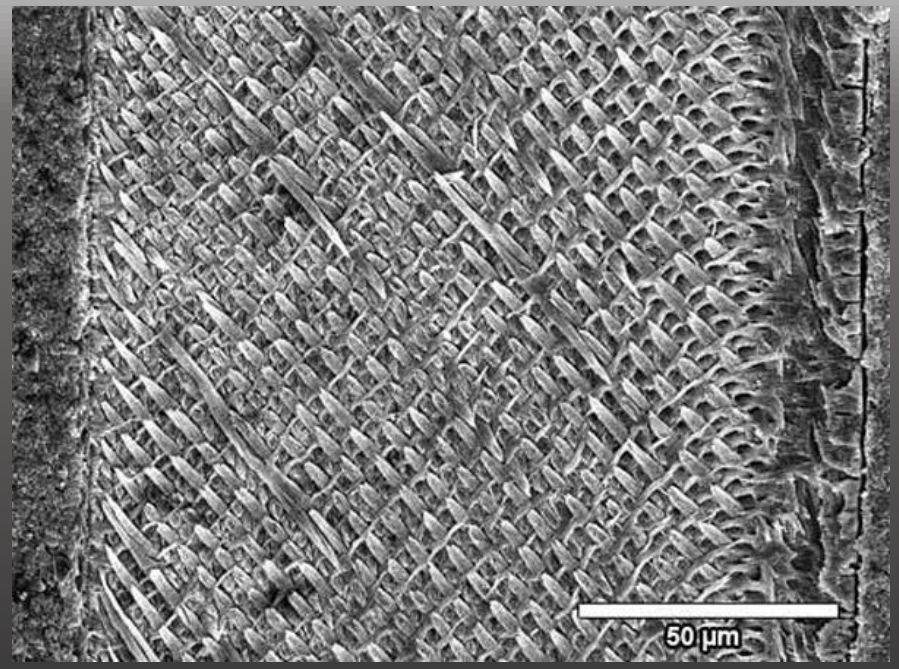
Enamel decussation pattern (rodents)

- Very precise and homogeneous organization of enamel microstructure
- Little differences within different species
- Fundamental mechanisms controlling decussation pattern formation are evolutionary conserved



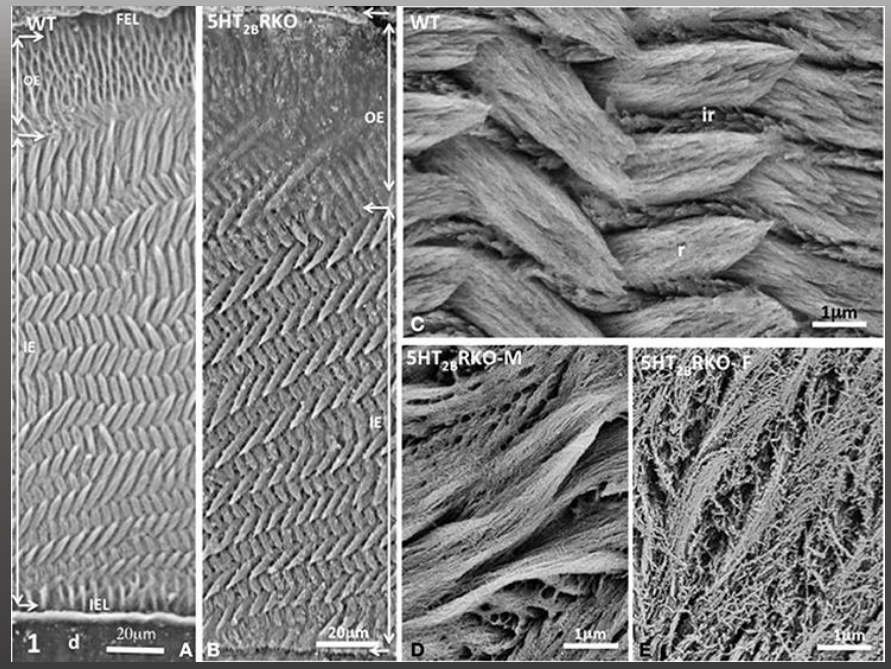
Daniela C. Kalthoff, 2007

Heterosminthus gansus
(late Miocene)



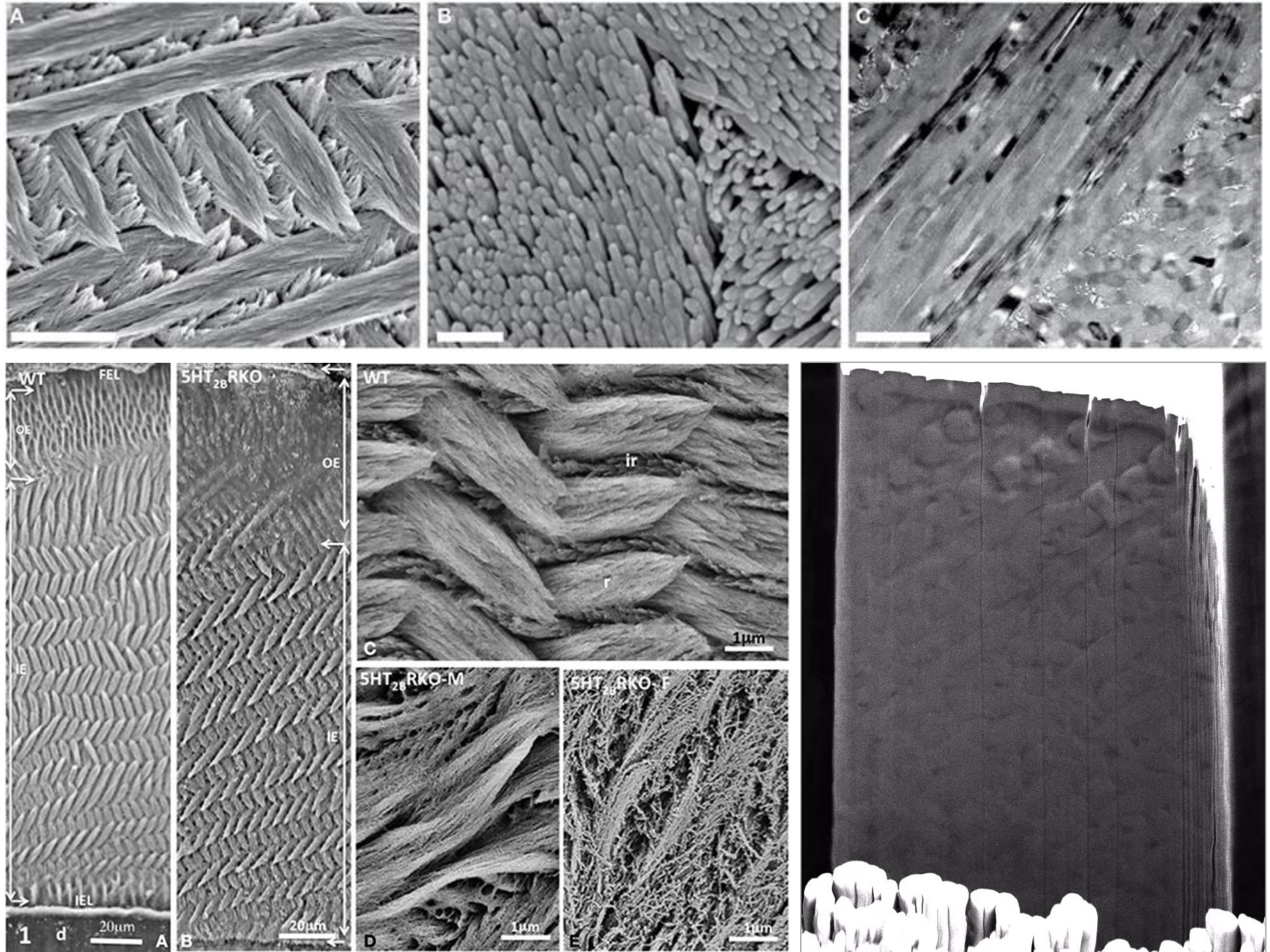
Daniela C. Kalthoff

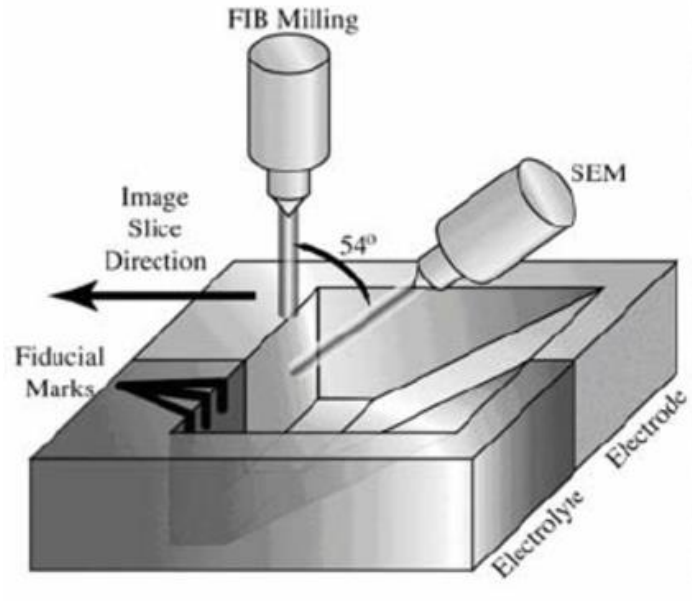
Wood Mouse *(Apodemus sylvaticus)*

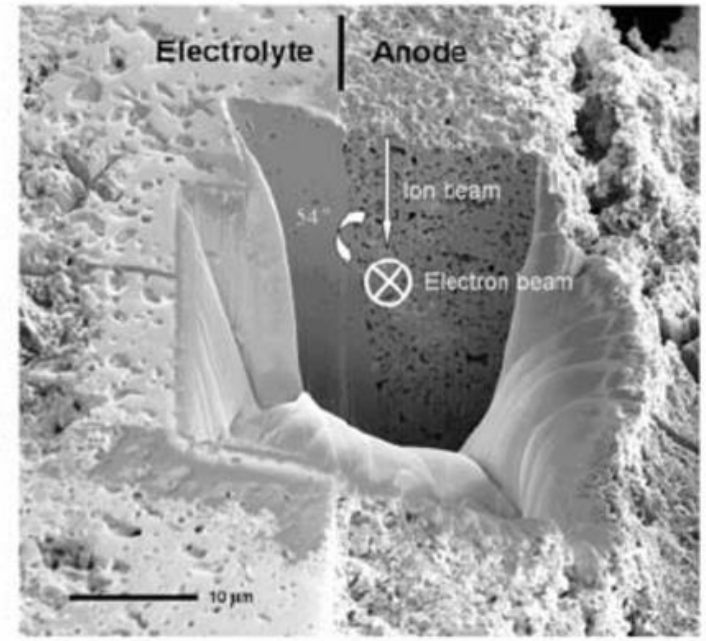


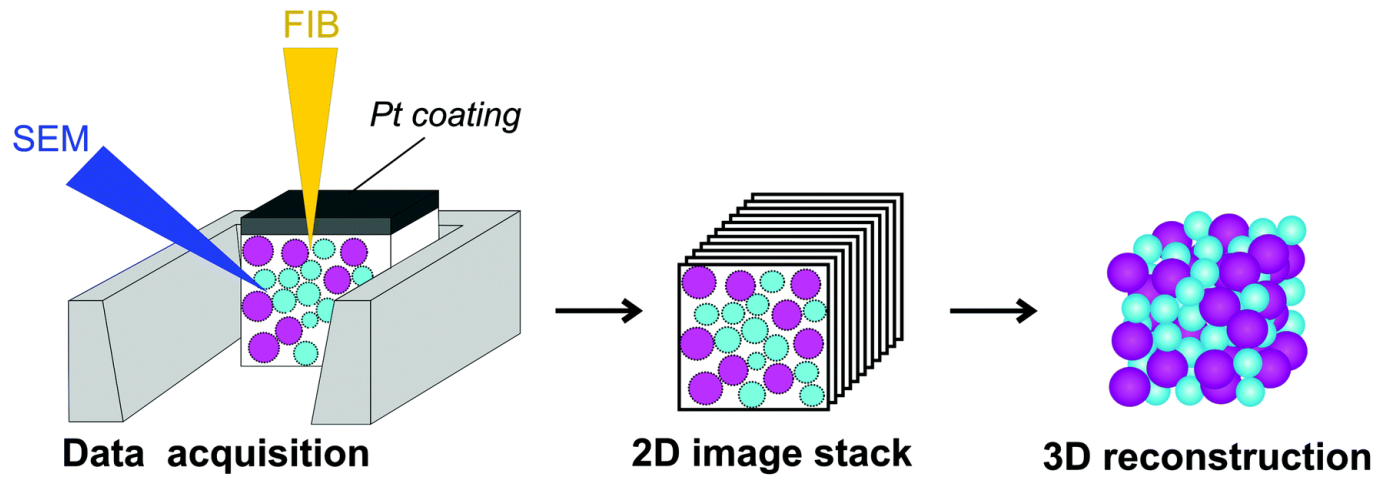
Goldberg et al, 2014

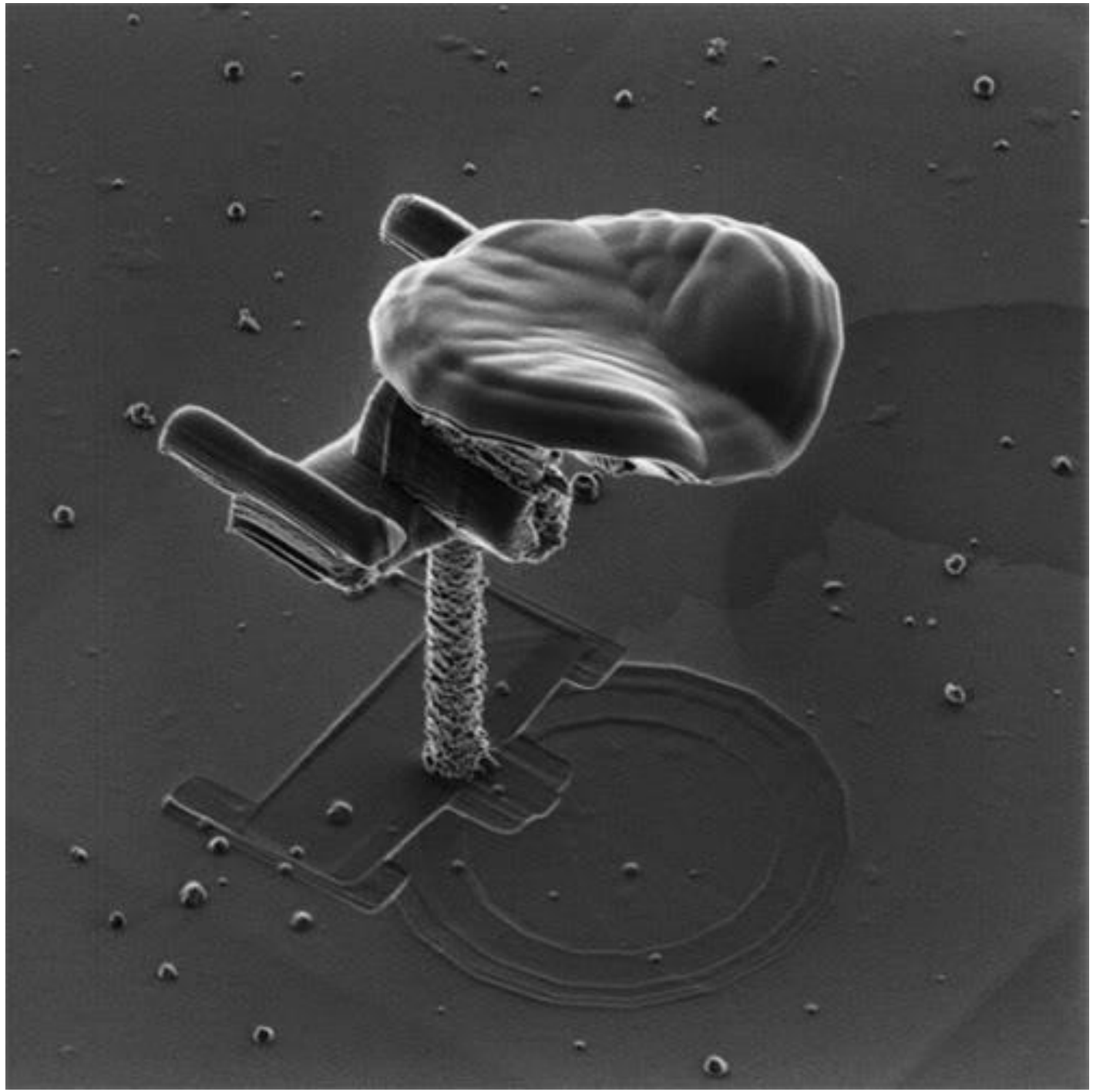
Mus musculus


A
B
C
WT
FEL
OE
IE
IEL
1 d
20µm
A
5HT2BRKO
OE
IE
20µm
B
WT
ir
r
1µm
C
5HT2BRKO-M
1µm
D
5HT2BRKO-F
1µm
E

