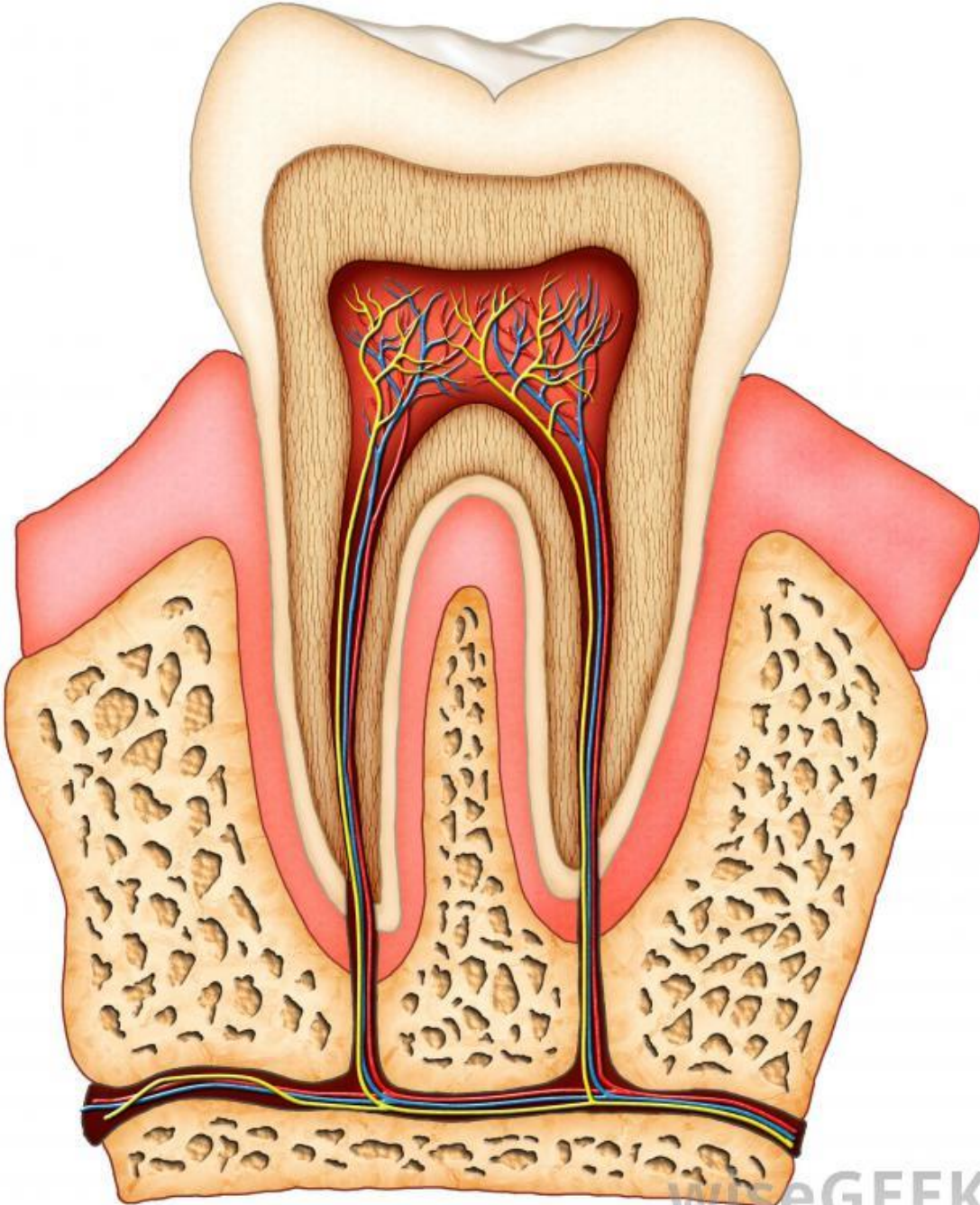
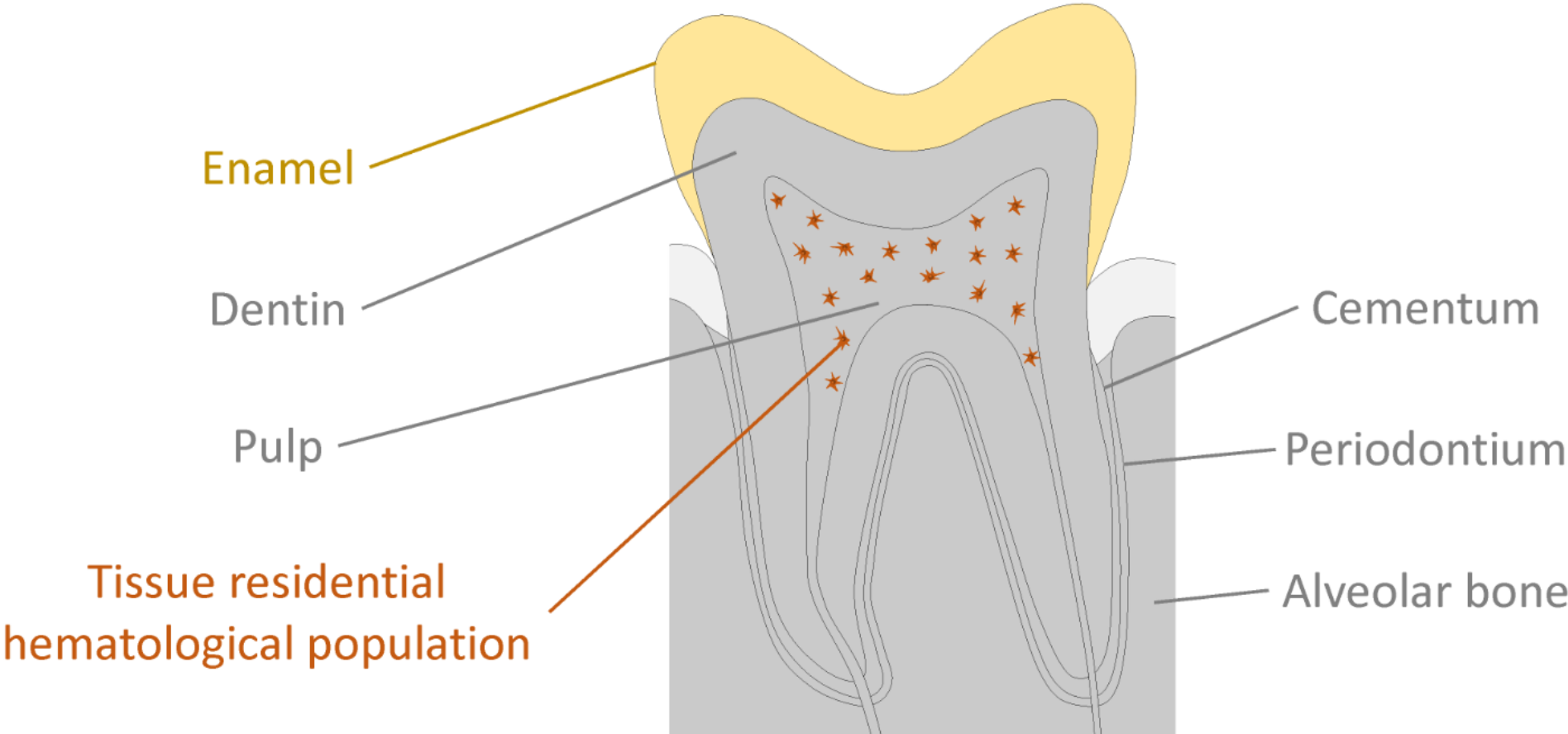


# Dental pulp Dentin

Jan Krivanek

5. 4. 2023

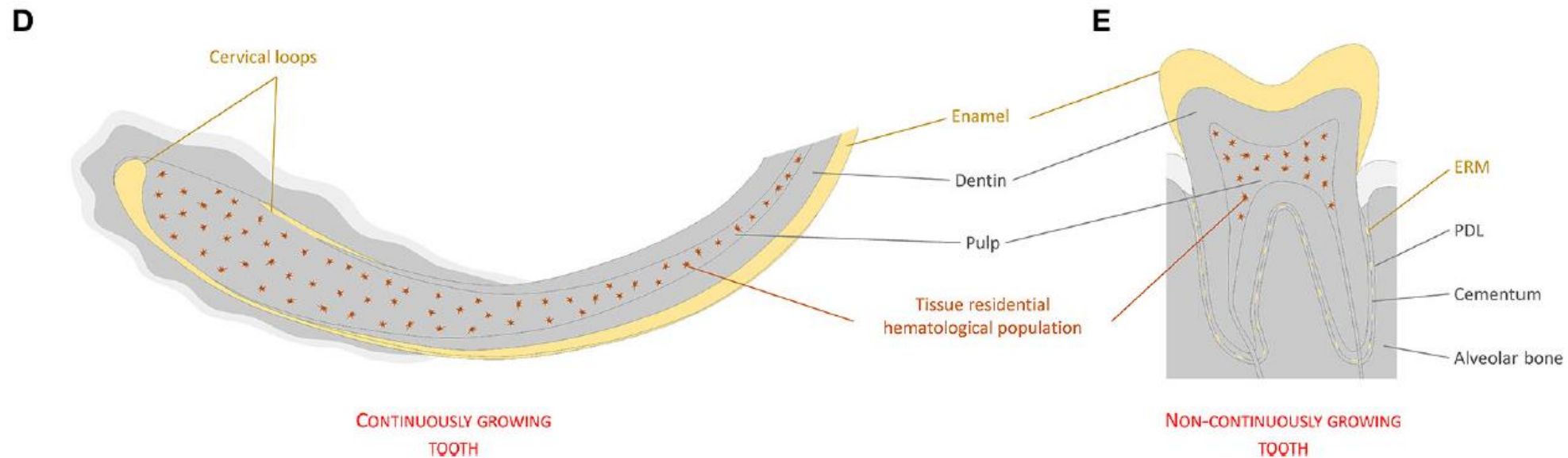
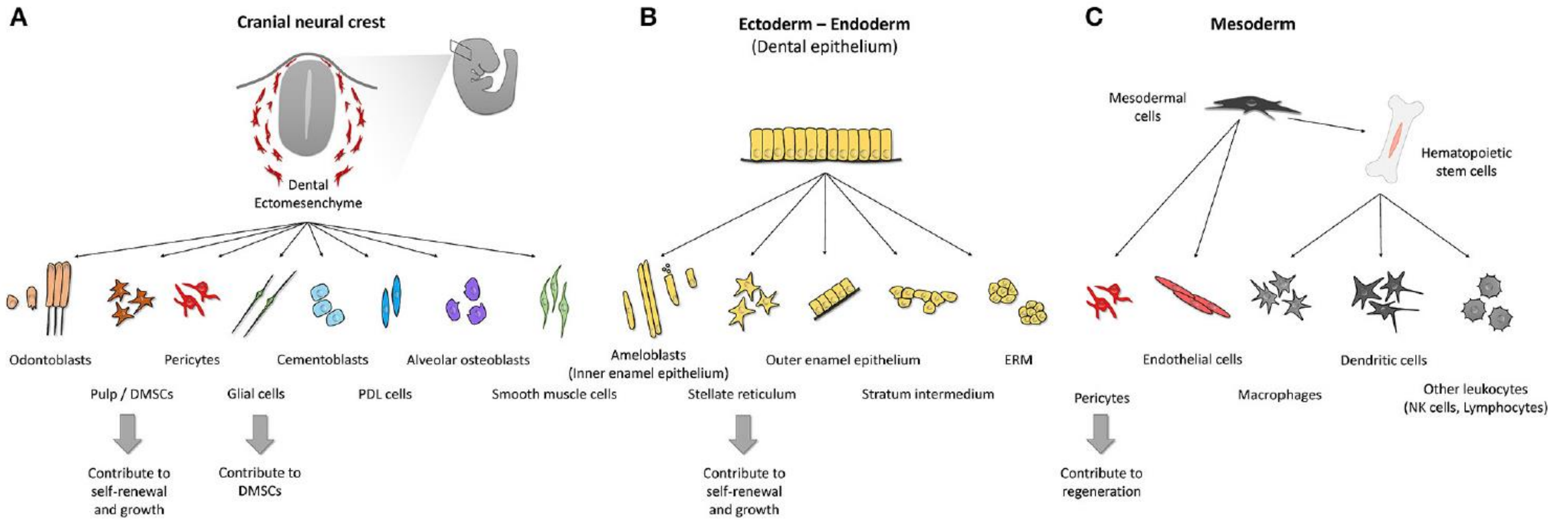


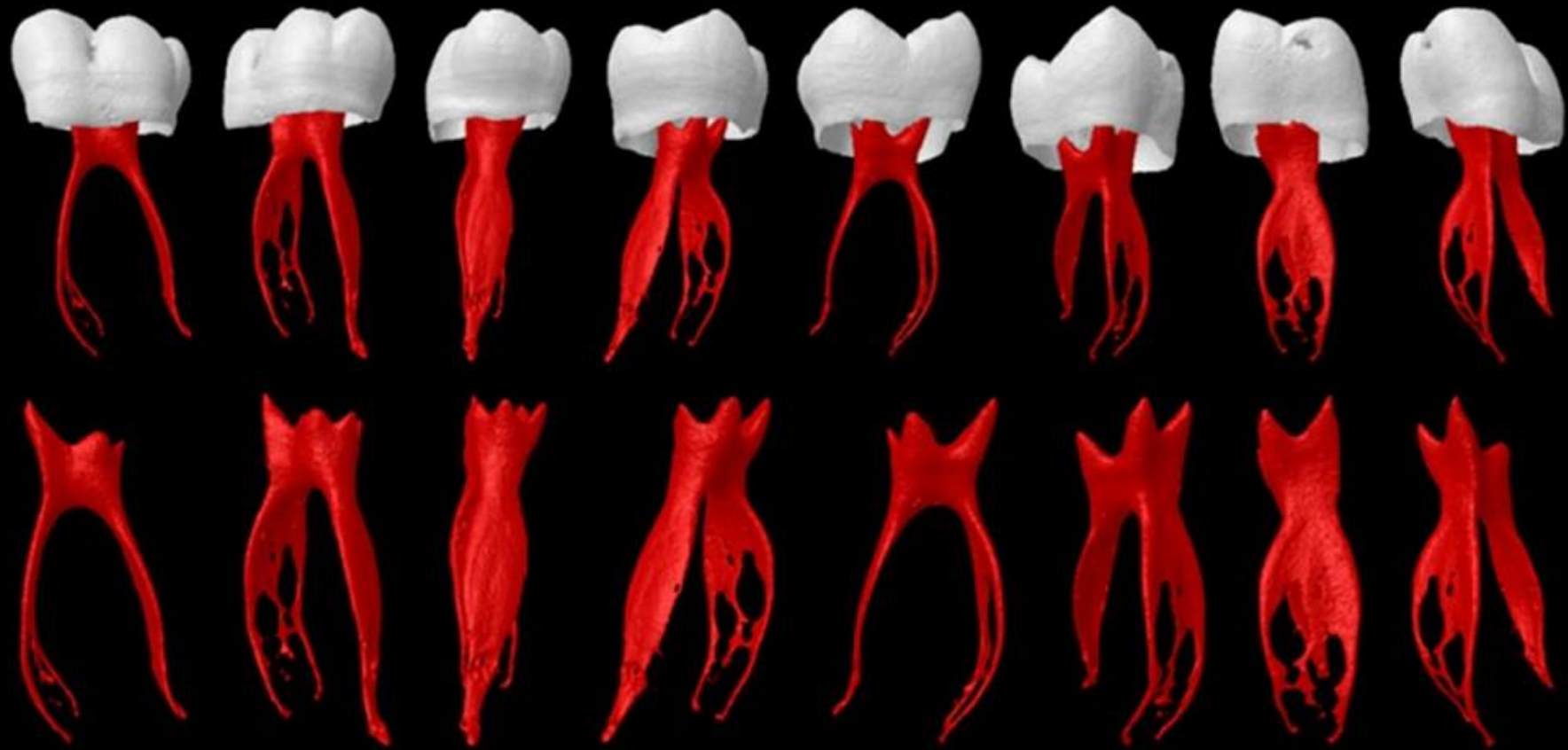


**Neural crest - derived**

**Epithelial - derived**

**Mesodermal - derived**





**The fundamental importance of the pulp:**

- a) **Tooth vitality** - nutrition and protection of odontoblasts against foreign and infectious agents
- b) **Reparative processes** - pool of undifferentiated cells for pulp fibroblasts and odontoblast-like cells

**Dental pulp shape depends on:**

- Tooth Type
- Age of the individual
- Pathological and repair changes

# Dentin-pulp complex

Summary term used for dental pulp and dentin  
Tight developmental, histological and functional connections  
Common development history (ectomesenchymal origin)



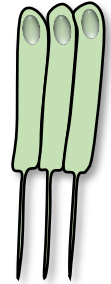
**Dental pulp Fibroblasts**

Stromal pulp tissue  
Support for odontoblasts  
Support for blood vessels and nerves  
Immune reactions  
Stem cell niche

Interactions



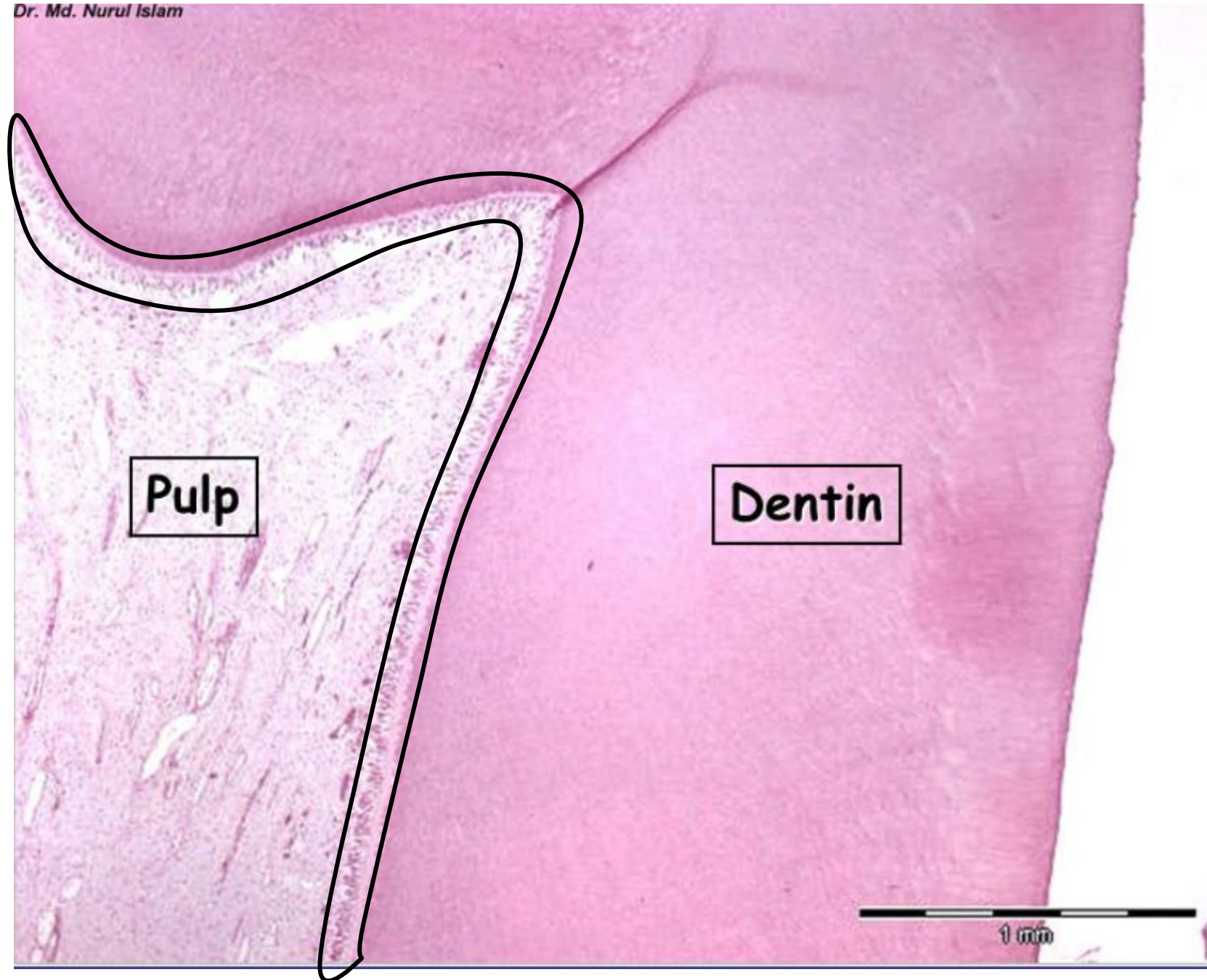
**Odontoblasts**



Dentin production  
Living component of dentin  
Reactions on tooth damage  
(pain, immune response, reparative processes)

