

# Enamel

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

# Enamel, cementum

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7. 4. 2022

# ENAMEL

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

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

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

## Physical properties

- Refractive index: 1,62; density: 2,9 g.cm<sup>-3</sup>,
- 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 resistance 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



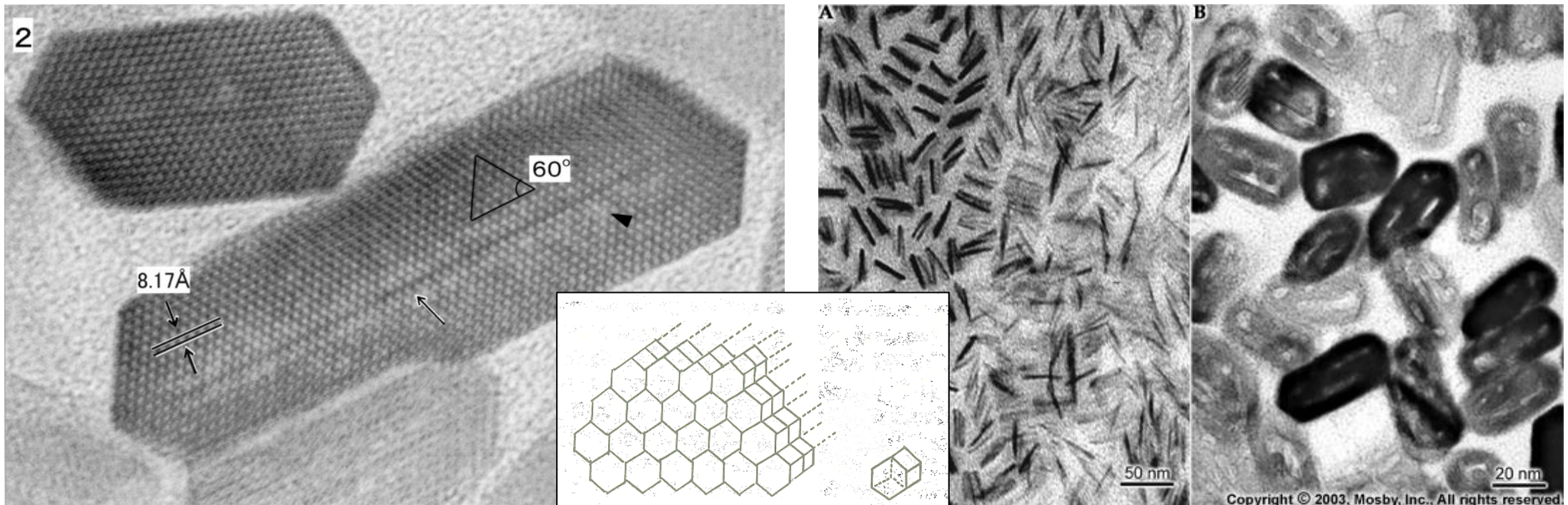
# Chemical composition

Inorganic  
96 - 97 %

Water  
2 - 3 %

Organic  
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 deposited, always there.



# Chemical composition

Inorganic  
96 - 97 %

Water  
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Organic  
1 %

## NON-collagenous proteins

### a) Amelogenins

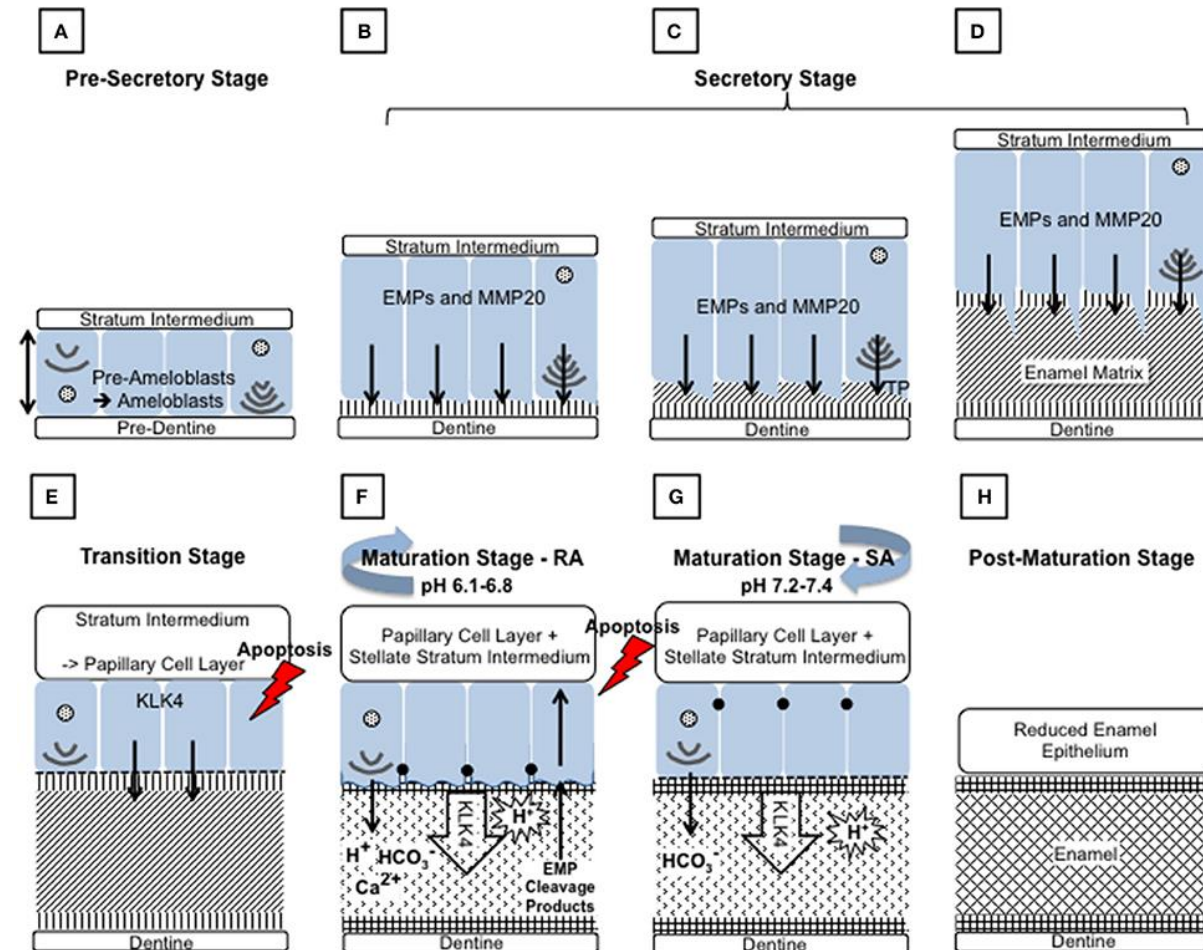
- 90 %
- Main product of ameloblasts secretory stage
- Spherical polymers, regulation of enamel prisms growth

### b) Non-amelogenins:

- Enamelin – Nucleation and direction of growth regulation of crystals
- Ameloblastin – Adhesive molecule
- Kalikrein 4 – Protease secreted by ameloblasts in the final secretory stage
- Tuftelin – Stabilizes connection to dentin

### c) Proteins with enzymatic activity

- Metalloproteases (MMP20) – amelogenin degradation
- Alkalic phosphatase, phosphomonoesterase and serinprotease 1

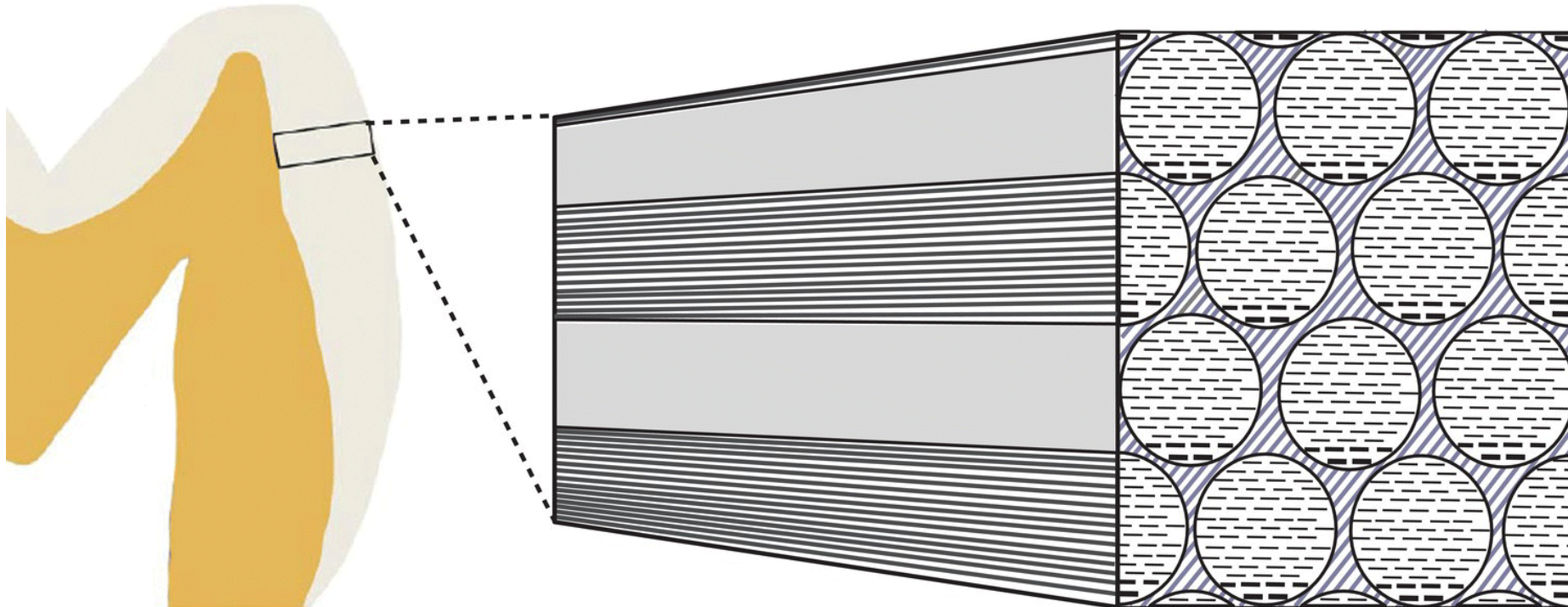


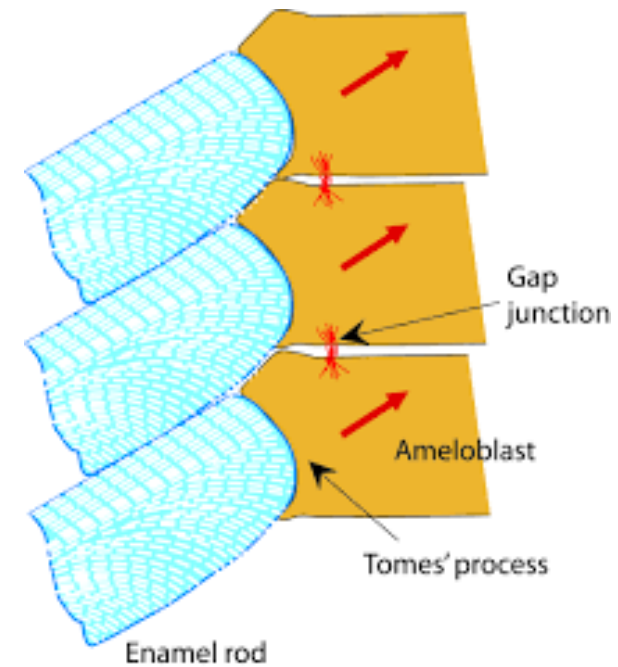
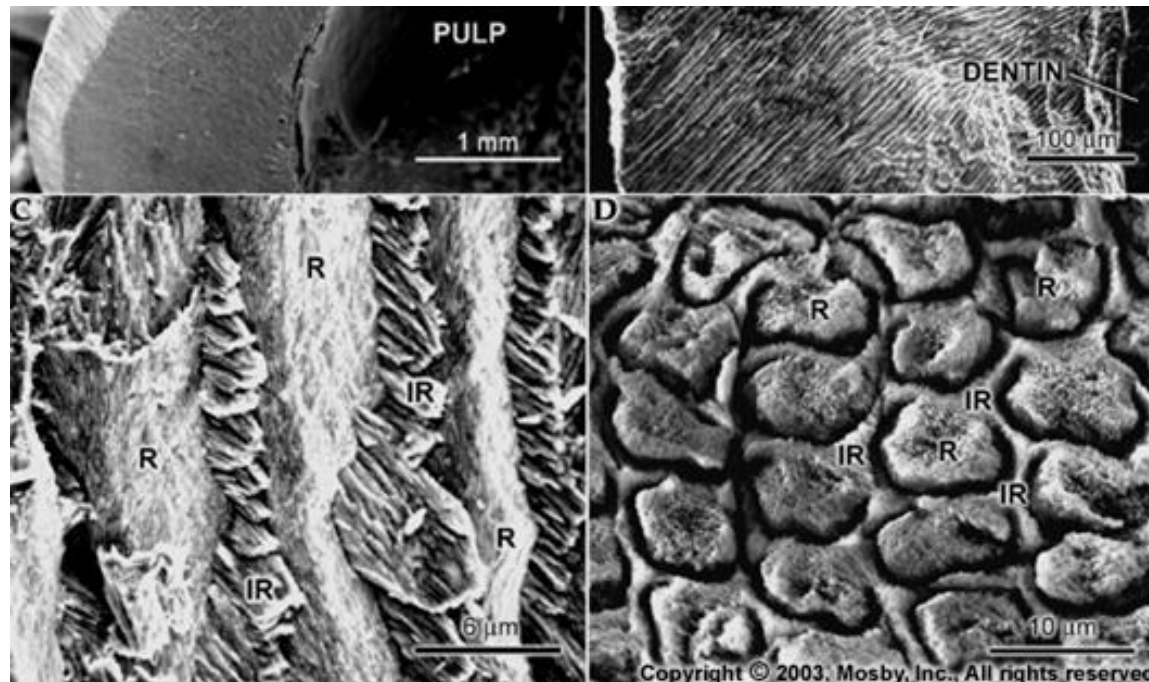
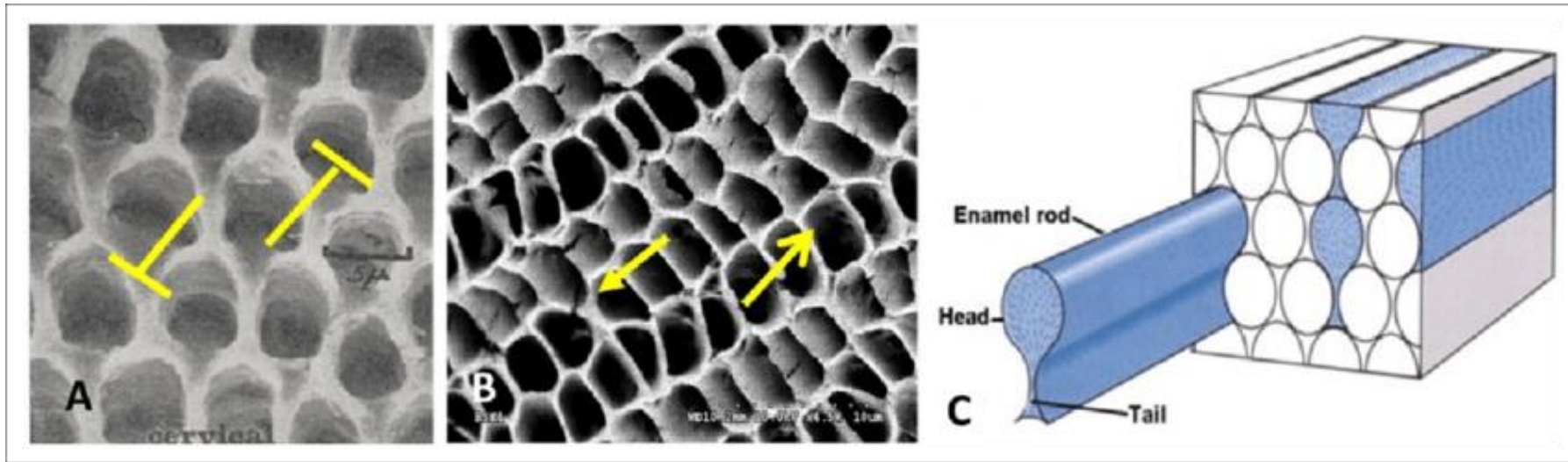
# Microscopic structure

Complicated and species-specific inner structure

**Enamel prisms** (prisms and interprismatic substance),  $\pm 1 \mu\text{m}$  wide

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

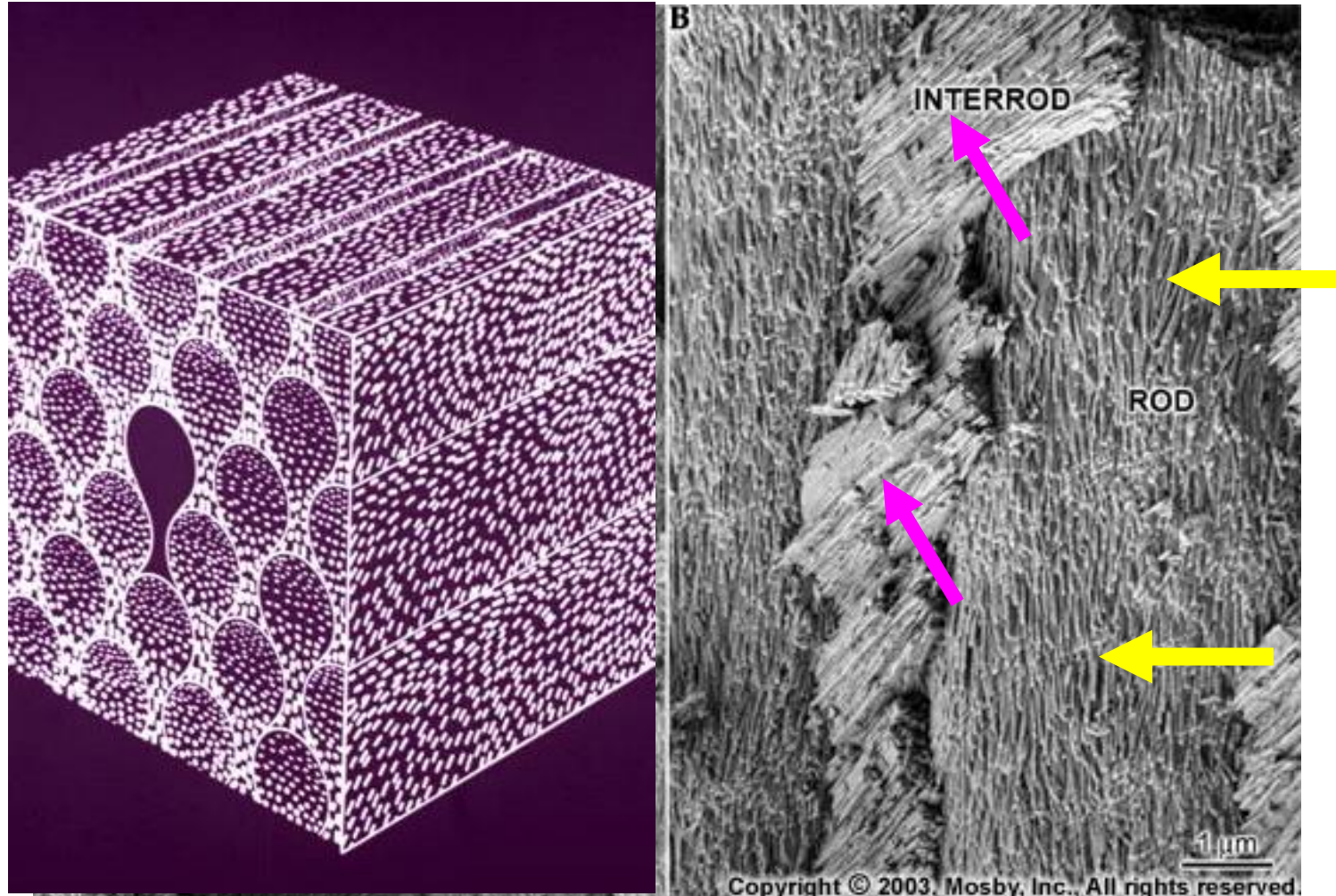




## Prisms ultrastructure

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

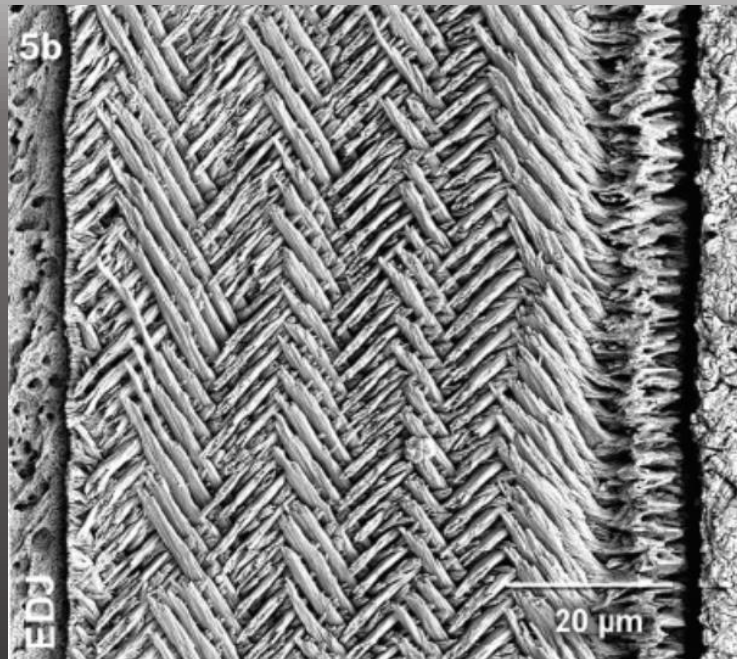
Interprismatic substance structure is the same, but crystals are laid down under different angle