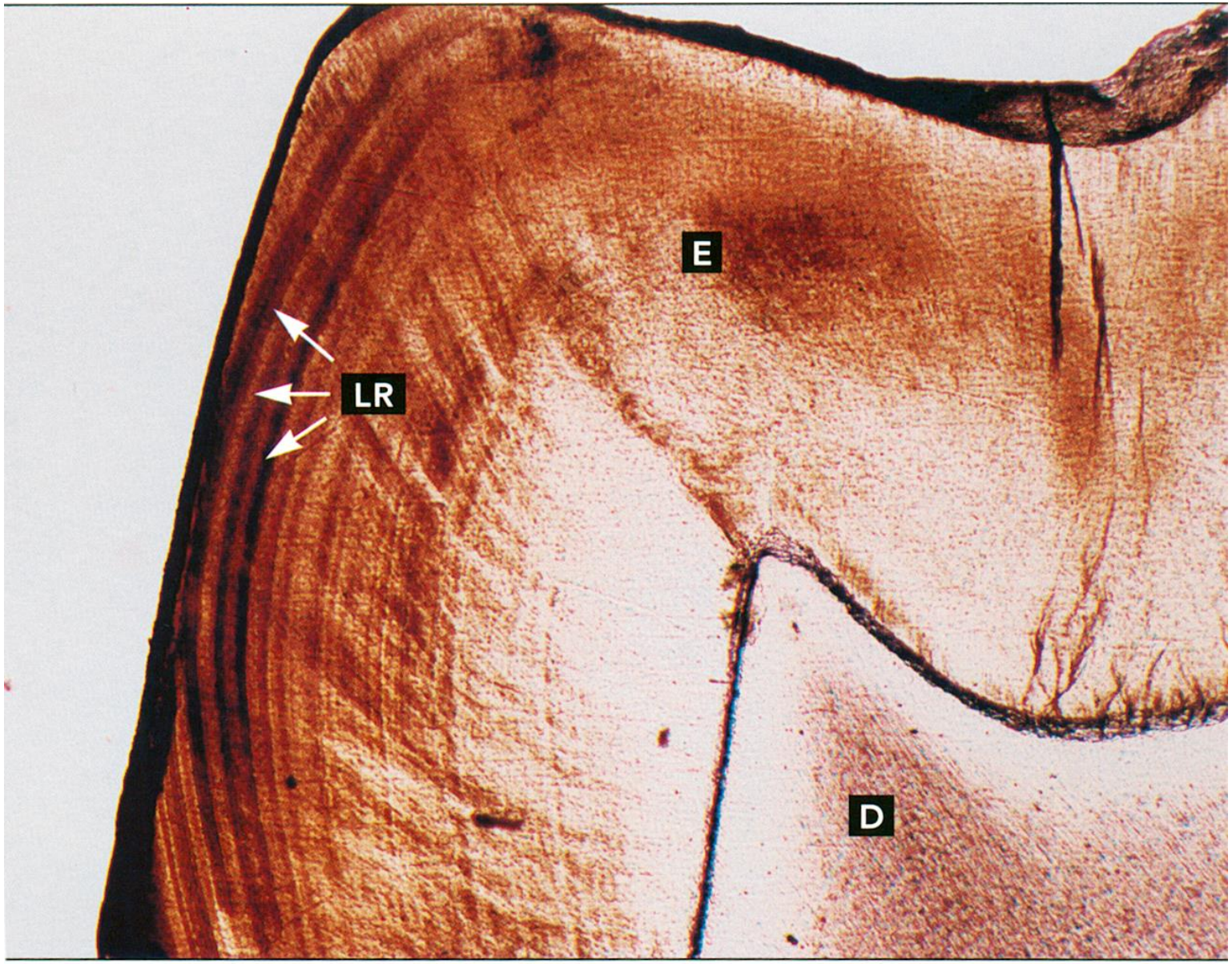

FIB Milling
SEM
Image
Slice
Direction
54°
Fiducial
Marks
Electrode
Electrolyte

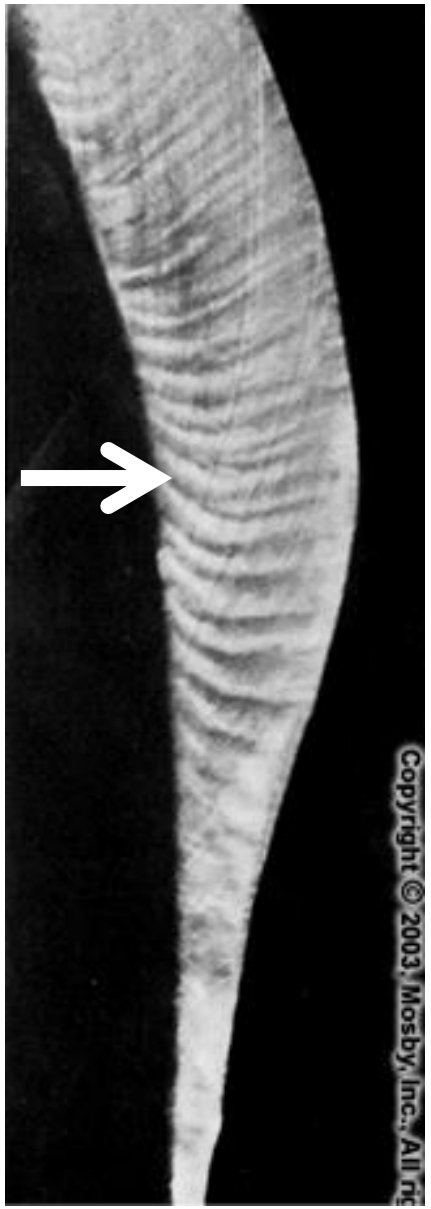

Electrolyte
Anode
Ion beam
54°
Electron beam
10 µm


FIB
SEM
Pt coating
Data acquisition
2D image stack
3D reconstruction



External characteristics of enamel





External characteristics of enamel

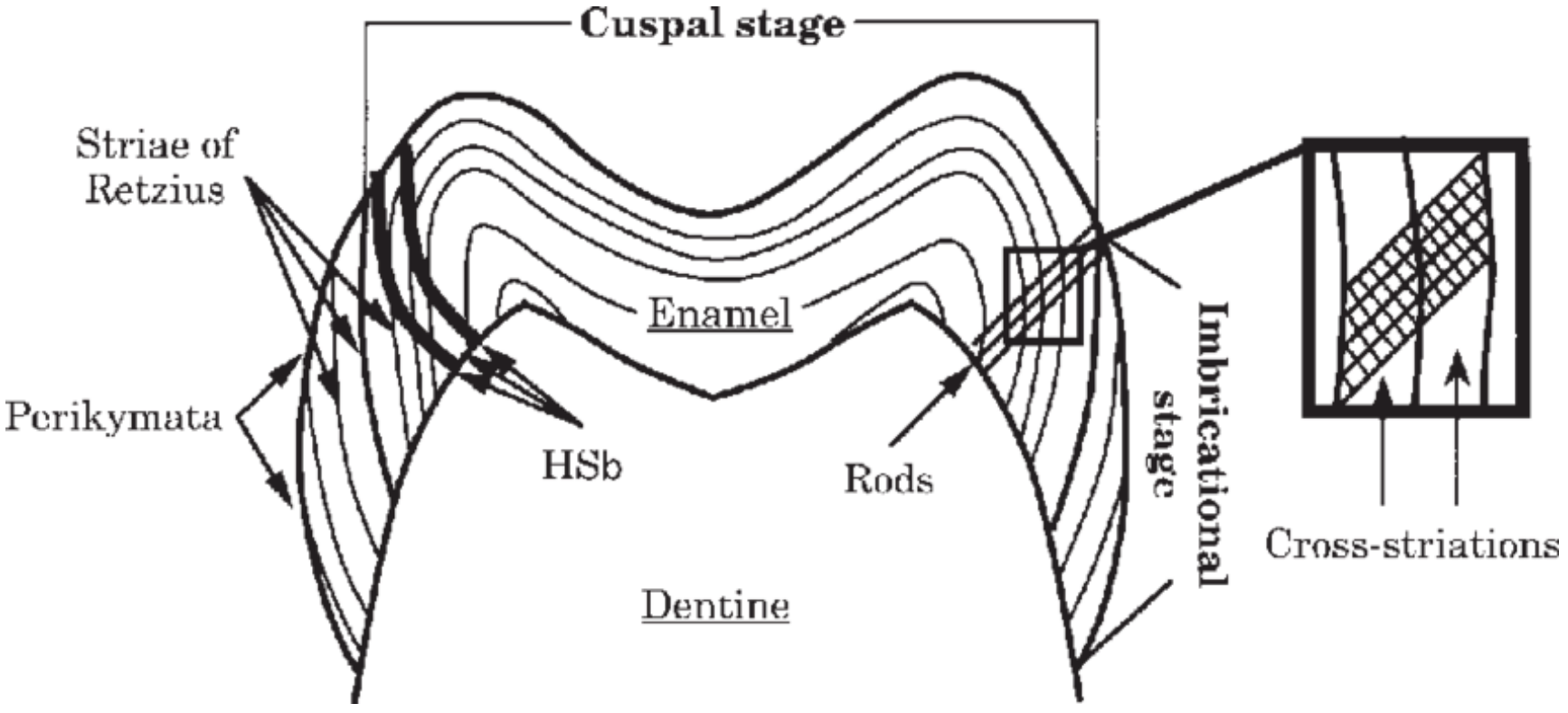
Striae of Retzius

Perikymata

Hunter - Schreger bands

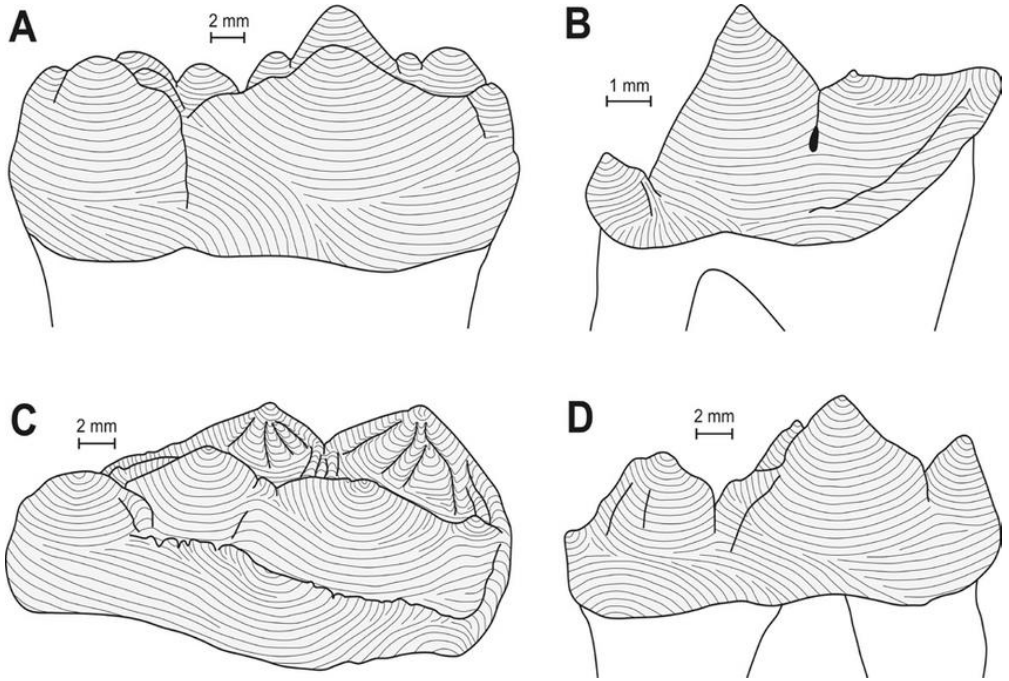
Neonatal line

Enamel tuffs



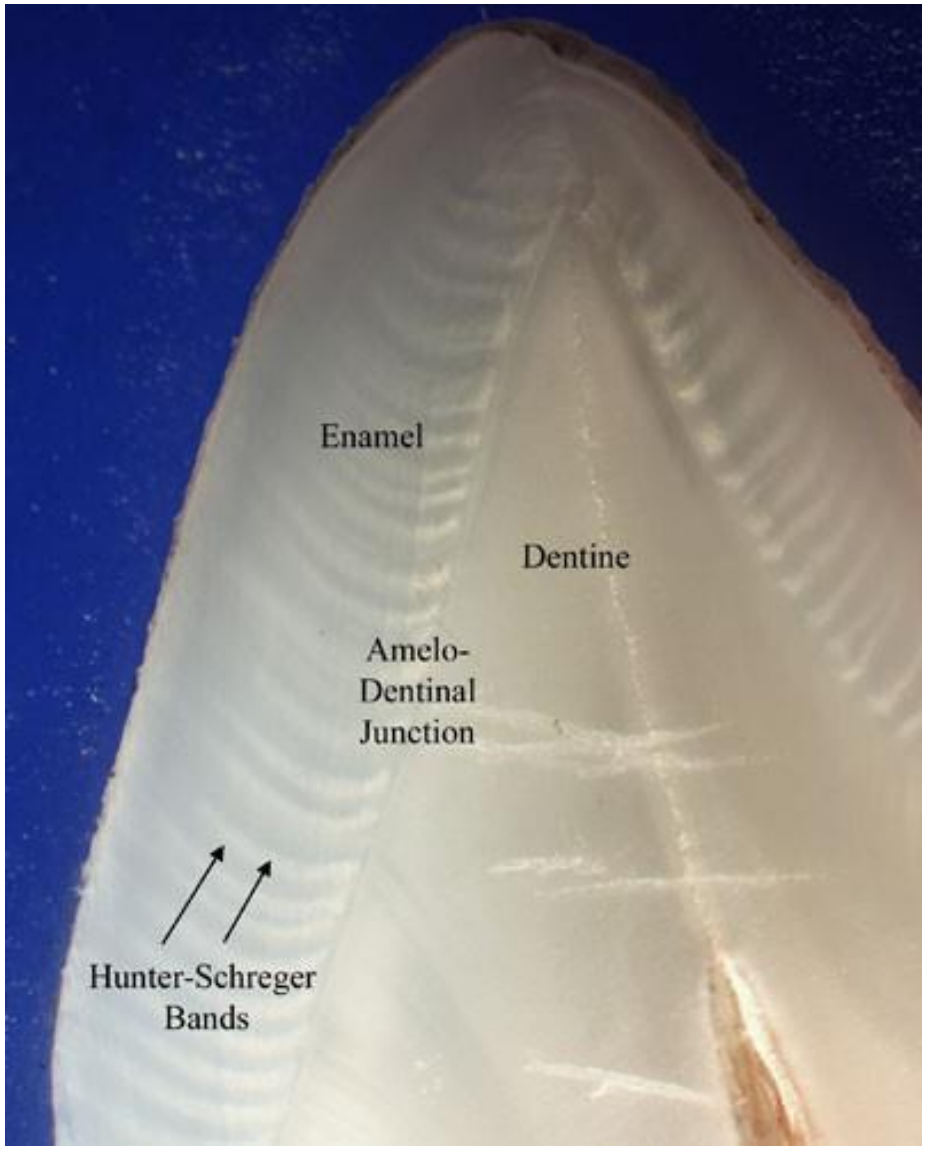
Hunter - Schreger bands

- Consequence **of changes in the direction of prisms**
- The course of enamel prisms changes in all directions, especially in premolars and molars.
- Optically, they appear as alternating lighter and darker bands



Course of Hunter-Schreger bands (HSB) on: the buccal side of M 2 from Ursus spelaeus (A), the buccal side of P 4 from Felis catus (B), the U. wenzensis M 2 viewed from the lingual and occlusal side (C) and the buccal side of M 1 from U. wenzensis.