# Dentin-pulp complex

Dr. Md. Nurul Islam



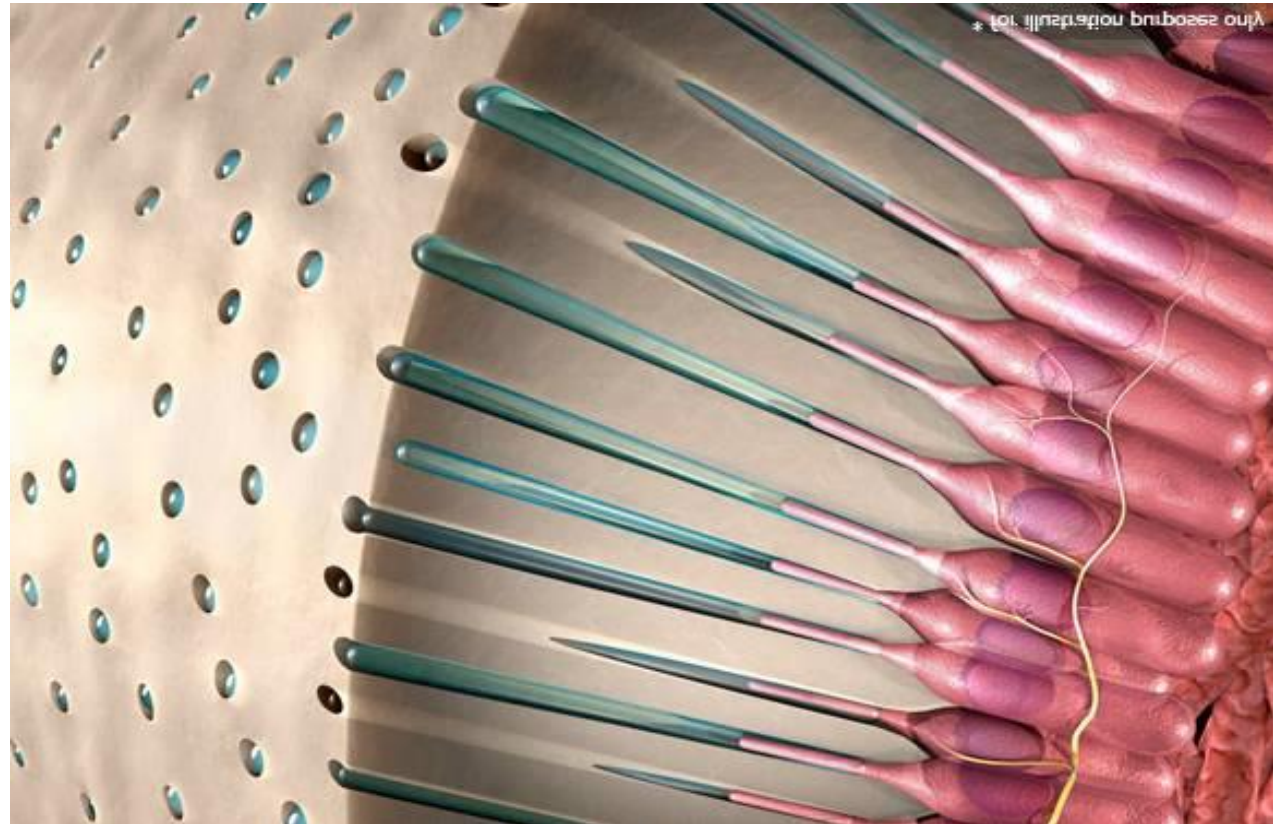
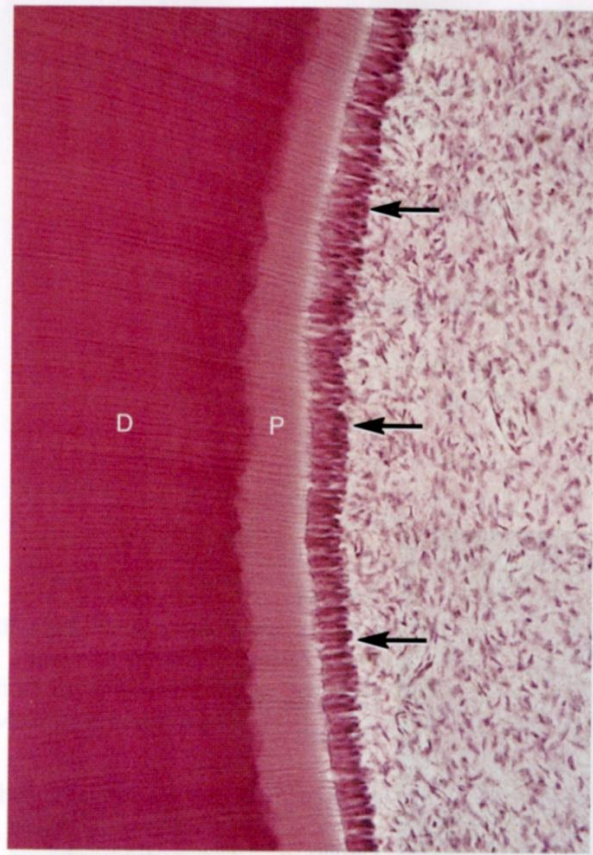
# Odontoblasts

Interface of dentin and the pulp

Elongated shape, polarization (nucleus with organelles in basal third)

Single cell layer

Secretory vesicles on apical side





# Odontoblasts function

- In healthy teeth, lifetime-active cells
- Odontoblasts' processes/fibres (Tomes Fibres) maintain dentin matrix formation, responsible for dentin viability
- Odontoblasts' processes involved in the pain perception
- Periodontoblastic space between the tubule wall and Tomes fibre, contains dentinal fluid and mucopolysaccharide material

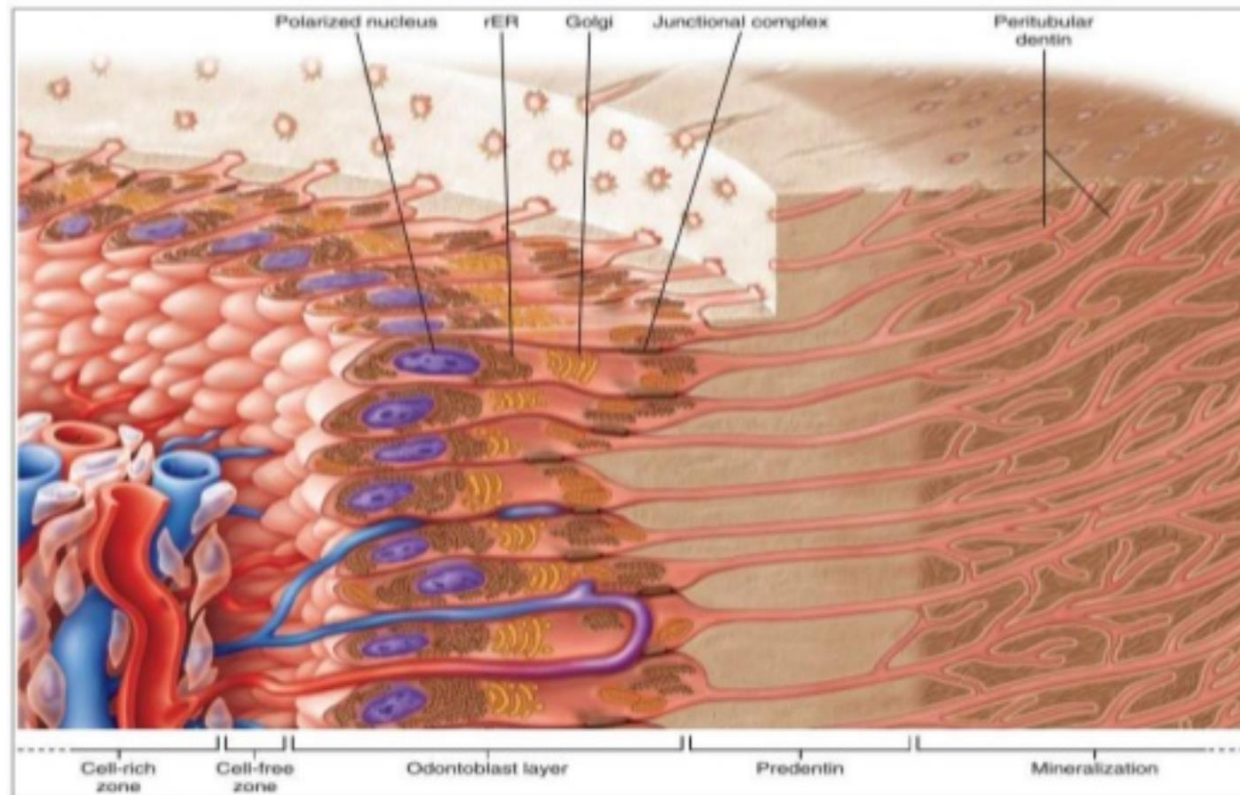
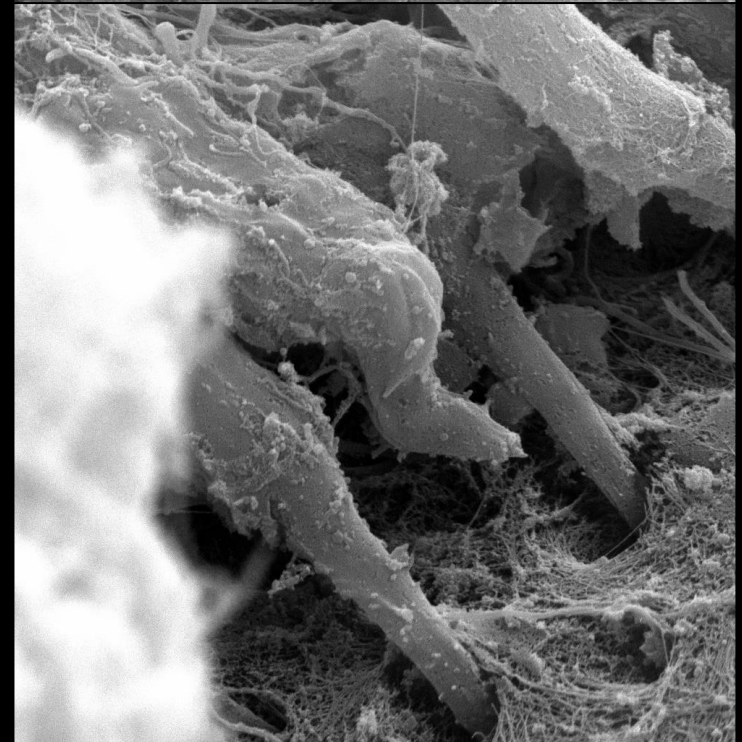
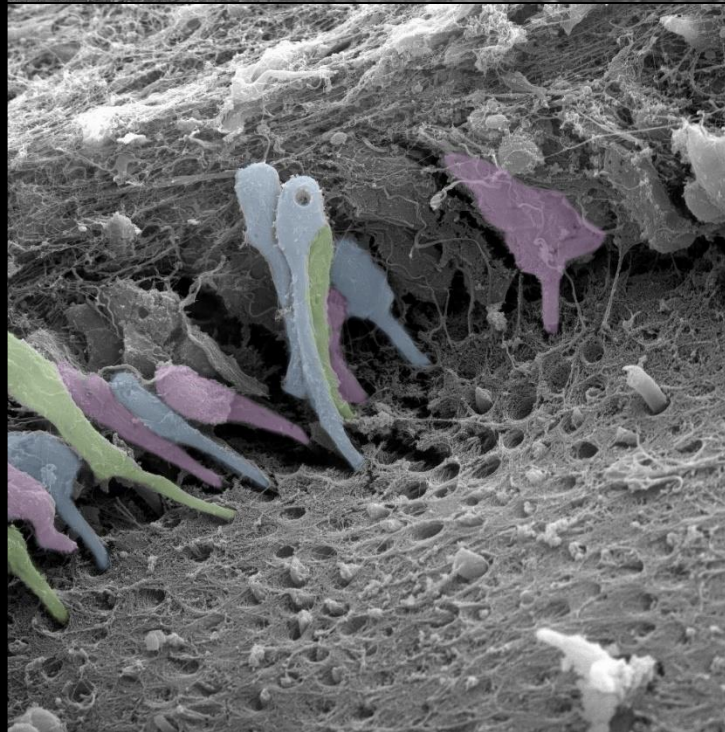
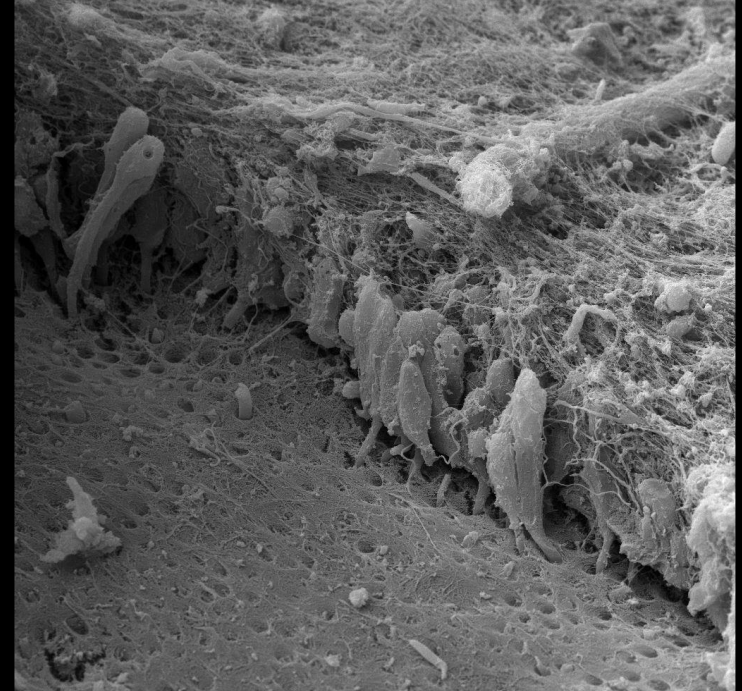
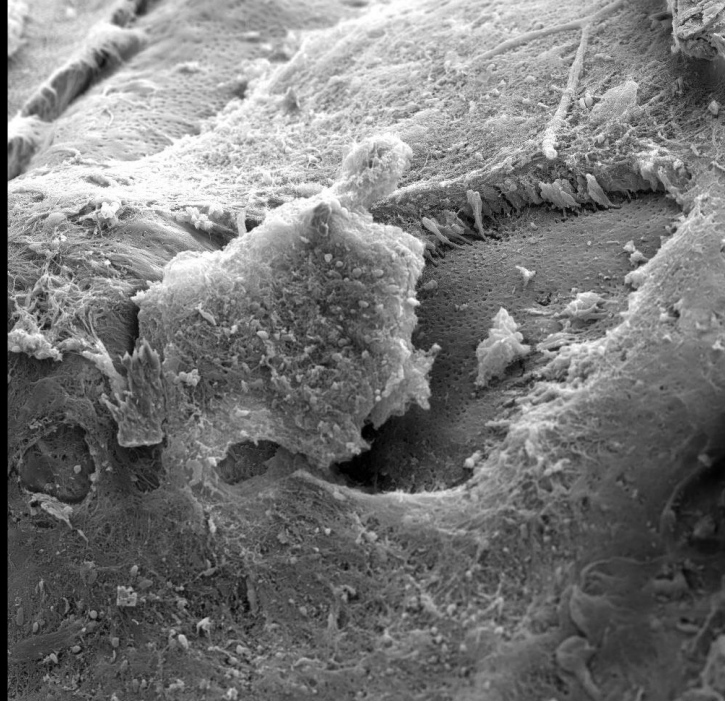
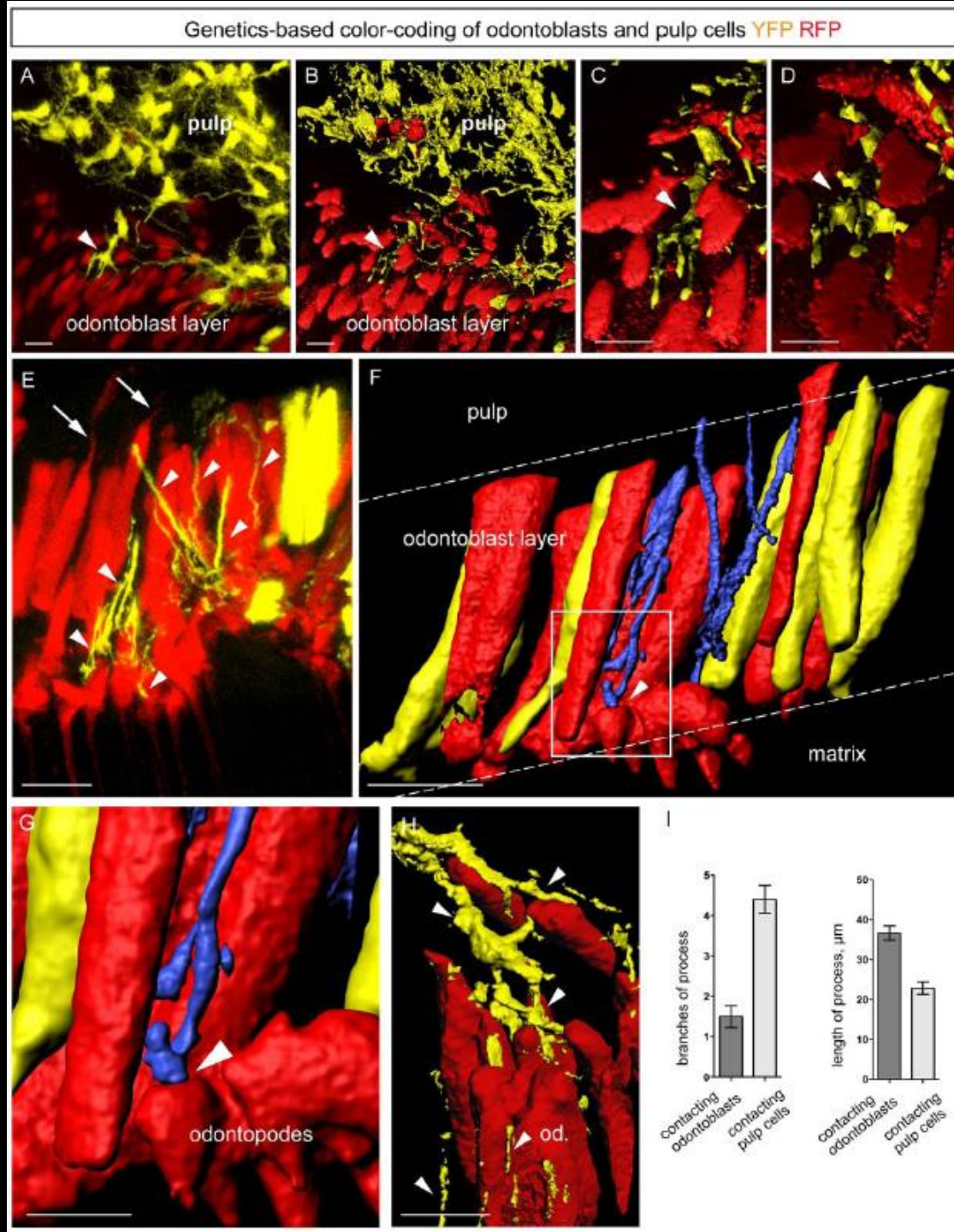


FIGURE 8-40 Schematic representation of the cells bordering pulp. *rER*, Rough endoplasmic reticulum.

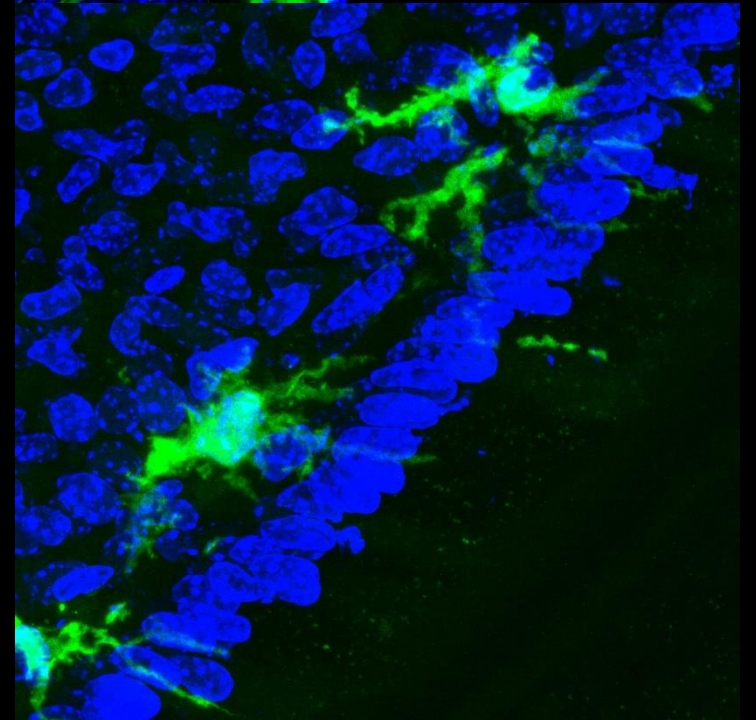
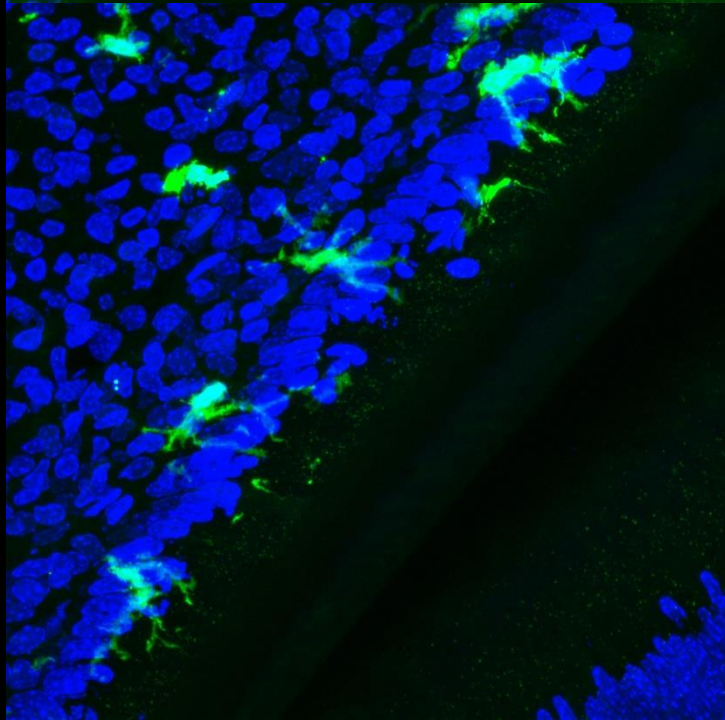
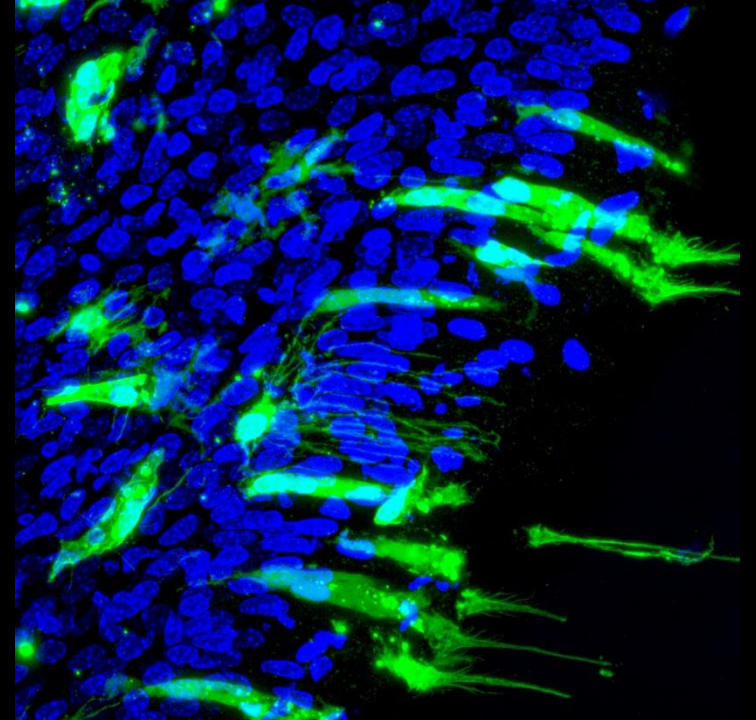
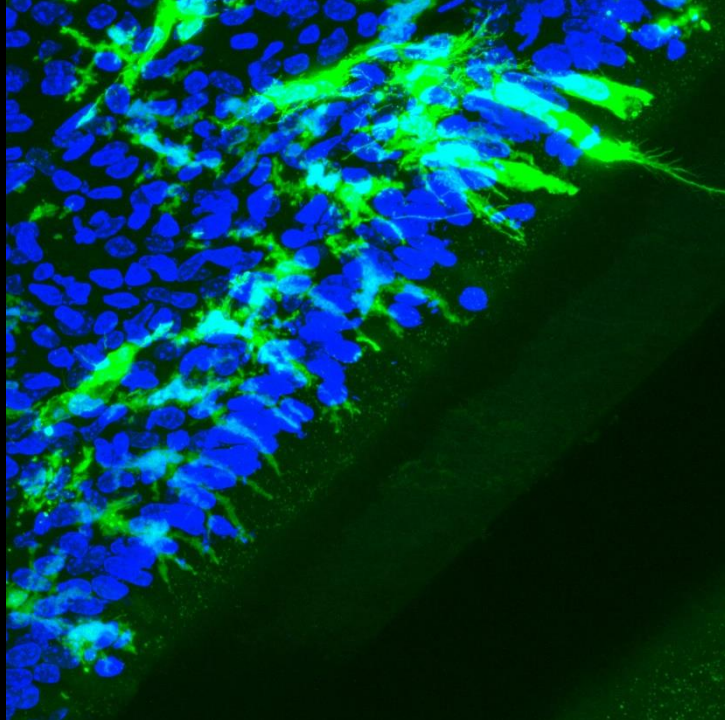
# Odontoblasts