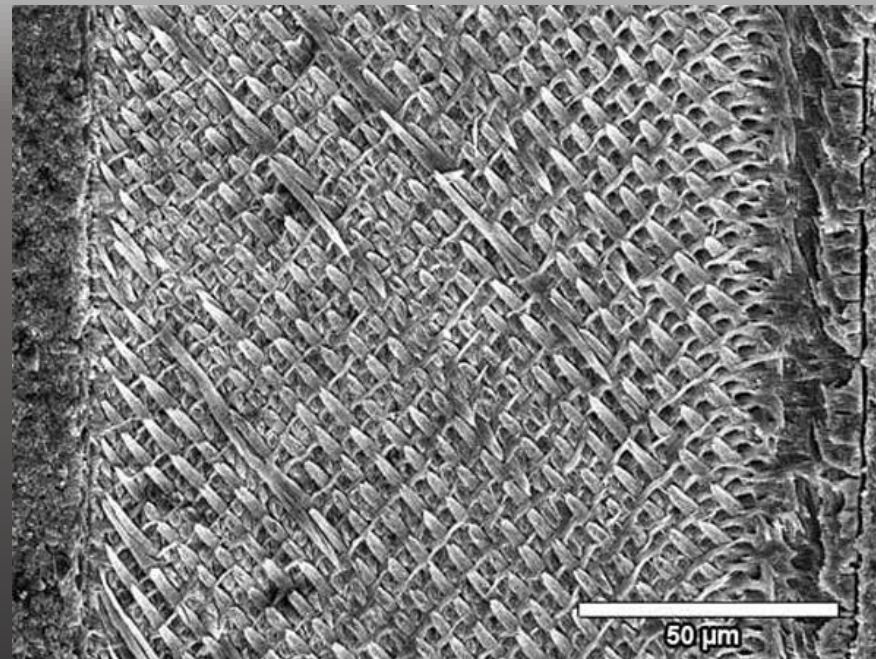
# Enamel decussation pattern (rodents)

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



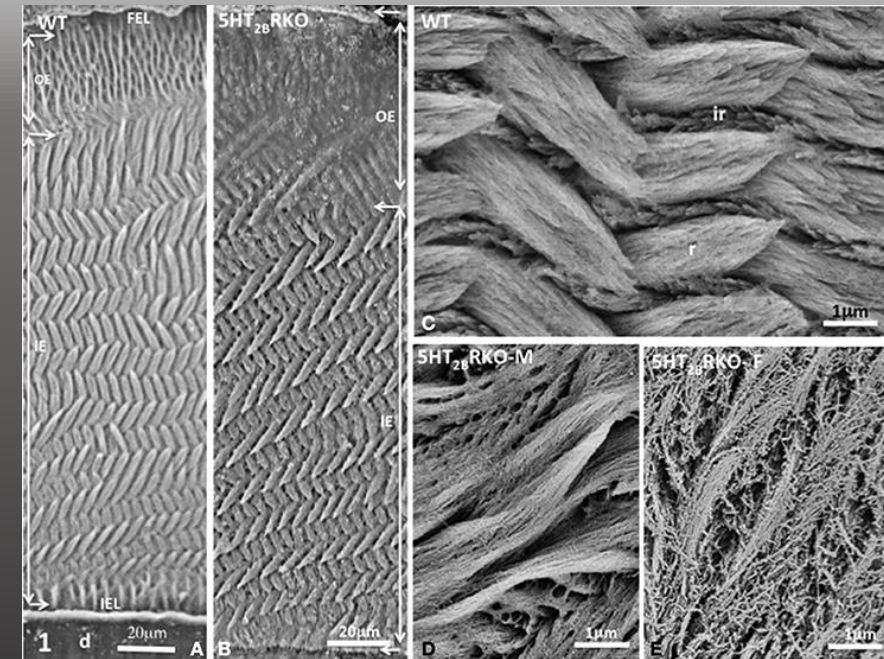
Daniela C. Kalthoff, 2007

*Heterosminthus gansus*  
(late Miocene)



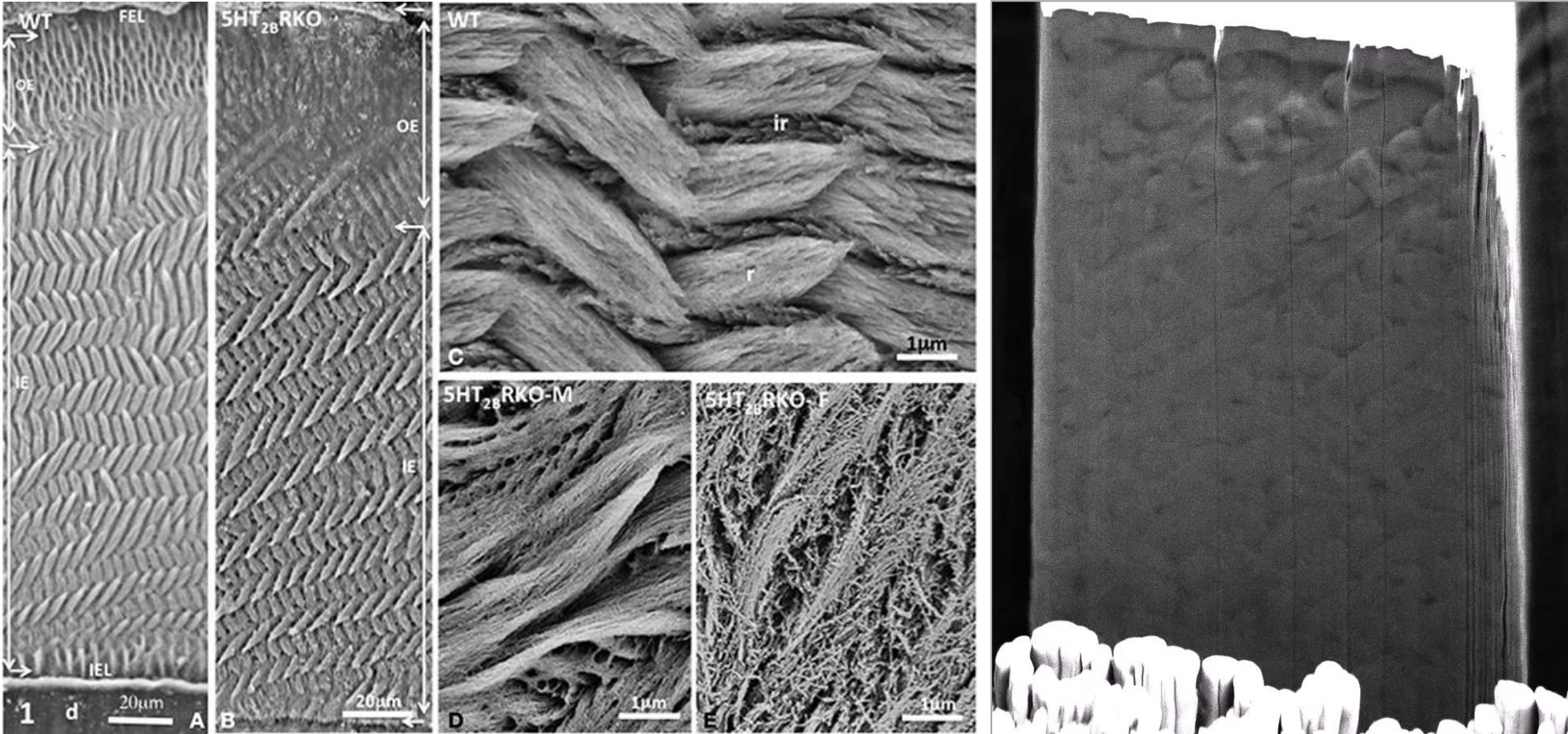
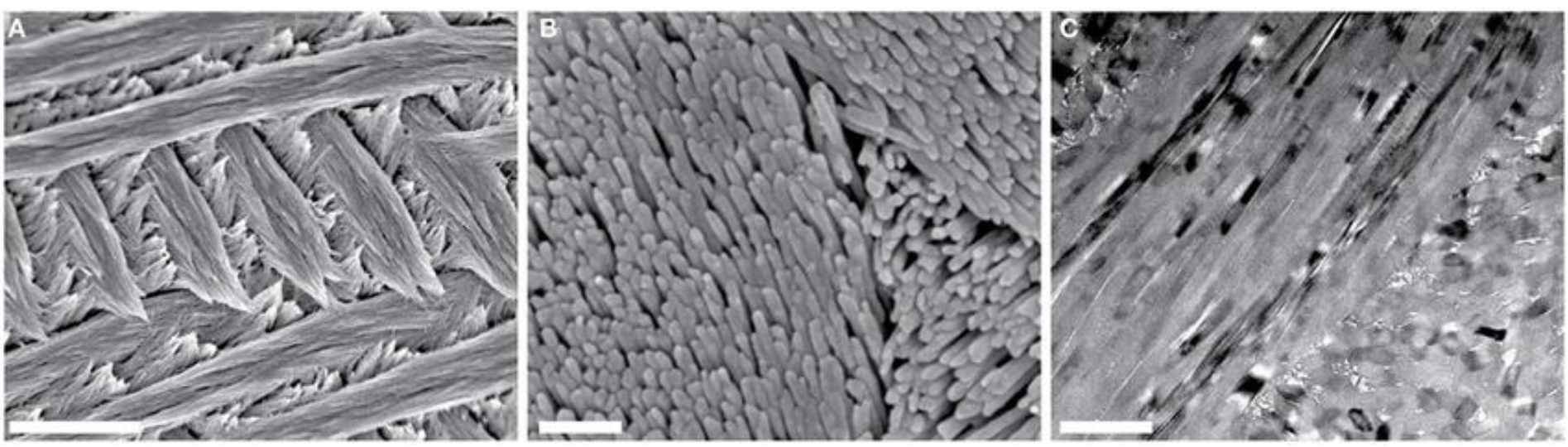
Daniela C. Kalthoff

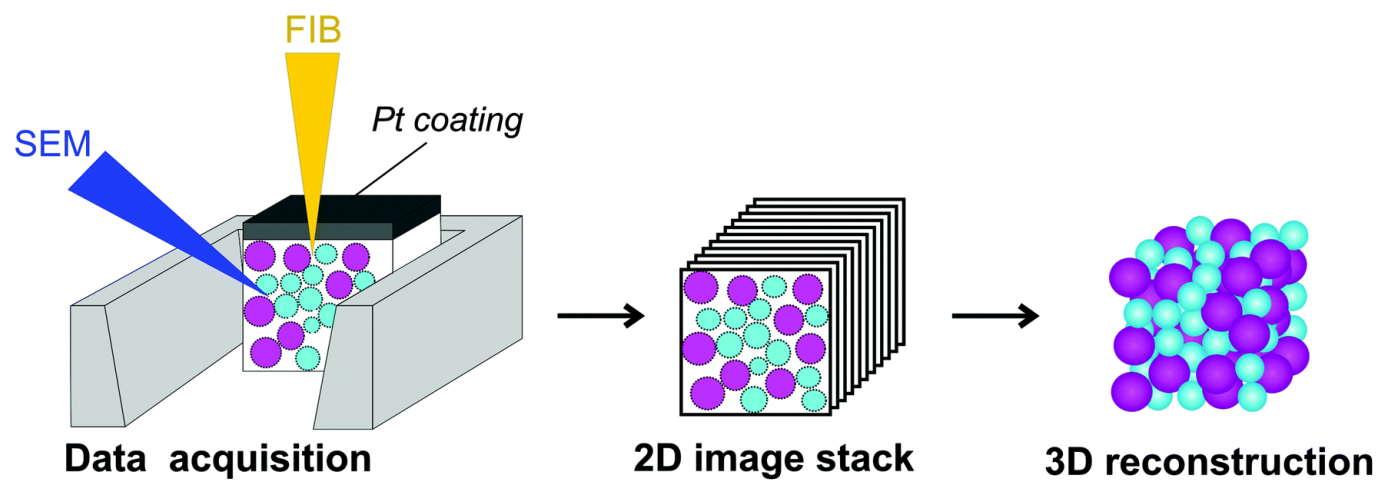
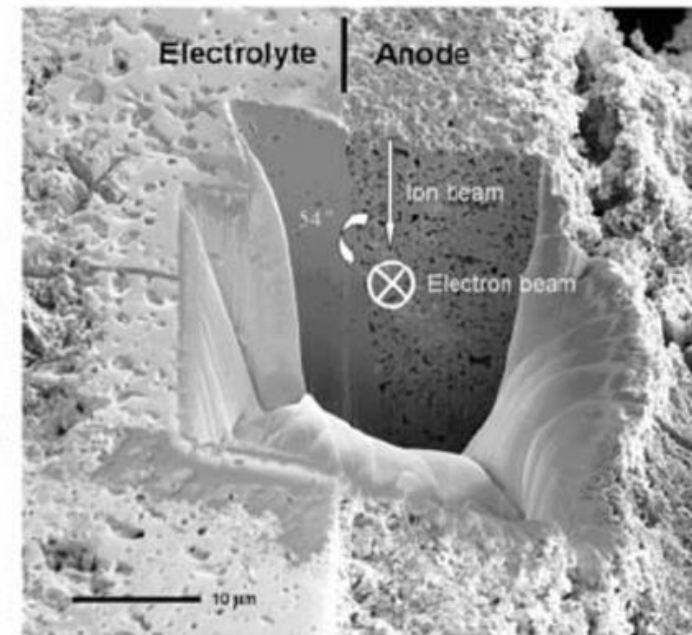
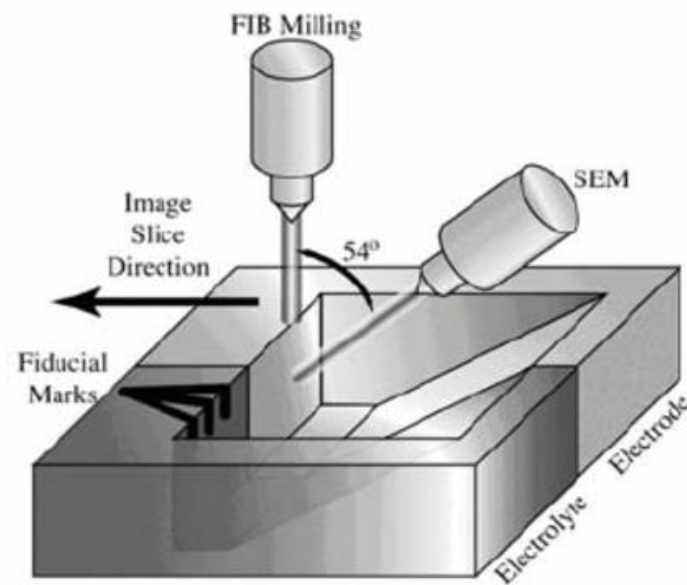
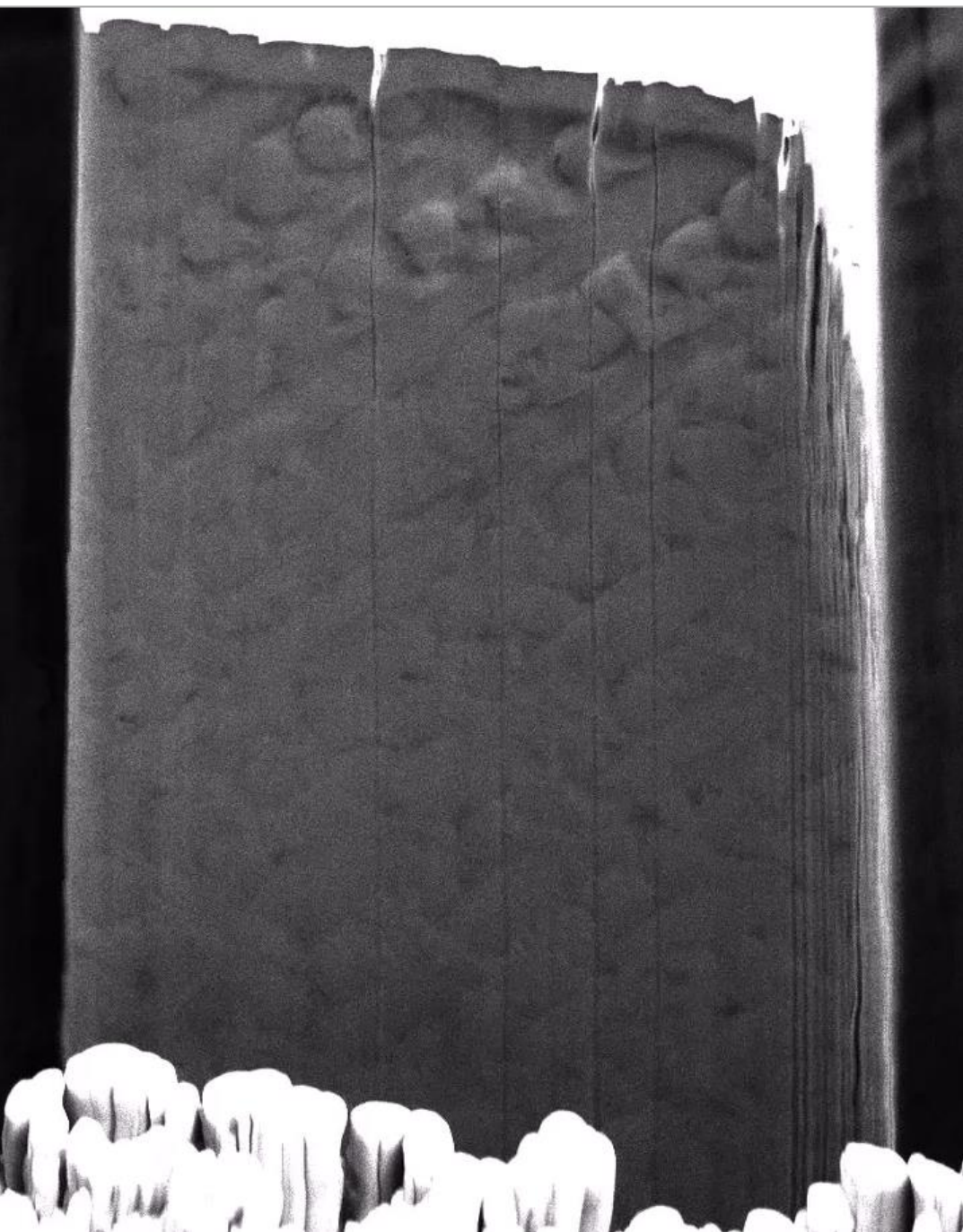
Wood Mouse (*Apodemus sylvaticus*)