Nowakowski et al., 2010



Lynch et al., British dental journal, 2010

Incremental enamel bands

The enamel grows periodically: the influence of **circadian rhythms**
Manifestation of periodic activity of ameloblasts or joint mineralization of a larger number of daily incremental lines
Based on the incremental lines, we distinguish the characteristic types of incremental bands

a) Daily incremental lines

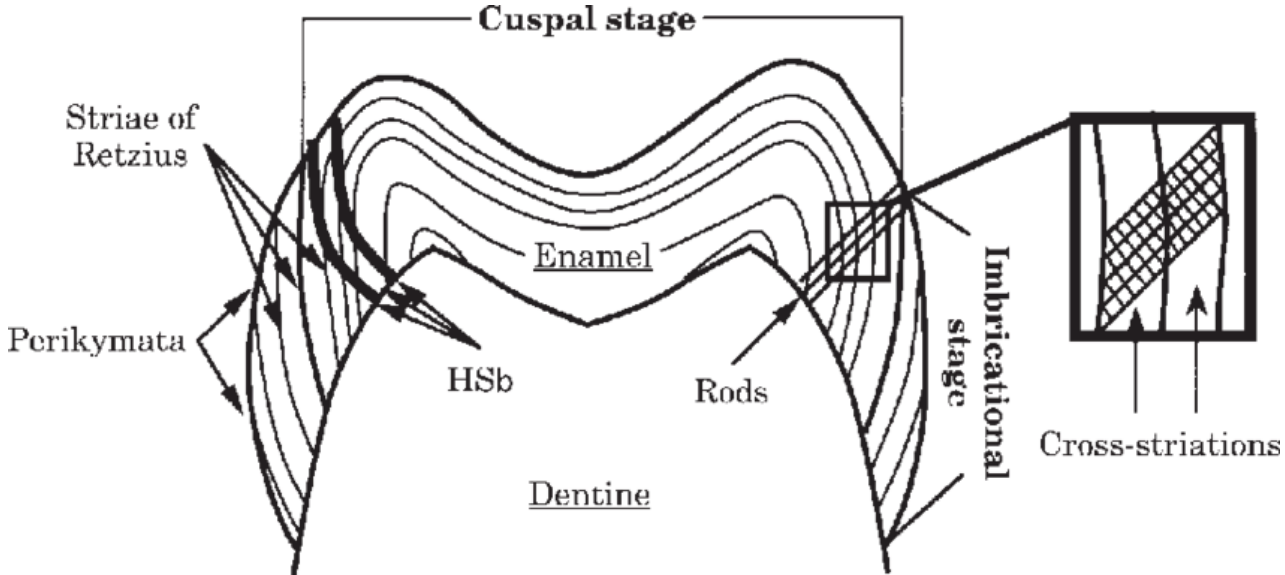
- Cause prisms cross-striation, very thin (2,5 - 6 µm)
- Circardial rhytms influenced
- Alternation of the phase of intense secretion with the resting phase

b) Stripes of Retzius (Retzium lines; enamel striae)

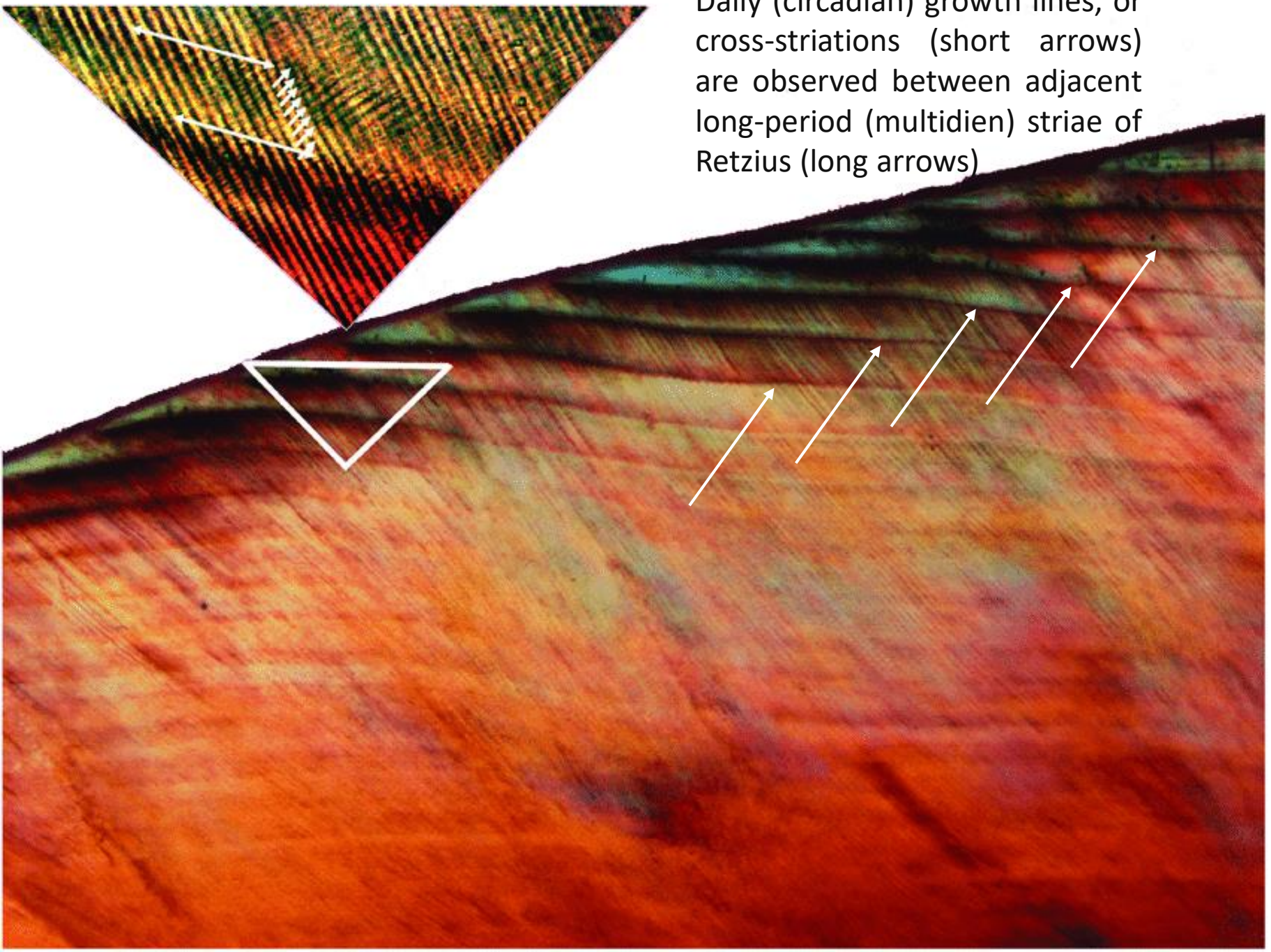
- Can be observed under optical microscope on ground sections (25-35 µm)
- From DEJ to enamel surface
- Forms perikymata

c) Neonatal line

- A distinctive stripe of less mineralized enamel
- In primary dentition and M1
- It belongs to the Retzius line
- Due to abrupt change in nutrition at birth



Daily incremental lines

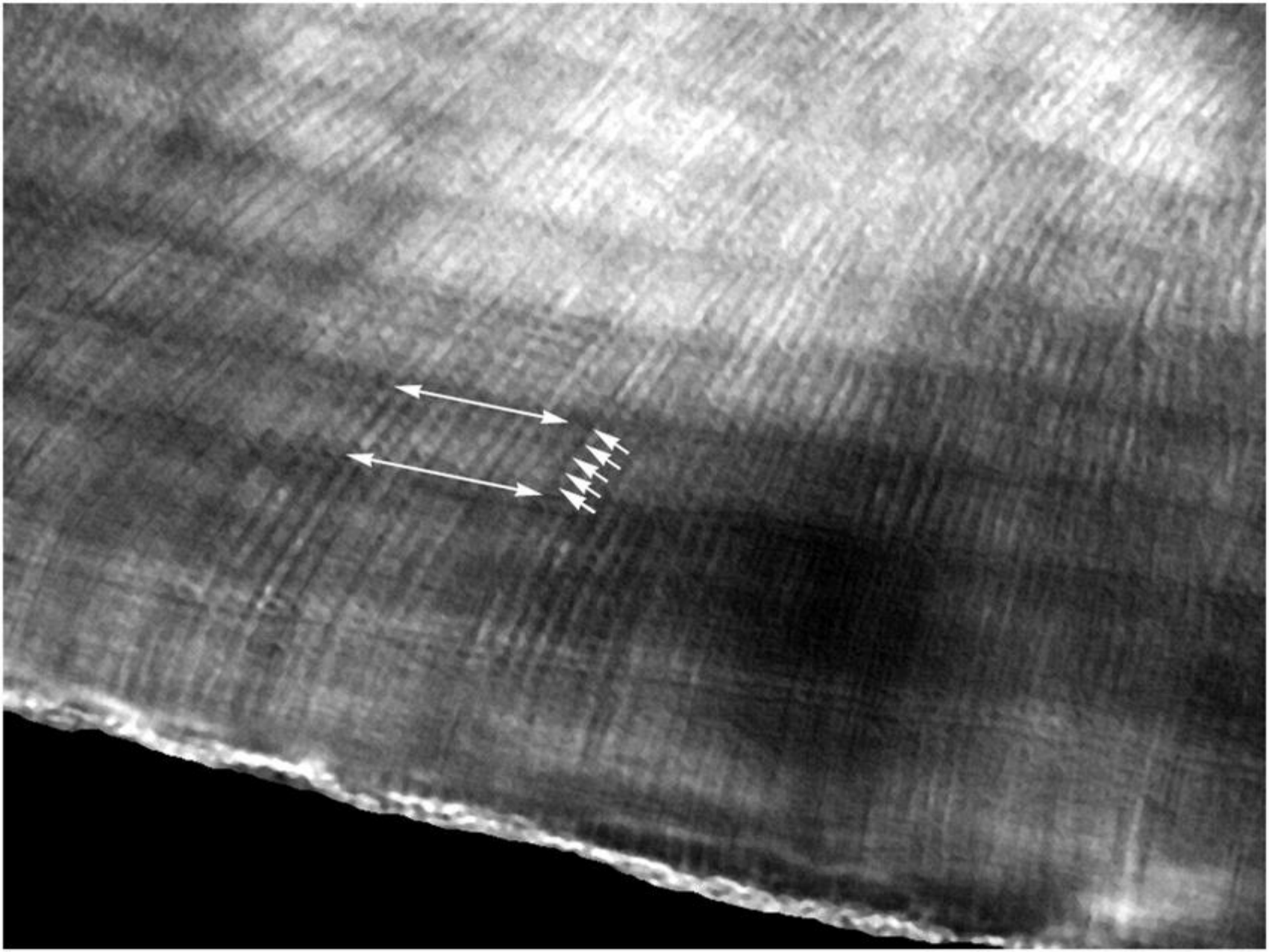


Daily (circadian) growth lines, or cross-striations (short arrows) are observed between adjacent long-period (multidien) striae of Retzius (long arrows)

Striae of Retzius may be seen to course across the horizontal field of view. The number of cross-striations between adjacent striae of Retzius is termed the "repeat period" (RP).

(Timothy G. Bromage et al., 2015, American Journal of Physical Anthropology; Hard Tissue Biology, Metabolomics, and Life History)

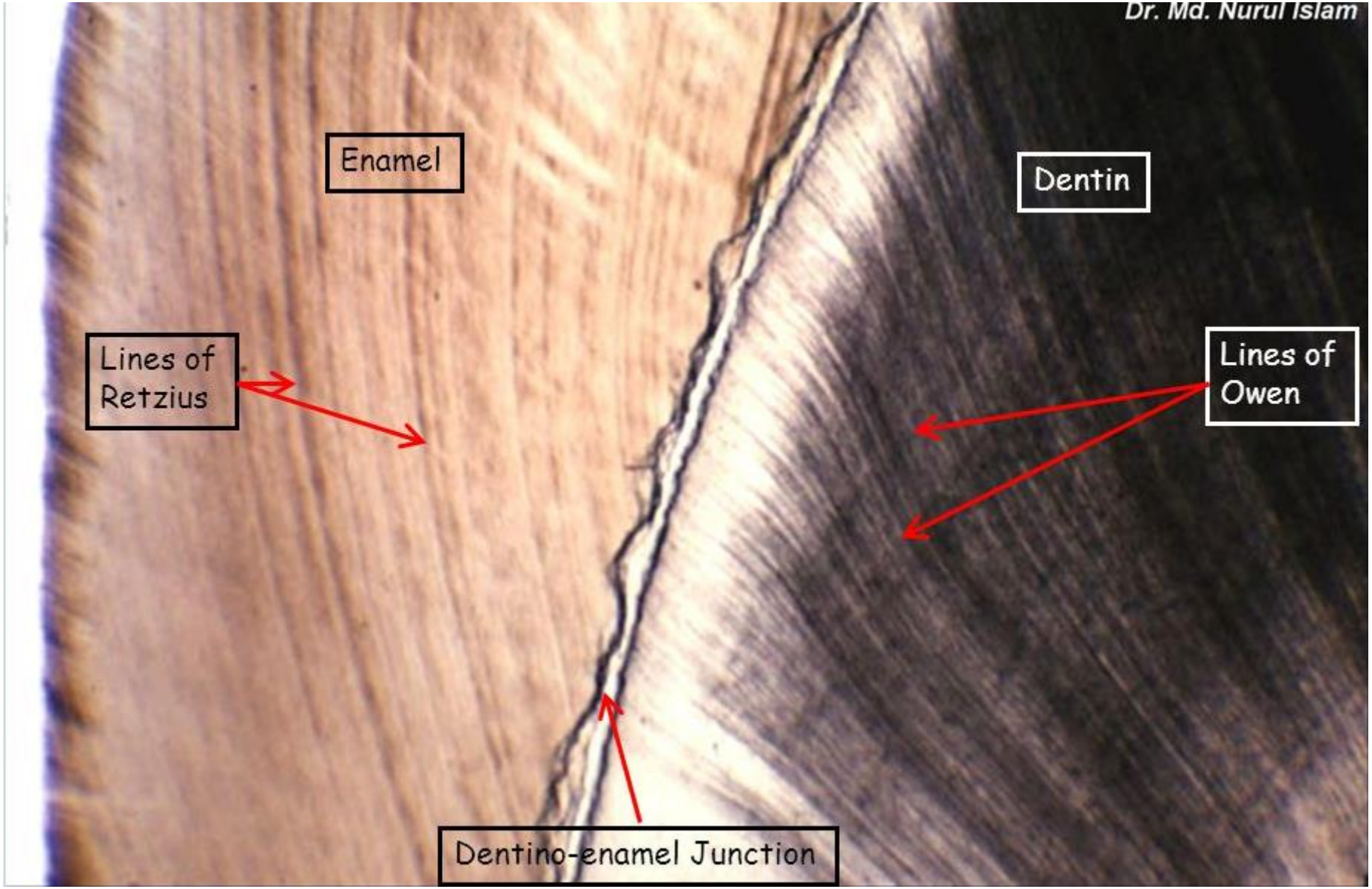
Daily incremental lines



Swine enamel circadian and multidien rhythms. Dark banding across the horizontal field are striae of Retzius (long arrows), while 5 daily events may be seen between adjacent striae (short arrows)

(Timothy G. Bromage et al., 2015, American Journal of Physical Anthropology; Hard Tissue Biology, Metabolomics, and Life History)