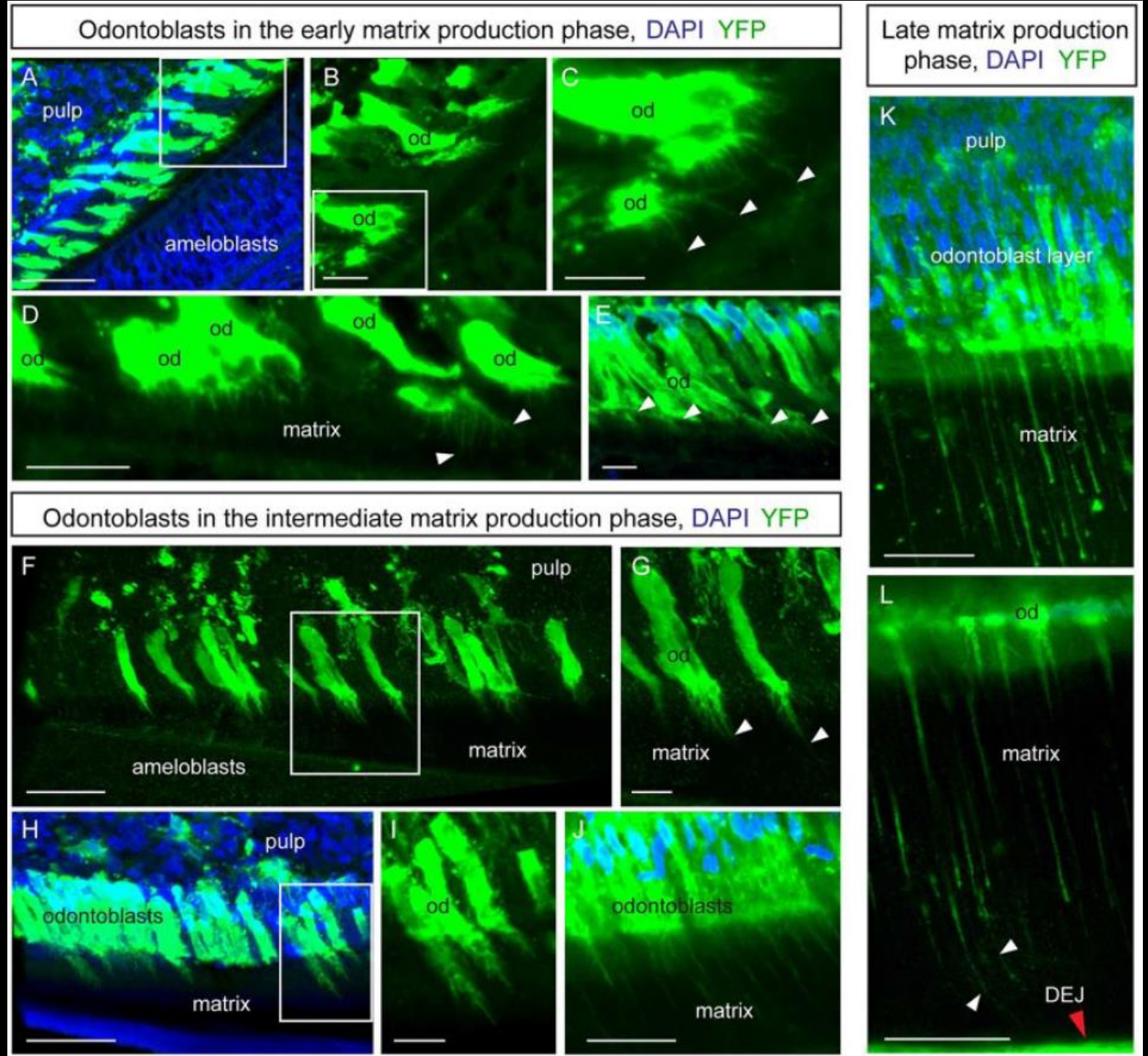
# Odontoblasts



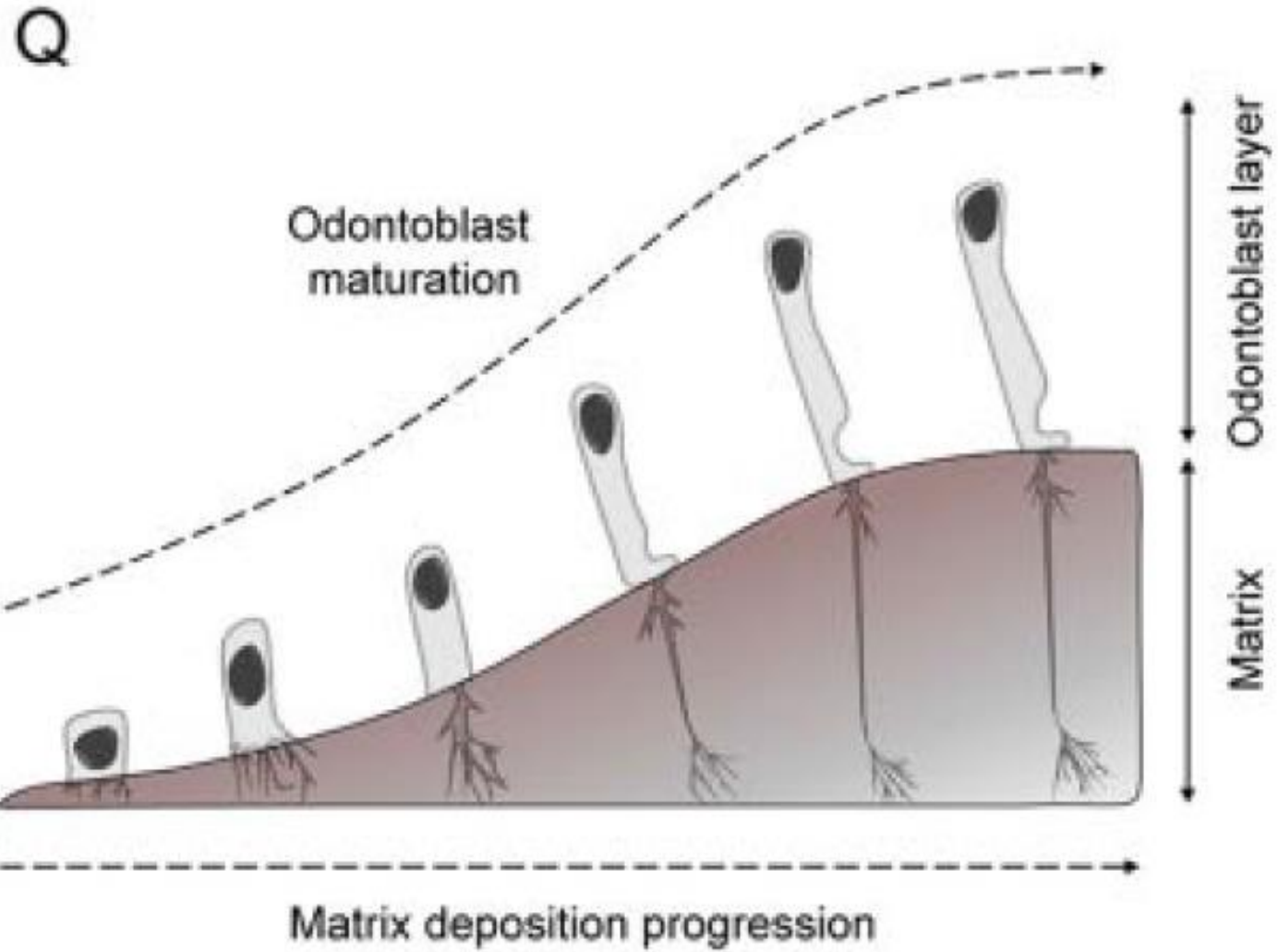
Odontoblasts /  
Pulp cells



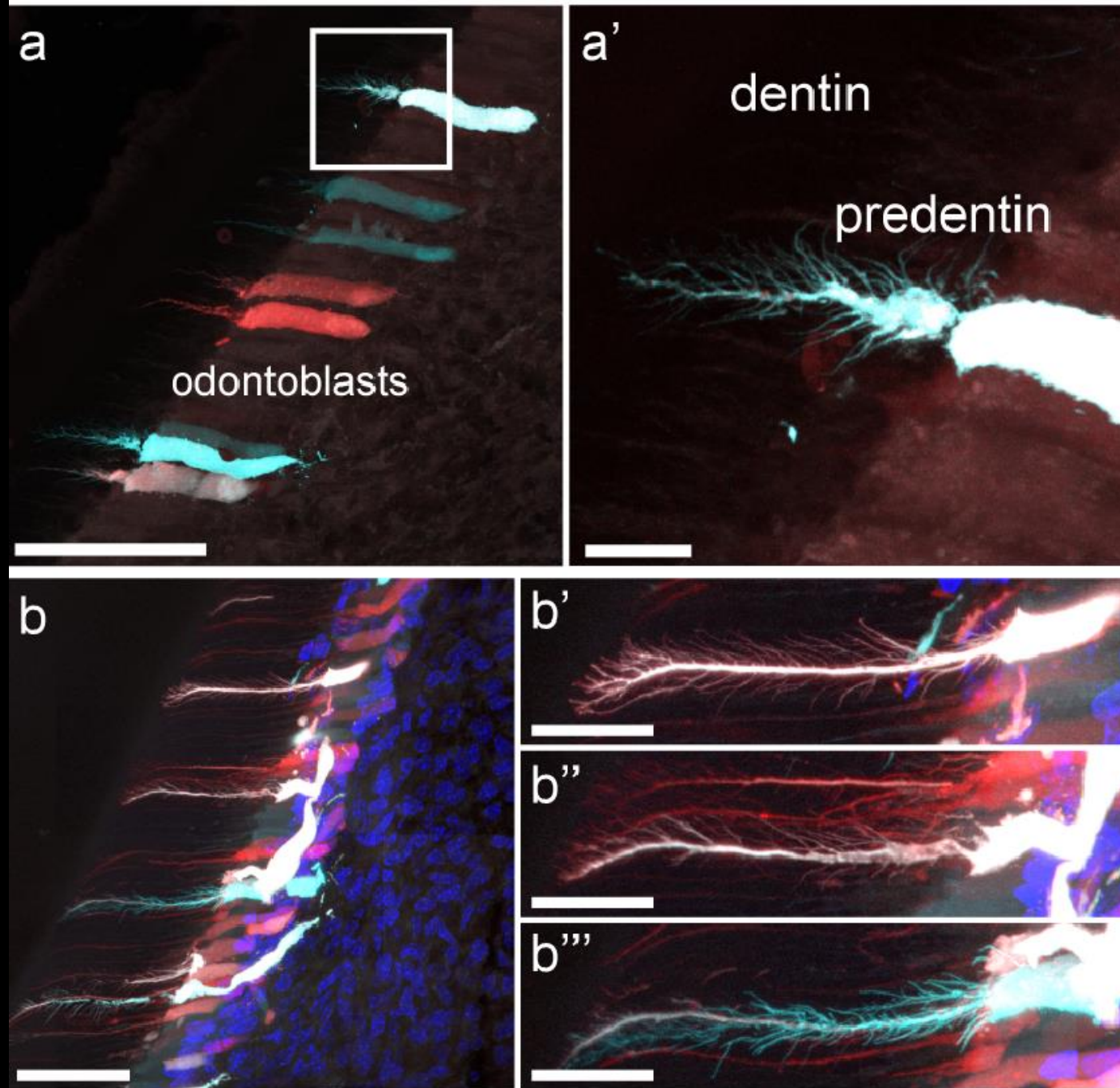
# Development of odontoblasts



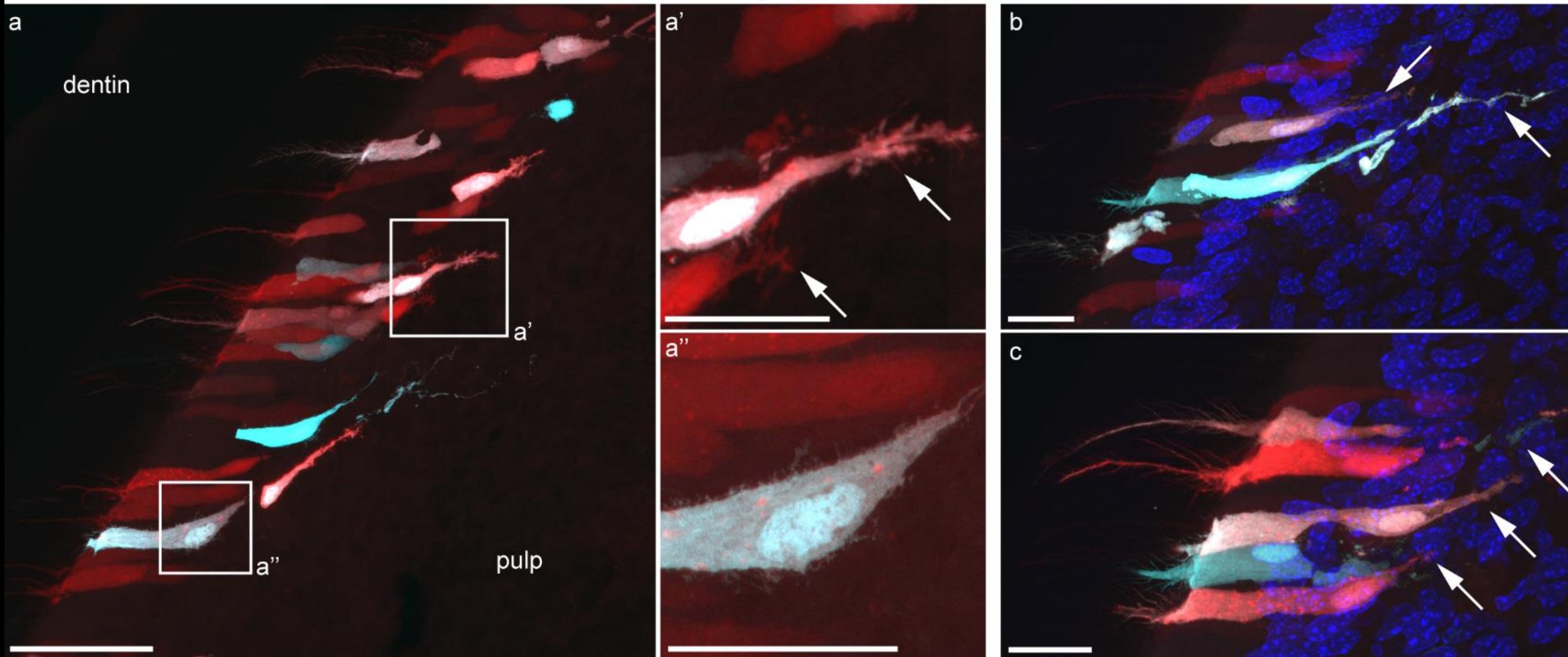
# Development of odontoblasts



# Odontoblasts dentinal processes analysis

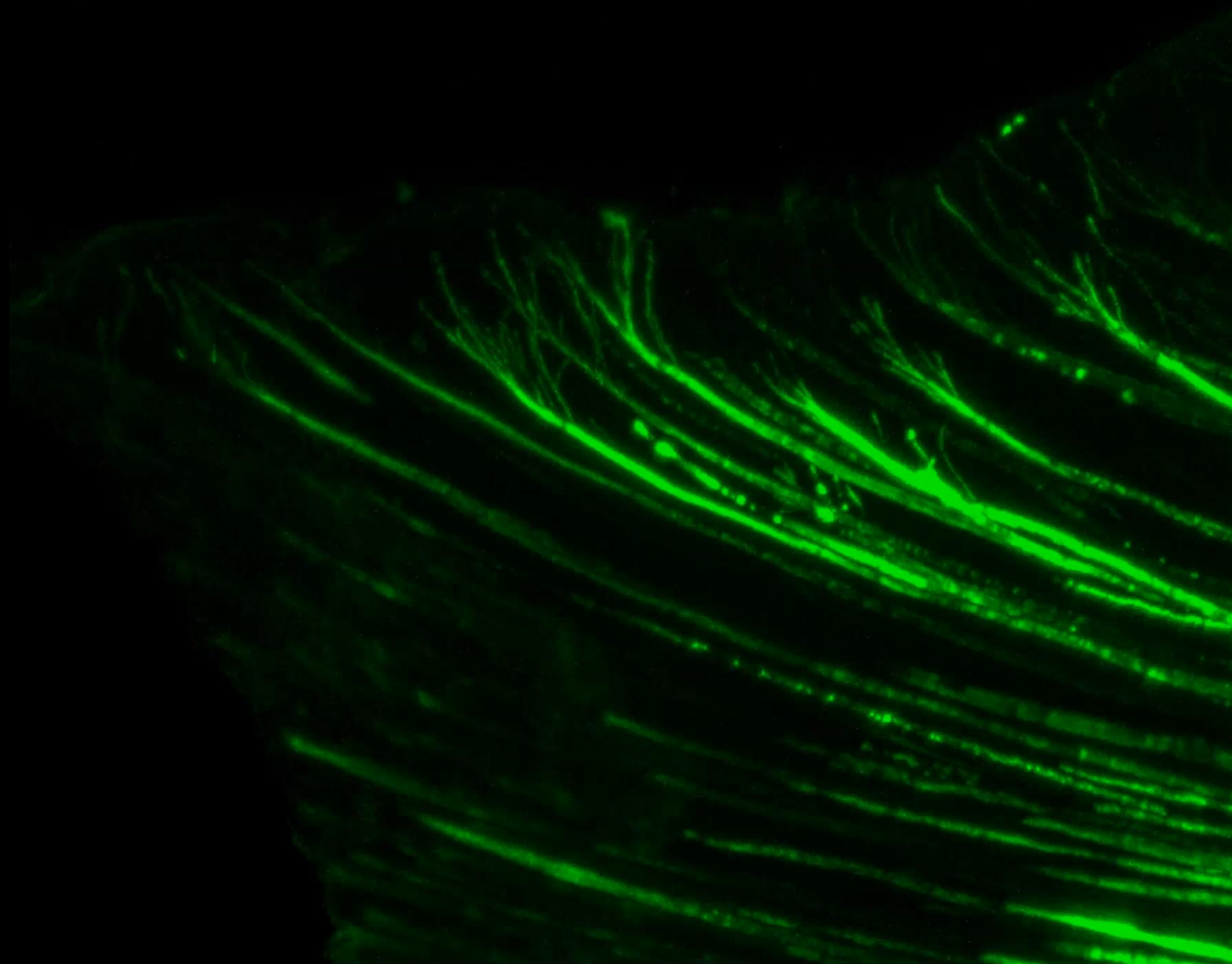


# Odontoblasts pulp-penetrating processes



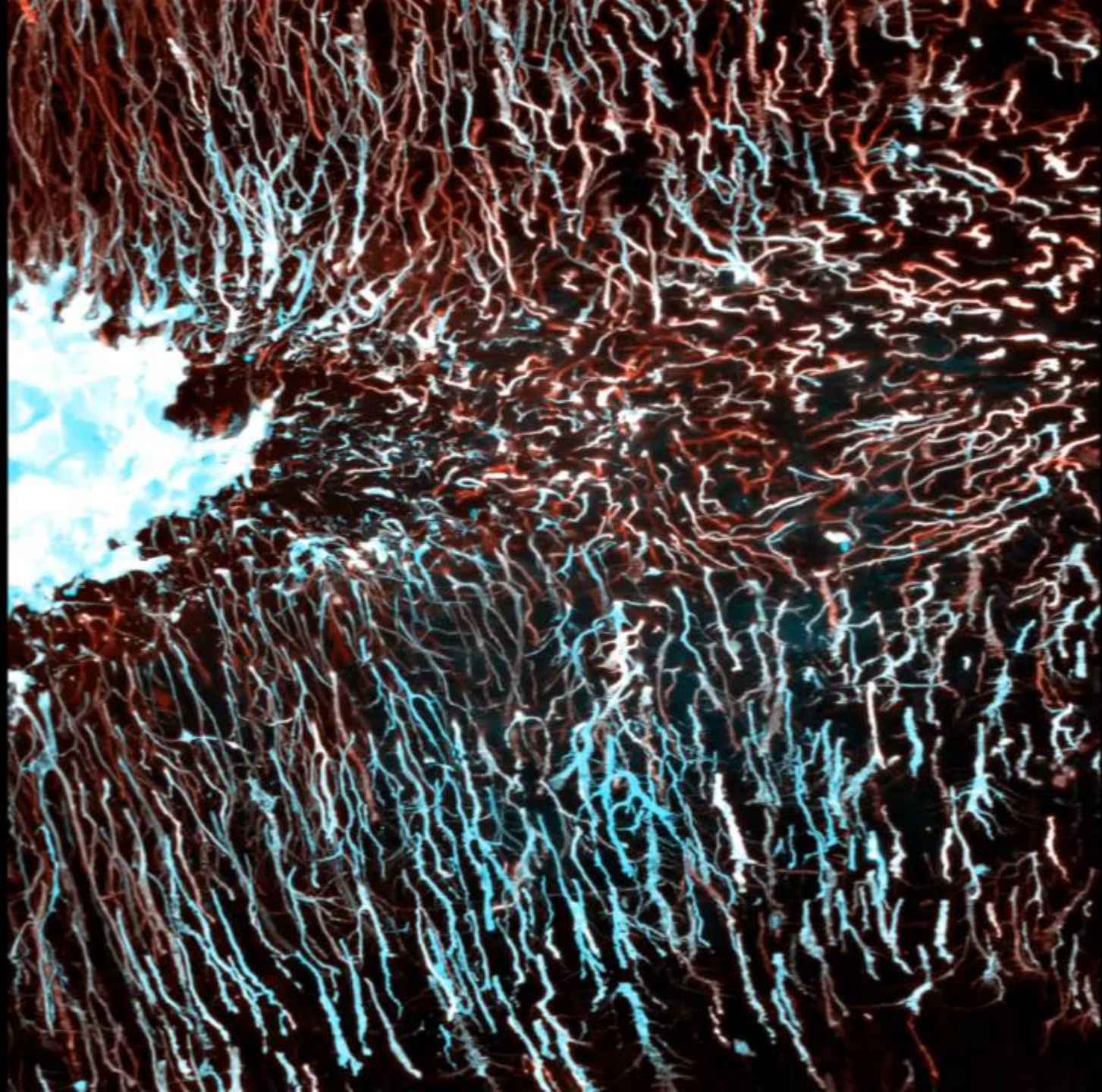


**Enamel**



**Dentin**





# Microscopic structure of dental pulp, function and changes during aging

Ectomesenchymal origin

Located in *cavitas dentis*

Reticular structure

In primary dentition structure similar to jelly-like connective tissue

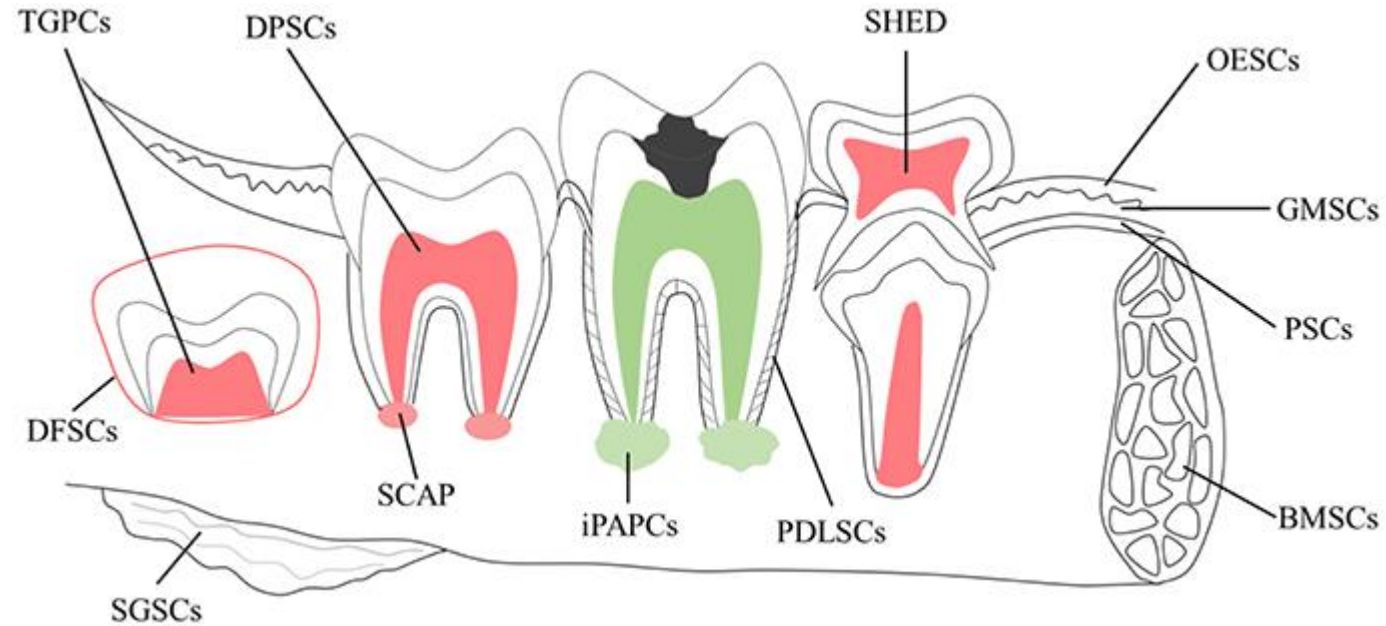
## Extracellular matrix (ECM)

- **Fibres:**
  - Collagen
  - Reticular fibres
- **Amorphous matter:**
  - Glycosaminoglycans and glycoproteins

## Cellular part

- Particularly fibroblasts,
- Immune system: macrophages, plasma cells, dendritic cells and tissue-residential blood cells (neutrophiles or eosinophiles, granulocytes, lymphocytes)