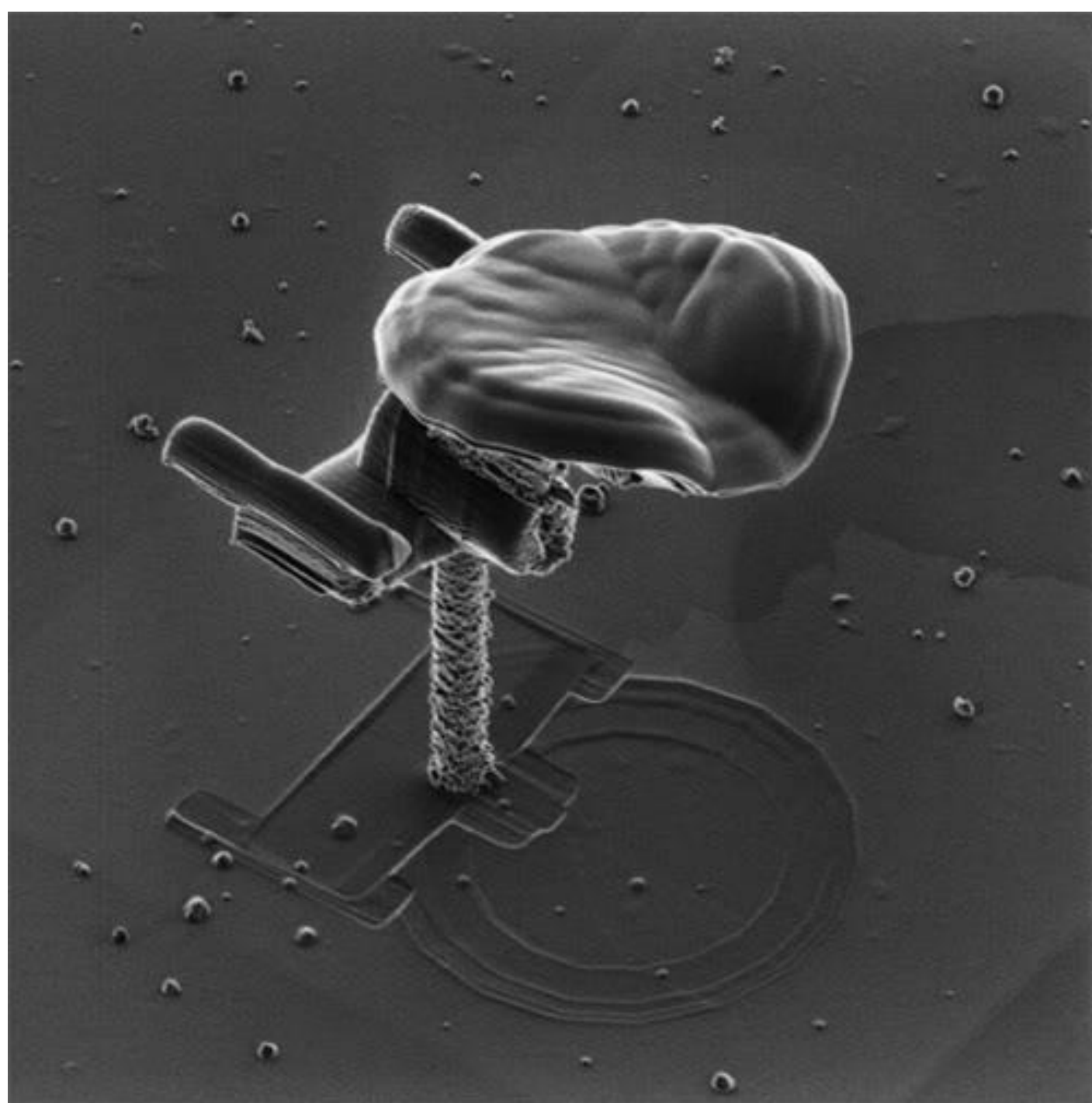


Goldberg et al, 2014

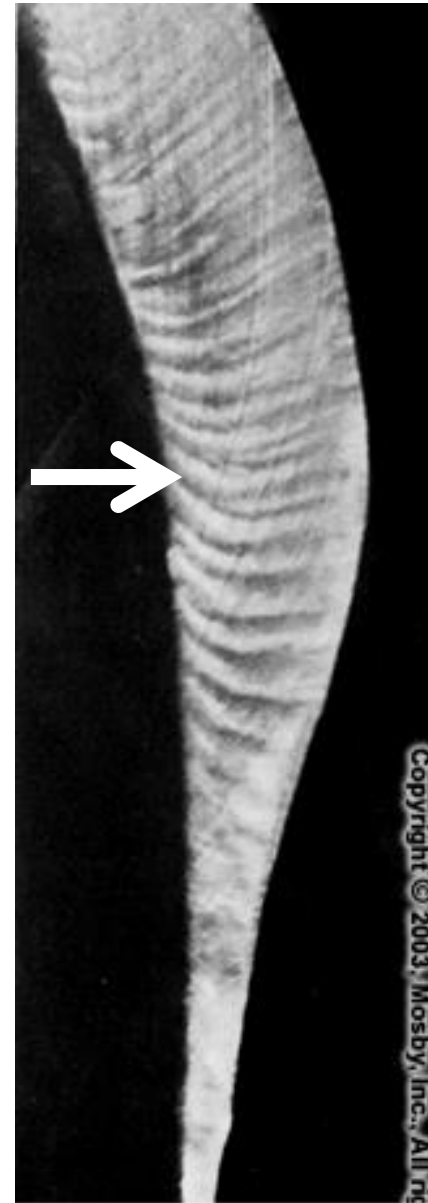
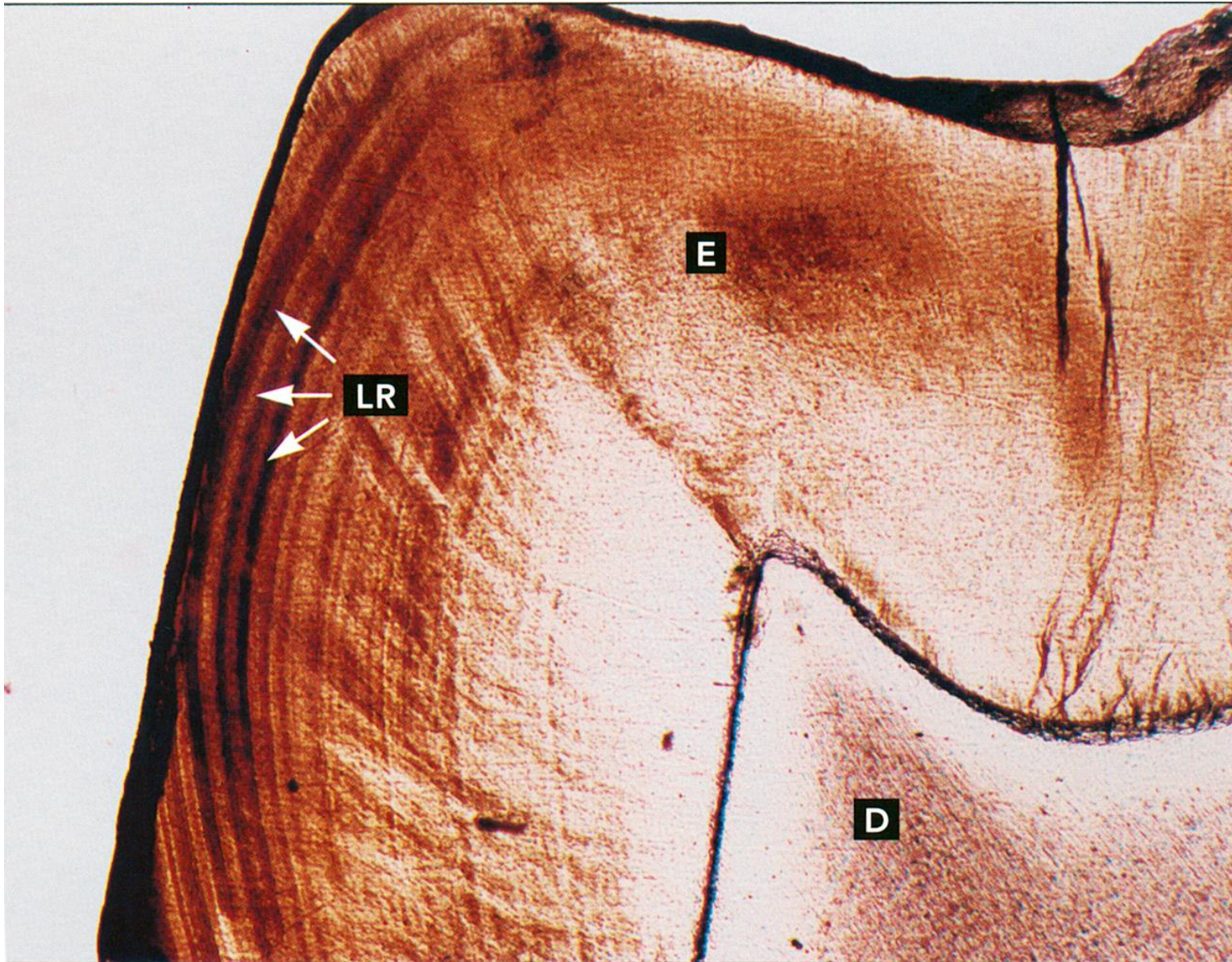
*Mus musculus*







## External characteristics of enamel



# External characteristics of enamel

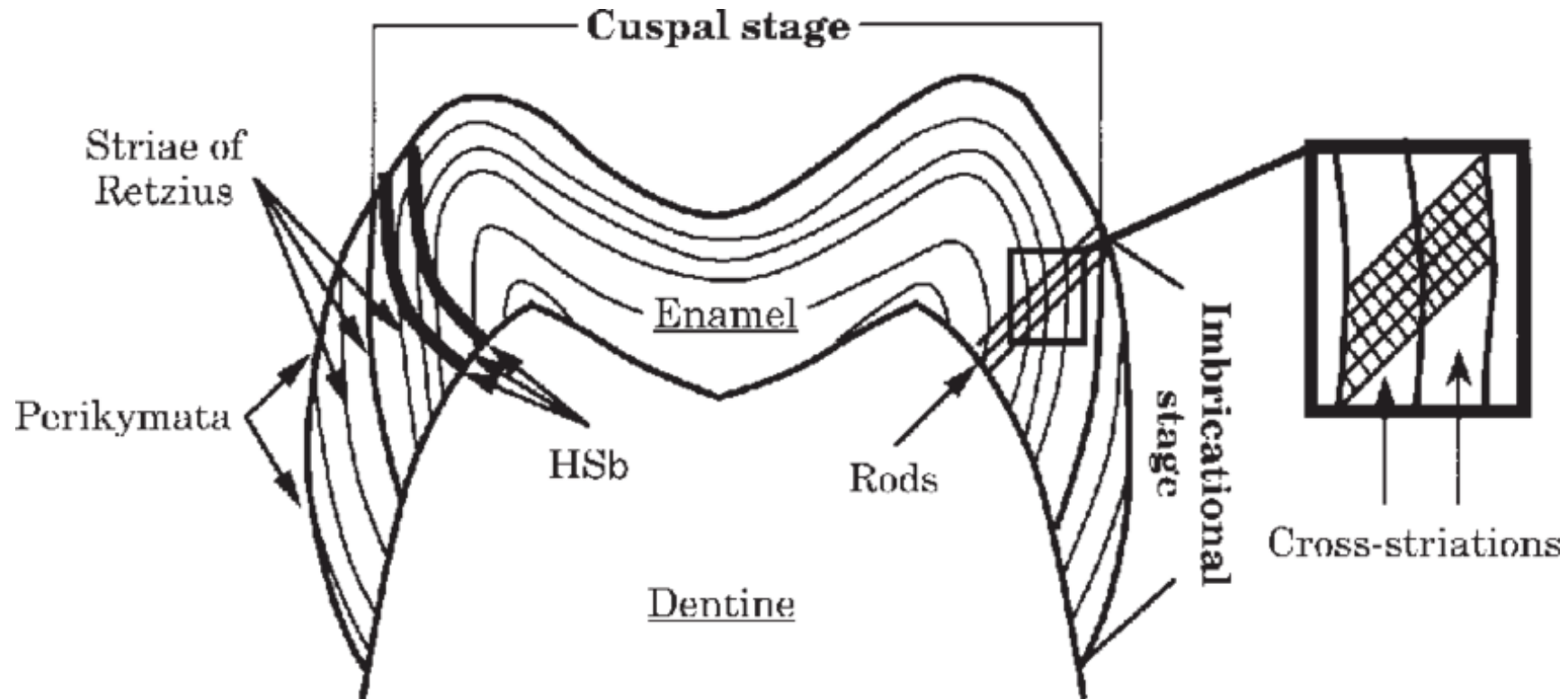
Striae of Retzius

Perikymata

Hunter - Schreger bands

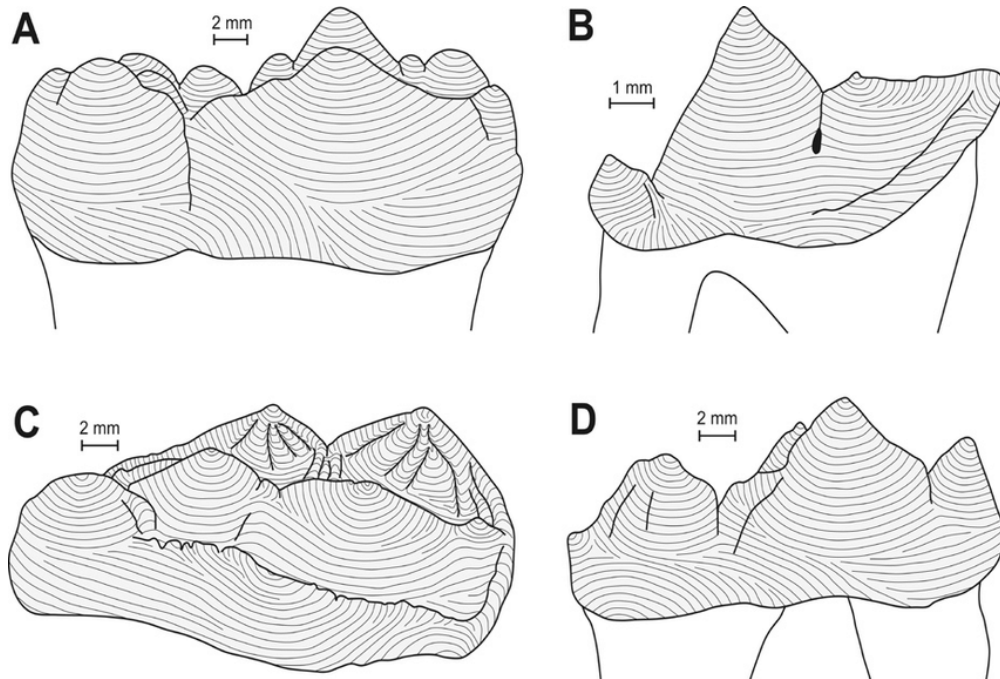
Neonatal line

Enamel tufts



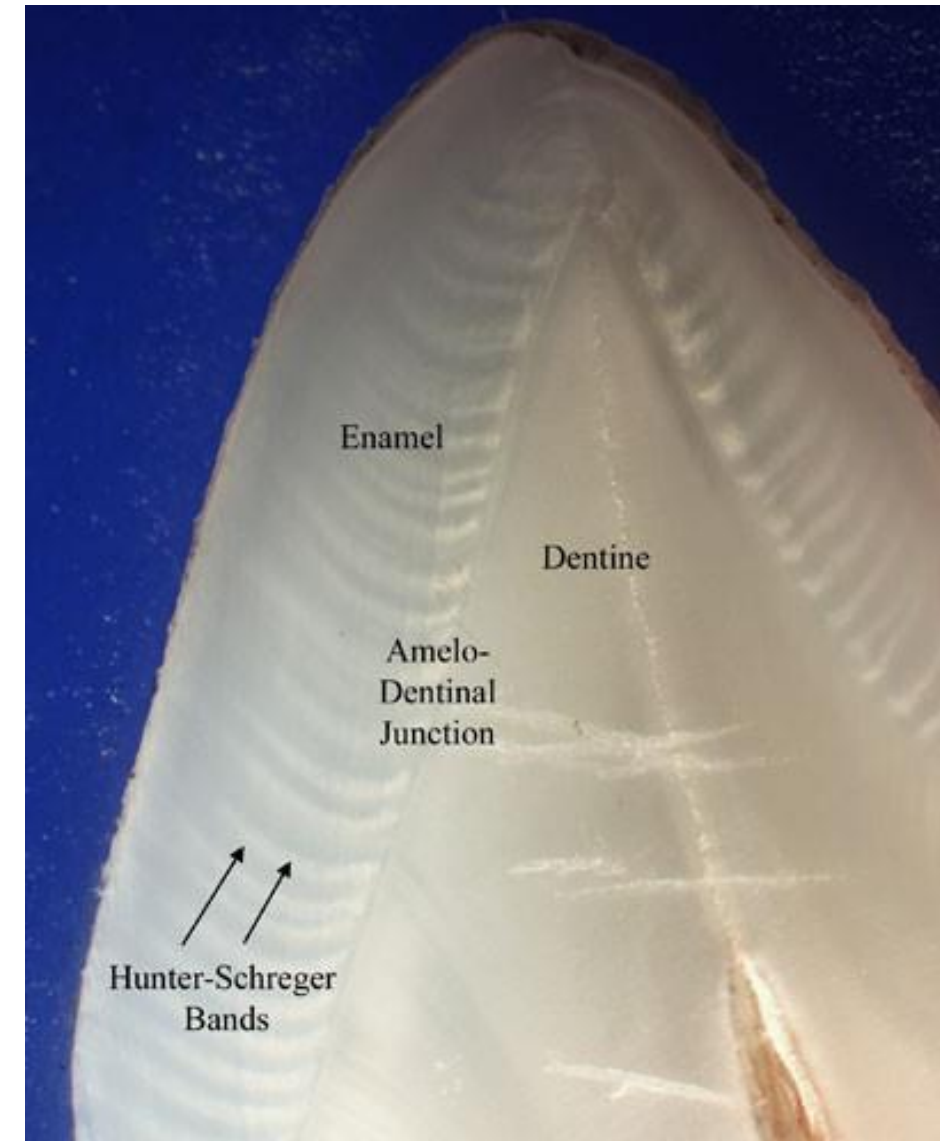
# Hunter - Schreger bands

- 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

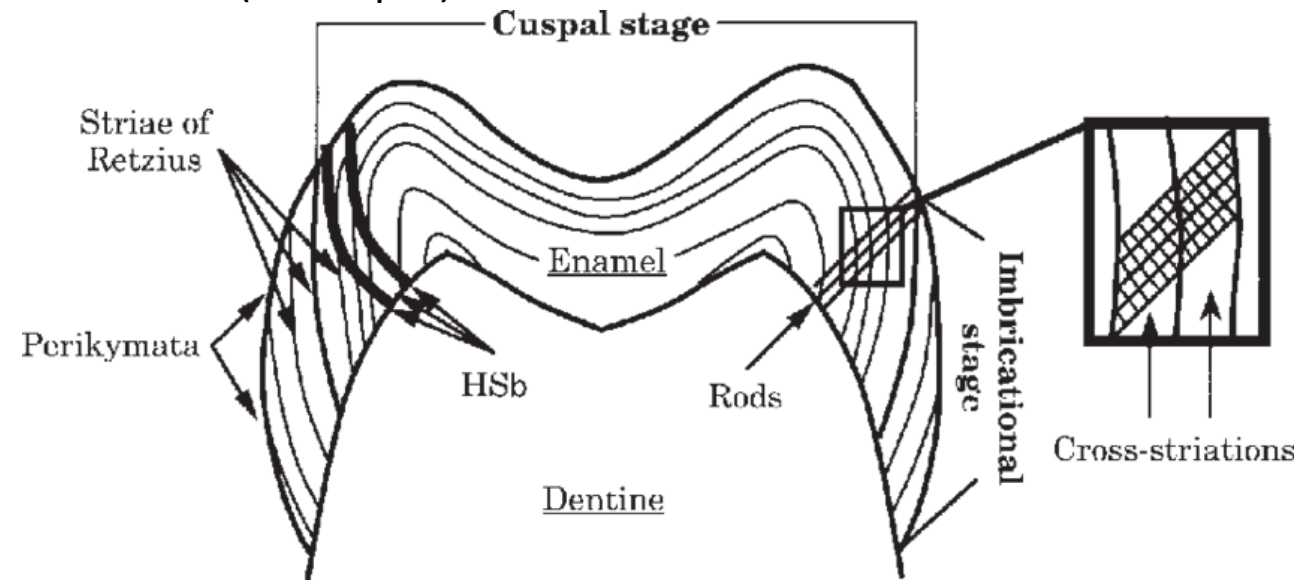
- Cause prisms cross-striation, very thin (2,5 - 6  $\mu\text{m}$ )
- Circadian rhythms influenced
- Alternation of the phase of intense secretion with the resting phase