Striae of Retzius



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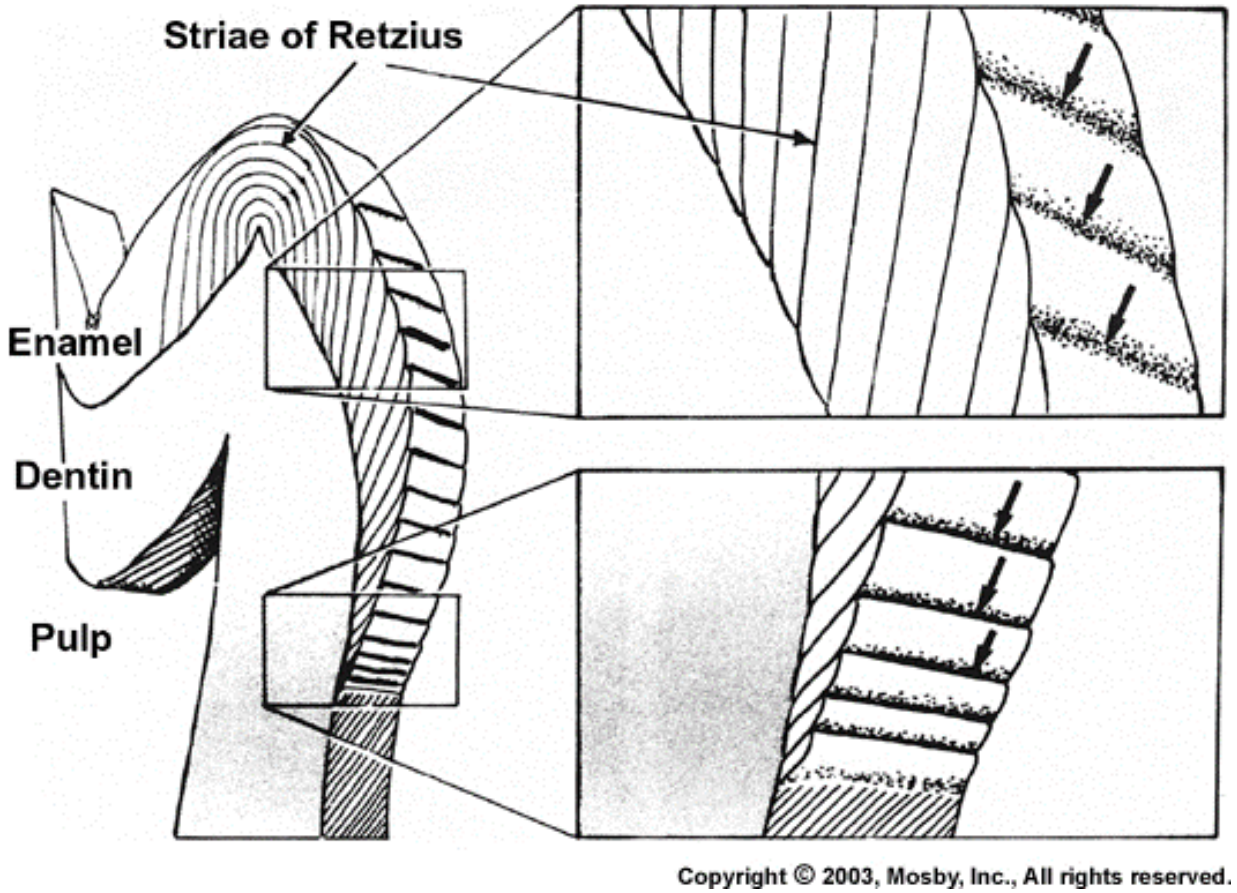
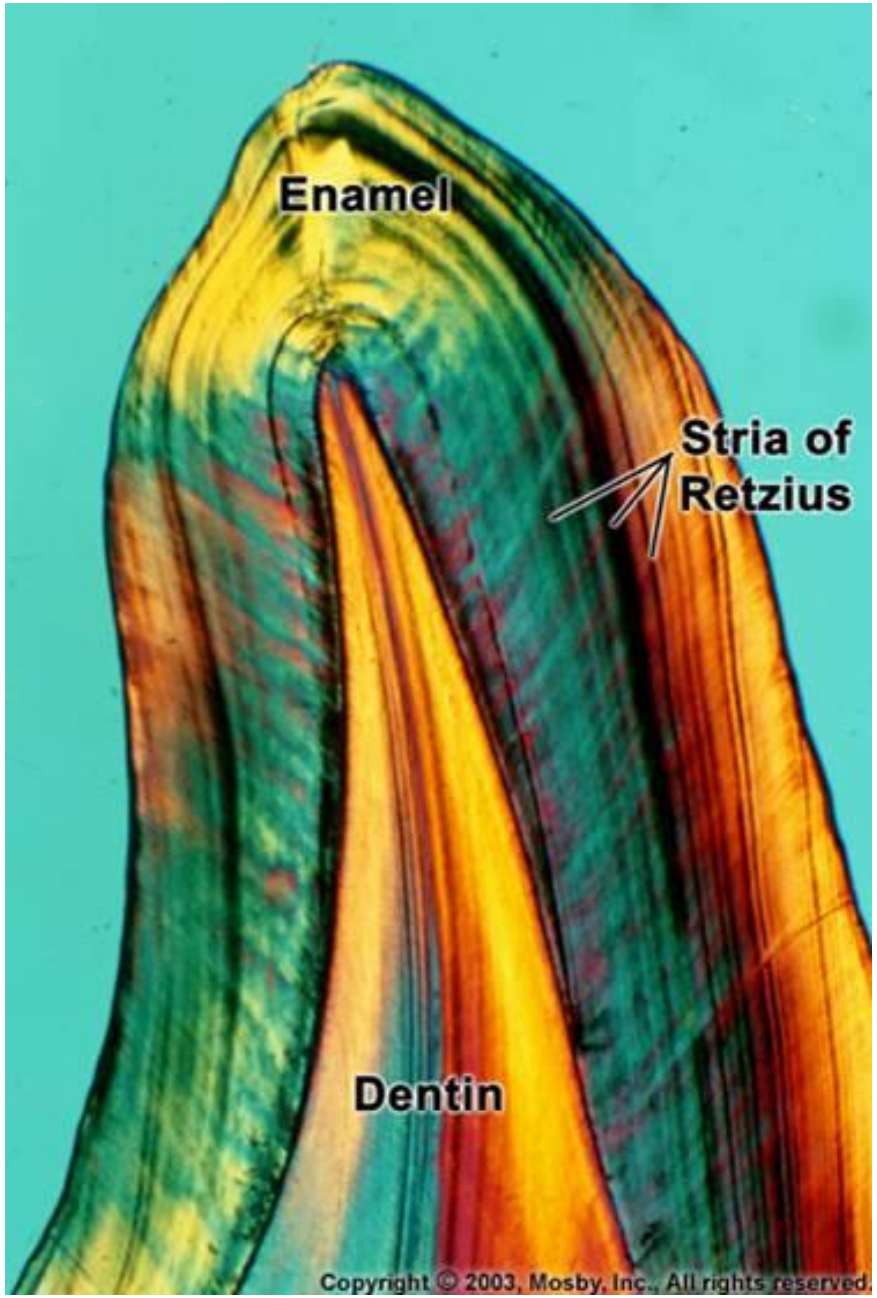
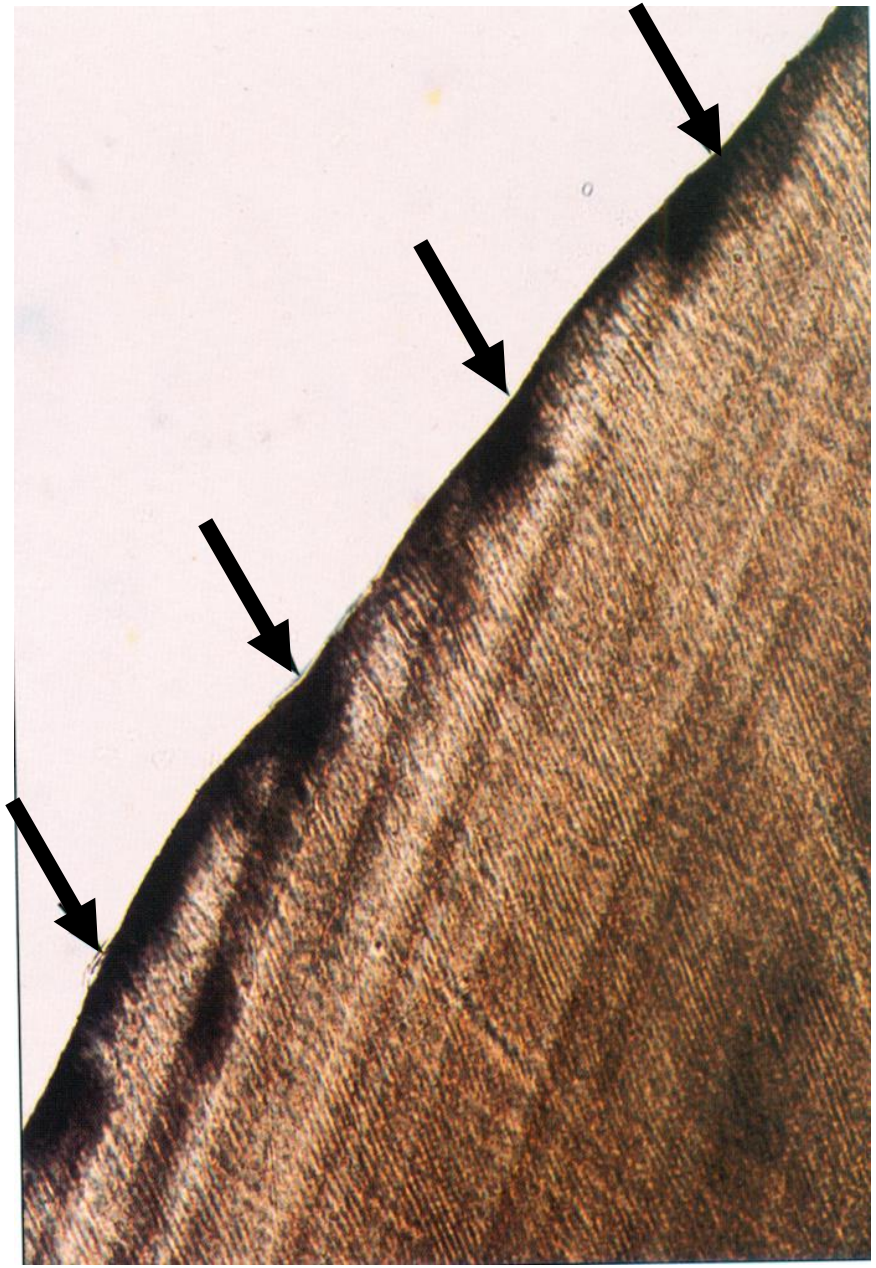
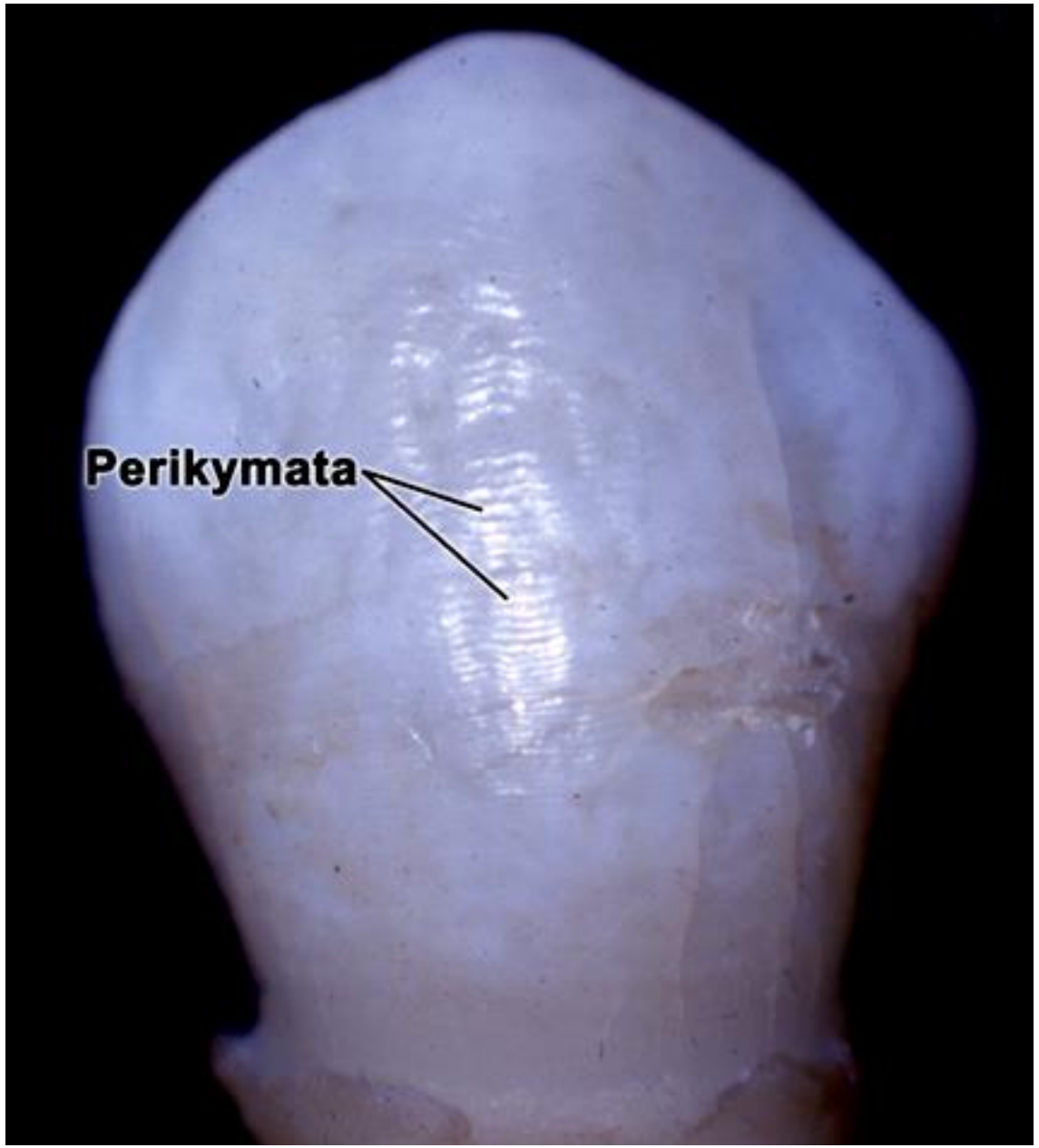


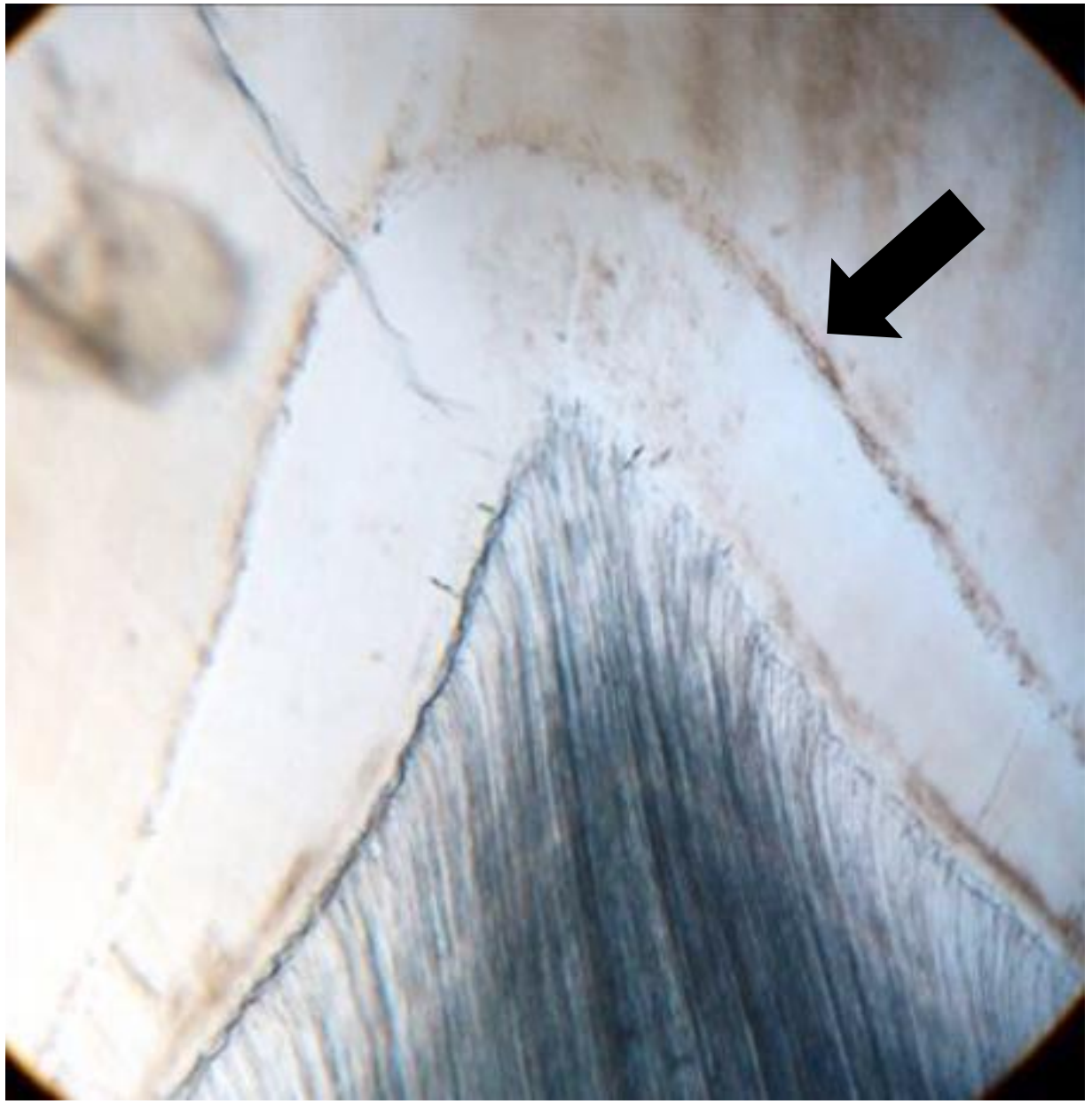


Perikymata

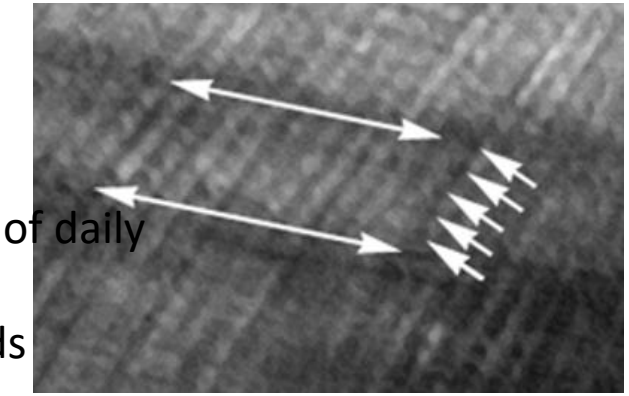




Neonatal line



Incremental enamel bands



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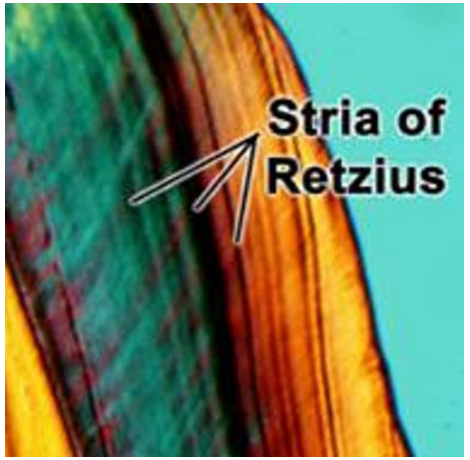