- Glial cells
- Endothelial cells, pericytes
- Dental mesenchymal cells

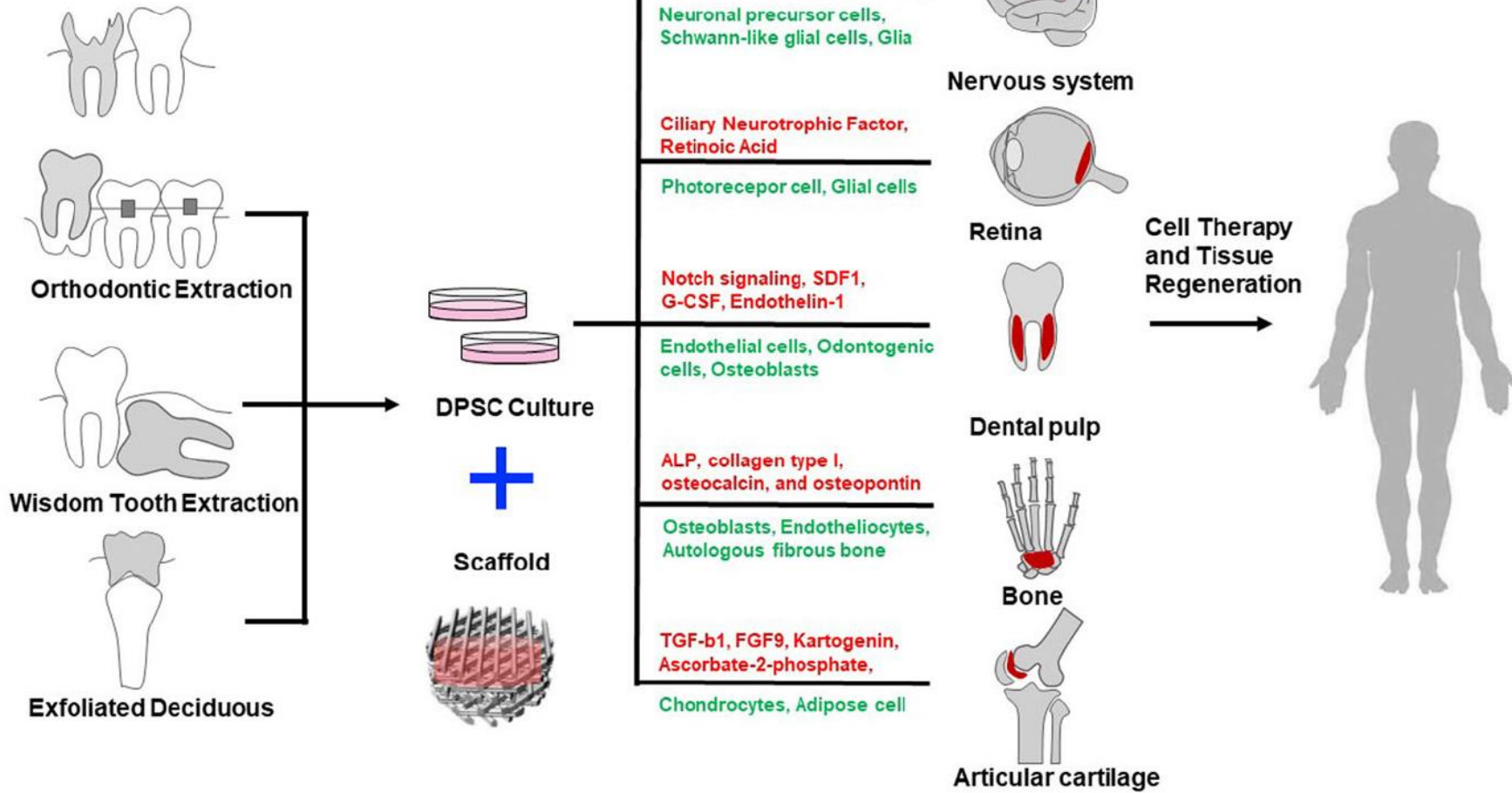
# Stem Cells in (human) teeth



Schematic of potential sources of adult stem cells in the oral environment

<b>TGPCs</b>	<b>tooth germ progenitor cells</b>
<b>DFSCs</b>	<b>dental follicle stem cells</b>
SGSCs	salivary gland stem cells
<b>SCAP</b>	<b>stem cells of the apical papilla</b>
<b>DPSCs</b>	<b>dental pulp stem cells</b>
iPAPCs	inflamed periapical progenitor cells
<b>SHED</b>	<b>stem cells from human exfoliated deciduous teeth</b>
<b>PDLSCs</b>	<b>periodontal ligament stem cells</b>
BMSCs	bone marrow stem cells
OESCs	oral epithelial stem cells
GMSCs	gingival-derived mesenchymal stem cells
PSCs	periosteal stem cells

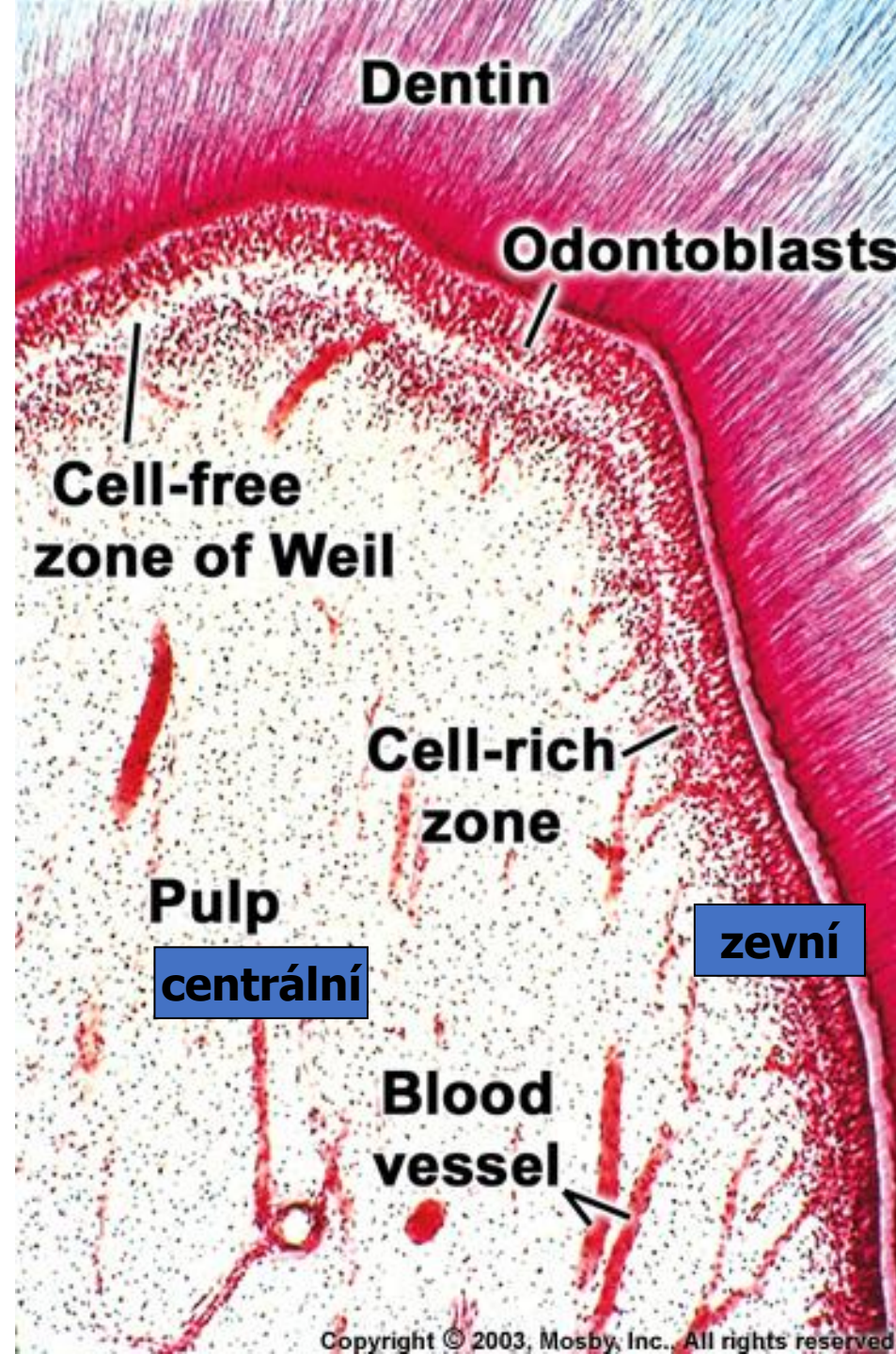
# Dental Pulp stem cell sources and multilineage application capability

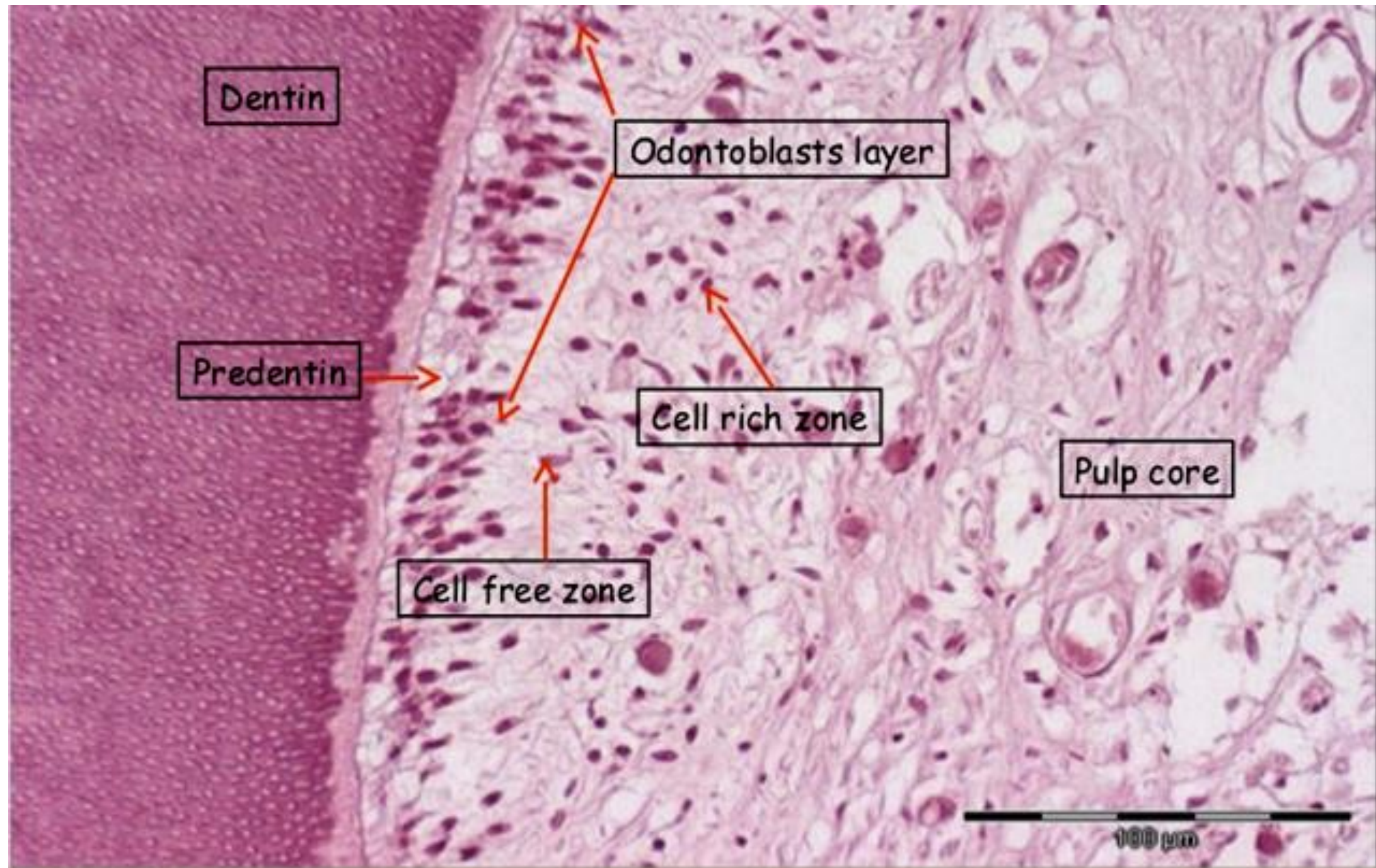


# Dental pulp stratification

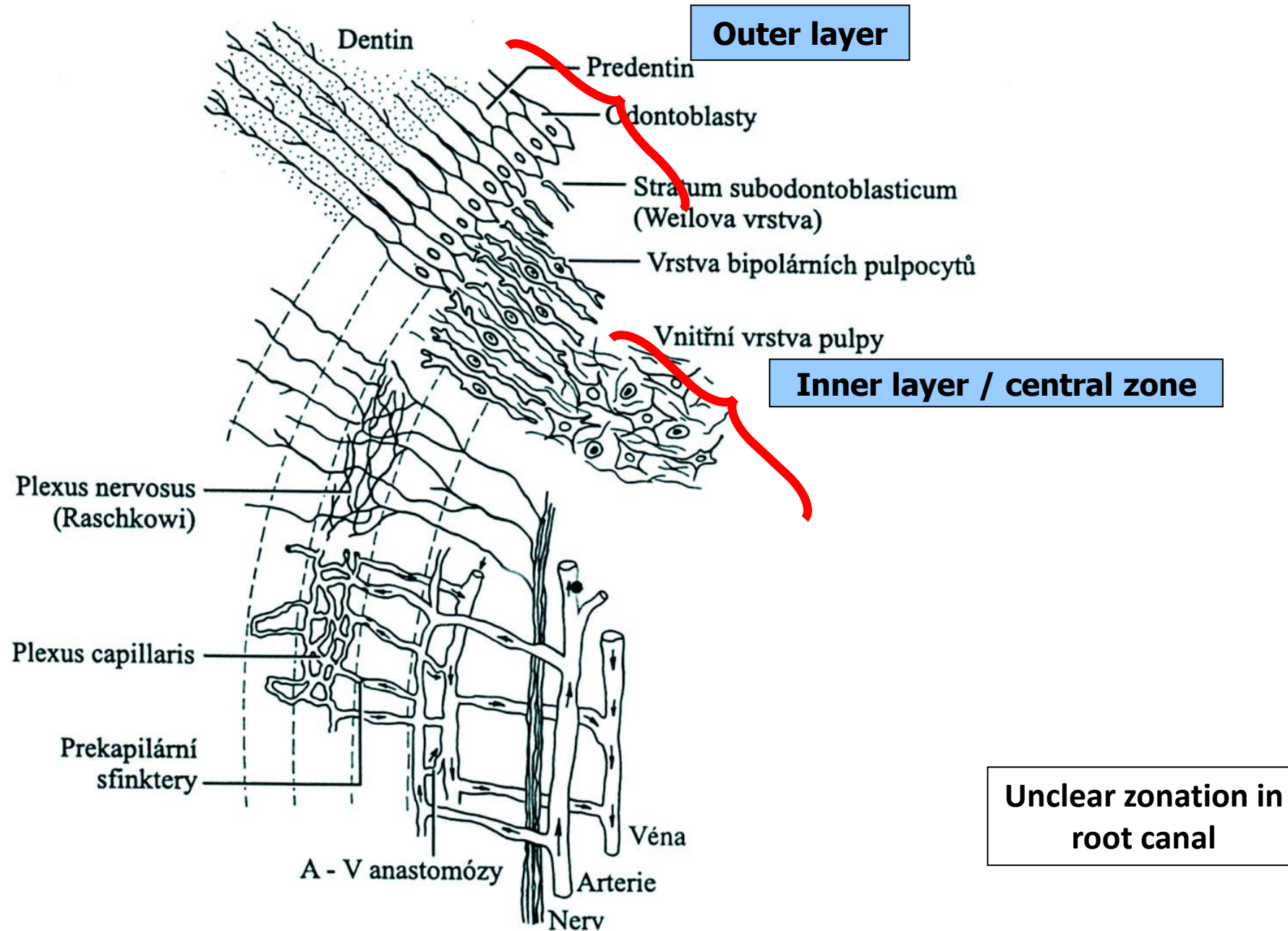
Two layers (crown part)