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

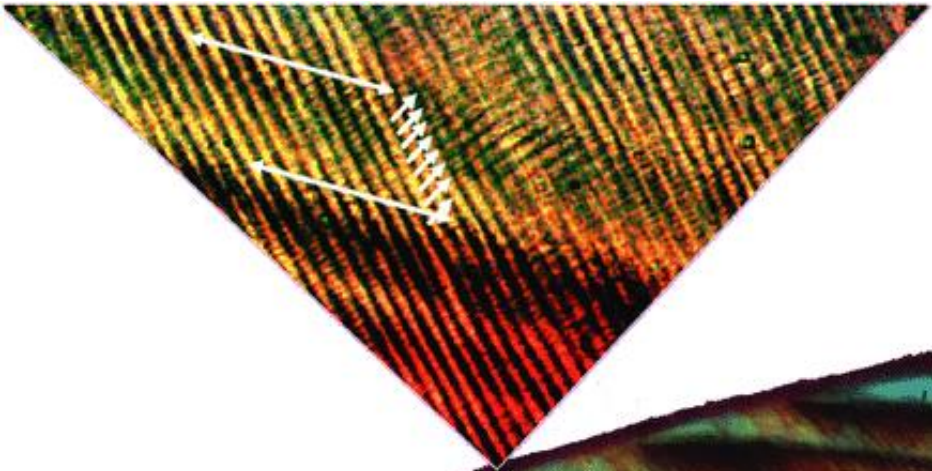
- Can be observed under optical microscope on ground sections (25-35  $\mu\text{m}$ )
- From DEJ to enamel surface
- Forms perikymata

## 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



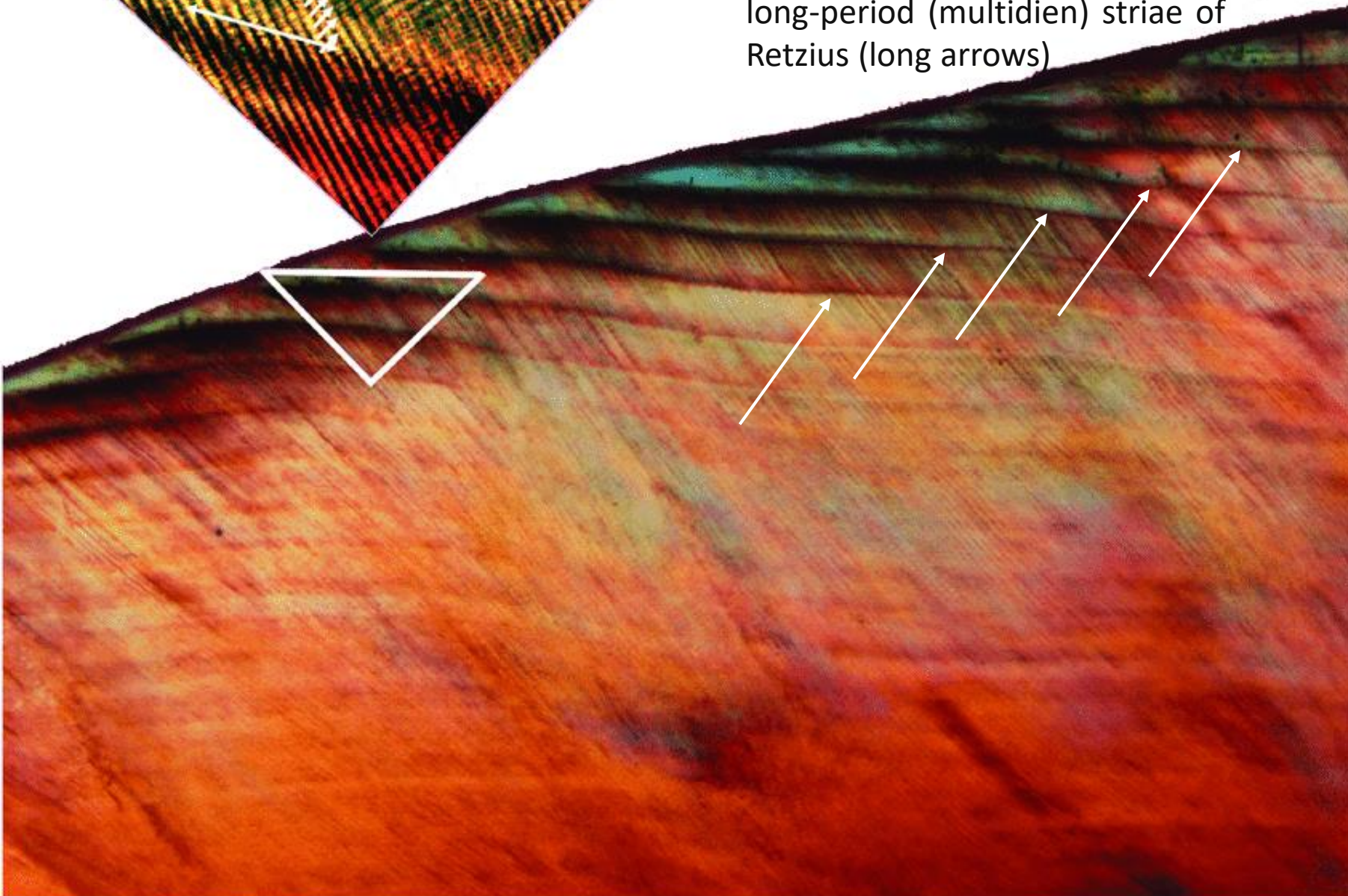




Daily (circadian) growth lines, or cross-striations (short arrows) are observed between adjacent long-period (multidien) striae of Retzius (long arrows)

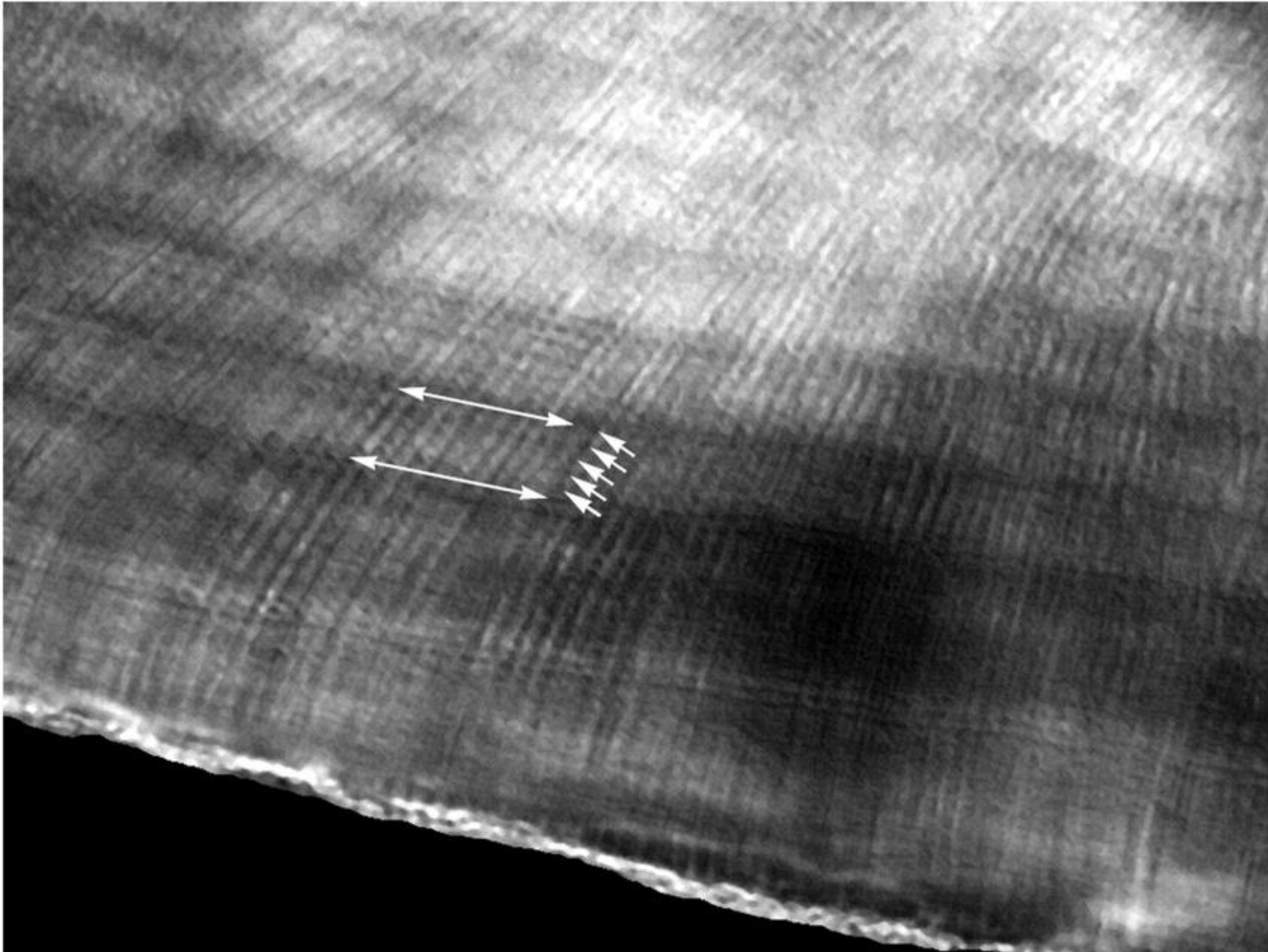
## Daily incremental lines

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)*

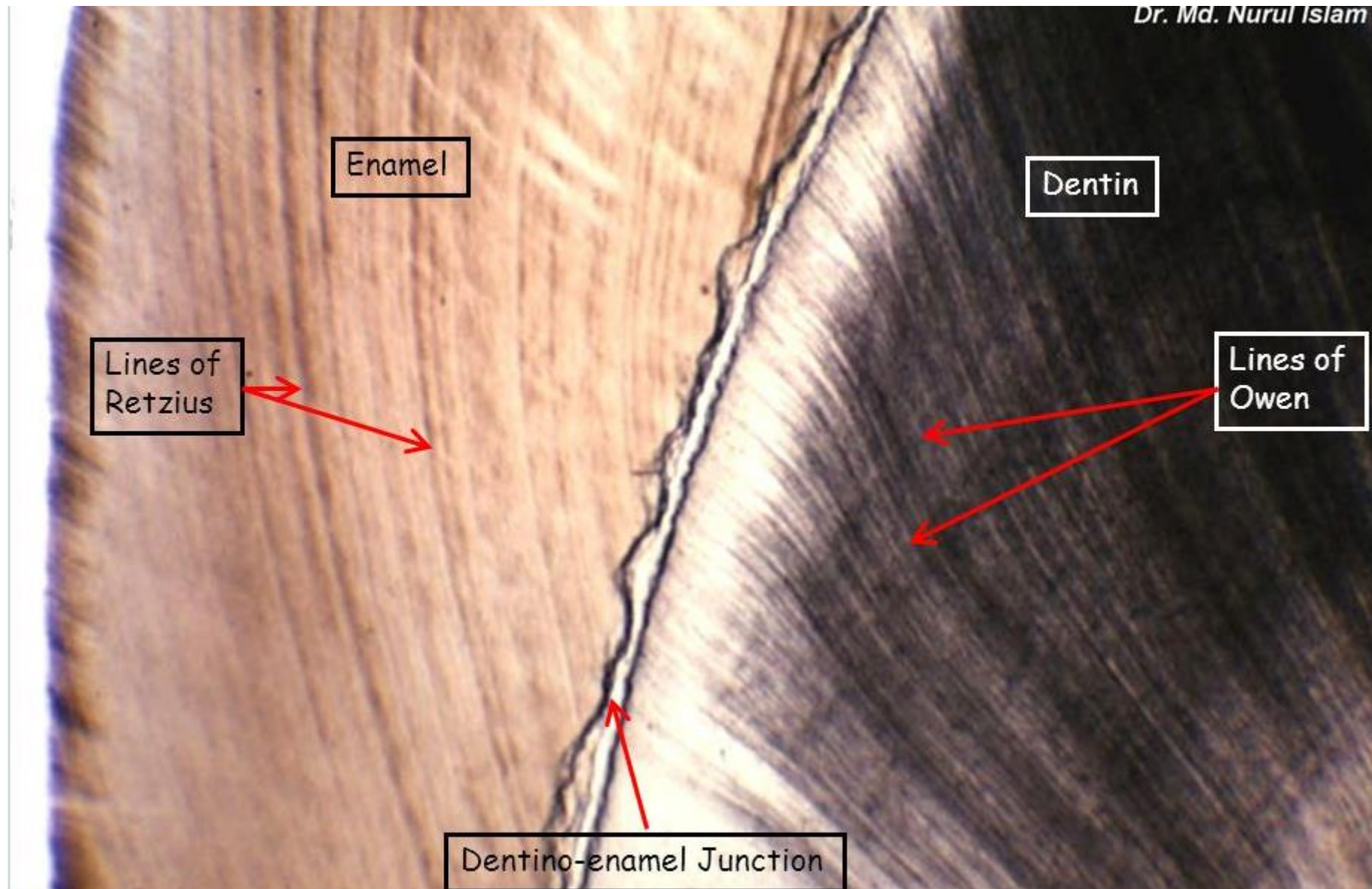
## Daily incremental lines



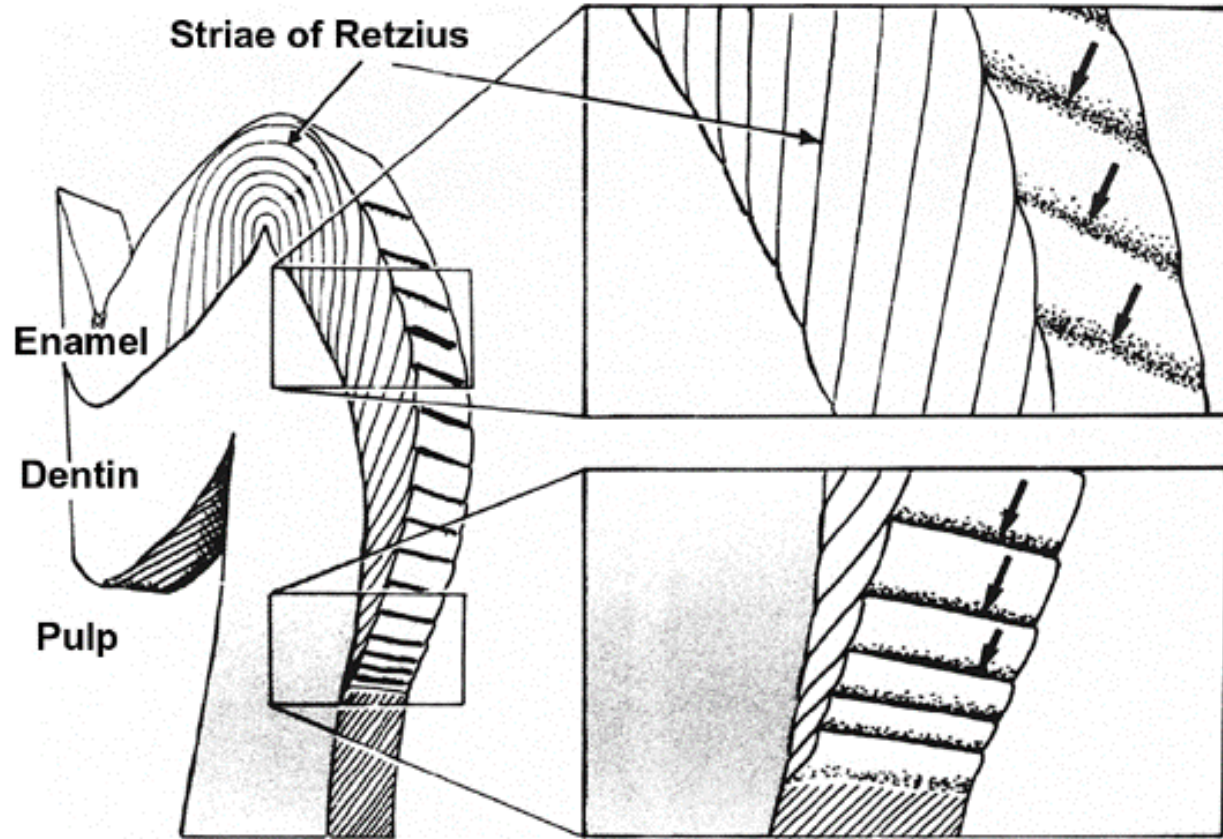
Swine enamel circadian and multidien rhythms. Dark banding across the horizontal field are striae of Retzius (long arrows), while 5 daily events may be seen between adjacent striae (short arrows)