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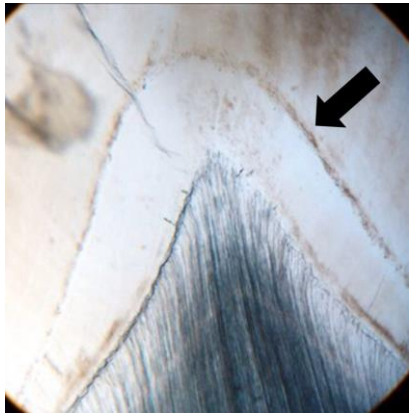
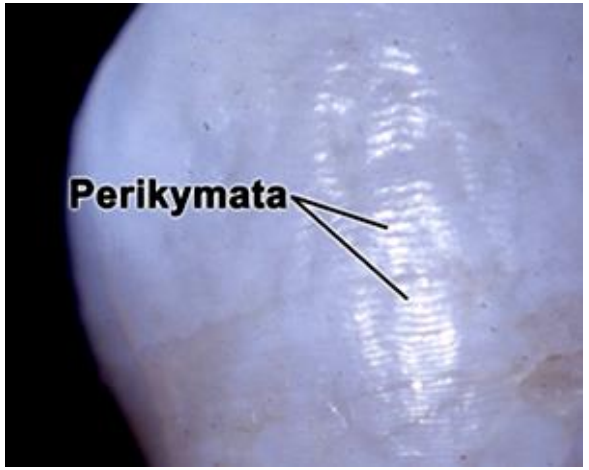
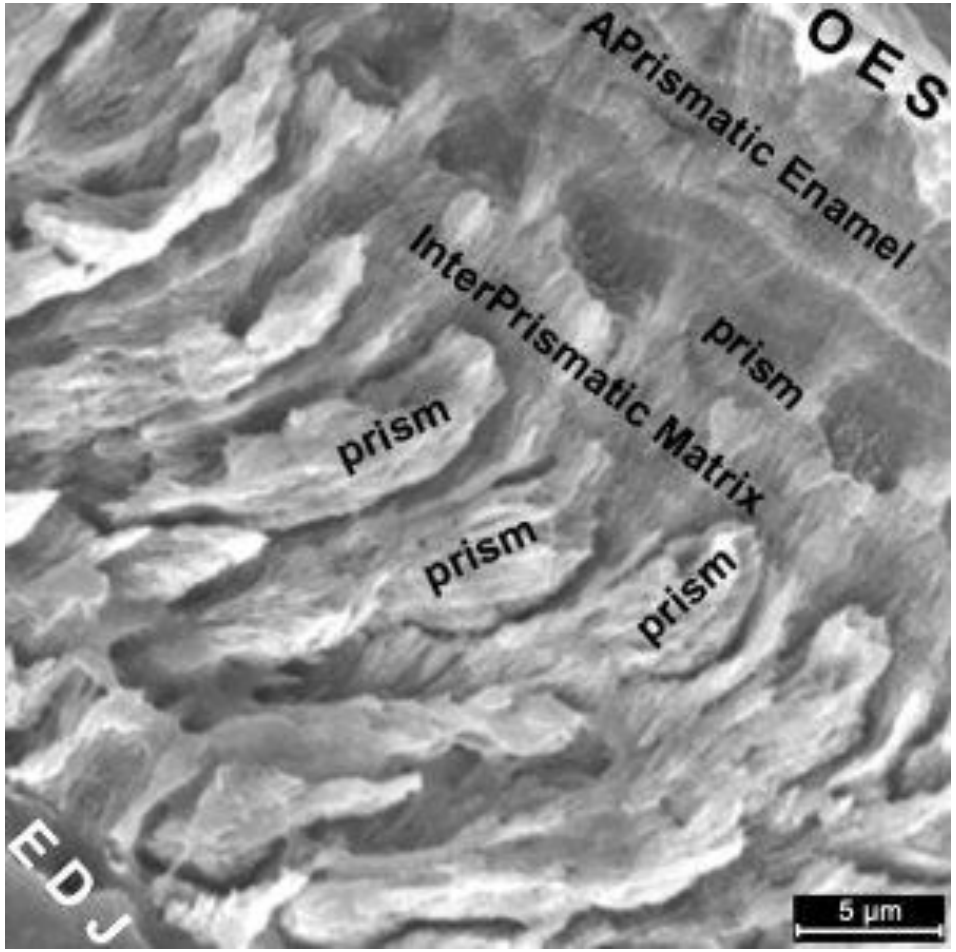
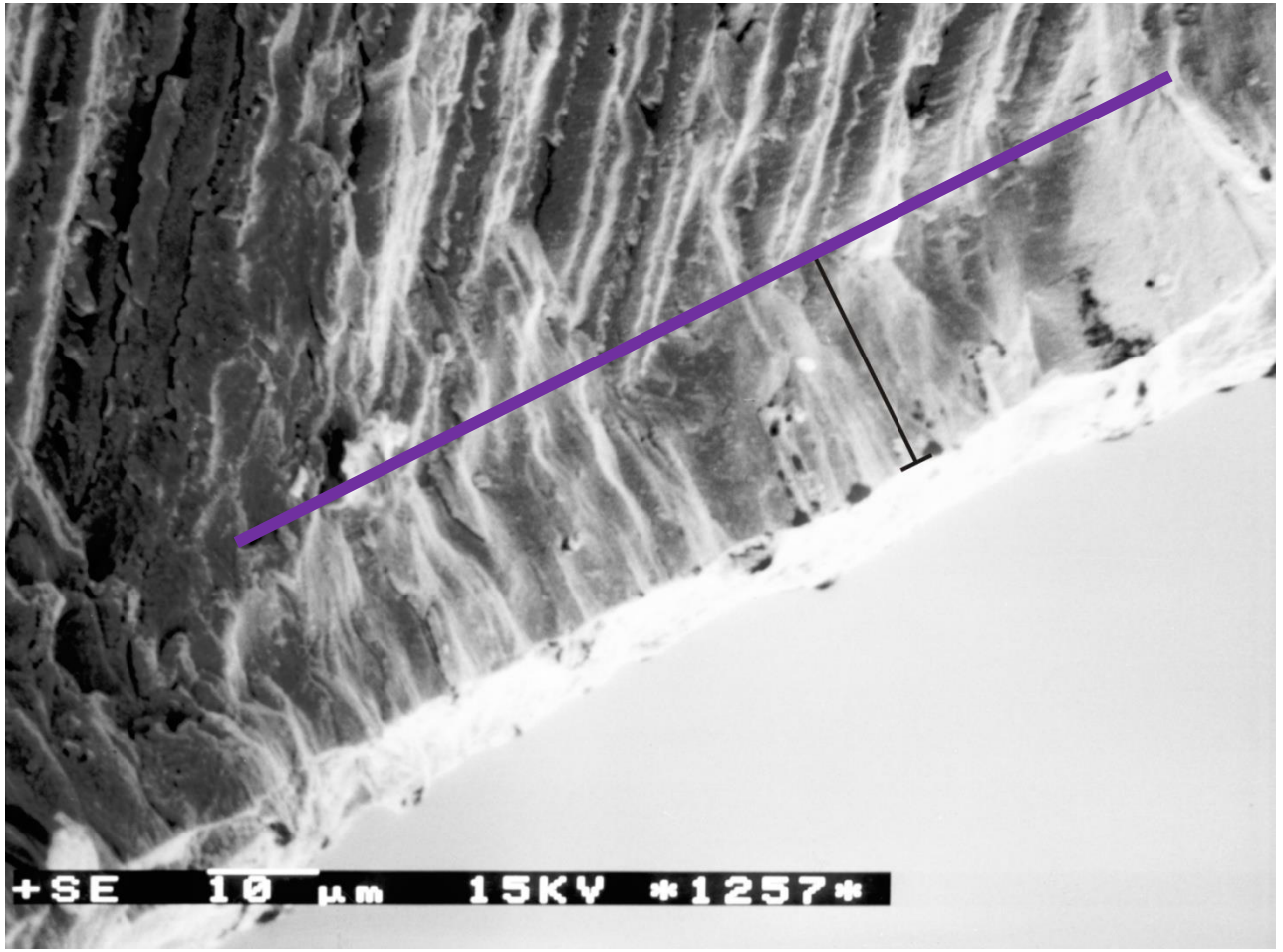


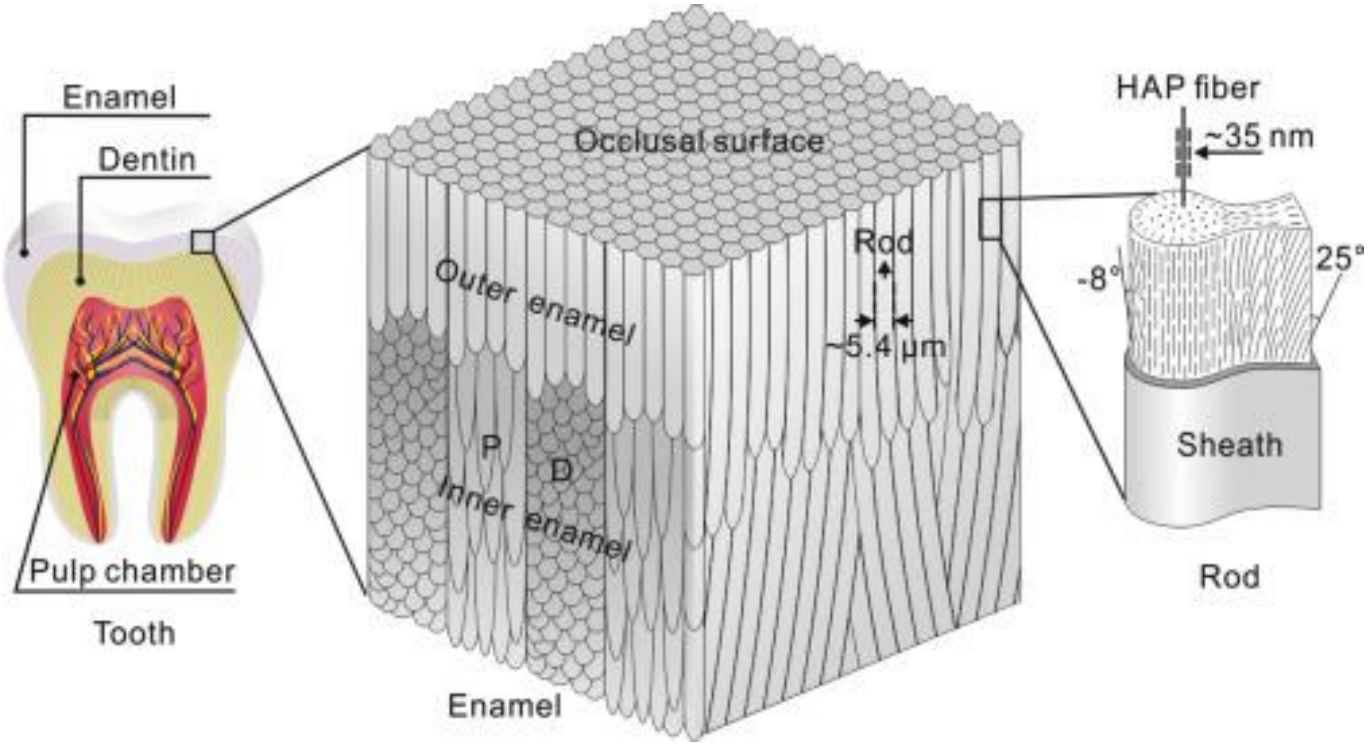


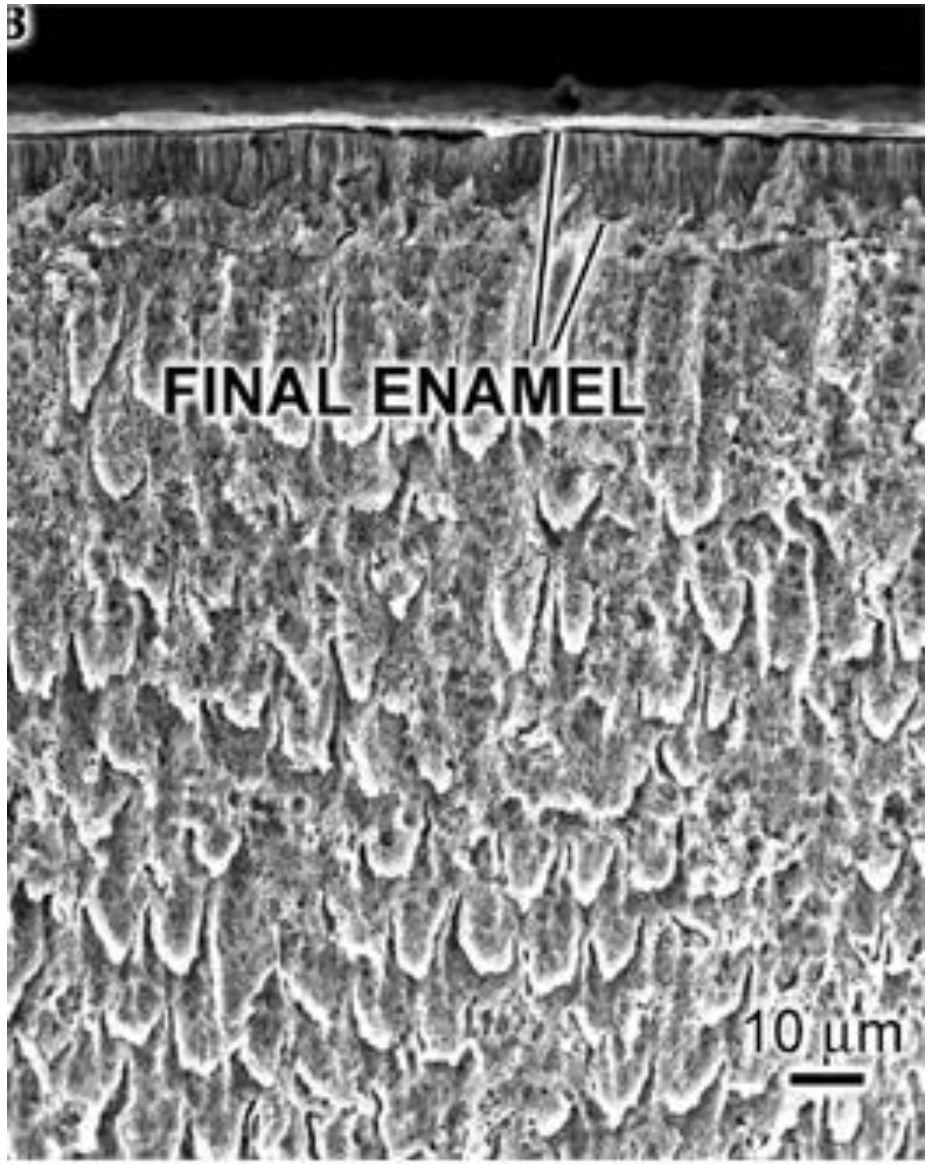
Aprismatic enamel

- 20-70 um wide layer on the surface of crown enamel
- Harder and more mineralized. Contains more fluoride
- Is formed just before the end of ameloblasts aktivity
- Hydroxyapatite crystals are hightly packed and perpendicular to enamel surface



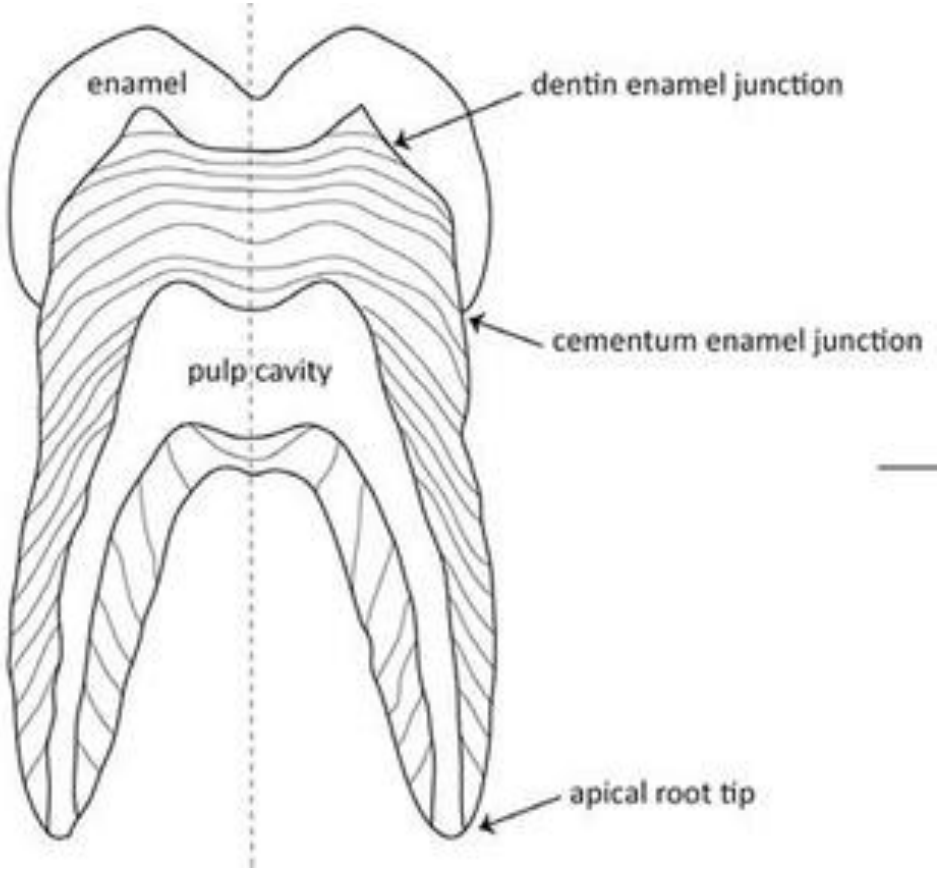


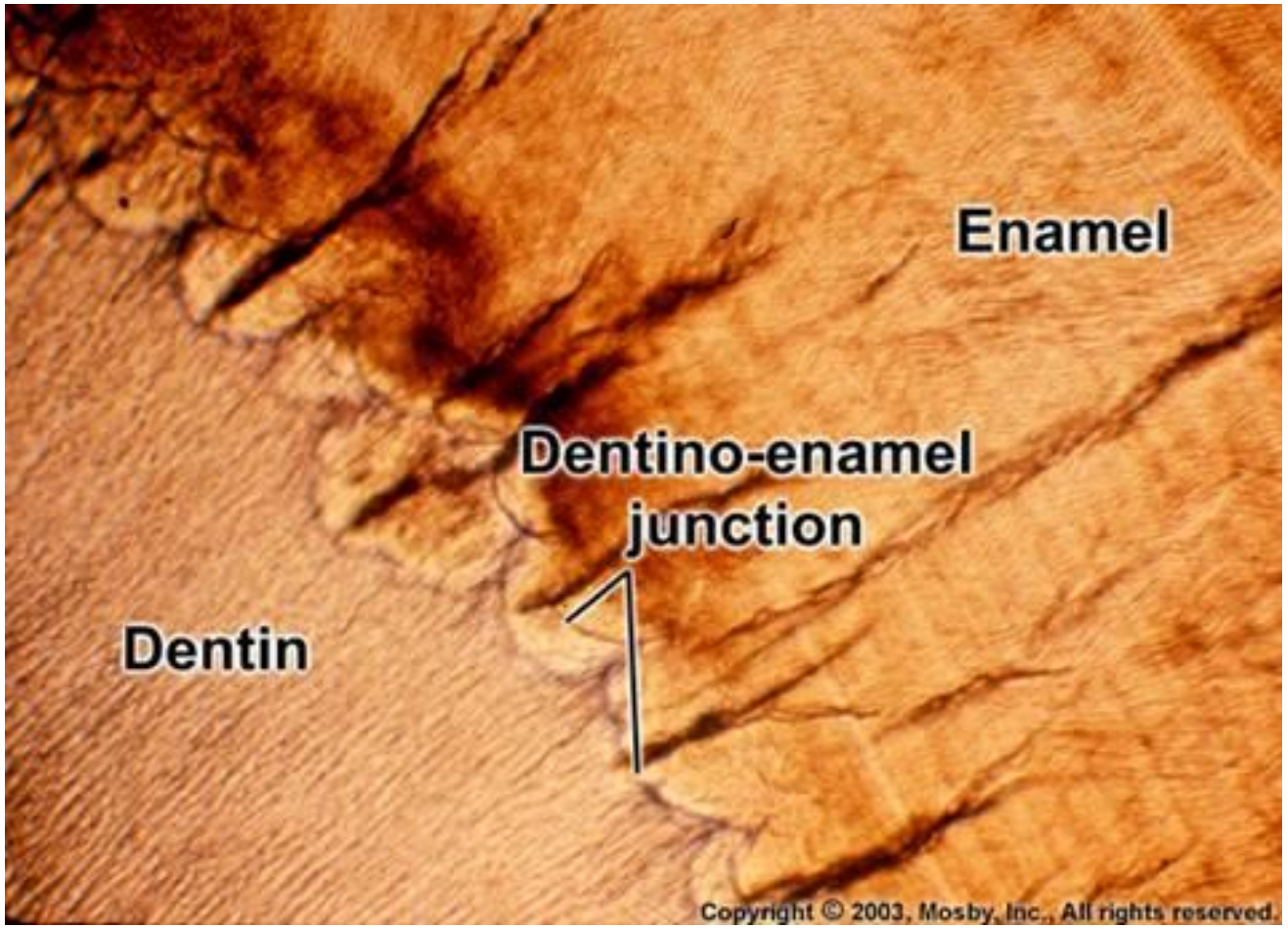




DEJ (Dentino-Enamel Junction)