Outer - surface  
Inner - central









Obr. 15-6. Schematický náčrt mikroskopické stavby zubní pulpy, její inervace a cévního zásobení

# Blood and lymph vessels

Very rich blood supply (especially at a young age)

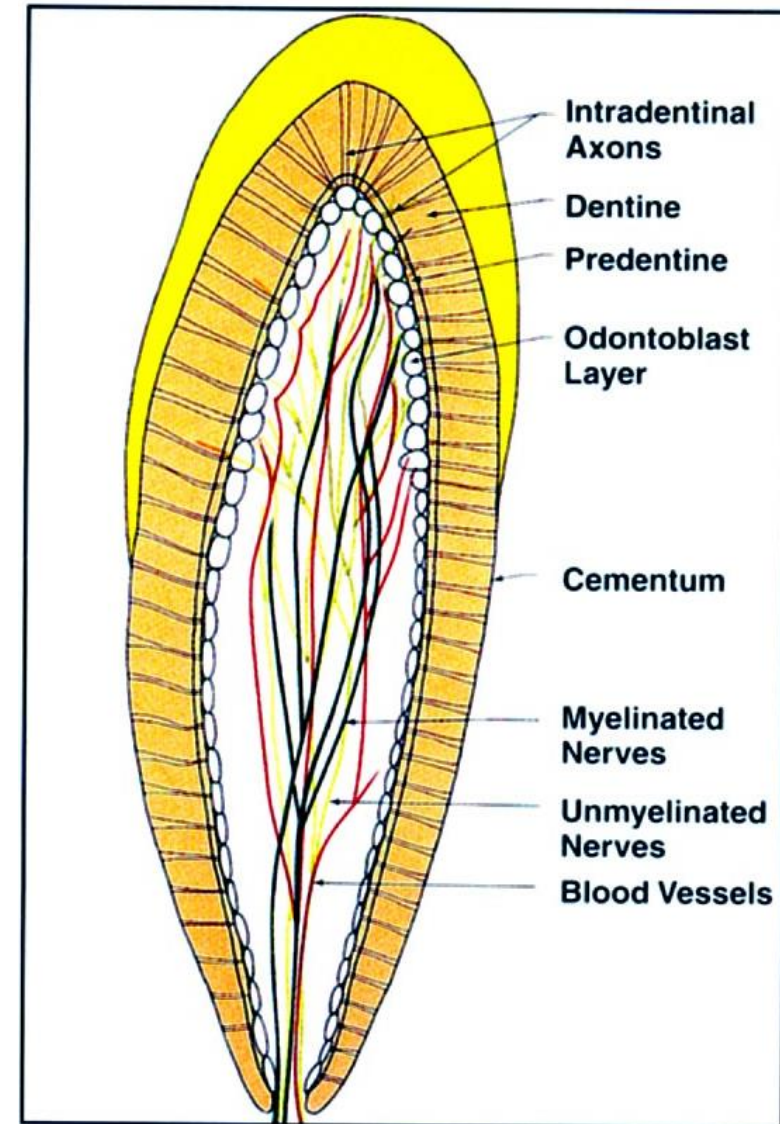
## Arteries (2-10)

- Oriented longitudinally through the center of the pulp
- Numerous side branches
- They divide into terminal networks – odontoblasts supply

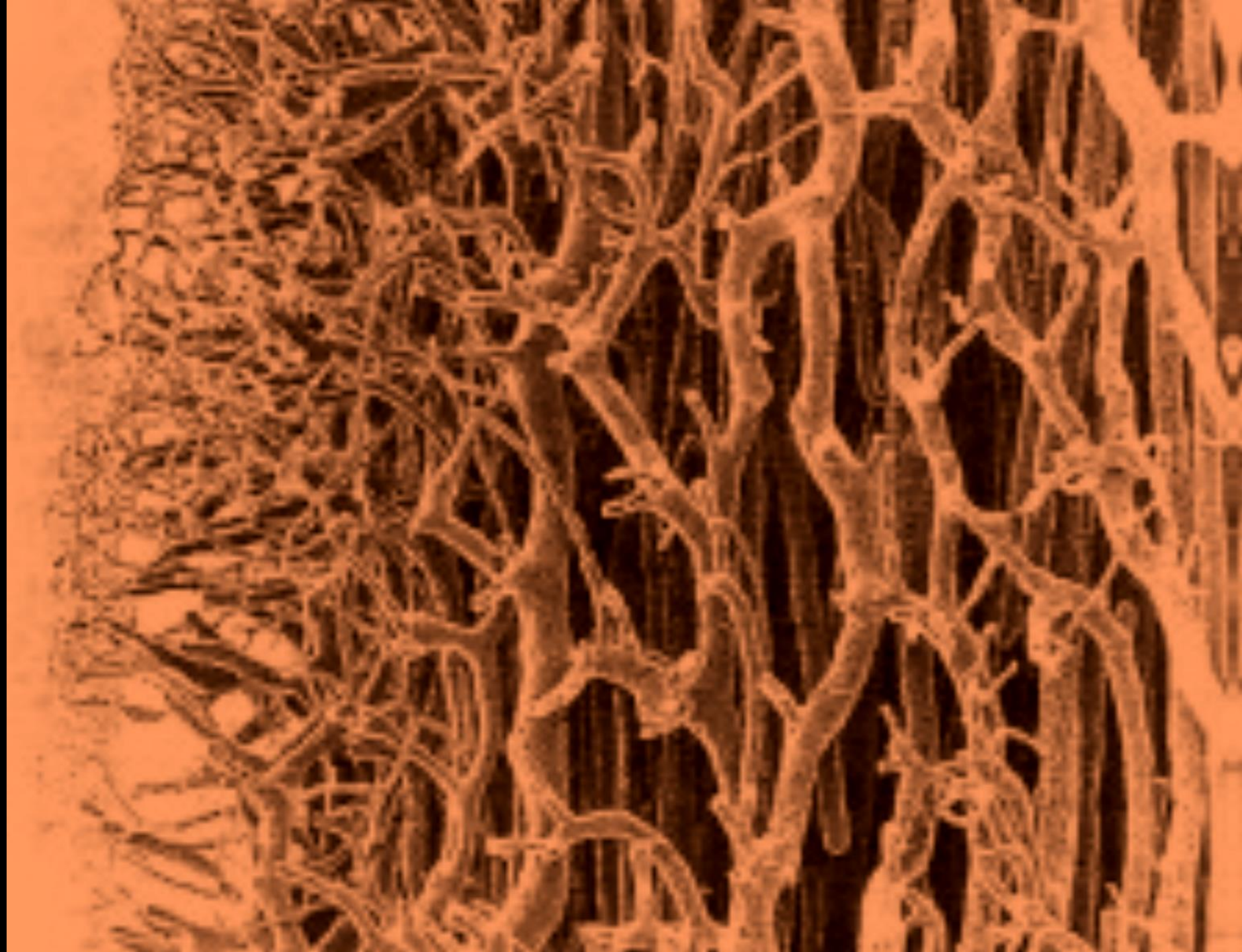
## Subodontoblastic capillary network

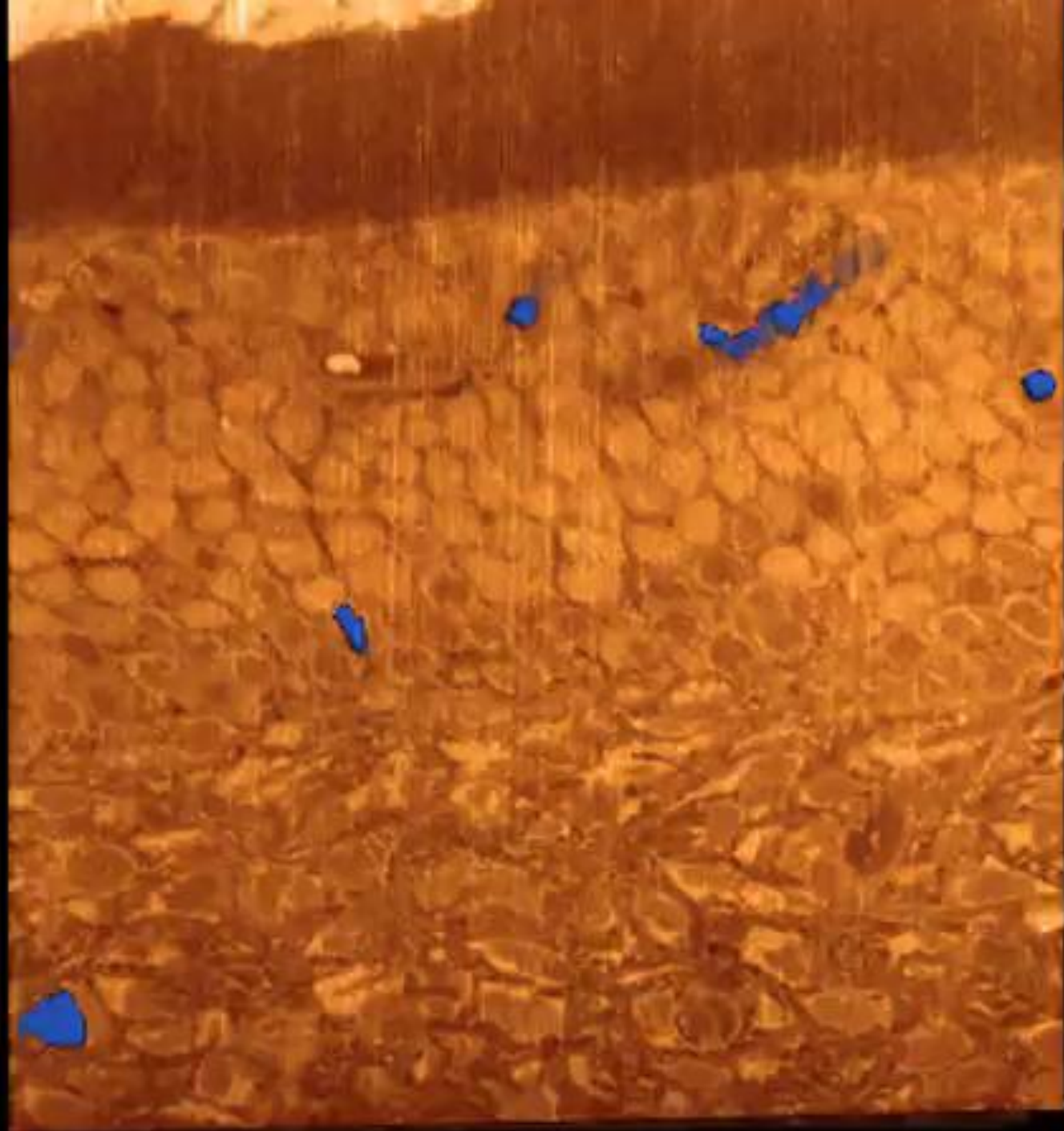
- Arteries with narrow lumen, thick wall reinforced by several layers of smooth muscle cells
- Veins and venules wall very thin, which strikingly contrasts with their wide luminosity

**Lymph circulation** begins with the lymph capillaries that connect to small lymph vessels leaving the dental pulp together with the blood and nerve vessels through the foramen of the apicis radialis dentis



32 General distribution of myelinated nerves (dark green), unmyelinated nerves (light green) and blood vessels (red) in the





## Pulp innervation

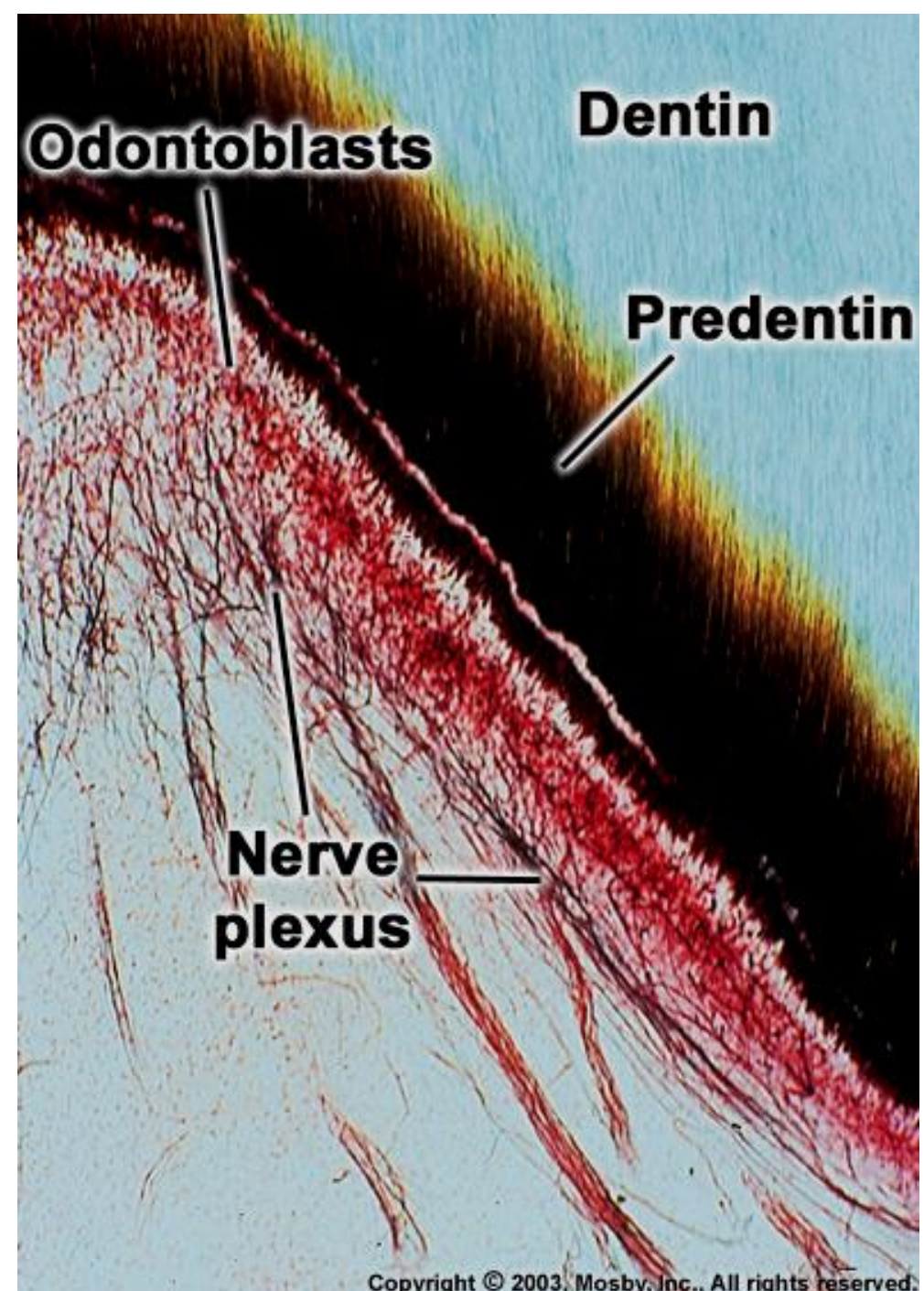
Both myelinated and non-myelinated

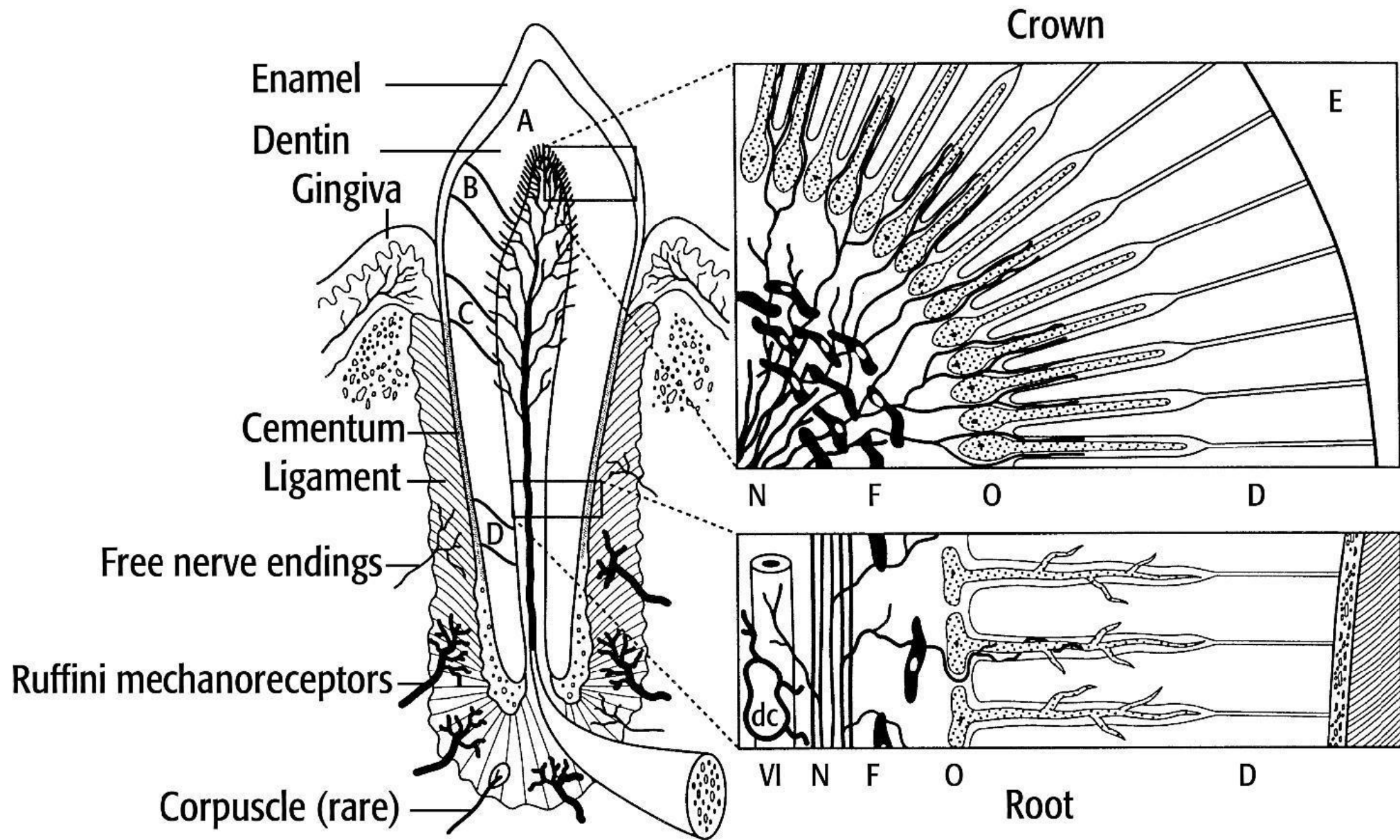
**Myelinated** nerve fibres in the dental pulp are rich in branches and reach up to the odontoblast bases under which they form a dense network:

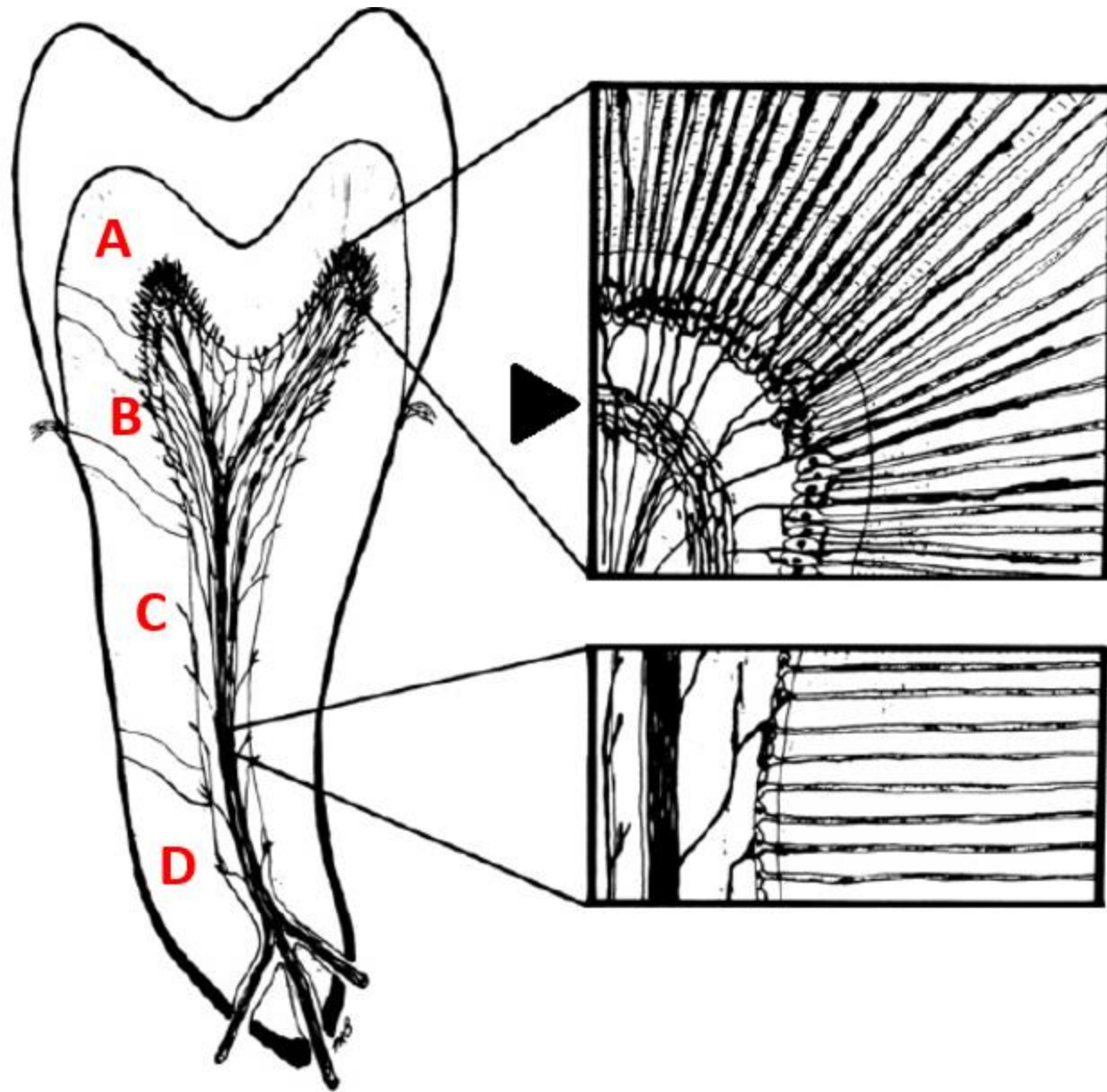
### Plexus subodontoblasticus Raschkowi

the nerve fibres ends on the bodies of the odontoblasts, some enters the predentin and dentin channels