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

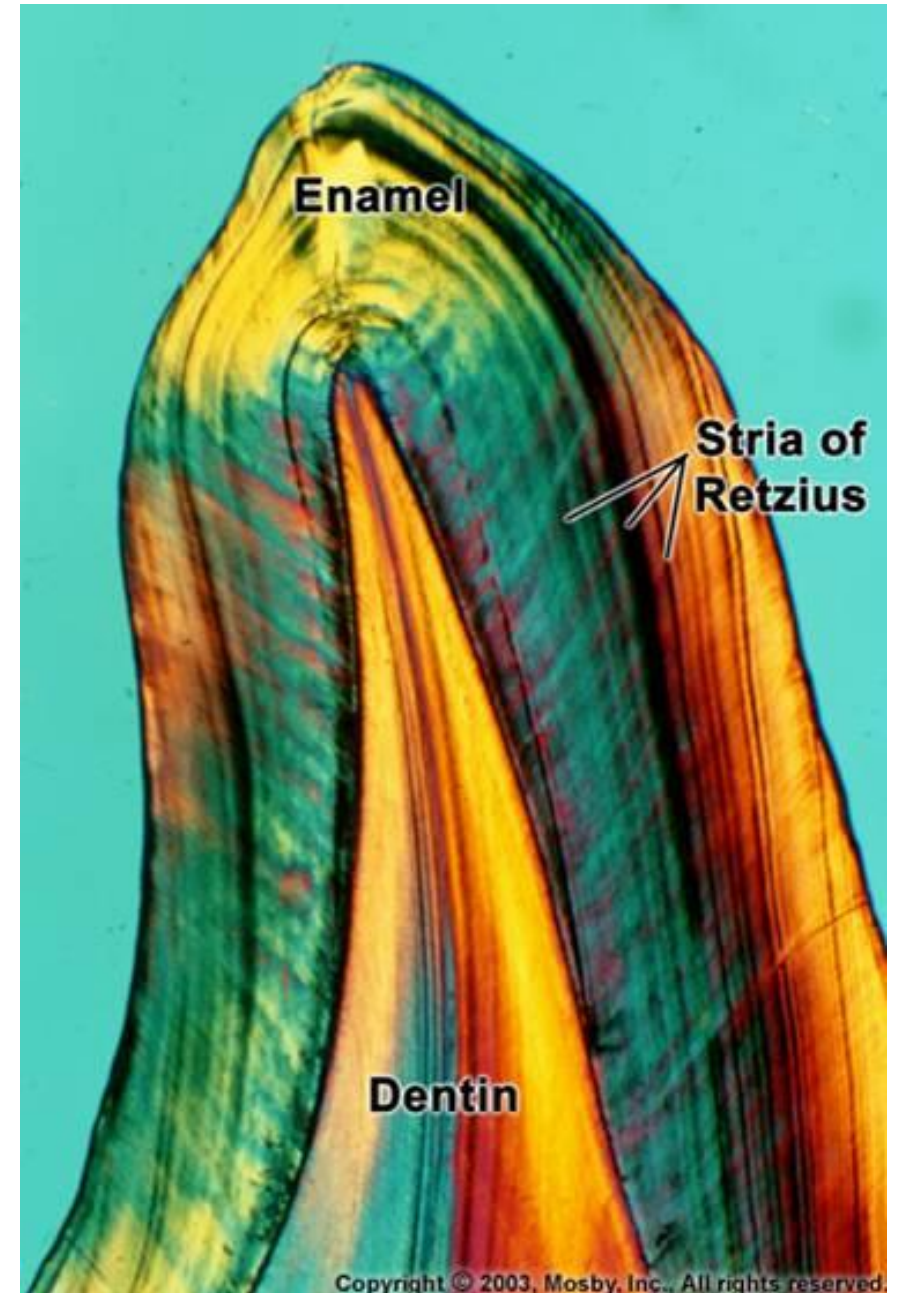
# Striae of Retzius



# Striae of Retzius

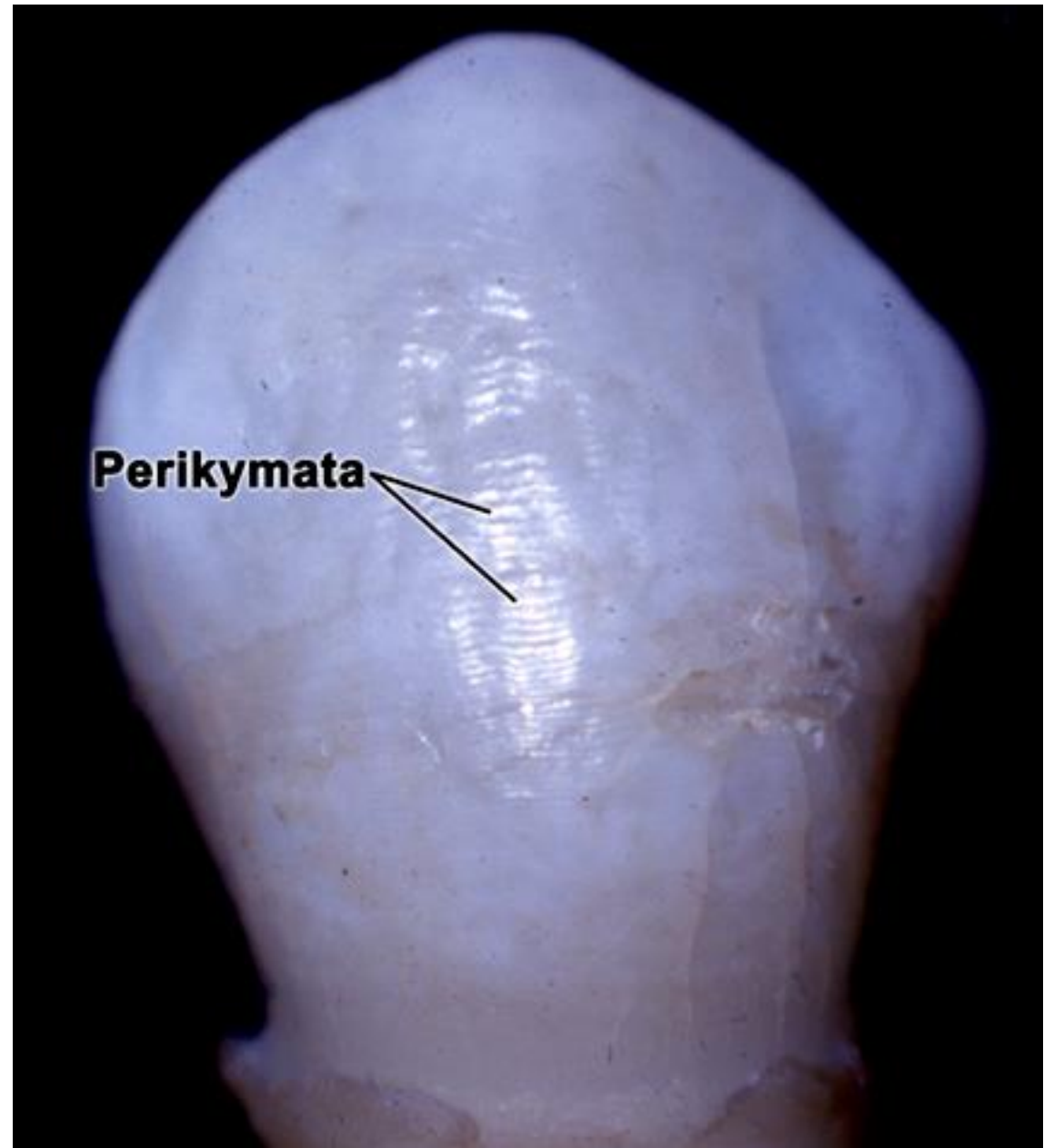
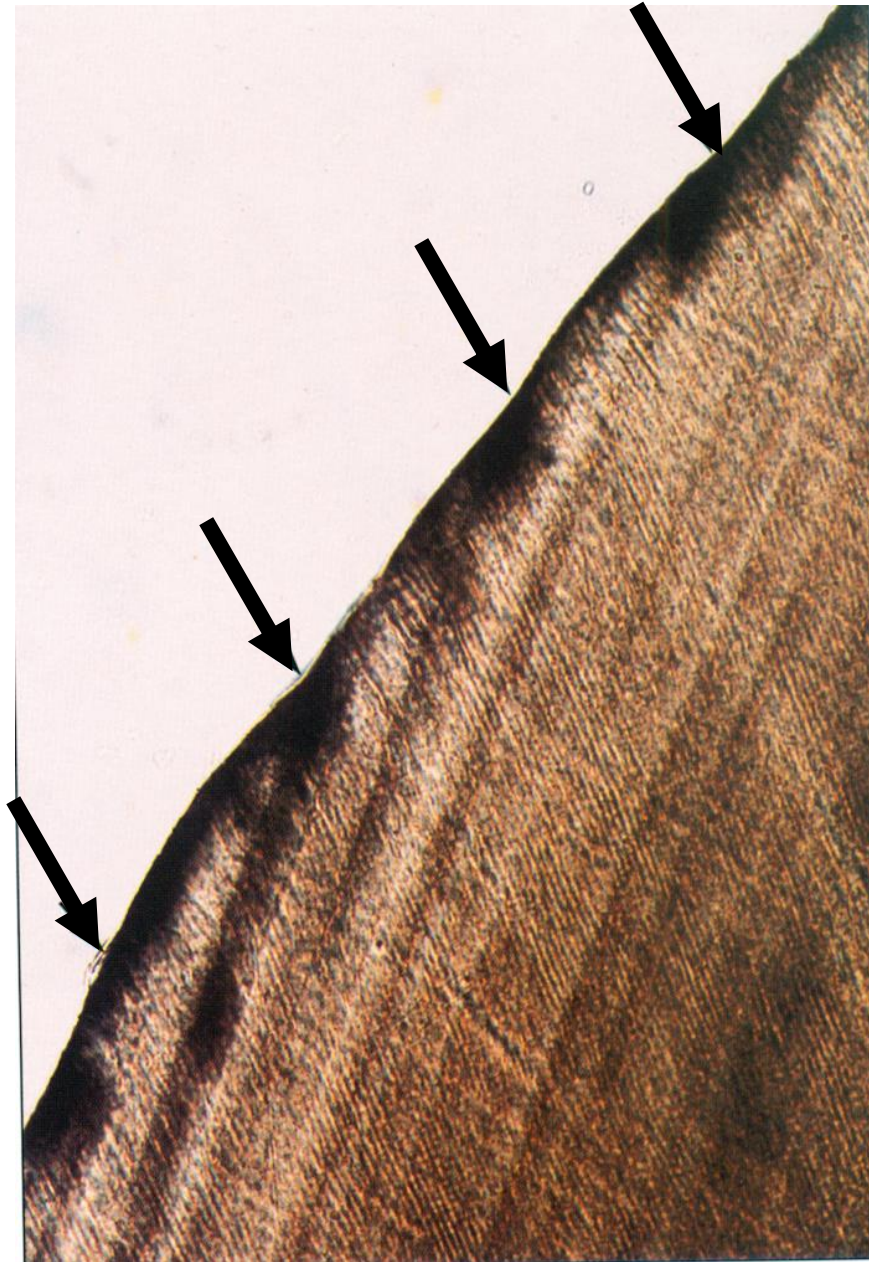


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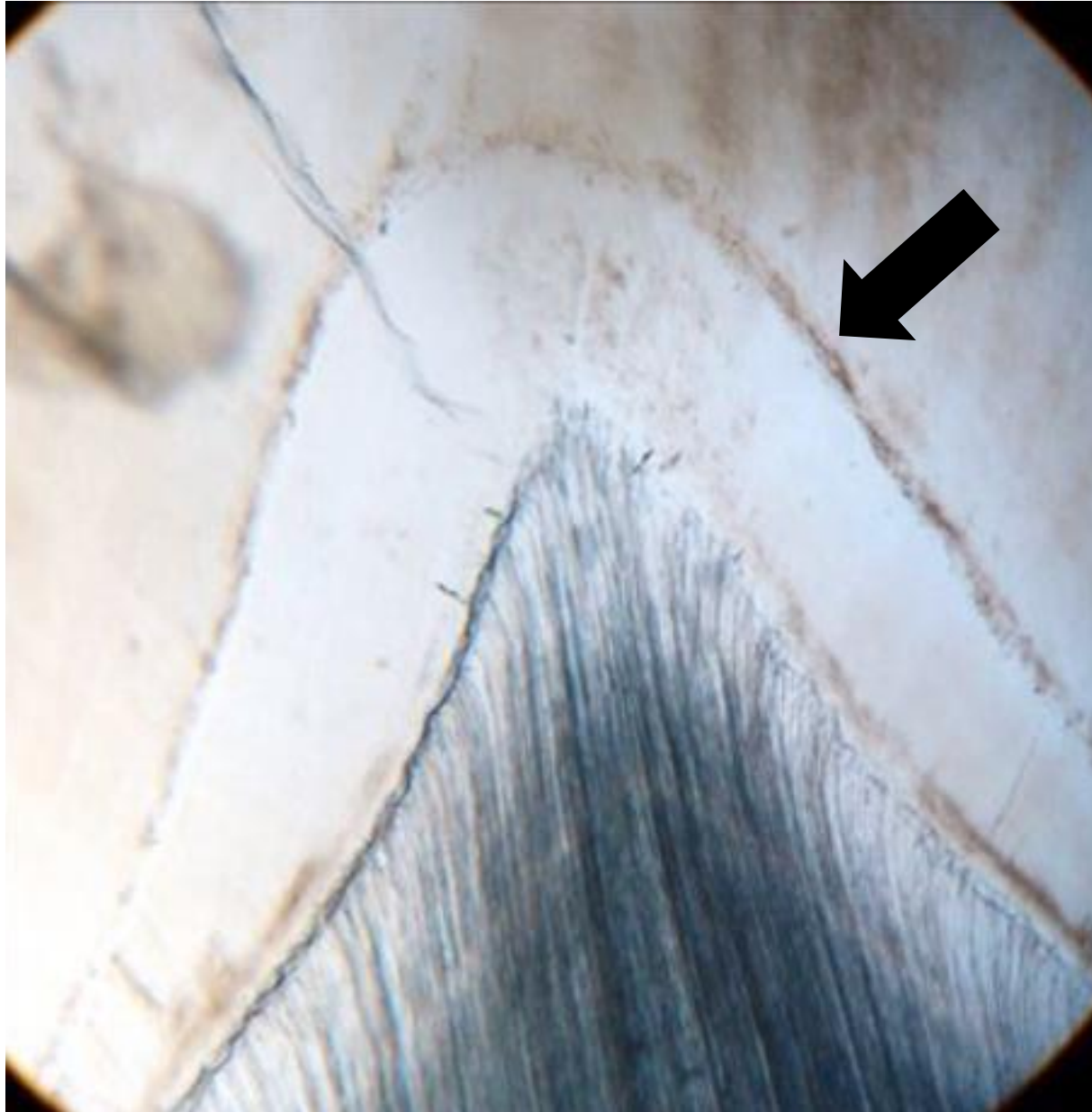