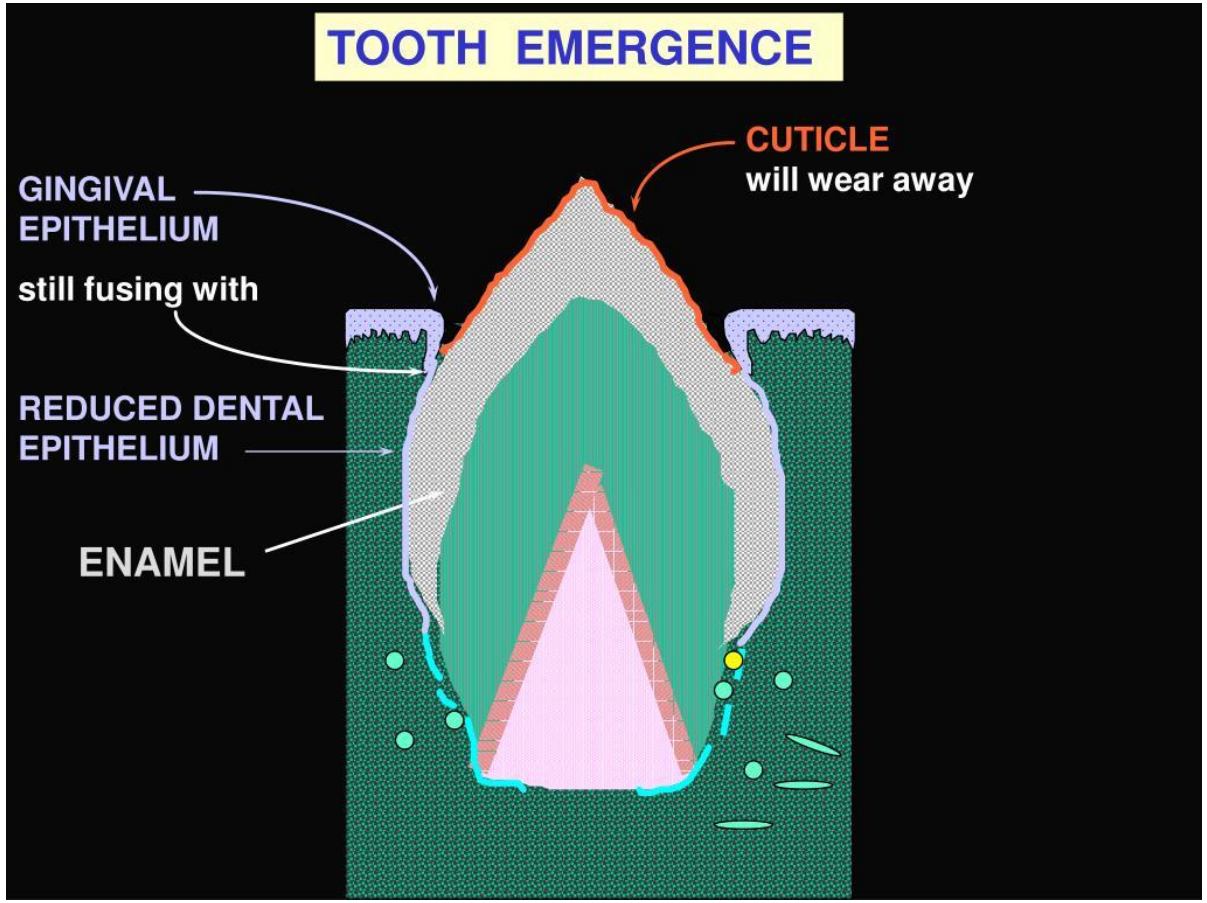
- The **boundary between the enamel and the dentin**, forms the **functional connection** of these two hard tissues
- Developmentally, it is located at the site of the (disintegrated) basal membrane of ameloblasts
- It has wavy structure
- Multiple small holes where enamel prisms bundles are connected

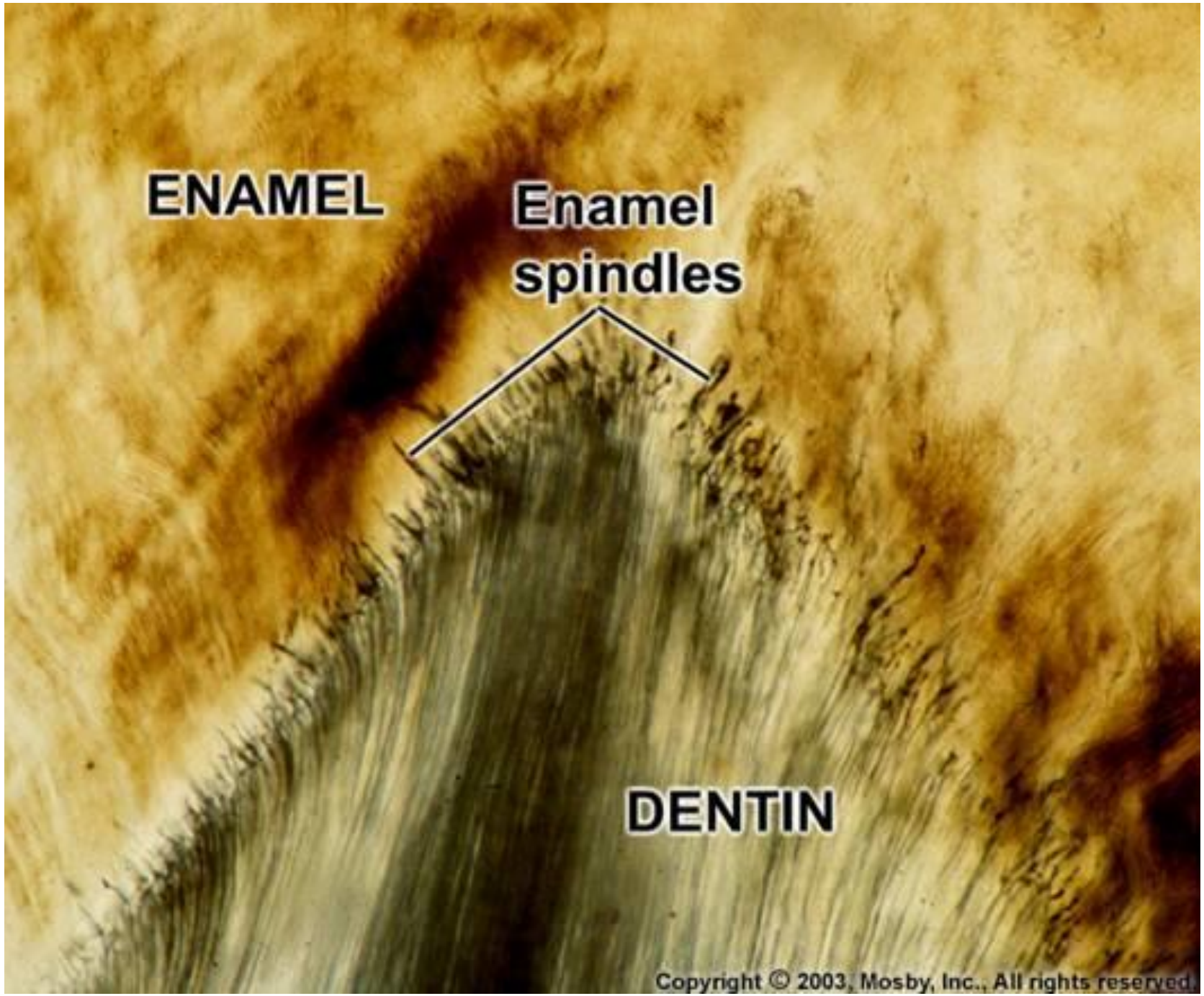




Cuticula dentis (Nasmyth's membrane)

- Covers a newly erupted tooth, after eruption its remnants can only be seen near the tooth neck
- A thin cuticular structure - remains of the enamel organ
- Formed by proteins and polysaccharides
- 1 um wide, remains on the surface of primary dentition nearby the neck





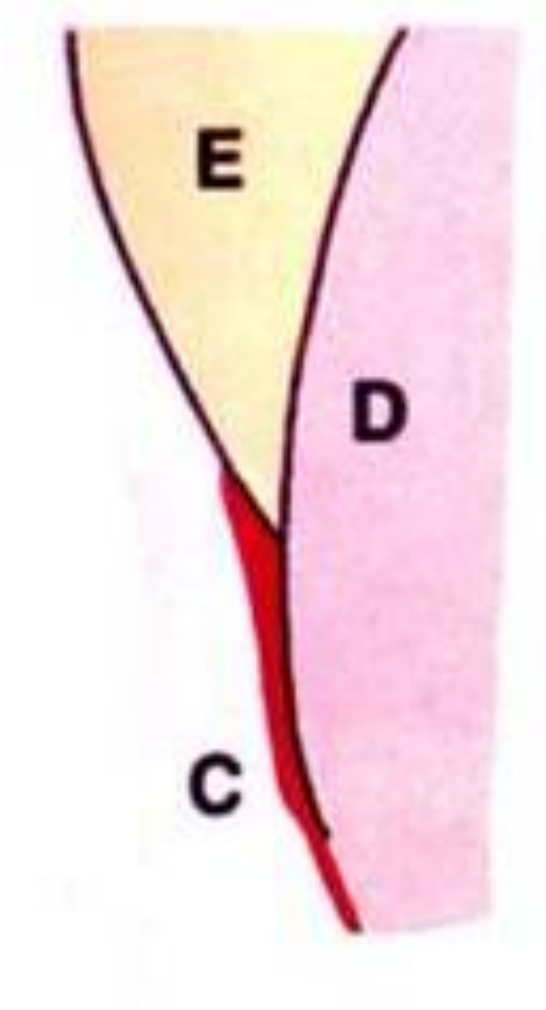
Enamel spindles
(fuzus enameli)

Up to 100 um prolongation of dentin tubules into enamel

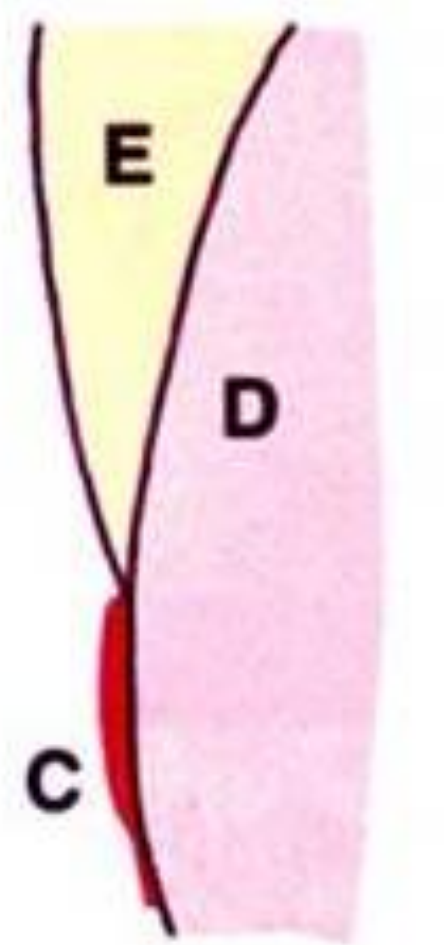
Cementum-enamel border

3 types:

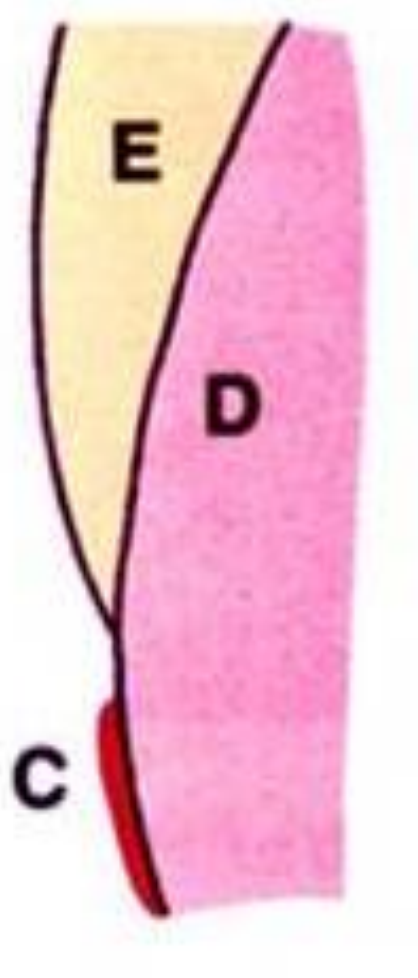
Cementum overlap over enamel
15 % (60 %)



sharp line
52 % (30 %)



with gap
33 % (10 %)



Enamel regeneration

Enamel do NOT regenerate!
Ameloblasts became apoptotic during eruption

Enamel reparation

Remineralization of damaged enamel by the action of saliva

Enamel hypoplasia

Enamel is soft and fragile
Etiology:

- Ameloblasts damage and/or premature end of their function
- Genetical disorders *(amelogenesis imperfecta)*
- Longterm increase of fluorides income (5x higher increase of fluorides in drinking water)
- Tetracykline antibiotics – incorporation into enamel during calcification
- High fevers

Age related changes in enamel

- **Abrasion** - in more advanced stages, dentin exposure may occur
- **Change of chemical composition** - increasing the content of fluorides, reducing of the water and organic compounds
- **Change in enamel pigmentation -** incorporation of organic material into the enamel, dentin thickening and darkening
- **Permeability changes** - decreases with age, crystals grow during life and the pores between them shrink

Cementum

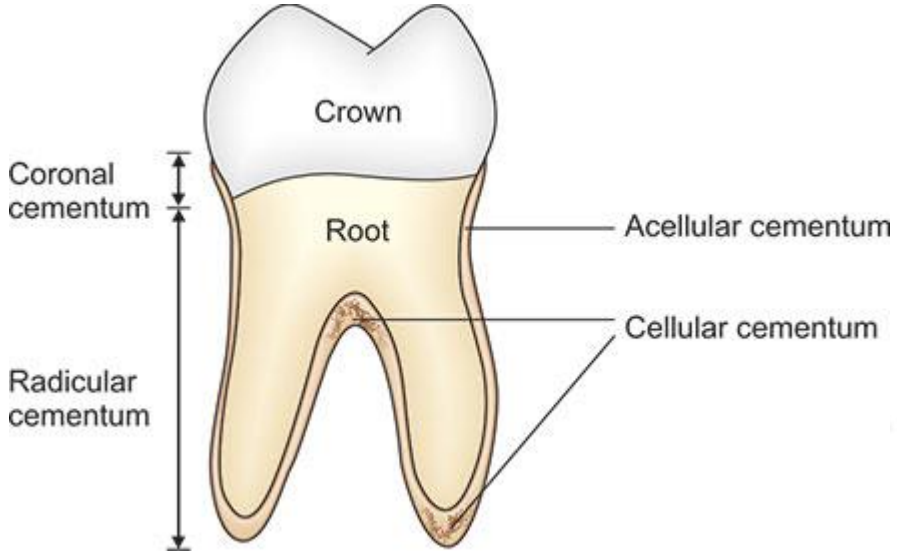
(cementum, substantia petrosa)