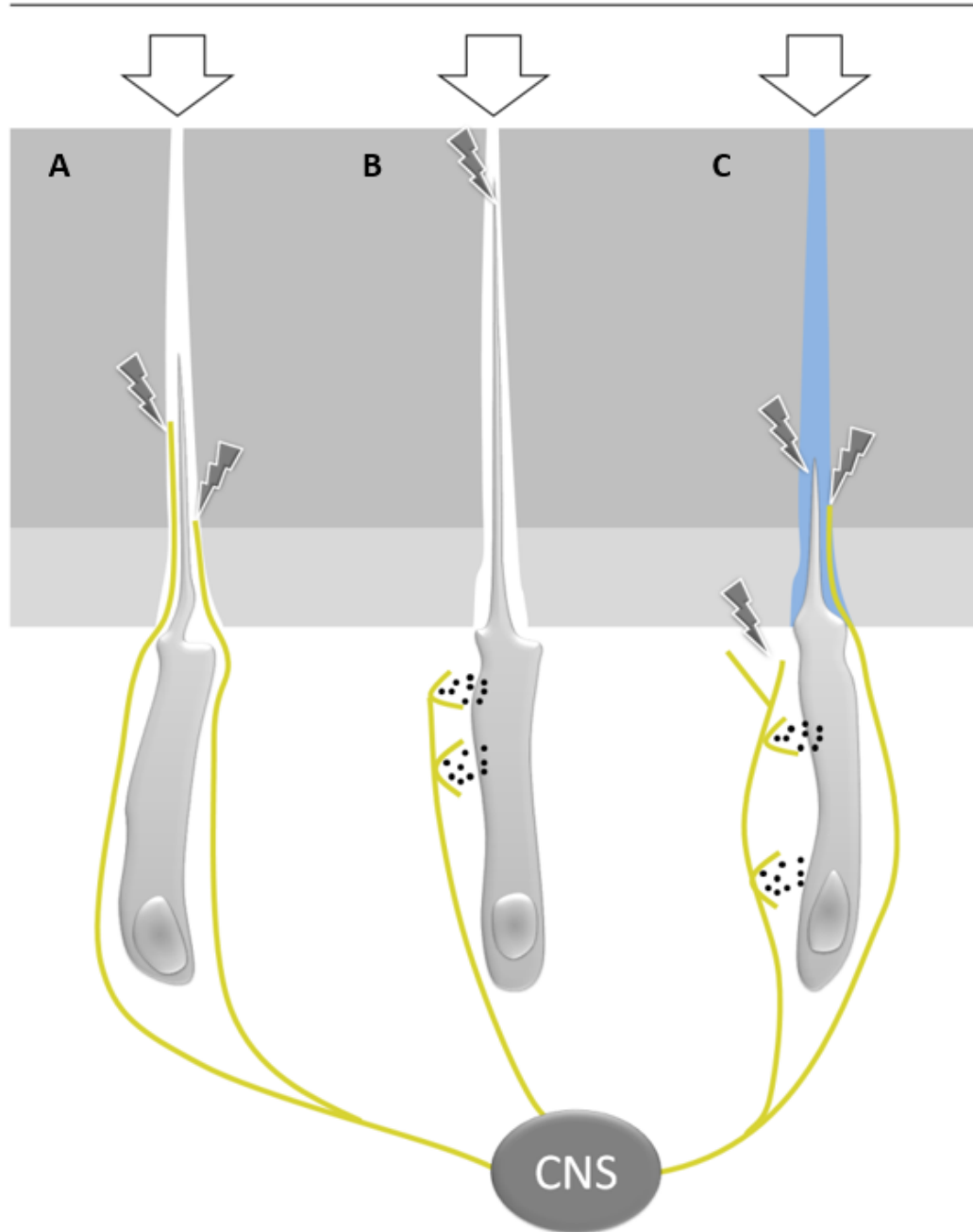
**Non-myelinated** nerve fibres innervate blood vessels in the dental pulp







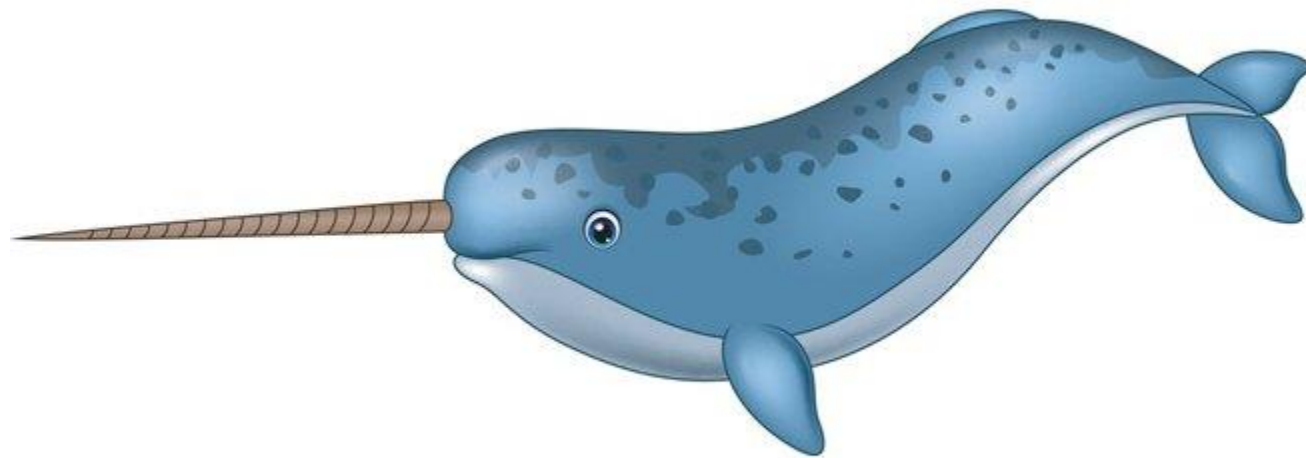
Temperature changes, mechanical or  
chemical stimuli, osmolarity changes



### Theories of dental pulp perception

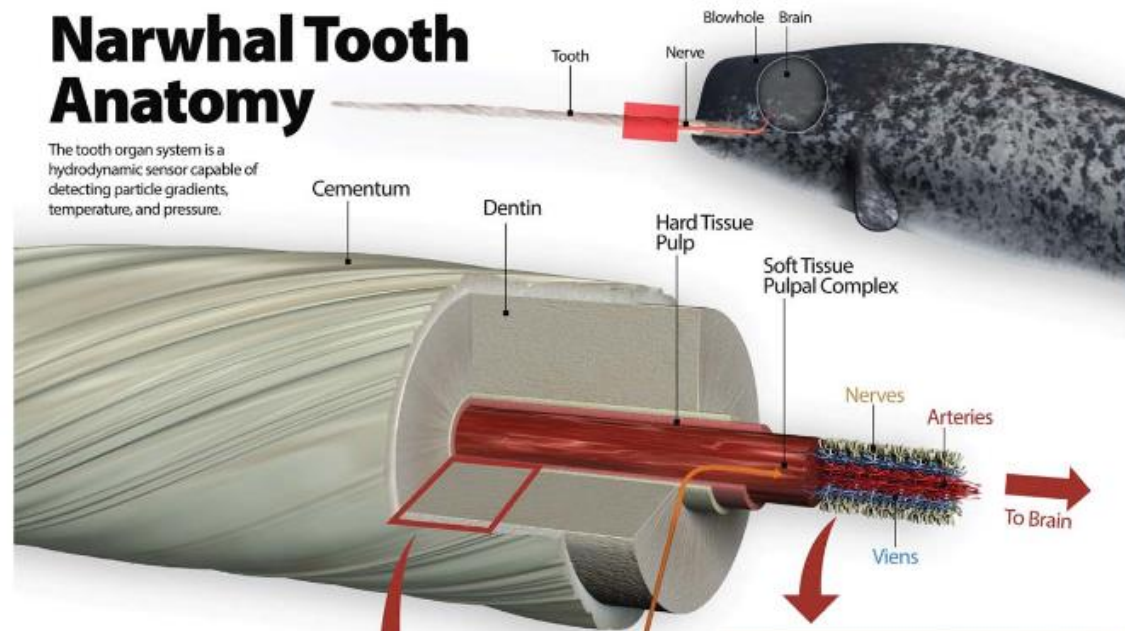
- a) Nerve endings in pulp and dentin
- b) Odontoblasts acting as sensory cells
- c) Hydrodynamic theory



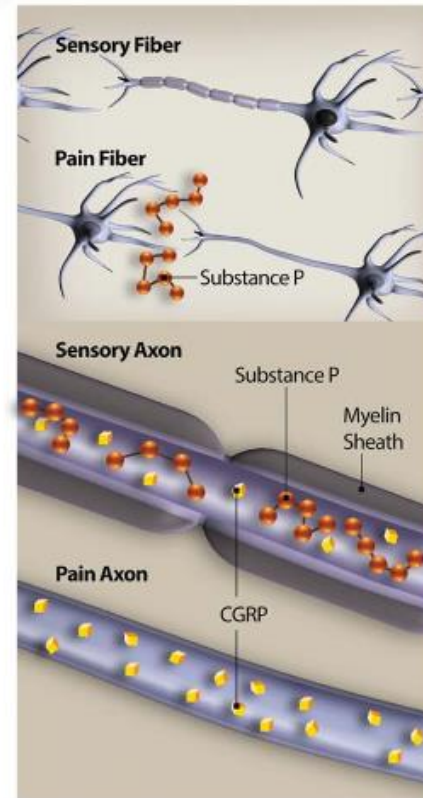
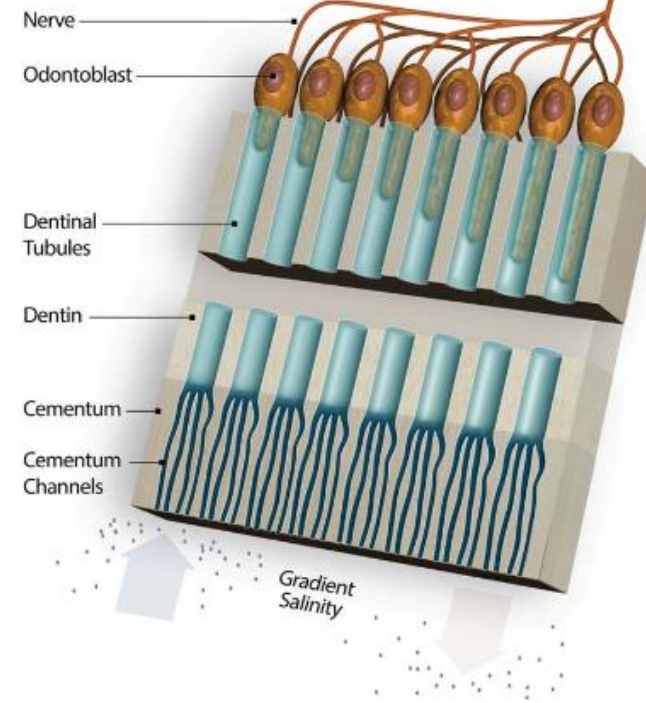


# Narwhal Tooth Anatomy

The tooth organ system is a hydrodynamic sensor capable of detecting particle gradients, temperature, and pressure.



## Hard Tissue



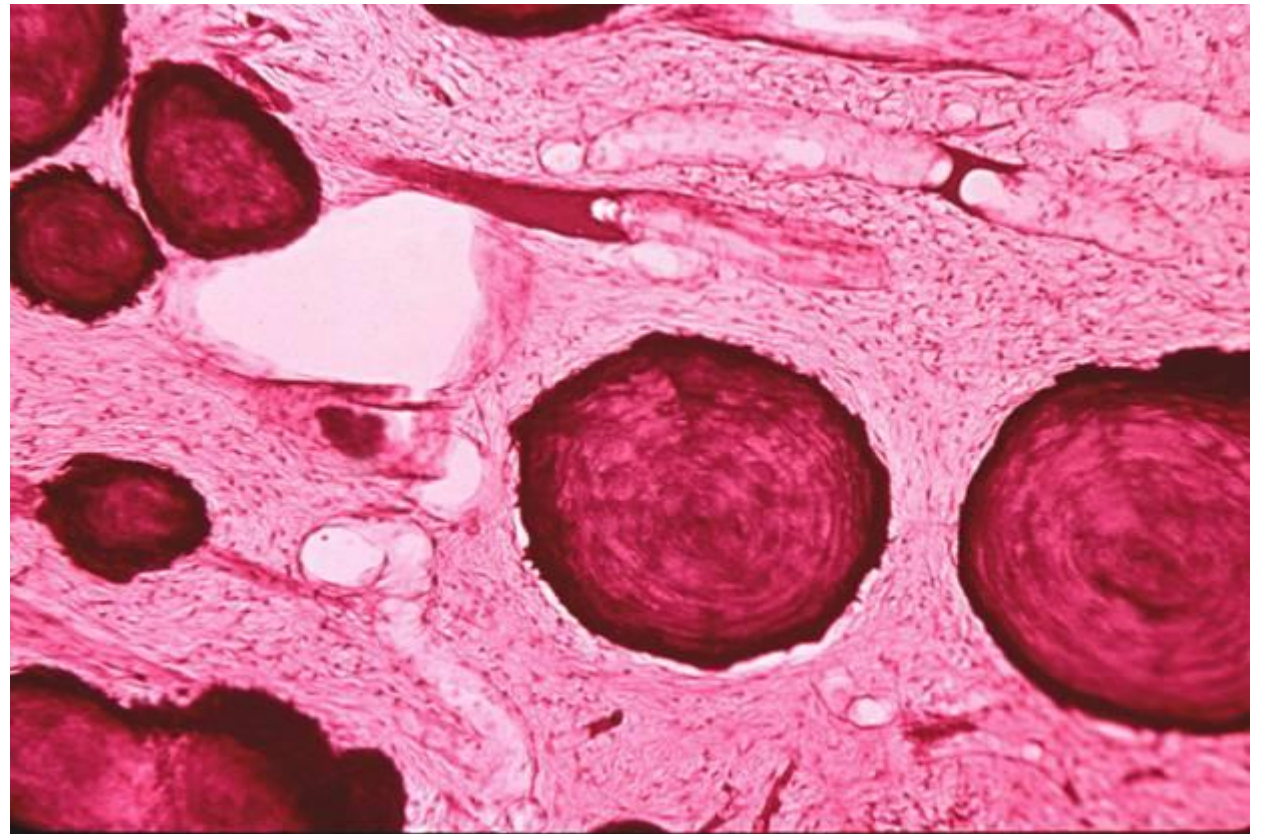
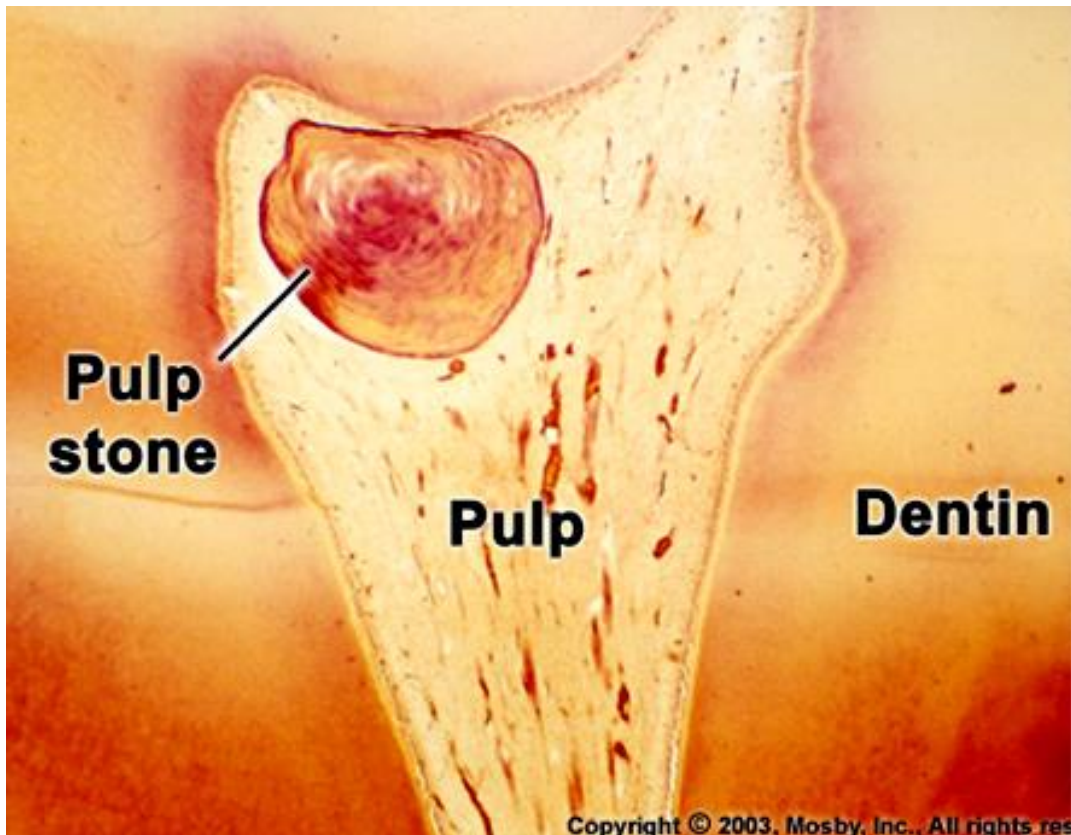
## Pulp changes during aging

- Fastest development immediately after pruning
- Age-related changes: chemical composition, structure and volume

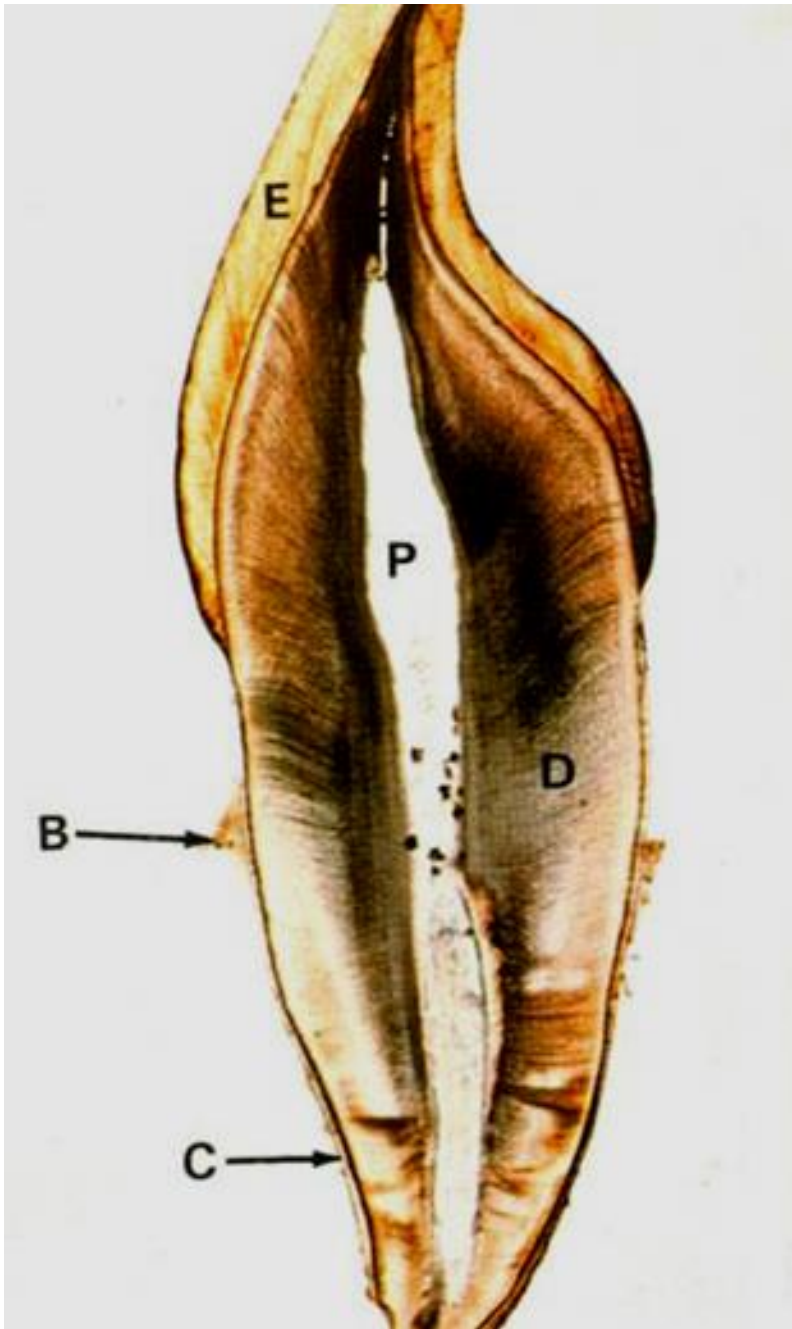
**Chemické složení** – amorphous matter loses its mucilaginous character