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# Perikymata



## Neonatal line

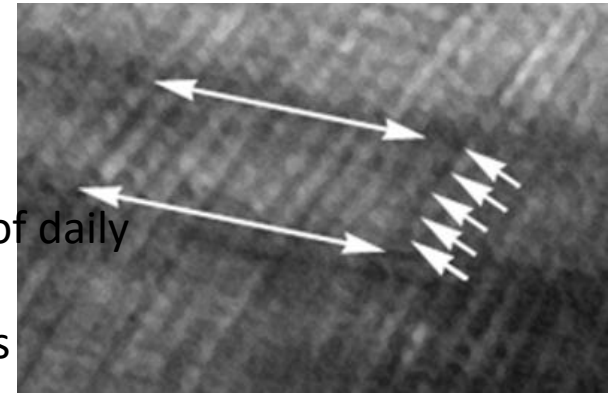


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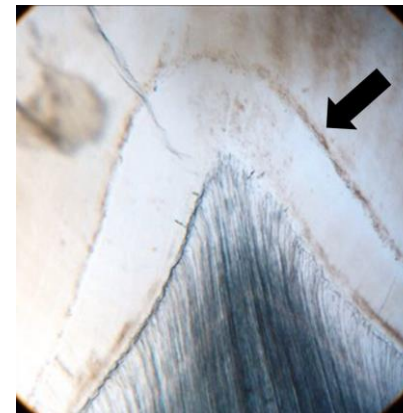
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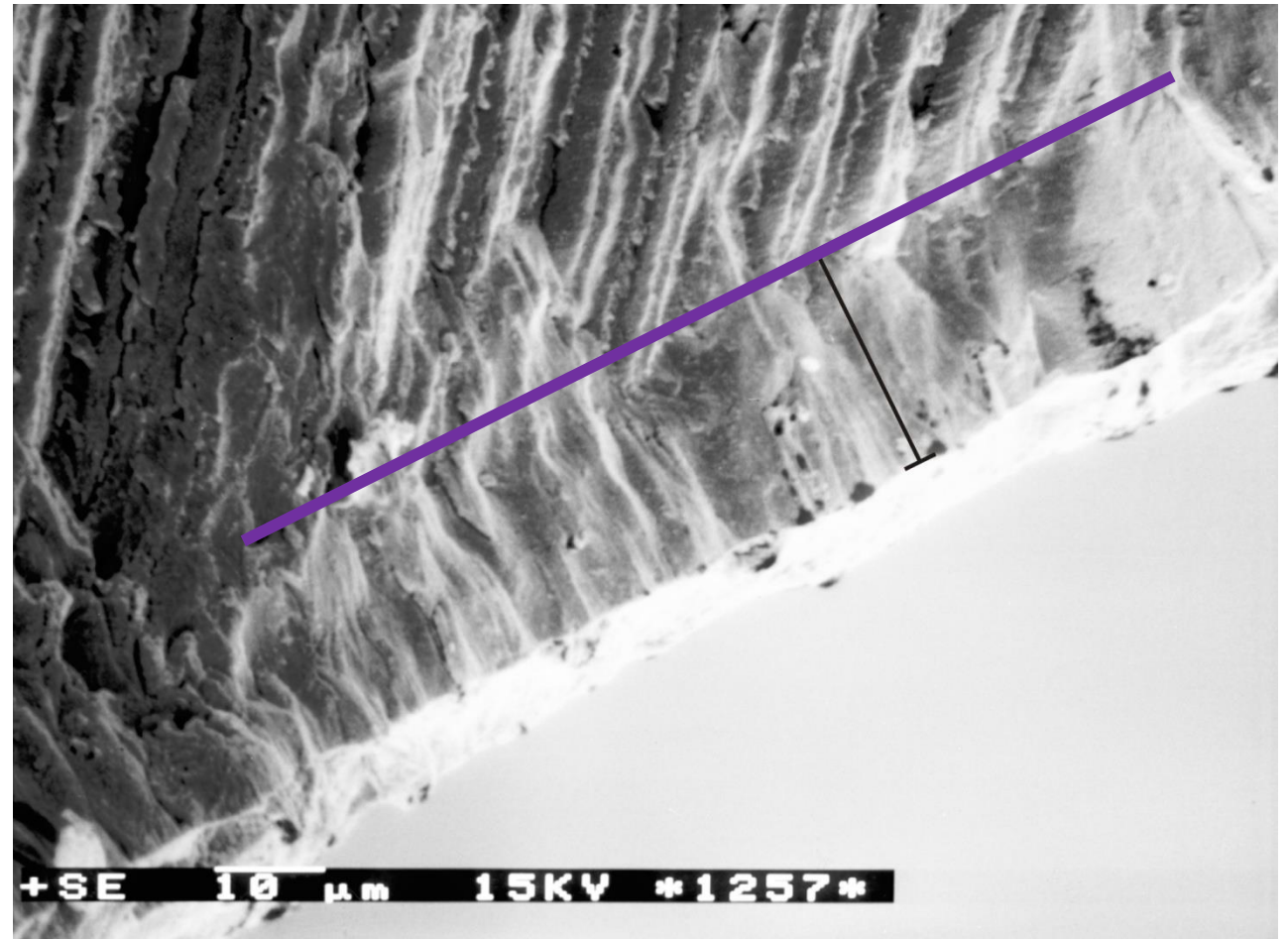
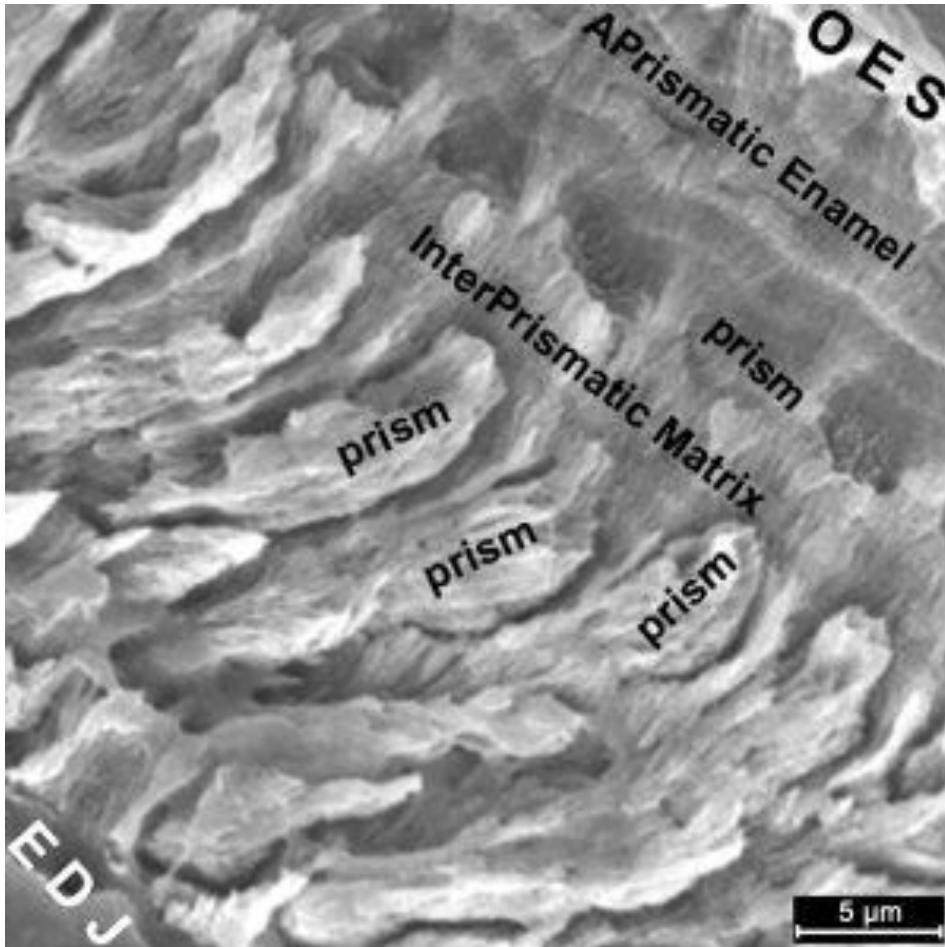
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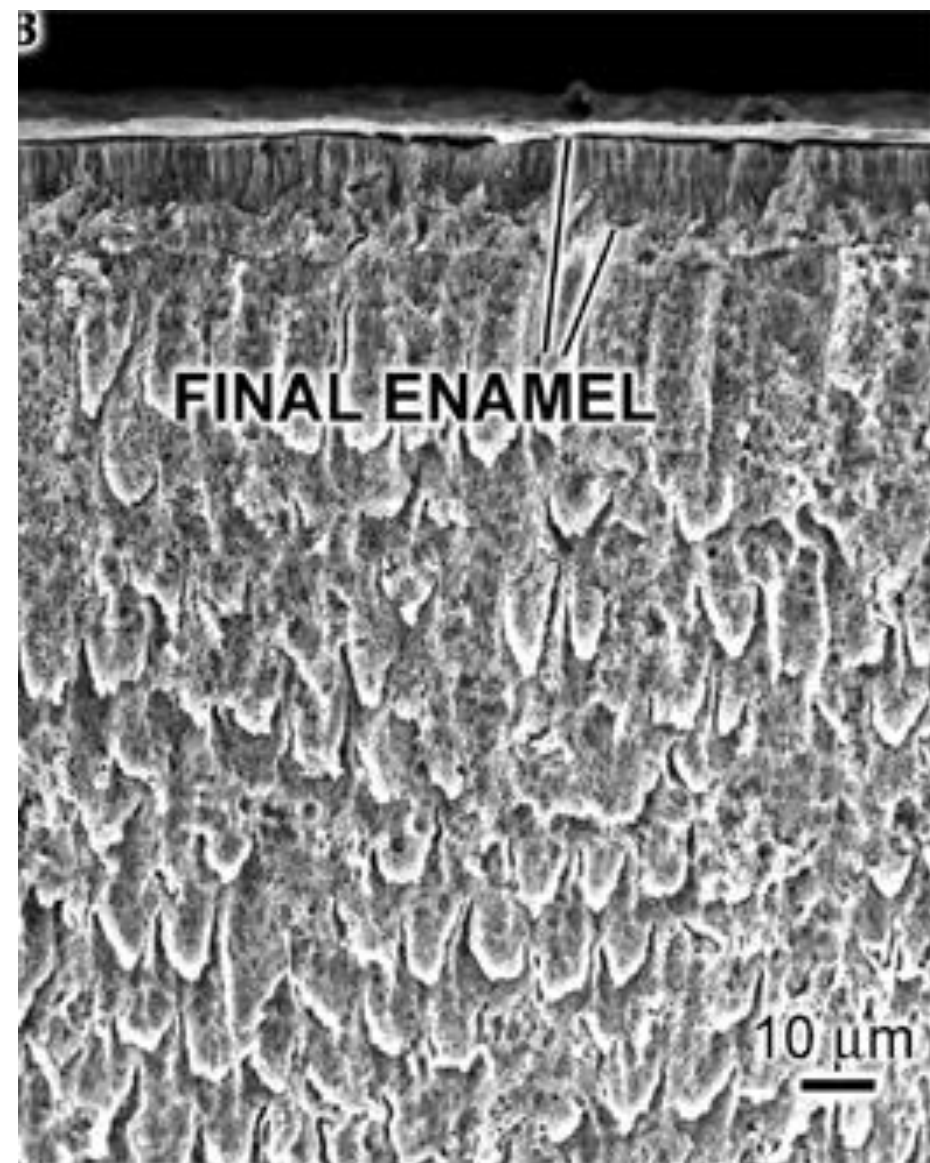
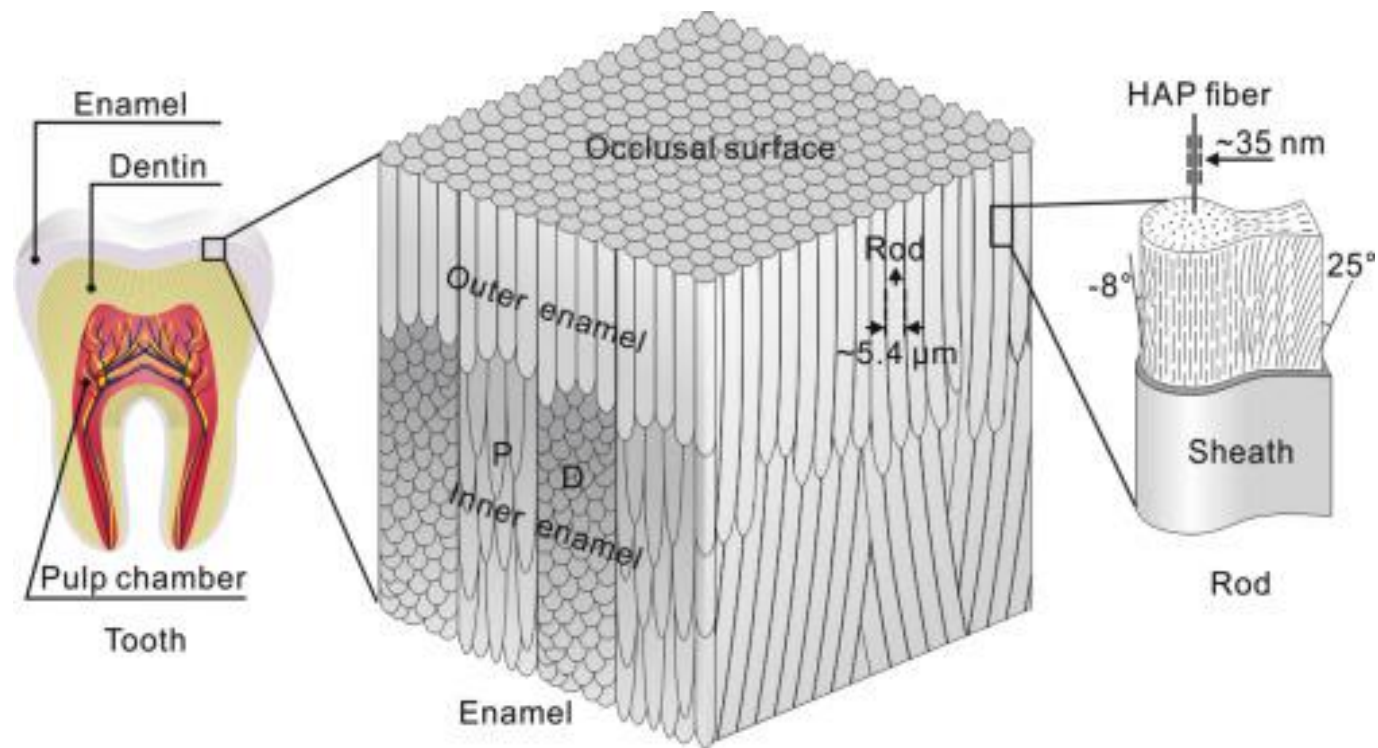


# Aprismatic enamel

- 20-70  $\mu\text{m}$  wide layer on the surface of crown enamel
- Harder and more mineralized. Contains more fluoride
- Is formed just before the end of ameloblasts activity
- Hydroxyapatite crystals are highly packed and perpendicular to enamel surface

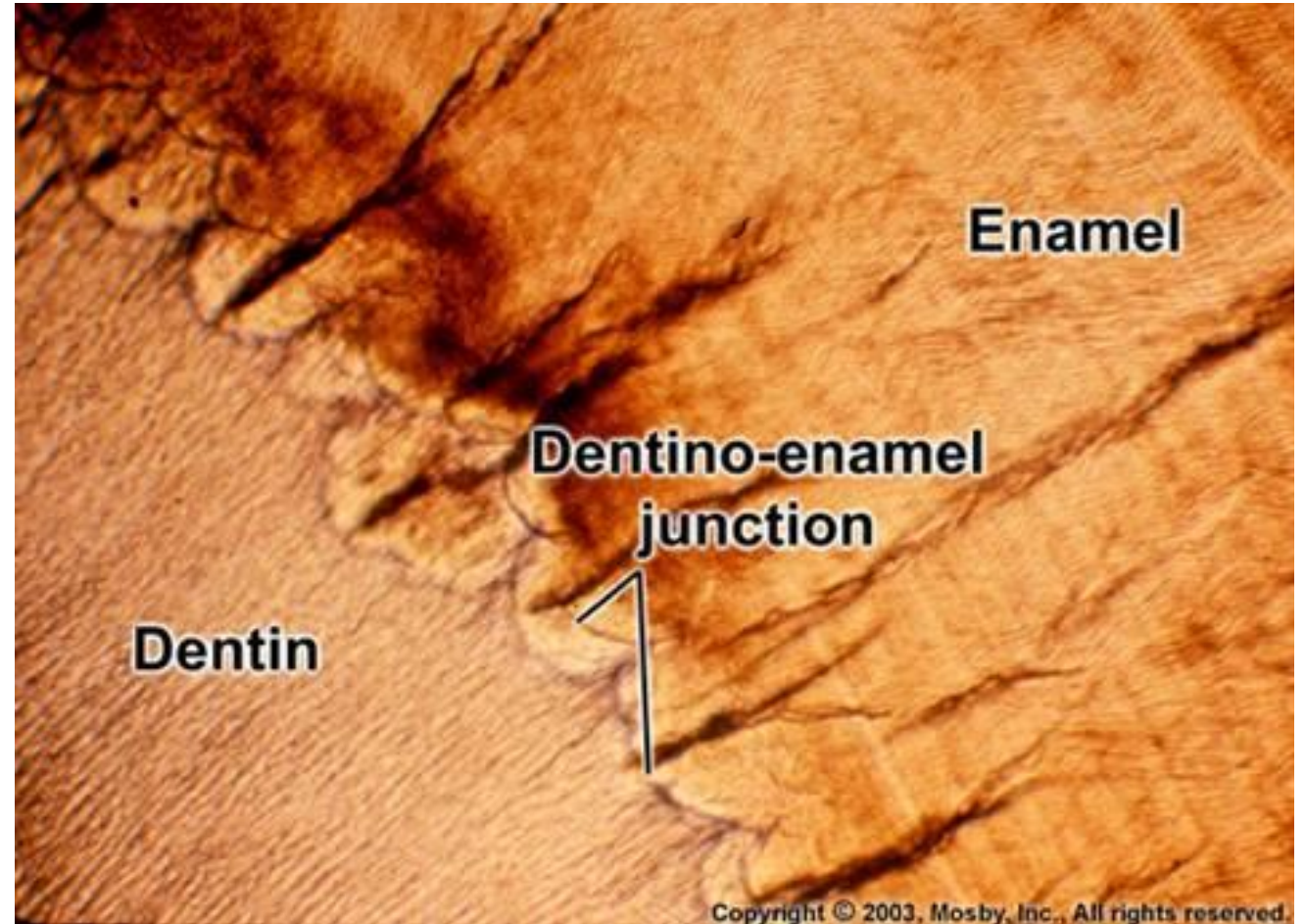
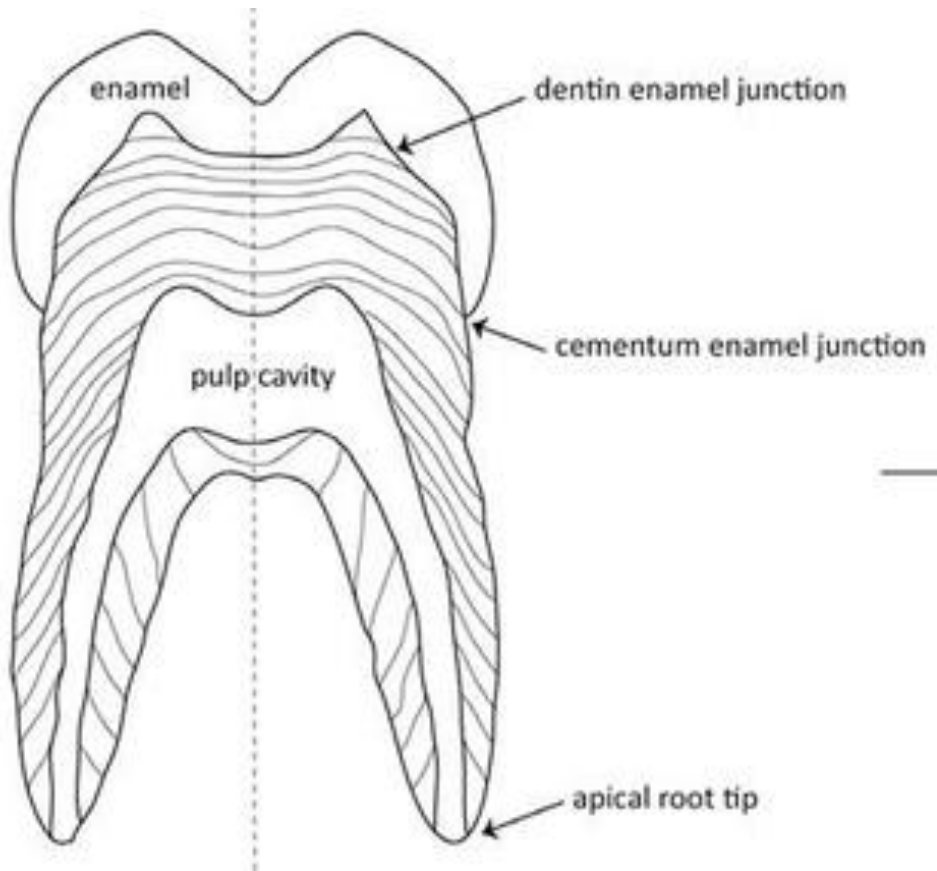






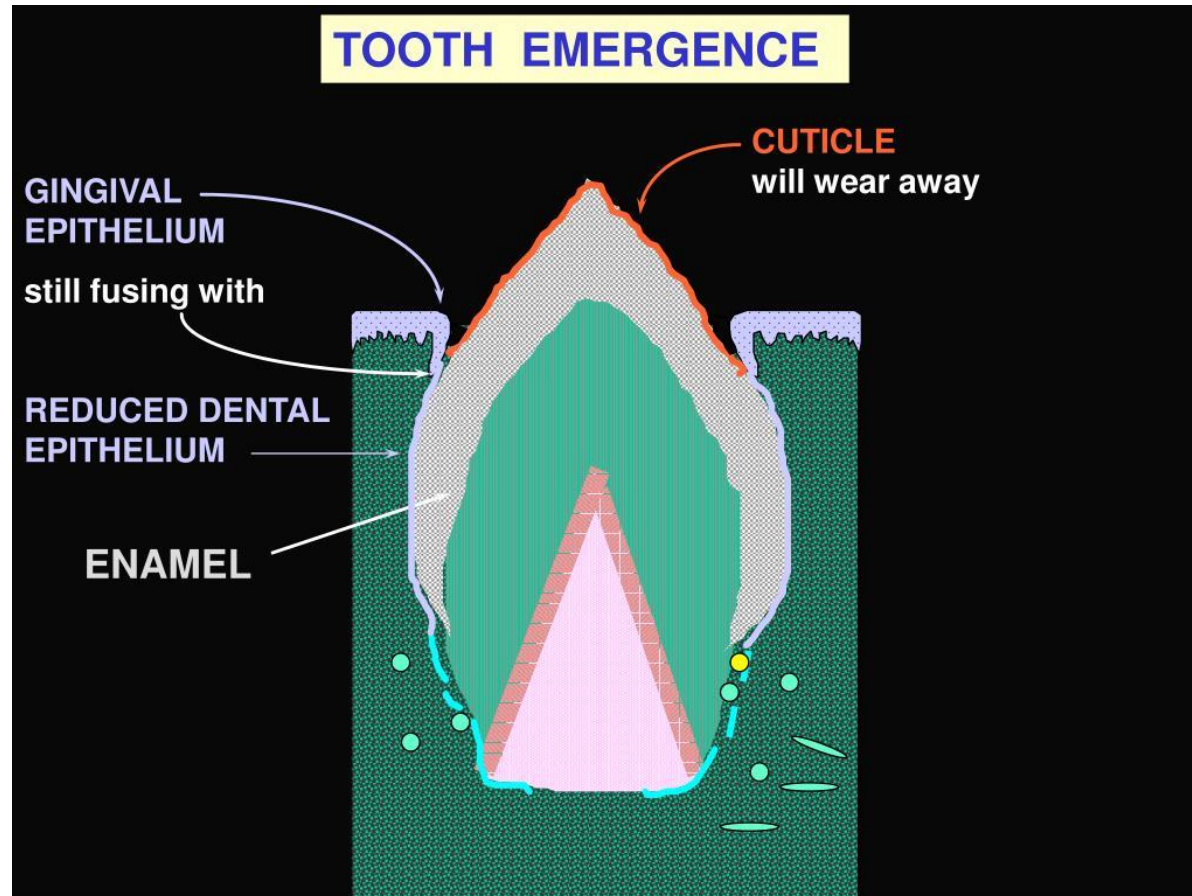
# DEJ (Dentino-Enamel Junction)

- 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  $\mu\text{m}$  wide, remains on the surface of primary dentition nearby the neck