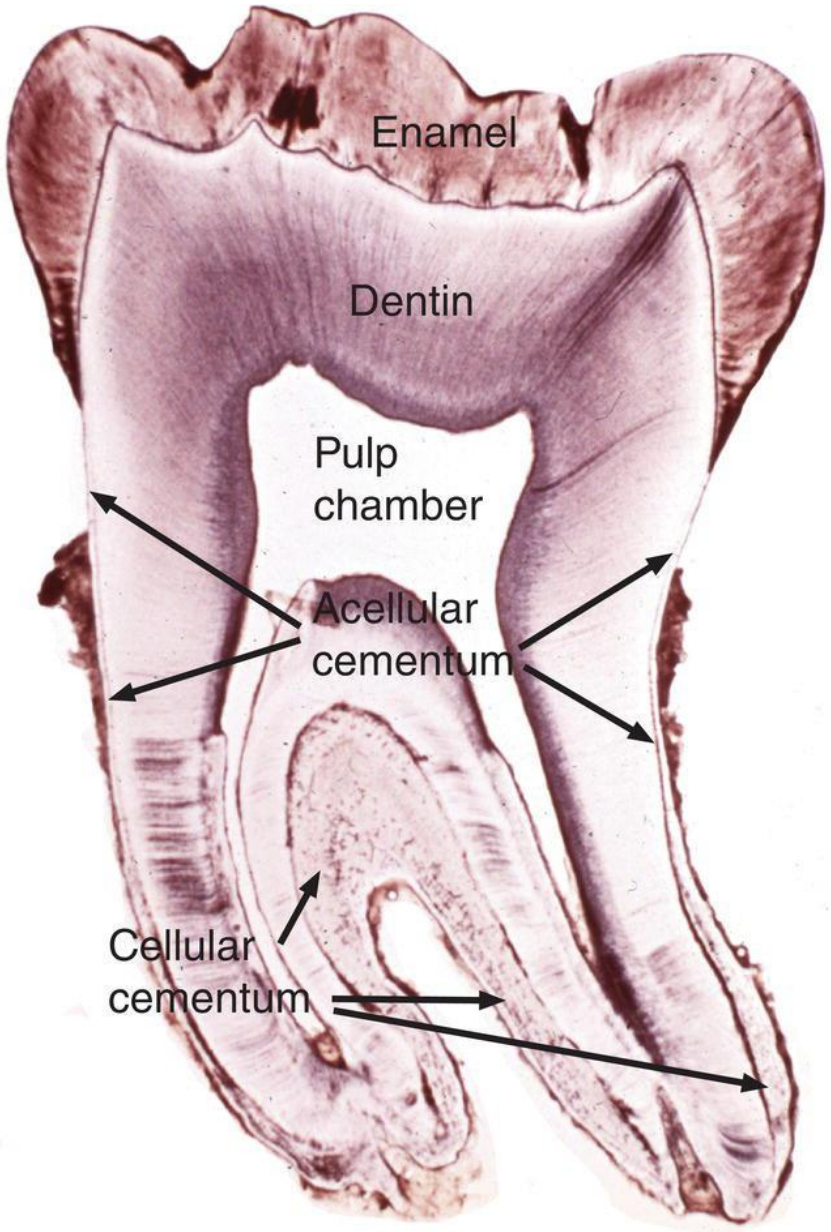
Cementum

- Hard, bone-like tissue covering the root of the tooth
- **Yellowish** color
- **Avascular** tissue
- **Does NOT rebuild** (in contrast to bone)
- Can be resorbed by **cementoclasts** - during the tooth replacement
- It is continuously deposited by new layers formation. Growth related to **circardial rhytms** – incremental lines.
- Development from **ectomesenchyme**

Composed of:

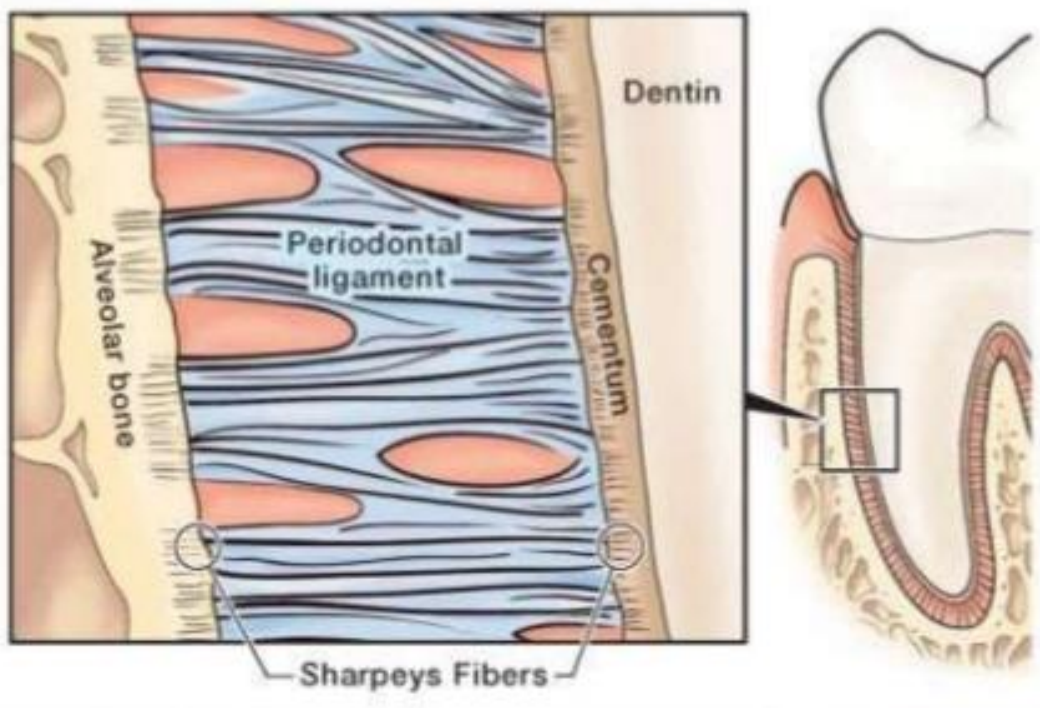
- **Cellular part**
- **ECM**

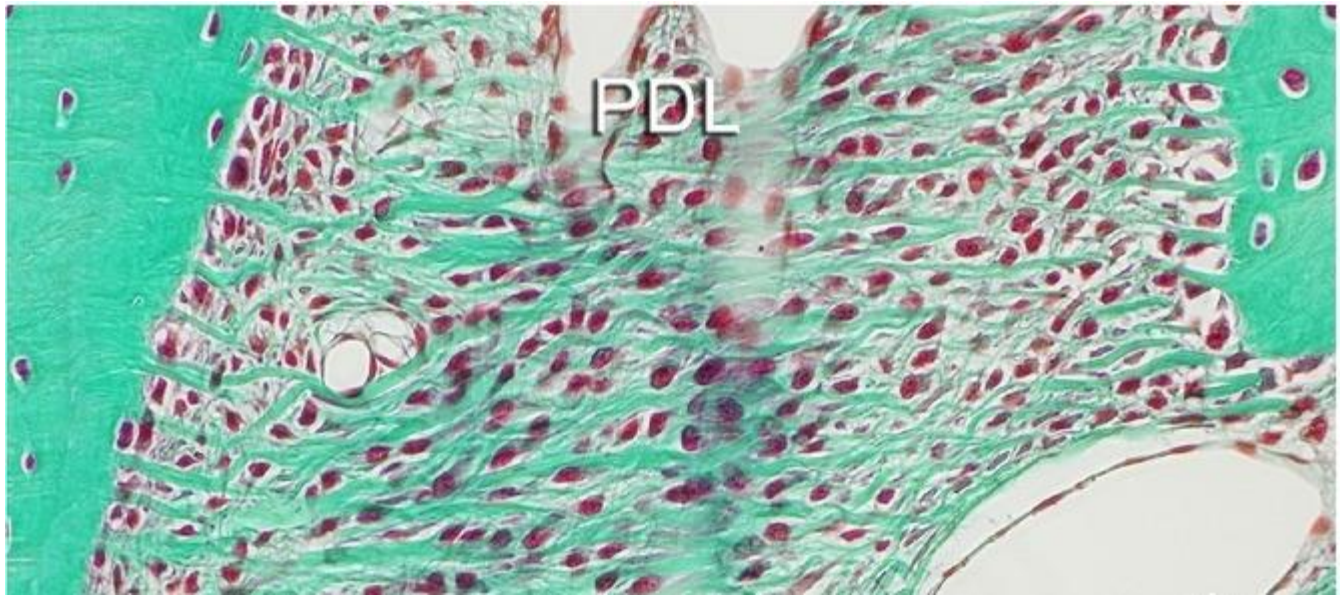




Sharpey fibers

- Collagen fibers (especially collagen 1) of periodontal ligaments, which are immersed on the one side in cementum and on the other side in the periosteum of alveolar bone
- It forms a functional attachment of the tooth in the alveolus
- They run all the way to acellular cementum, where they are fully mineralized





Microscopic anatomy

Cementocytes, Cementoblasts, (Cementoclasts)

Extracellular matris (ECM) = Cementum

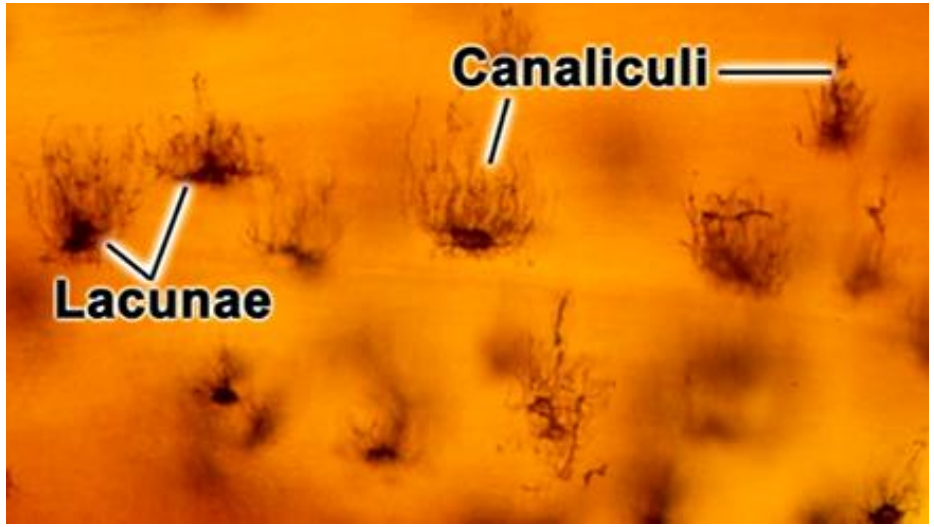
- **Acelular (primary)**
- **Celular (secondary)**

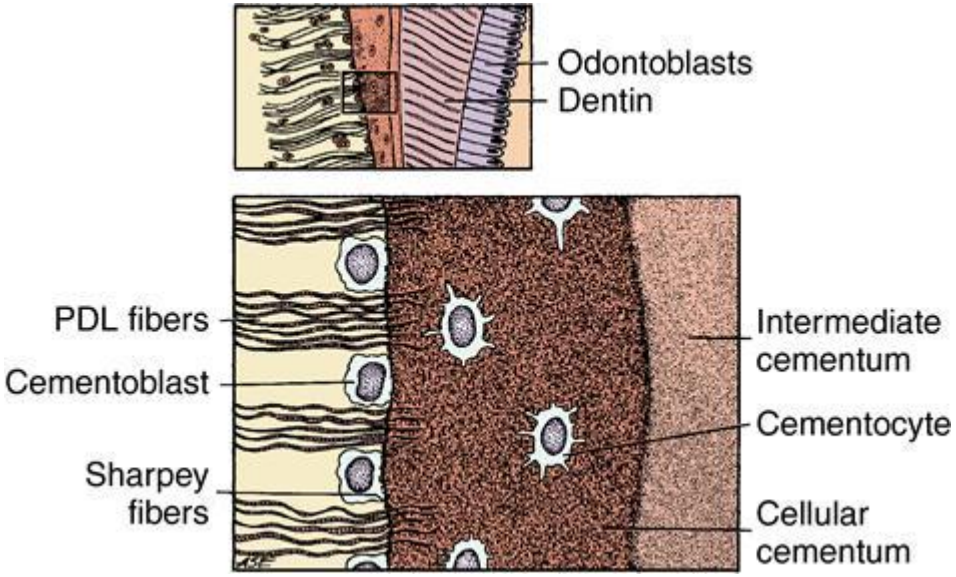
Cells

Cementoblasts
Actively involved in ECM formation

Cementocytes
Cells surrounded by cementous tissue, bodies placed in cavities (*lacunae*), processes in small tubules (similar to Osteocytes in Bone) - *canaliculi cementi*

Cementoclasts
Involved in cementum resorbation in temporary teeth





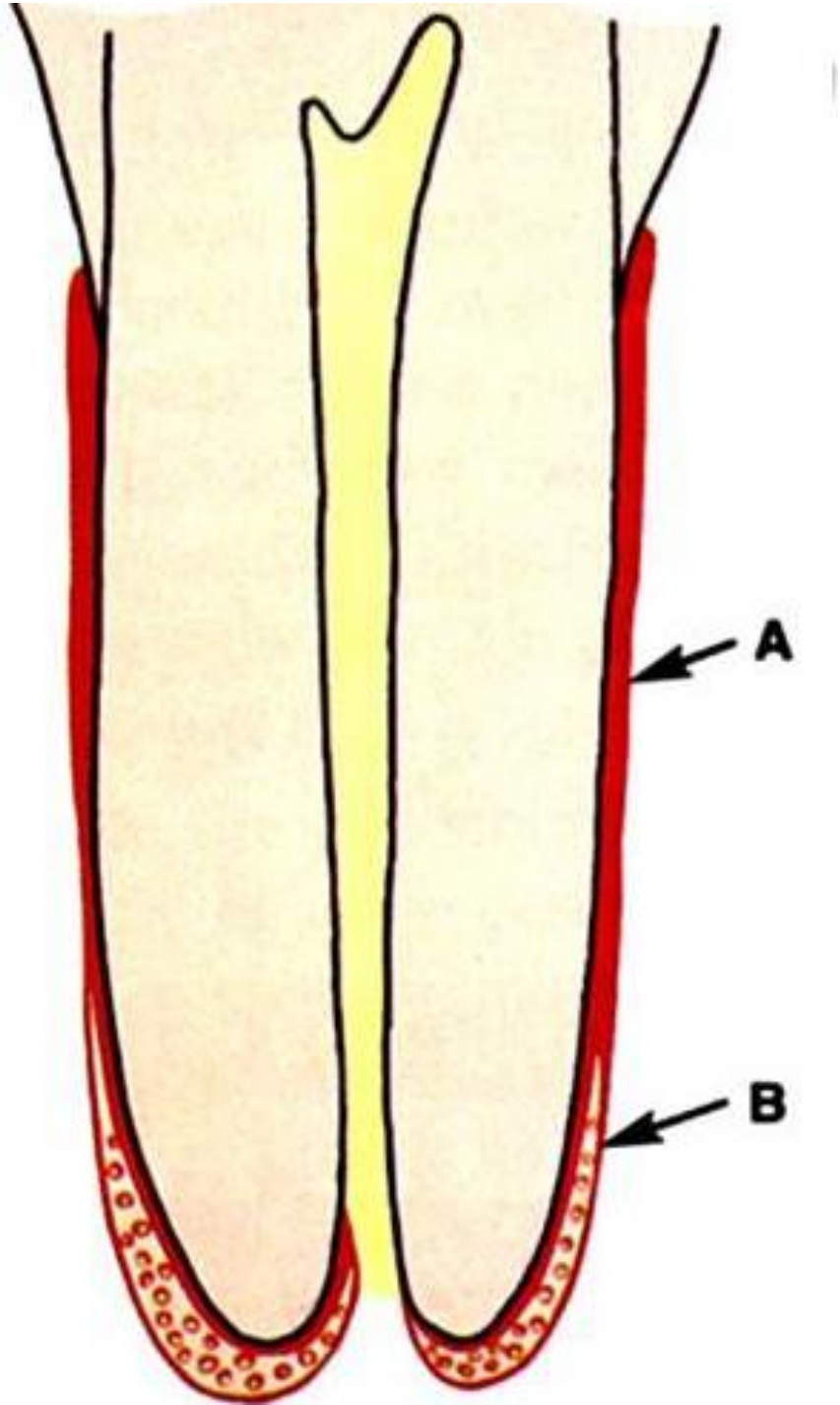
Cementum matrix

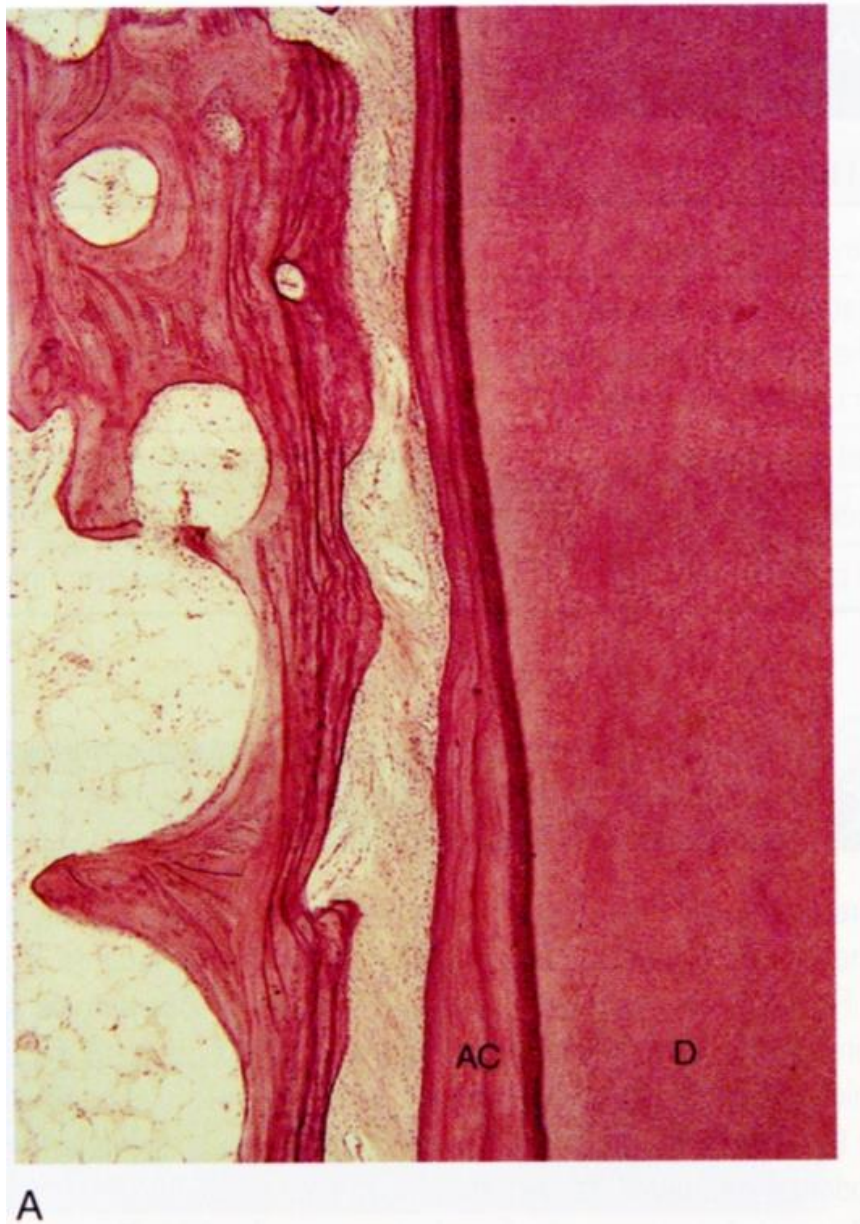
Collagen fibres and calcified amorphous mass
Collagen fibres run in bundles (orientation is determined by the forces on teeth)