**Structure** – cell loss, increase of fibres - transformation into dense collagenous connective tissue

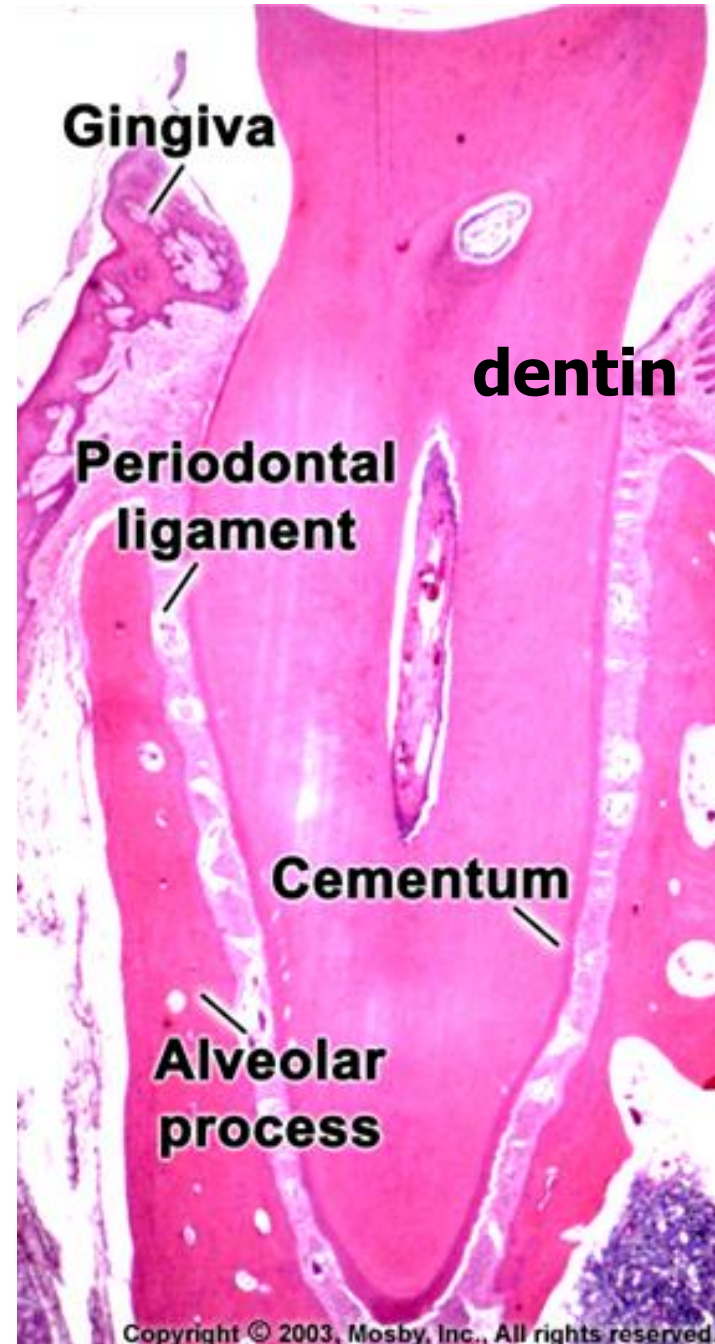
**Volume** – loss due to deposition of secondary and tertiary dentin and denticles formation



**DENTIN**

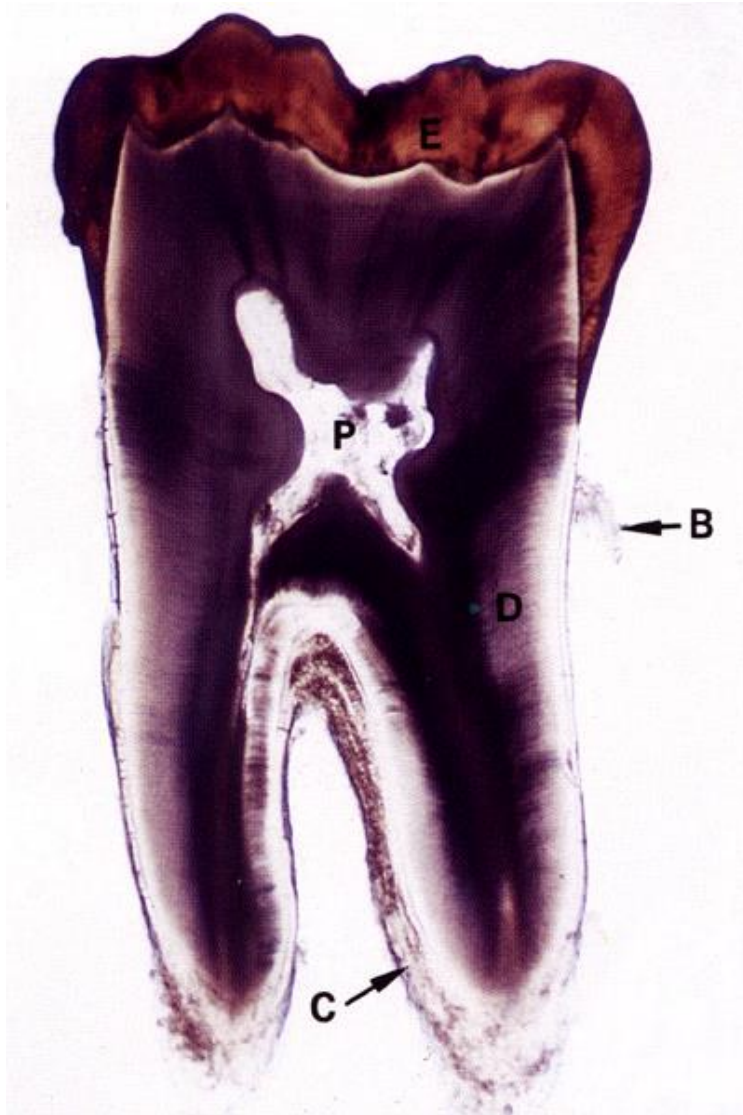


Podélný výbrus



Dekalcifikovaný řez

# Microstructure of dentin, dentin types, clinical significance



The most abundant dental tissue  
Living tissue - contains parts of living cells  
No blood vessels nor bone-lamellar structure  
Derives from ectomesenchyme

**Functional and developmental connection with the pulp  
(dentin-pulp complex)**

## Physical properties

Ivory color

Harder than bone or cementum, but softer than enamel

Refractive index 1.62 (same as enamel)

Specific weight 2.14 g/cm<sup>3</sup> (lower than enamel)

Flexible and permeable (permeability decreases with age)

Thickness 2-4 mm (primary dentition half)

## Comparison of the hard tooth tissues (and lamellar bone)

	Enamel	Dentin	Cementum	Lamellar bone
<b>Colour</b>	White (to light blue)	Ivory	Brown-yellow	Brown-yellow
<b>Inorganic (%)</b>	96 (86)	70 (45)	61 (33)	45 (23)
<b>Organic (%)</b>	1 (2)	20 (30)	27 (31)	30 (37)
<b>H<sub>2</sub>O (%)</b>	3 (11)	10 (25)	12 (36)	25 (40)
<b>Collagen fibres</b>	NO	YES (perpendicular to the dental tubules)	YES (in all directions)	YES (same direction in lamellas)
<b>Cells</b>	<b>Ameloblasts</b> (missing in adults)	<b>Odontoblasts</b> (on the pulpal side of dentin)	<b>Cementoblasts</b> (cementocytes)	<b>Osteoblasts</b> osteocytes
<b>Blood vessels</b>	NO	NO	NO	YES (in Haversian canals)
<b>Nerves</b>	NO	YES (on entry of dental tubules)	NO	YES (in Haversian canals)

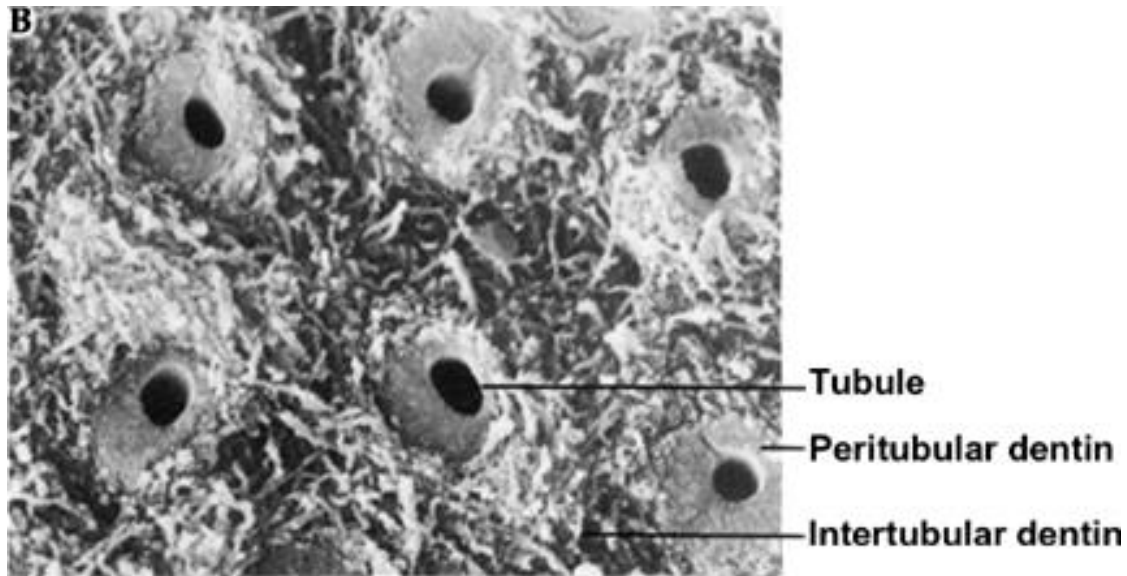
# Dentin matrix

Consists of collagen fibrils (collagen type I) forming bundles

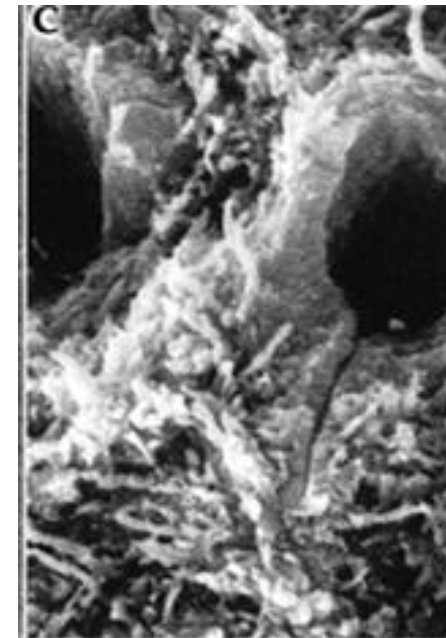
The fibres run parallel to the tooth surface from the root tip to the crown (perpendicular to the the dentin tubules)

Amorphous matrix - glycosaminoglycans, proteoglycans and lipids, impregnated with hydroxylapatite crystals

In the **tubular dentinal matrix, the collagen fibers are missing**, contain more hydroxylapatite crystals, compact appearance, about 15% harder than the matrix between the channels



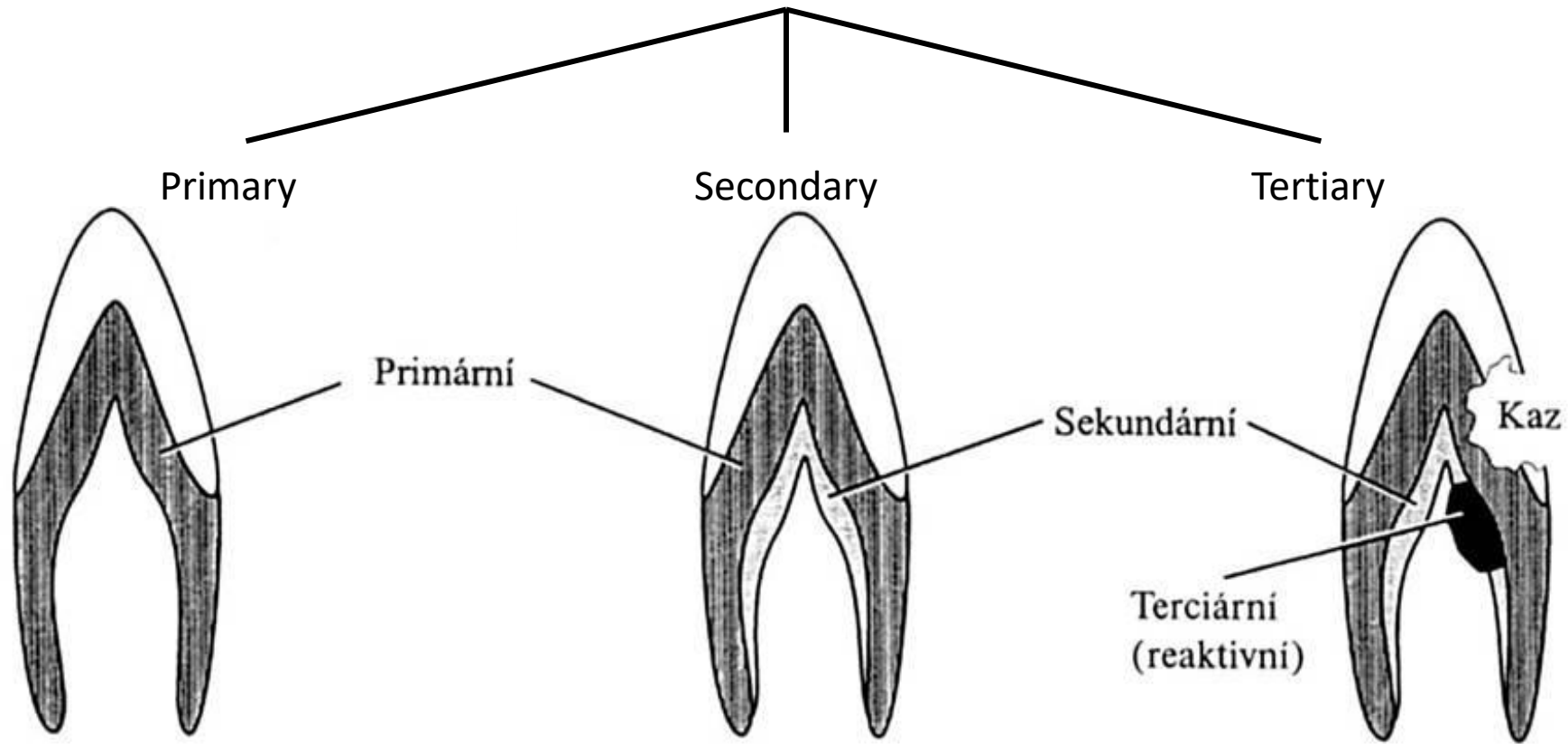
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# Dentin types



## Secondary dentin

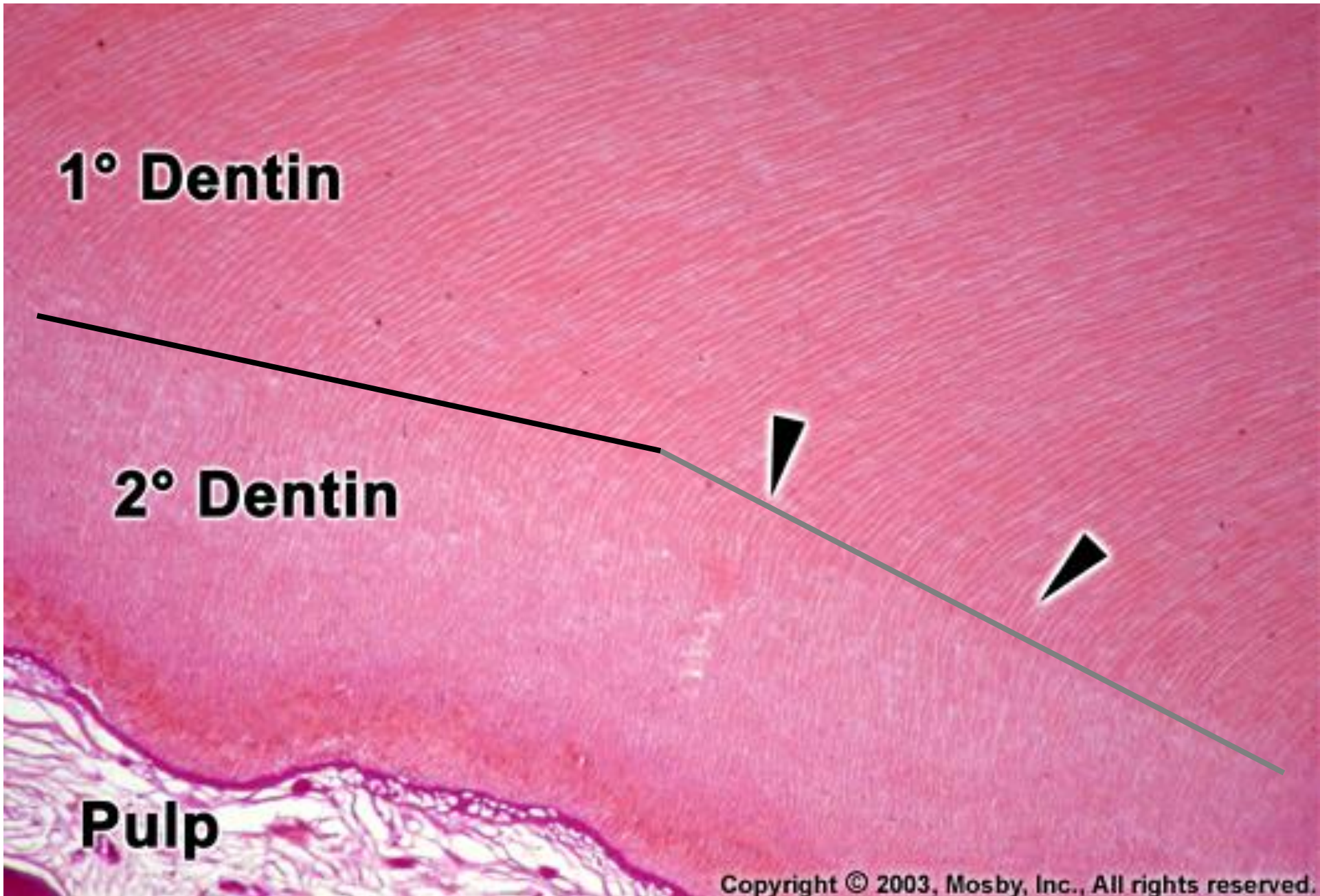
Laid down **after the root growth is finished**, when the crowns have reached the occlusal plane and the teeth are functionally loaded

### Only for permanent dentition teeth

Stored slowly throughout the whole existence of a permanent tooth.