**ENAMEL**

**Enamel  
spindles**

**DENTIN**

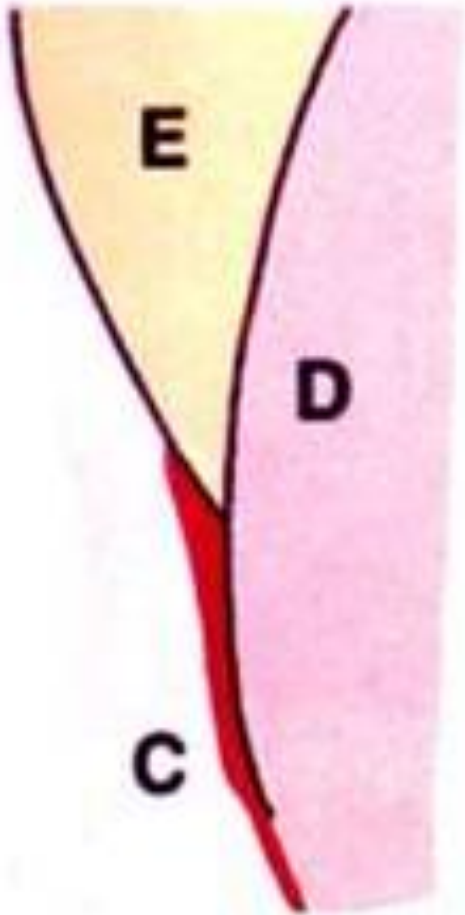
**Enamel spindles**  
(fusus enameli)

Up to 100 um prolongation of  
dentin tubules into enamel

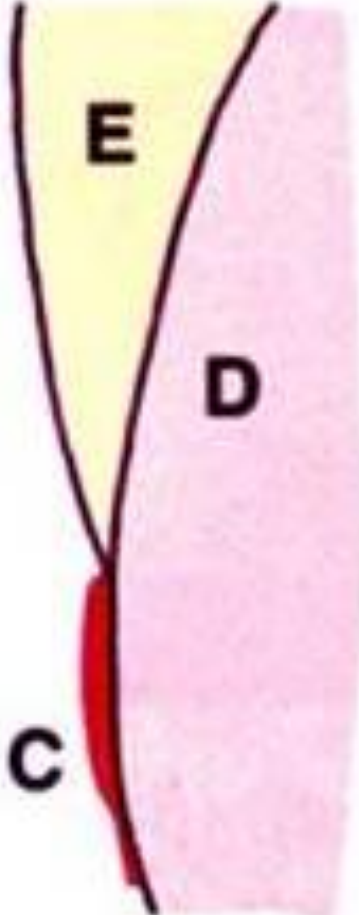
# Cementum-enamel border

3 types:

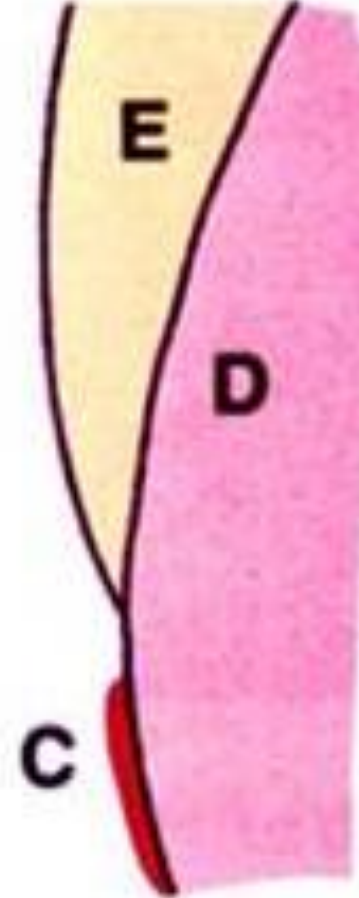
Cementum overlap over enamel  
15 % (60 %)



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)
- Tetracycline 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)*



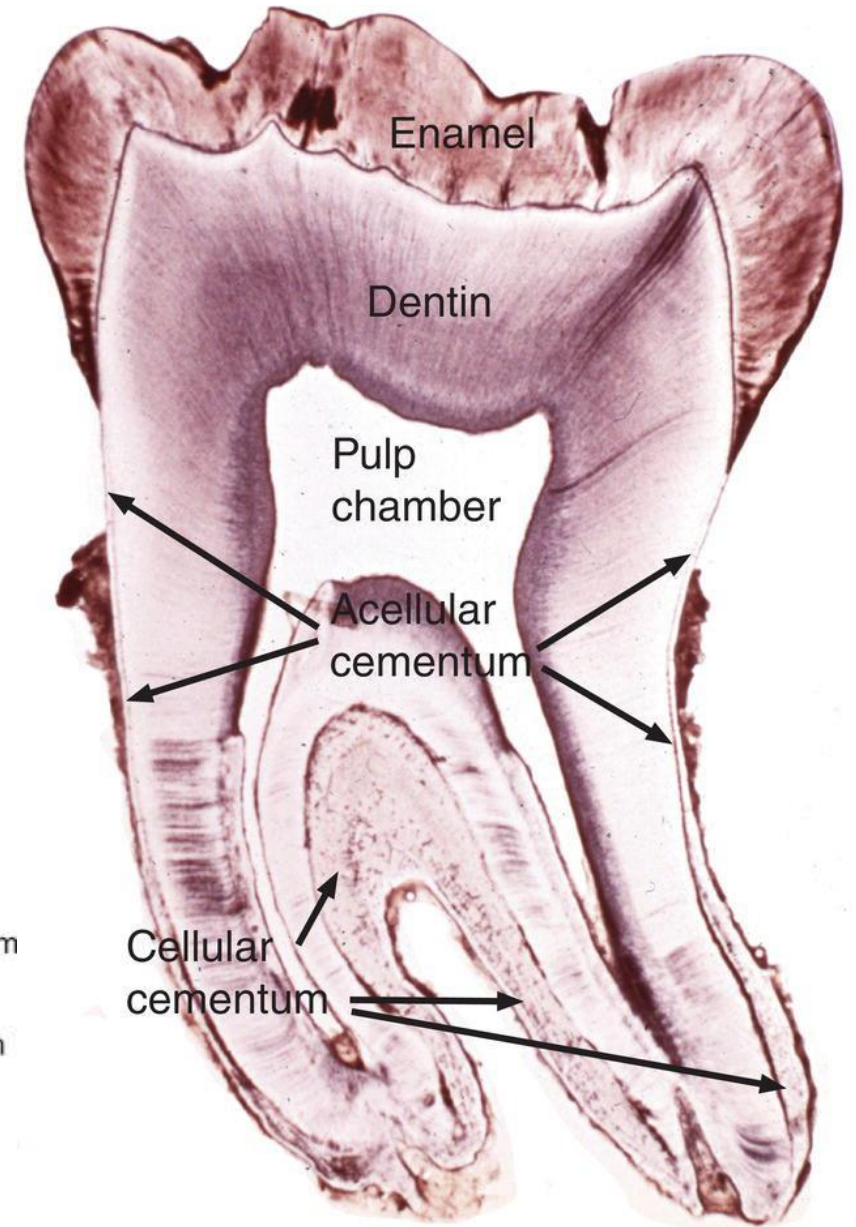
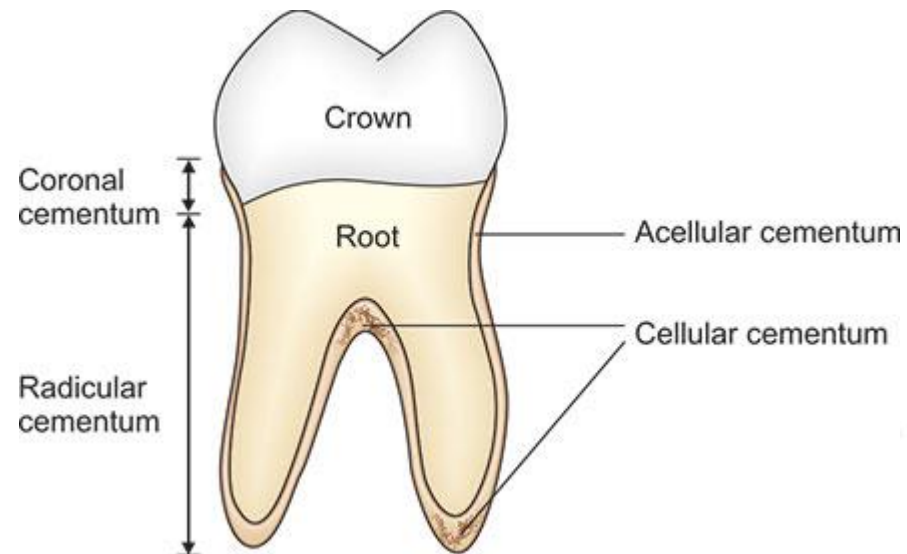


# Cementum

- 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 rhythms** – incremental lines.
- Development from **ectomesenchyme**

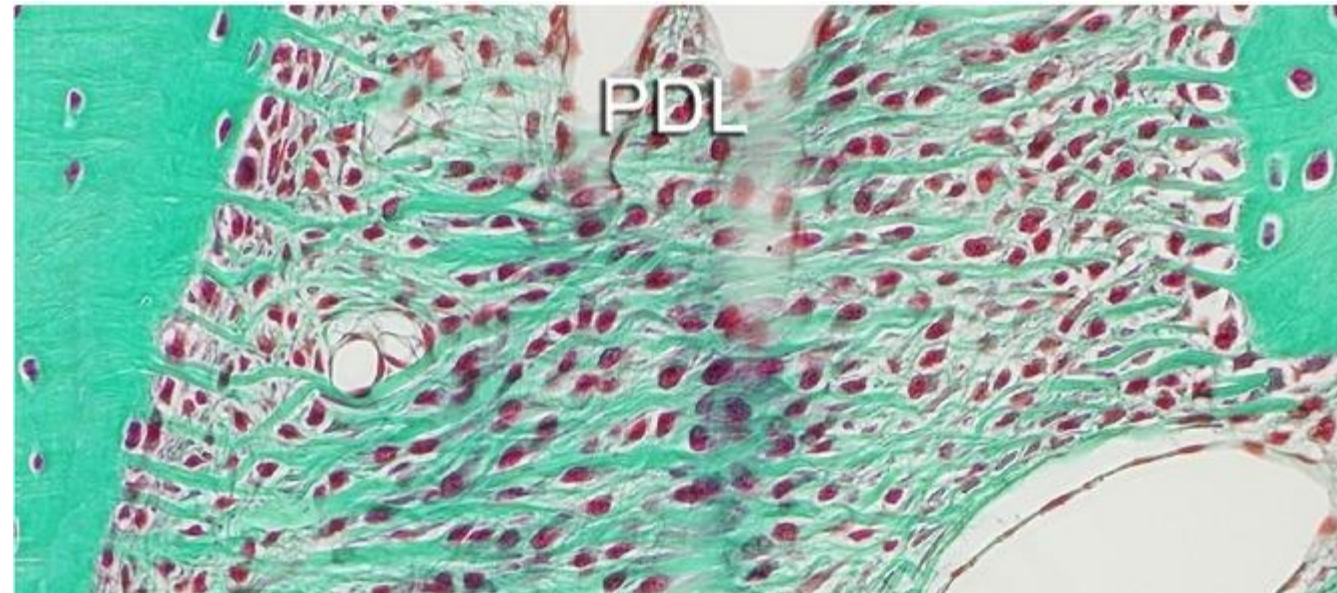
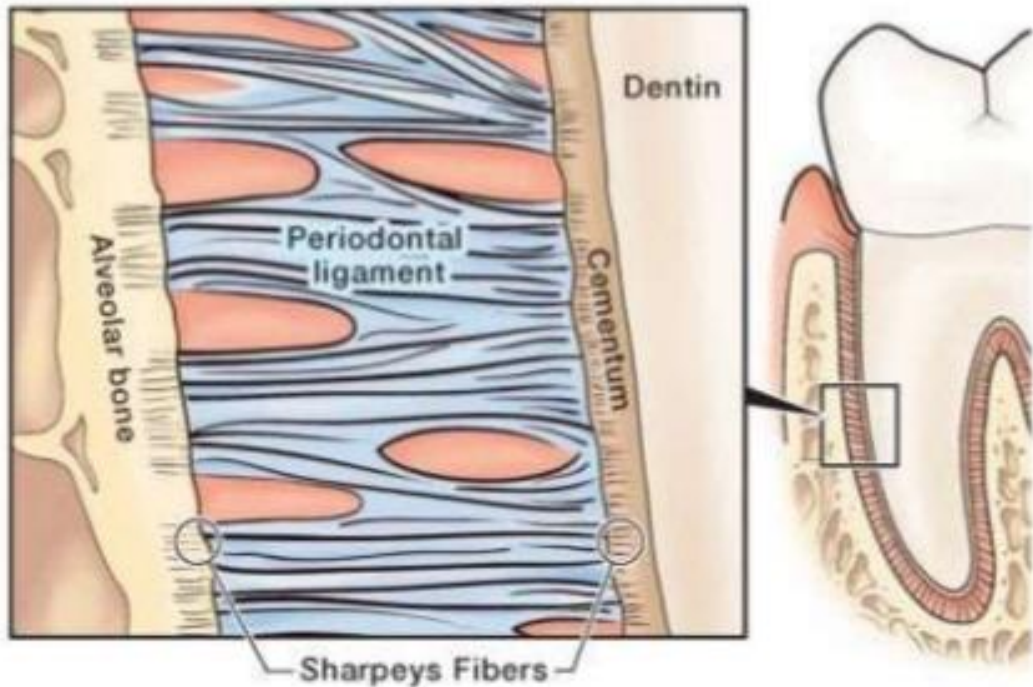
## Composed of:

- **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 matrix (ECM) = Cementum**

Acellular (primary)

Cellular (secondary)

**Cells**

**Cementoblasts**

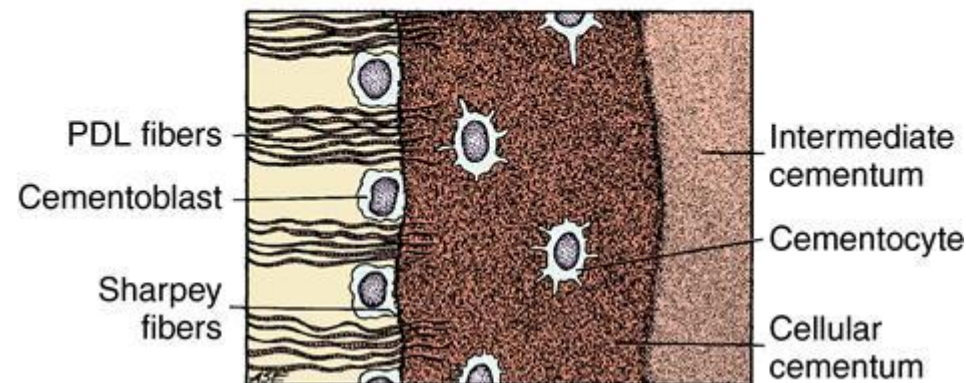
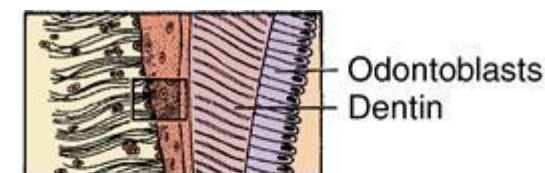
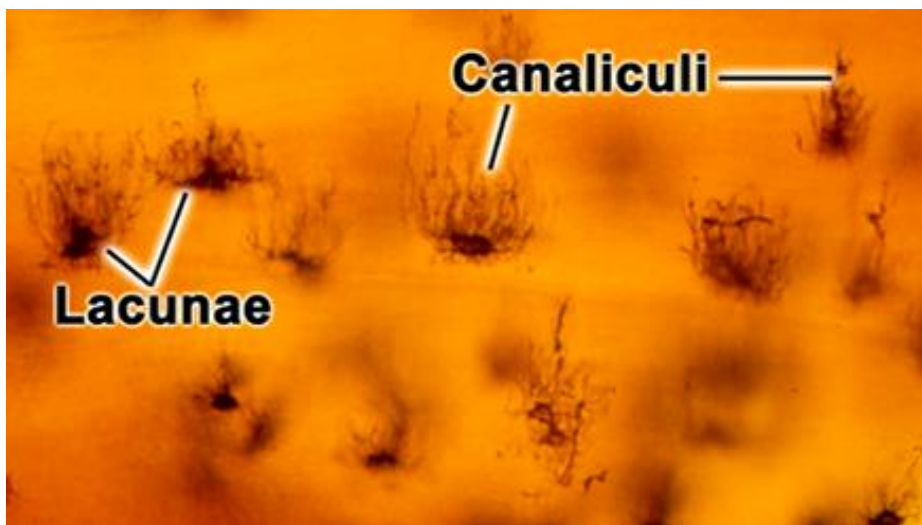
Actively involved in ECM formation

**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 resorption in temporary teeth



# Cementum matrix

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

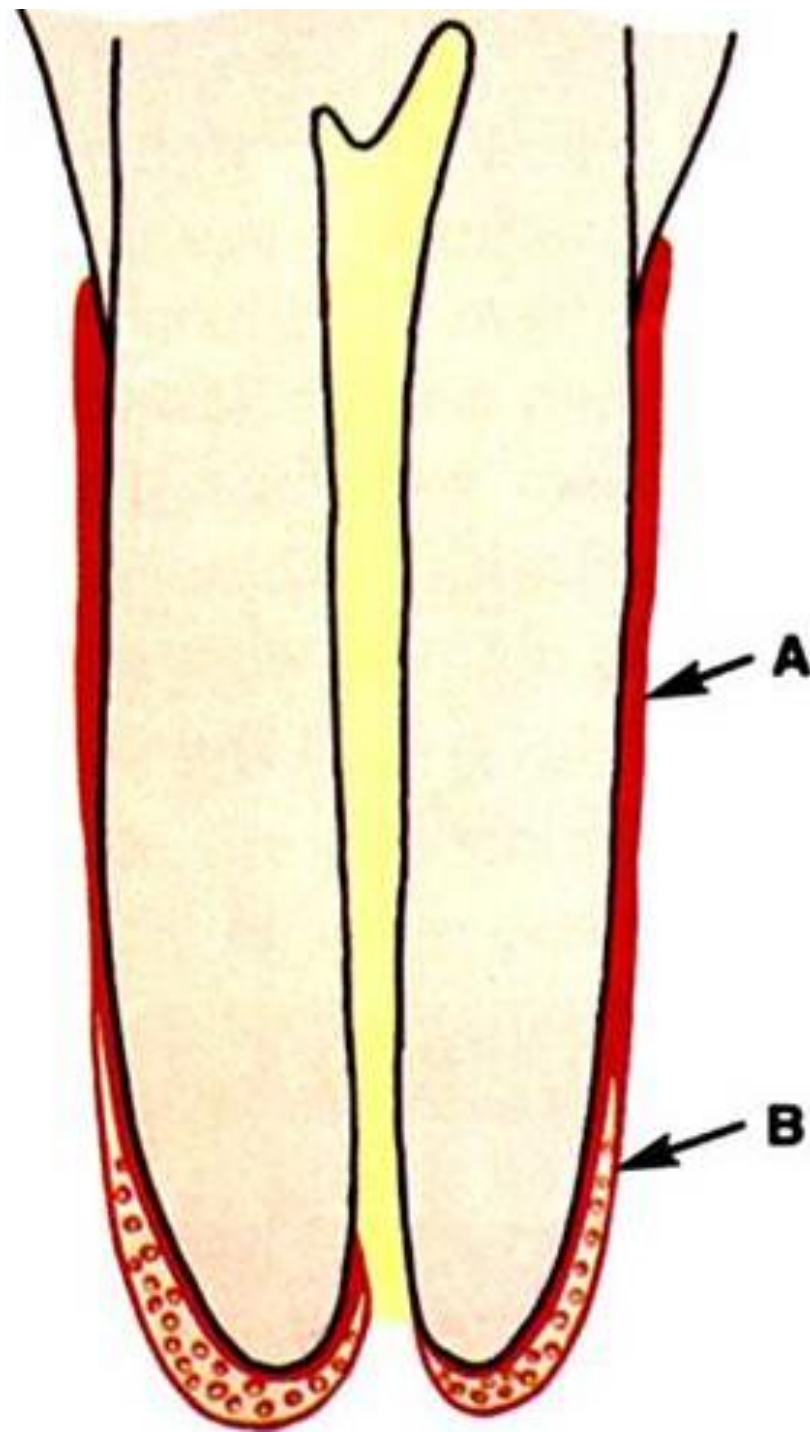
Cementum is divided by origin into:

## Primary (acellular)

Does not contain cementocytes  
In the range of the entire tooth root  
Directly connected to the dentine  
Thickness: **10 to 200  $\mu\text{m}$**

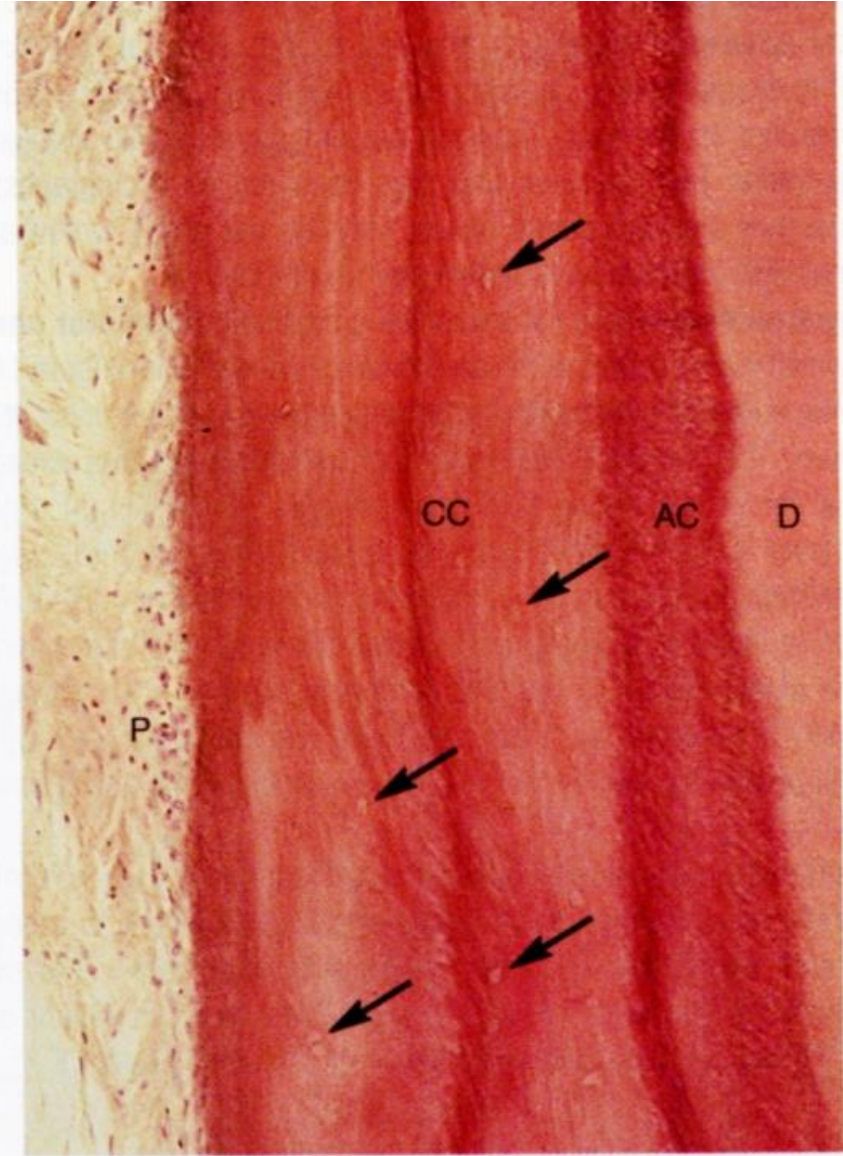
## Secondary (cellular)

Contains cementocytes  
Especially on dental apices  
Grows **up to 500  $\mu\text{m}$  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

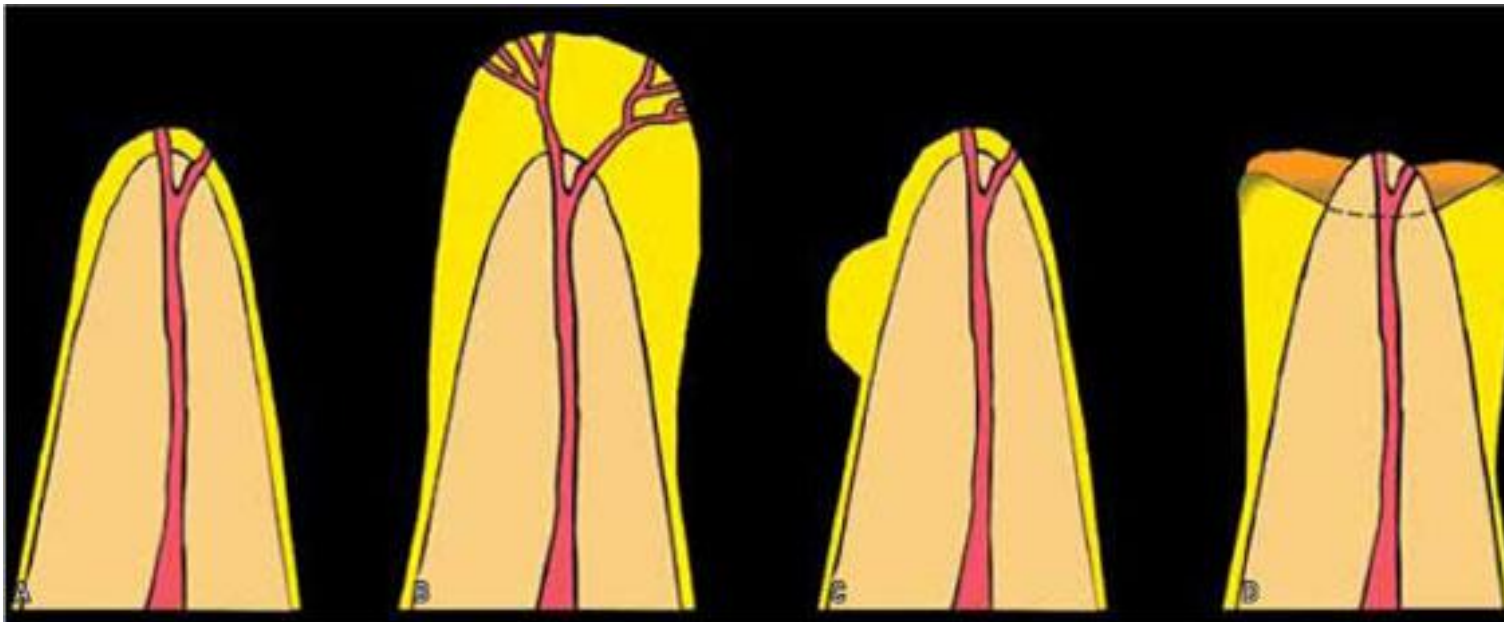
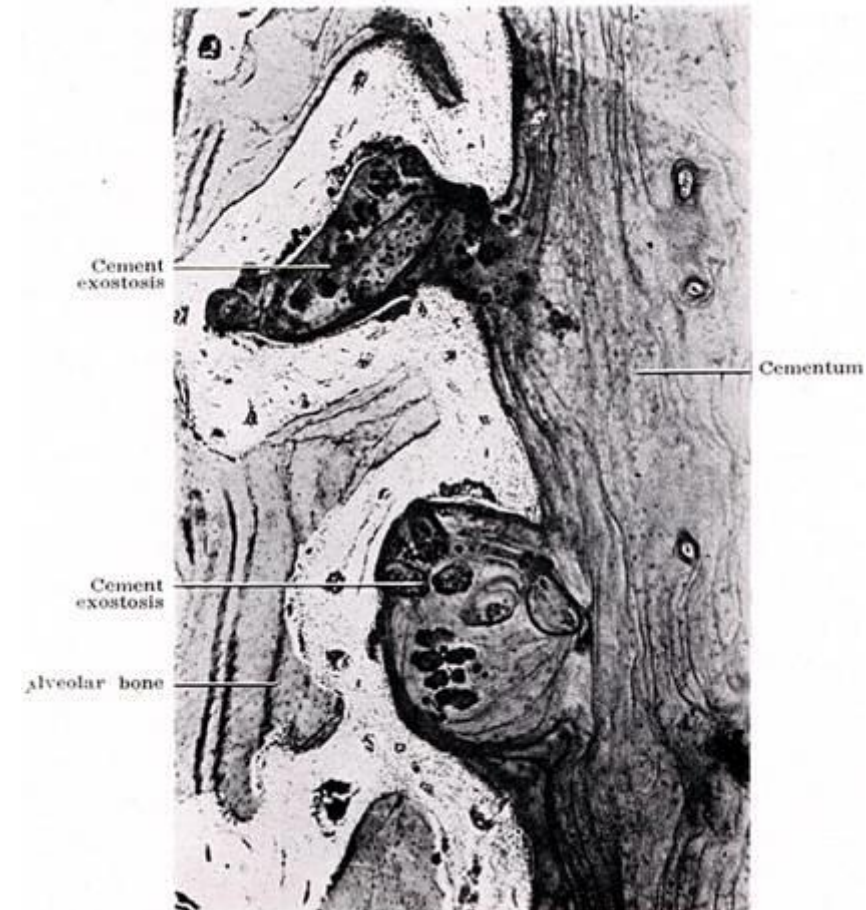
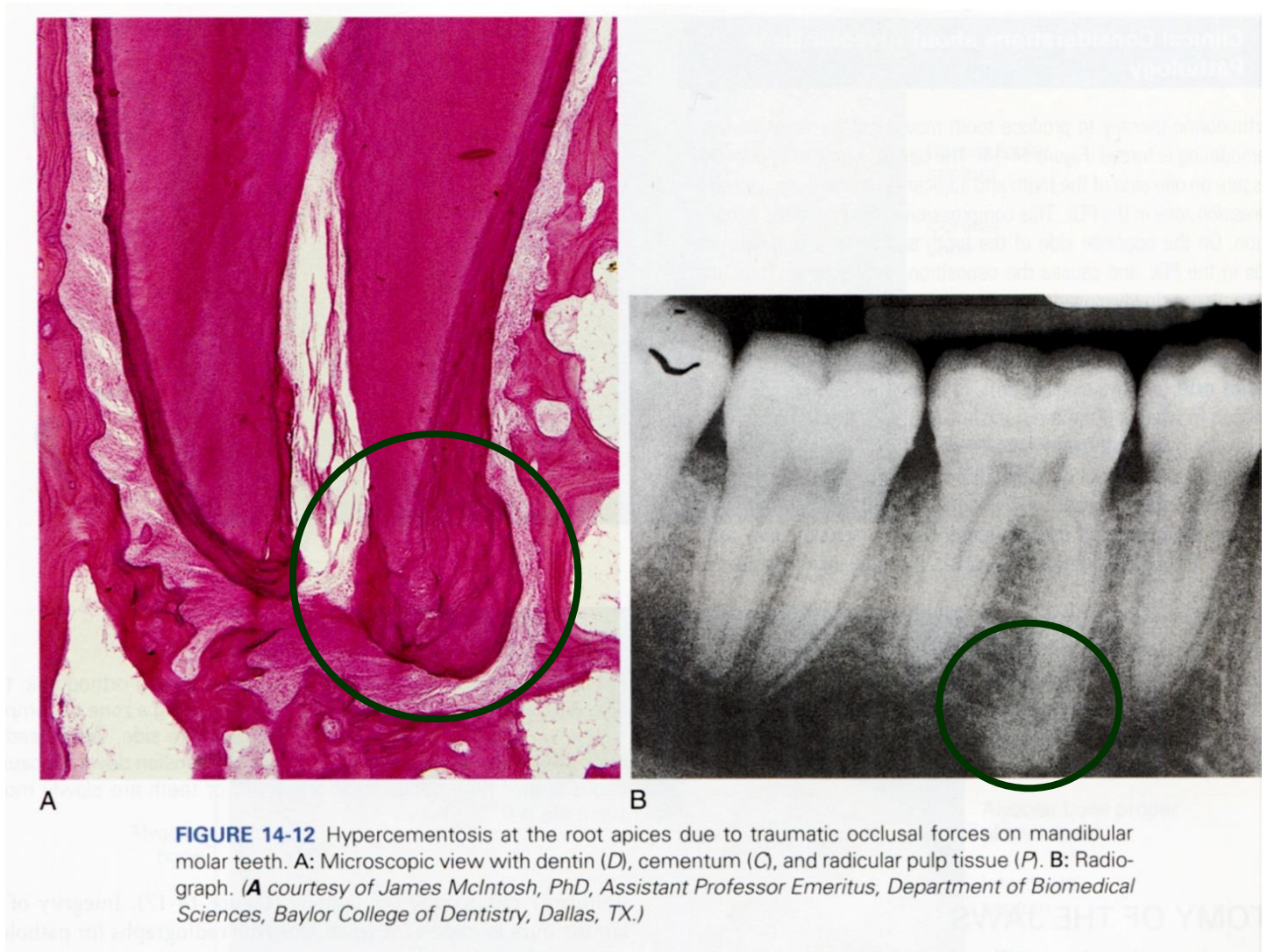


FIGURE 1 - Morphological types of hypercementosis: In (A) the root is normal; in (B) diffuse hypercementosis, when the root assumes a club shape. In (C) focal or localized hypercementosis, which is restricted to an isolated root surface; in (D) hypercementosis in the shape of a shirt sleeve cuff, which does not involve the most apical part and occurs on the periphery, as result of chronic periapical lesion (Source: Pinheiro<sup>25</sup>).





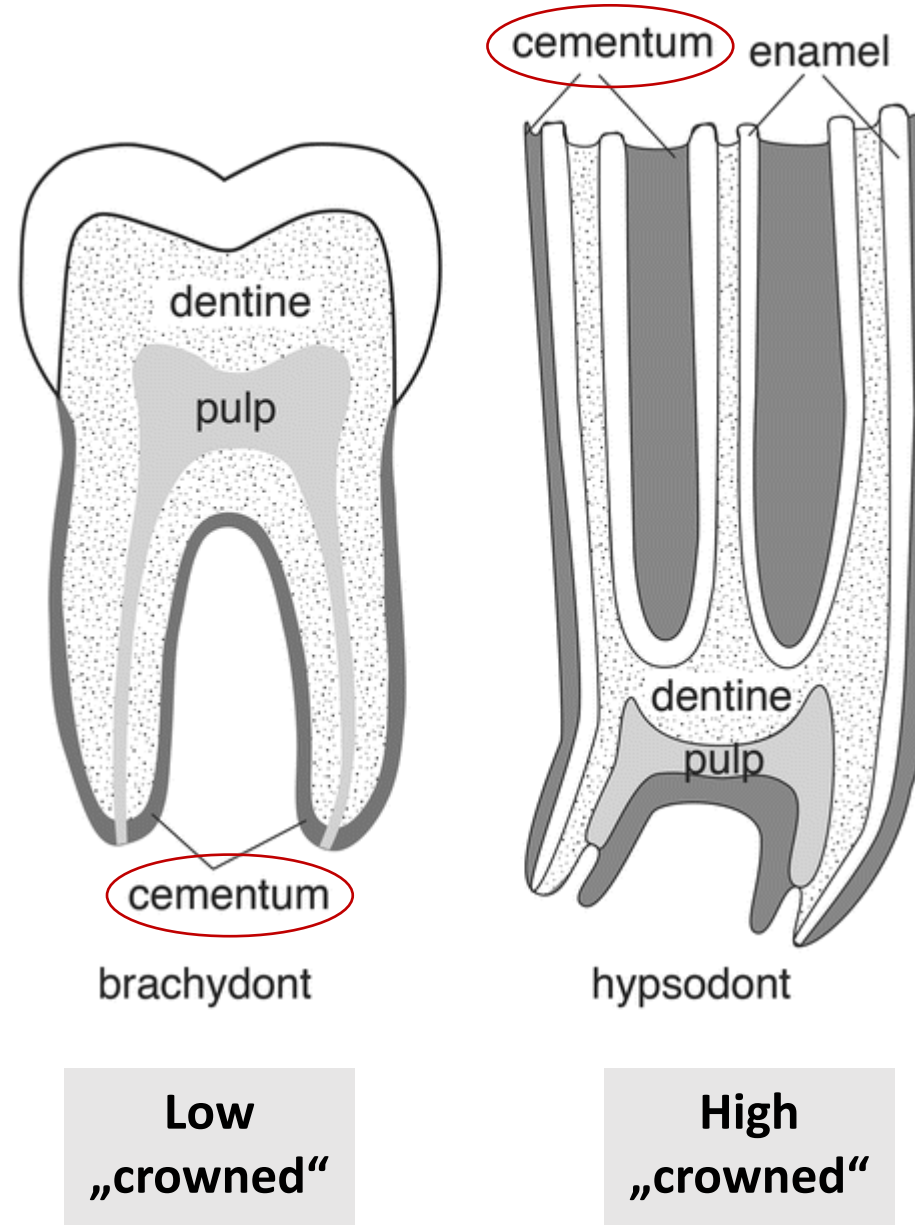
**FIGURE 14-12** Hypercementosis at the root apices due to traumatic occlusal forces on mandibular molar teeth. **A:** Microscopic view with dentin (*D*), cementum (*C*), and radicular pulp tissue (*P*). **B:** Radiograph. (**A** courtesy of James McIntosh, PhD, Assistant Professor Emeritus, Department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

# Attachment of hypsodont teeth in the jaw

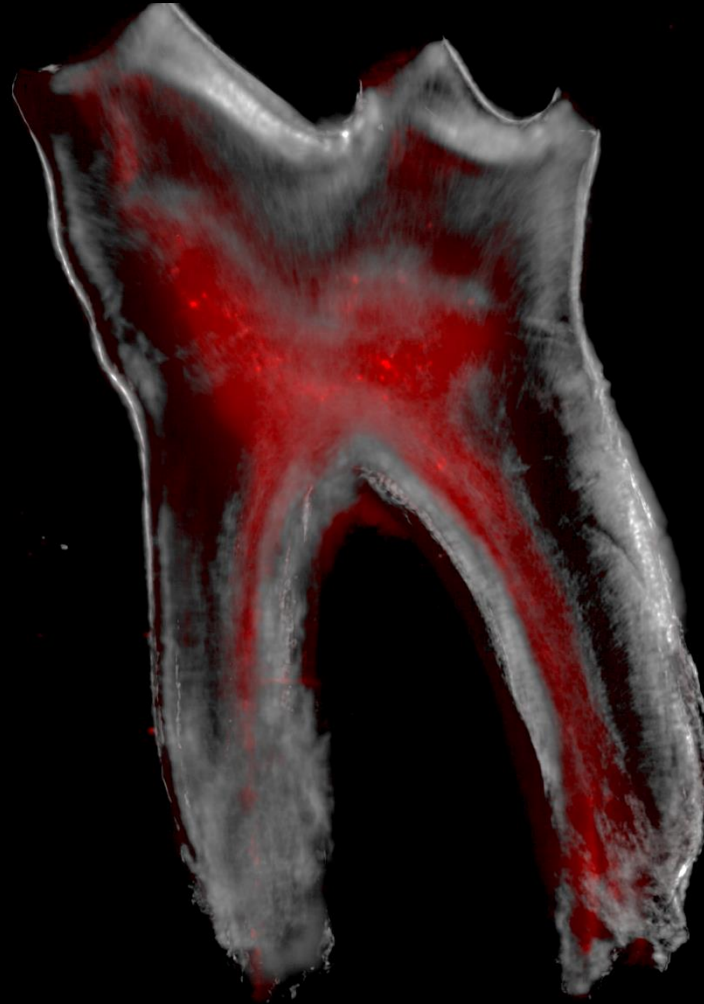
Development of hypsodont teeth in animals with highly abrasive diets.

Gradual, uneven abrasion of the "crown" part.

**What is the crown?**







Thank you for your attention!