Cementum is divided by origin into:

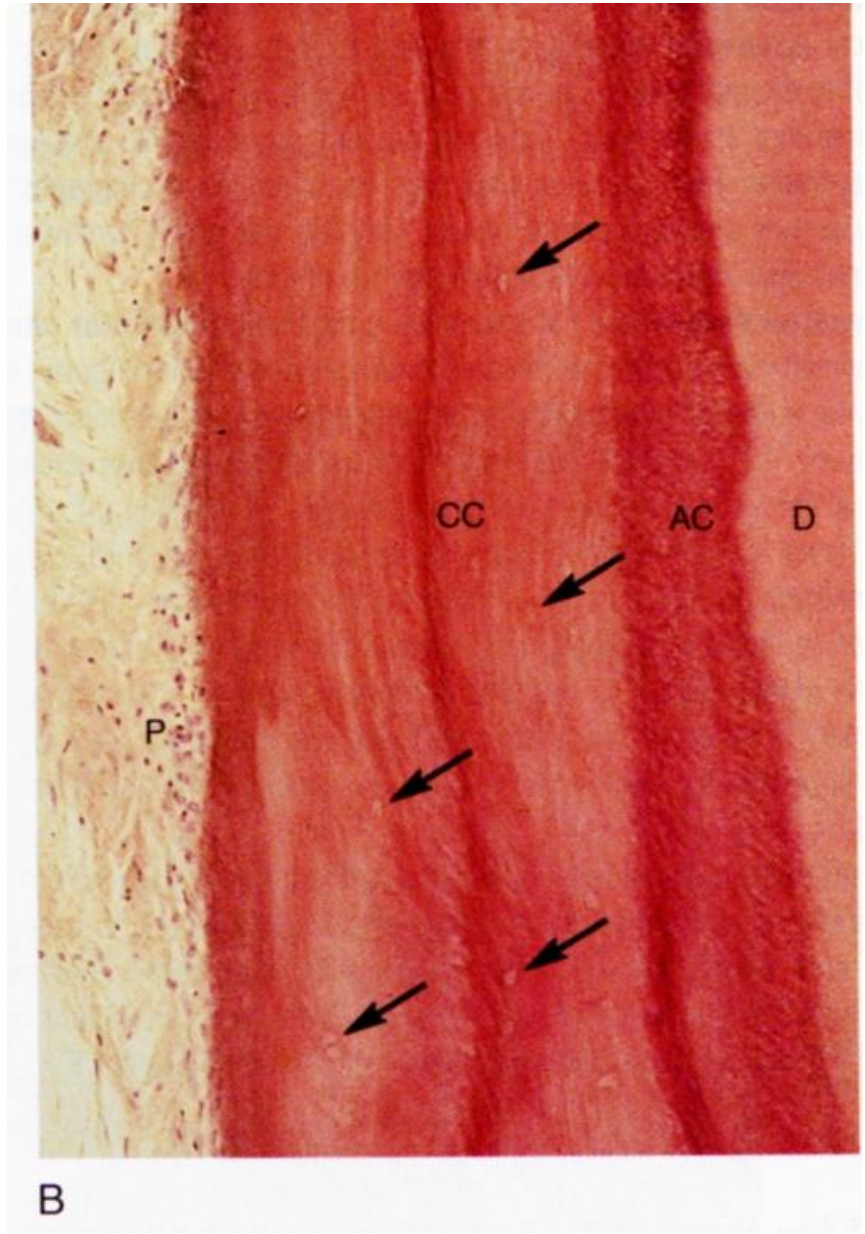
Primary (acellular)
Does not contain cementocytes
In the range of the entire tooth root
Directly connected to the dentine
Thickness: **10 to 200 µm**

Secondary (cellular)
Contains cementocytes
Especially on dental apexes
Grows **up to 500 µm thick**





A



B

Cementum hyperplasia
(hypercementosis)

Abnormal cement thickening

Occurs either in single tooth/teeth or in a whole dentition (Paget's disease)

The most frequent cause of hypercementosis is long-term and excessive tooth load

Cementicles – in PDL

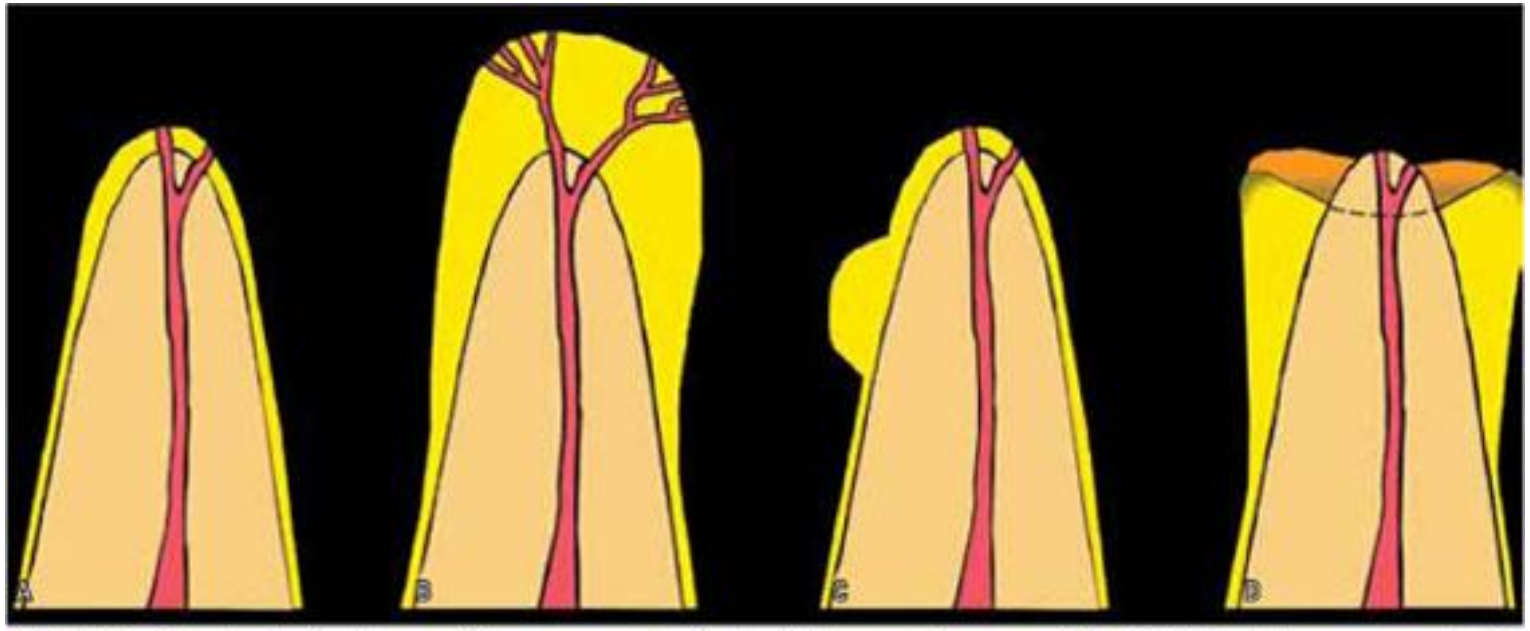
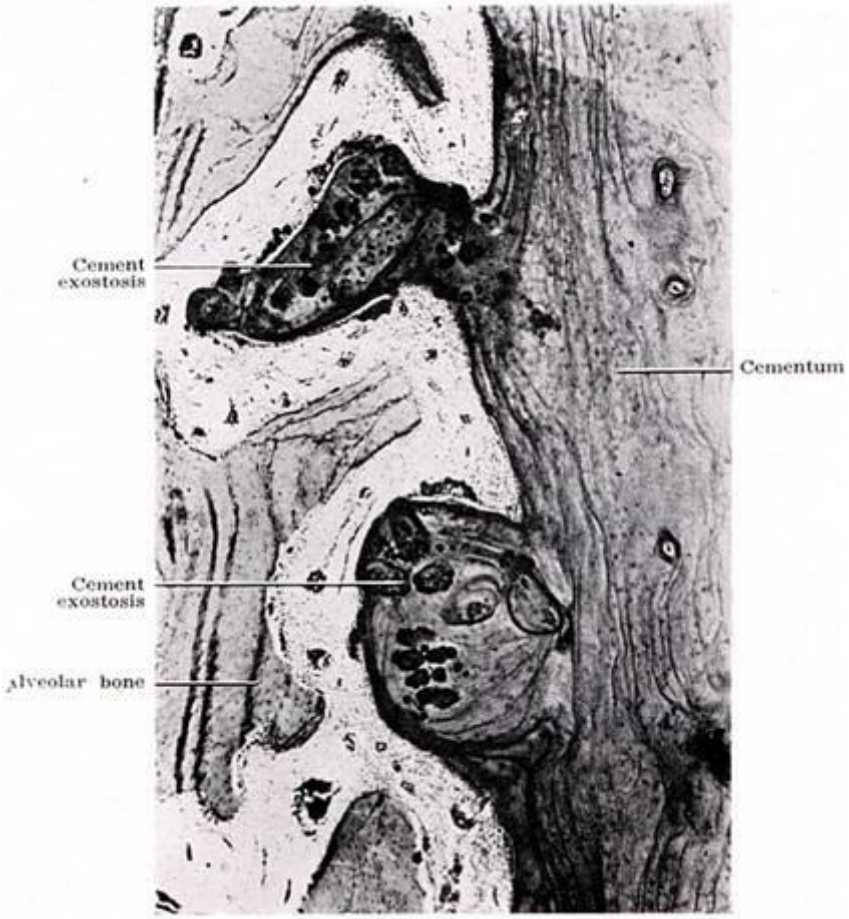
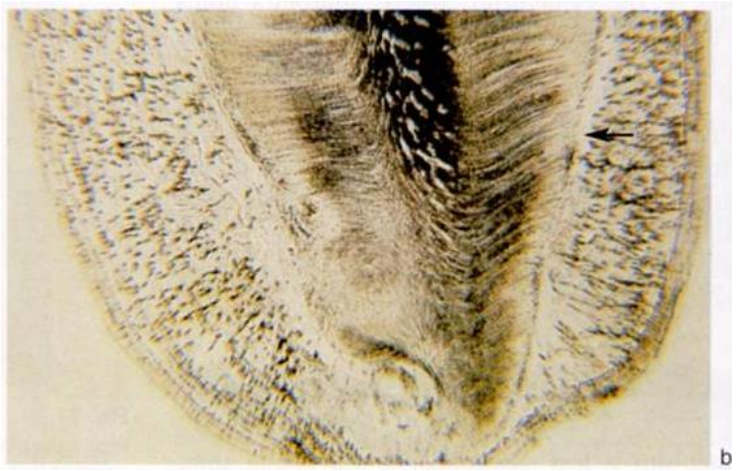
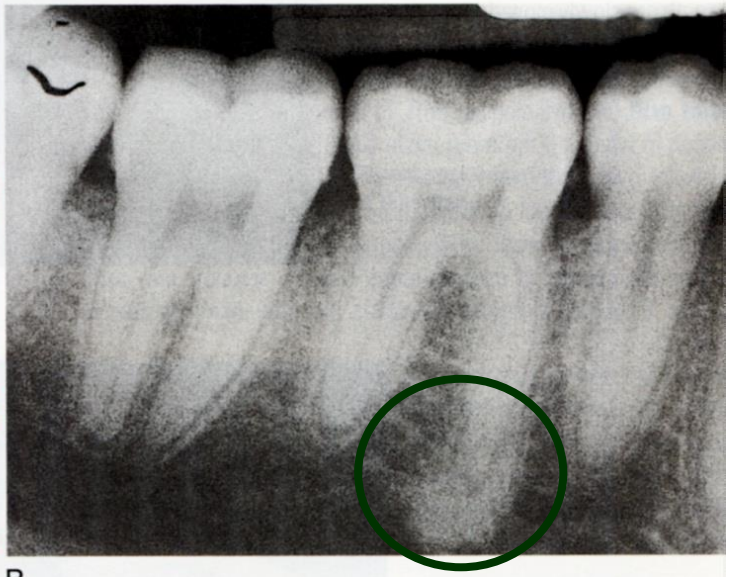


FIGURE 1 - Morphological types of hypercementosis: In (**A**) the root is normal; in (**B**) diffuse hypercementosis, when the root assumes a club shape. In (**C**) focal or localized hypercementosis, which is restricted to an isolated root surface; in (**D**) hypercementosis in the shape of a shirt sleeve cuff, which does not involve the most apical part and occurs on the periphery, as result of chronic periapical lesion (Source: Pinheiro[75]).







A B

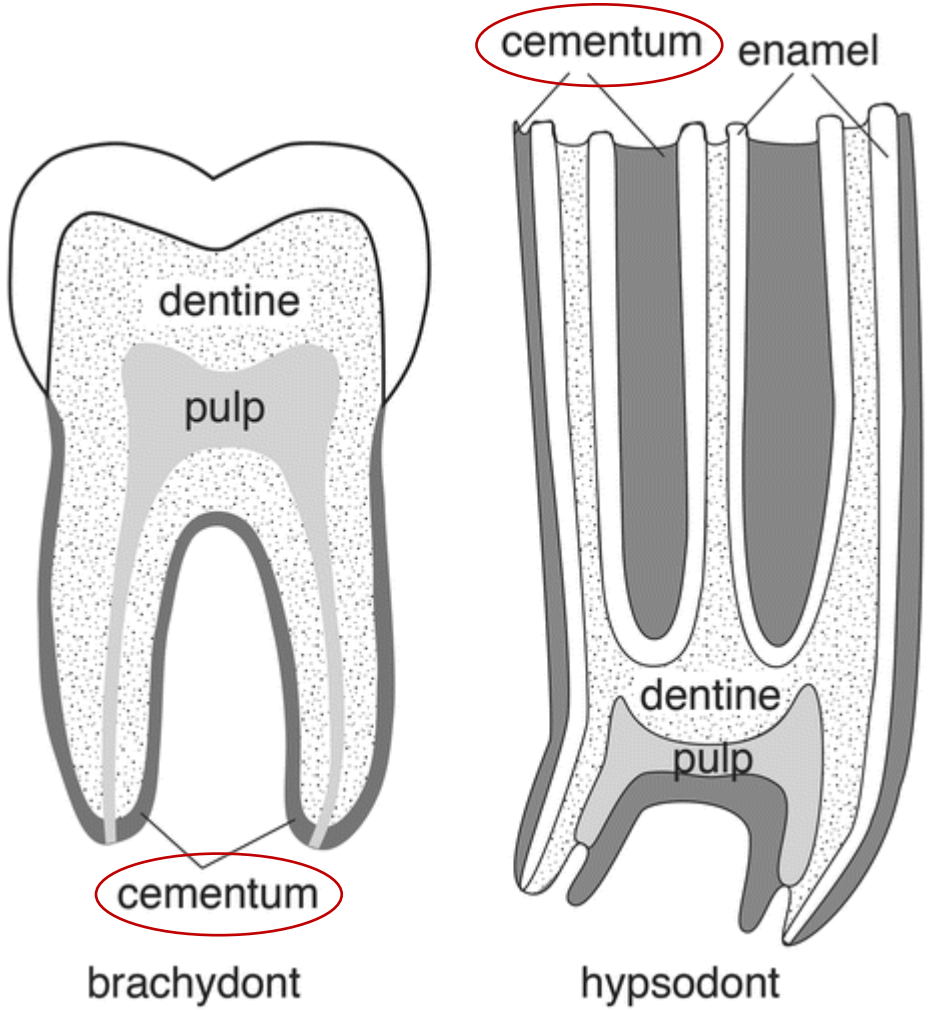
FIGURE 14-12 Hypercementosis at the root apices due to traumatic occlusal forces on mandibular molar teeth. **A:** Microscopic view with dentin (*D*), cementum (*C*), and radicular pulp tissue (*P*). **B:** Radiograph. (***A*** *courtesy of James McIntosh, PhD, Assistant Professor Emeritus, Department of Biomedical Sciences, Baylor College of Dentistry, Dallas, TX.)*

Attachment of hypsodont teeth in the jaw

Development of hypsodont teeth in animals with highly abrasive diets.

Gradual, uneven abrasion of the "crown" part.

What is the crown?



Low „crowned“

High „crowned“