Can be separated from the primary dentin by a more pronounced incremental line

Secondary dentine deposition results in a reduction in the pulpal cavity

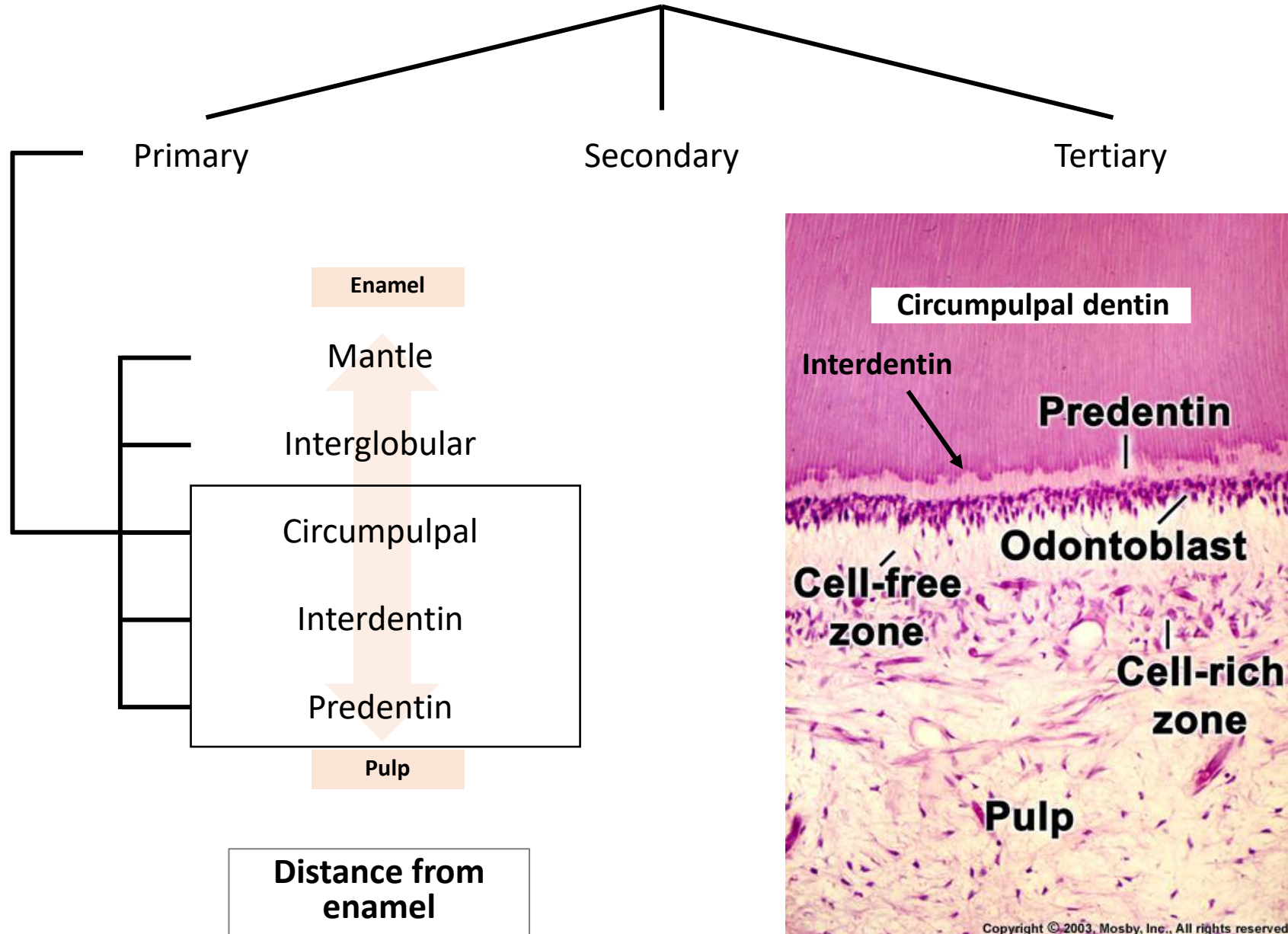


**1° Dentin**

**2° Dentin**

**Pulp**

# Dentin types



## Circumpulpal dentin

90 % of all dentin

Contains dentinal tubules

## Interdentin

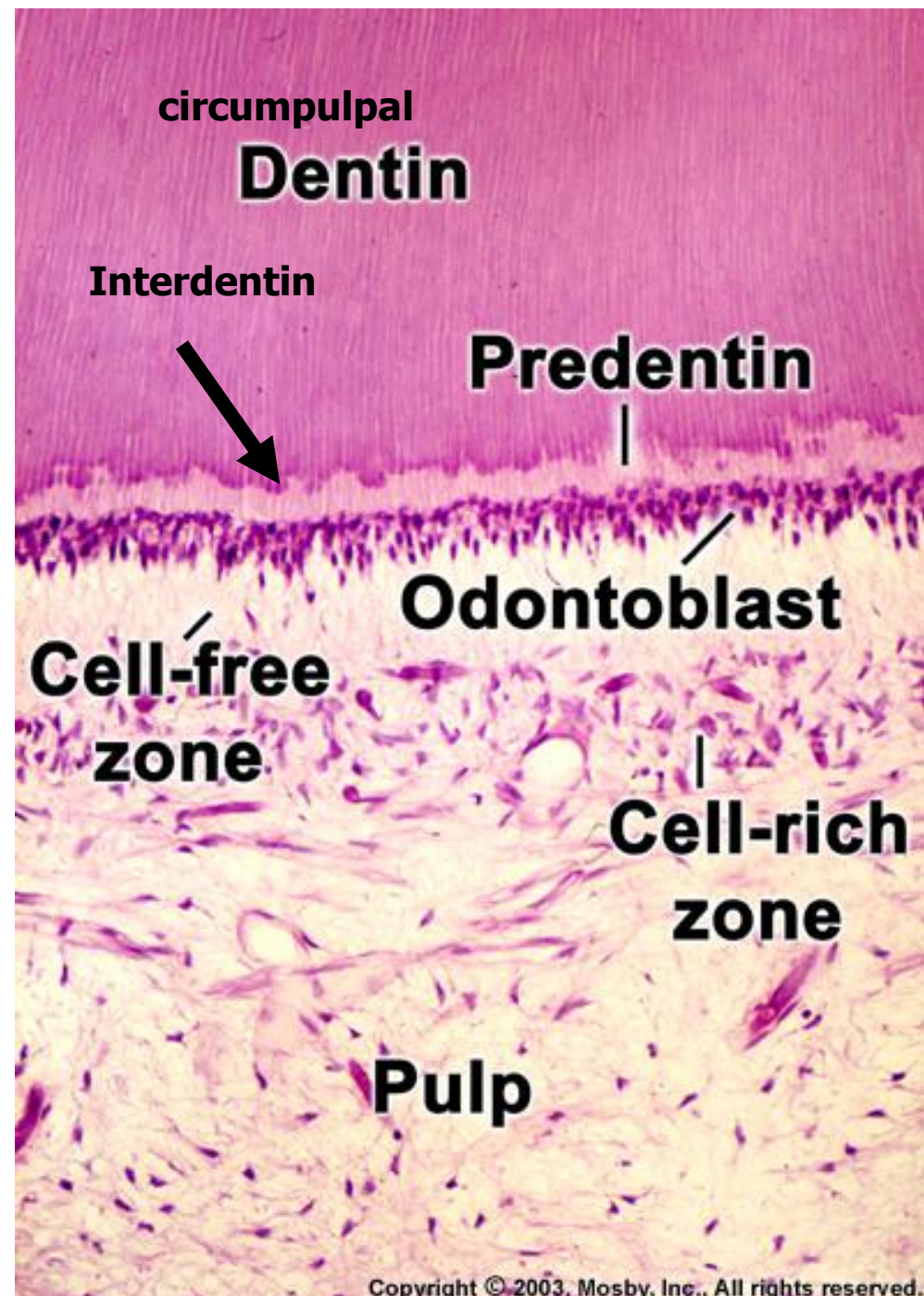
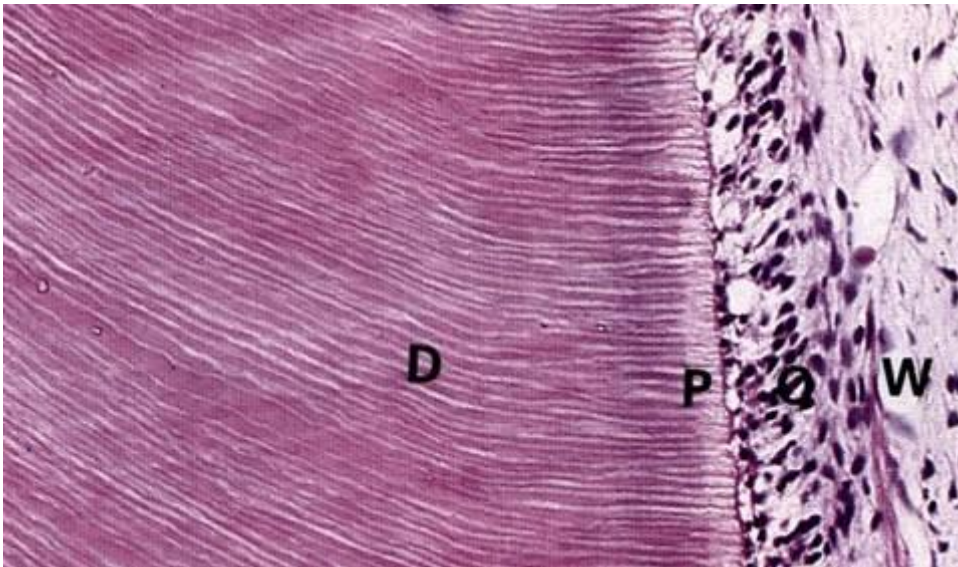
Thin layer between circumpulpal dentin and predentin where dentin mineralization starts

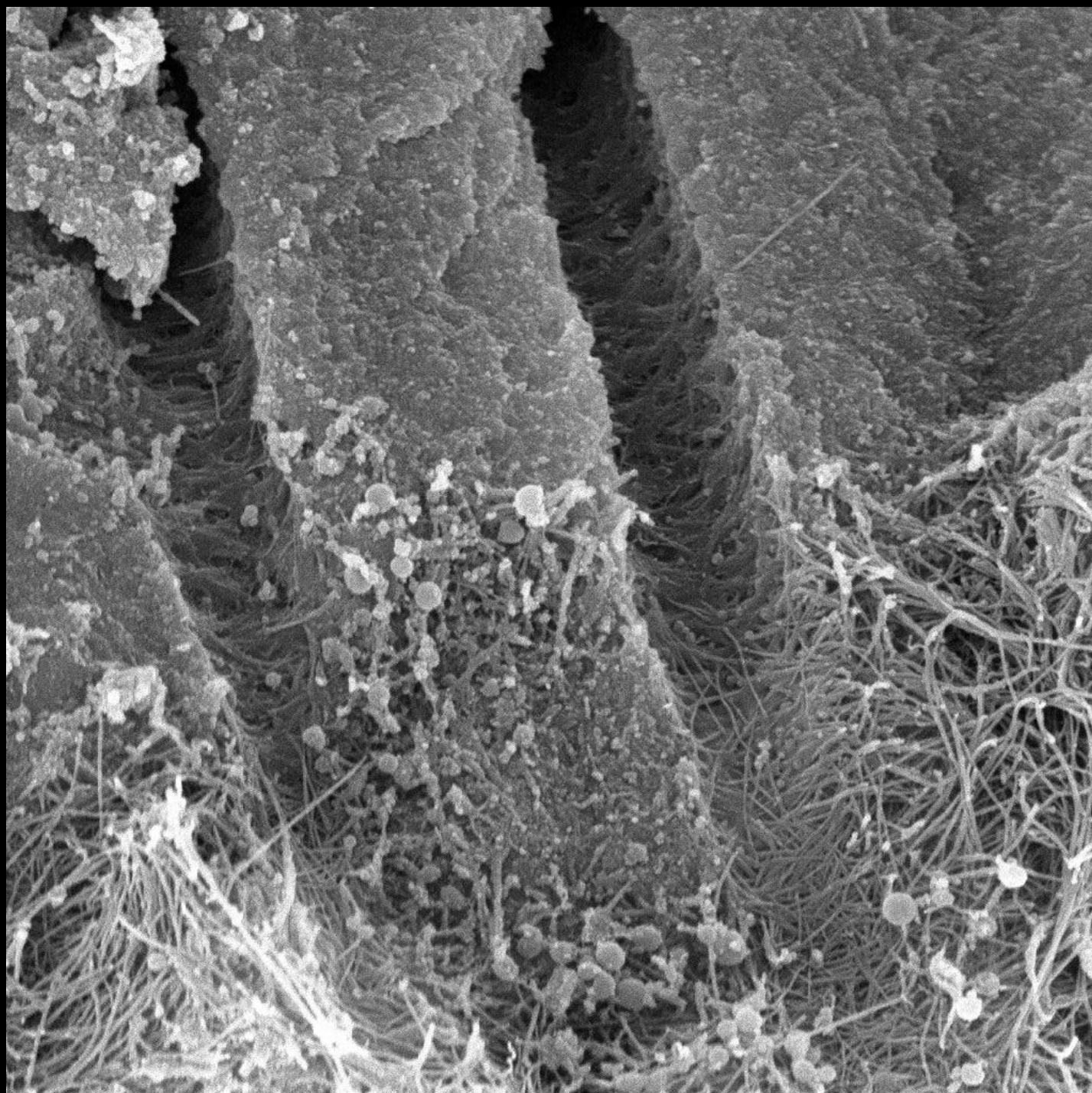
## Predentin

Non-calcified layer near odontoblasts

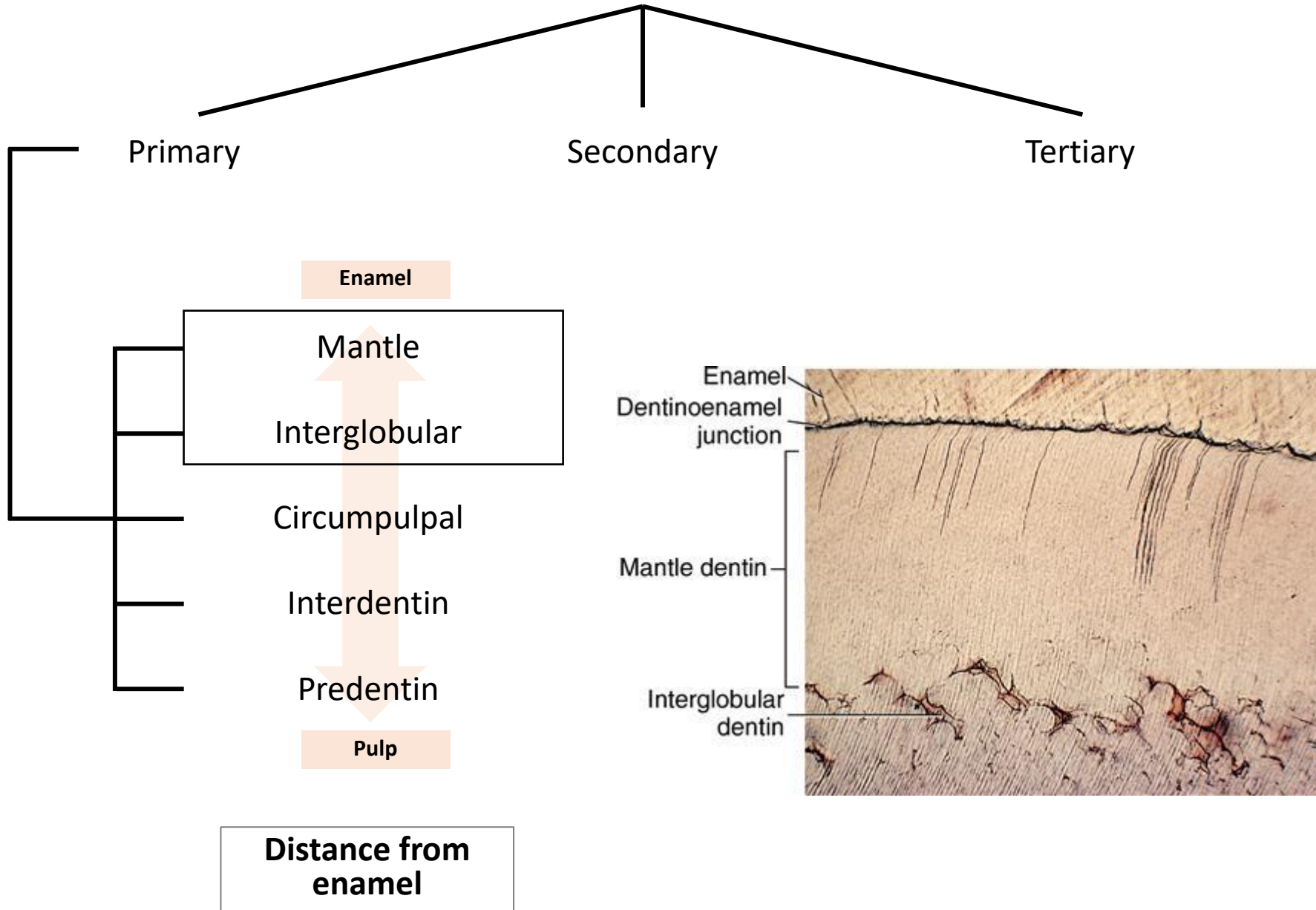
Forms a collagen skeleton for mineralization

In both temporary and permanent teeth





# Dentin types



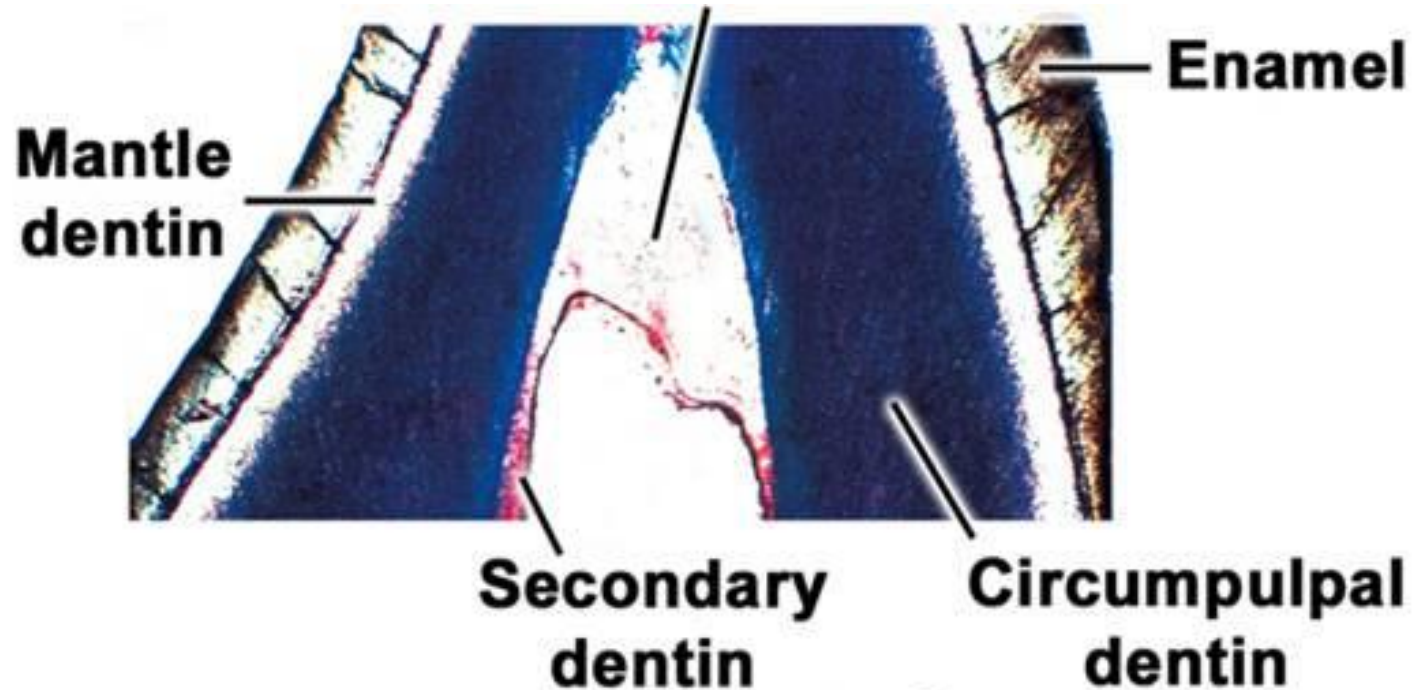
## Mantle dentin

Firstly-formed dentin, **thickness** around **30 um**

Variable mineralization

Collagen fibres oriented perpendicular to the DEJ surface (Korff bundles)

Branched terminal parts of dentin tubules terminates here



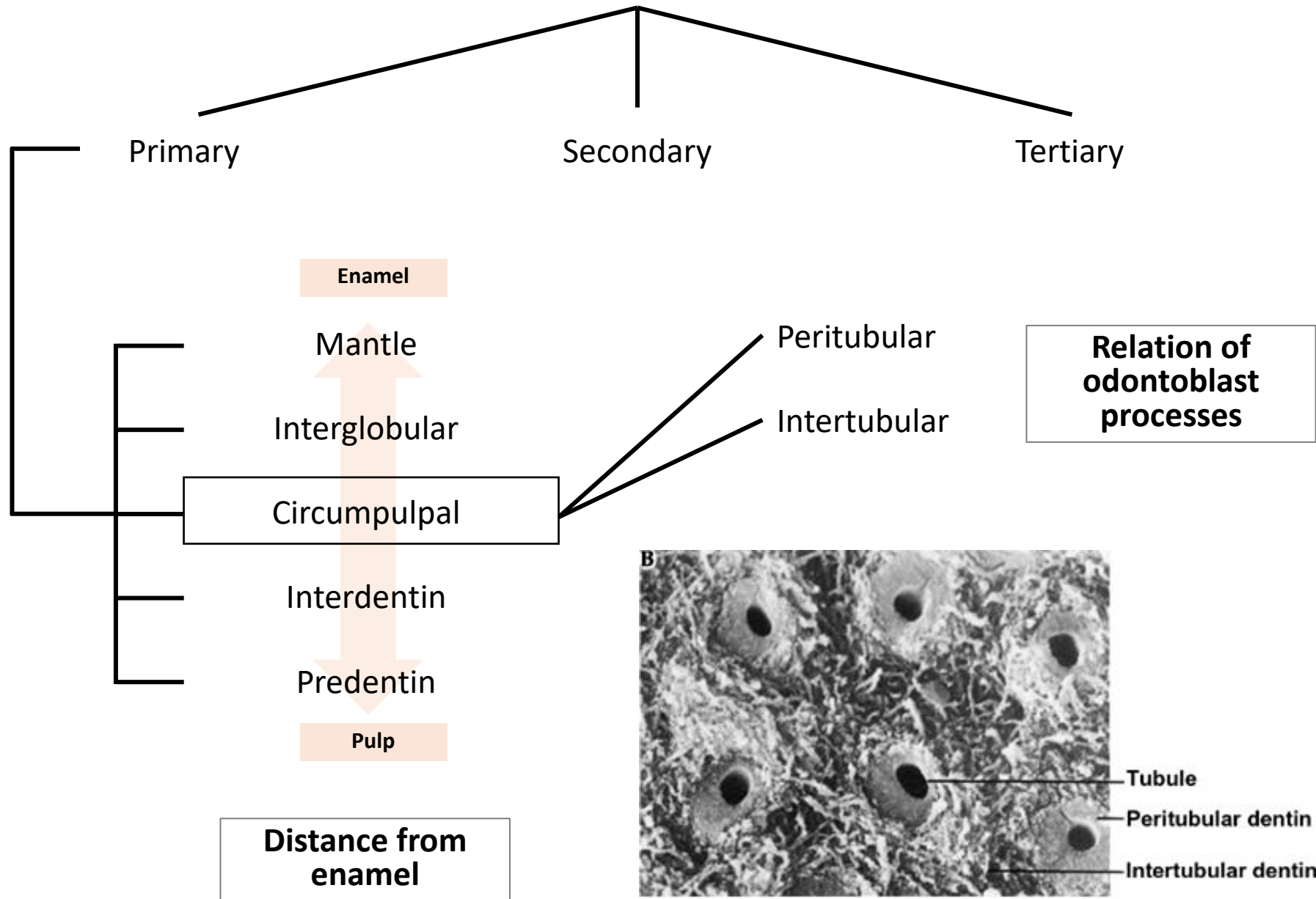
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## Interglobular dentin

Imperfectly calcified dentin at the interface of mantle and circumpulpal dentin

Fusion of dentin globules is impaired

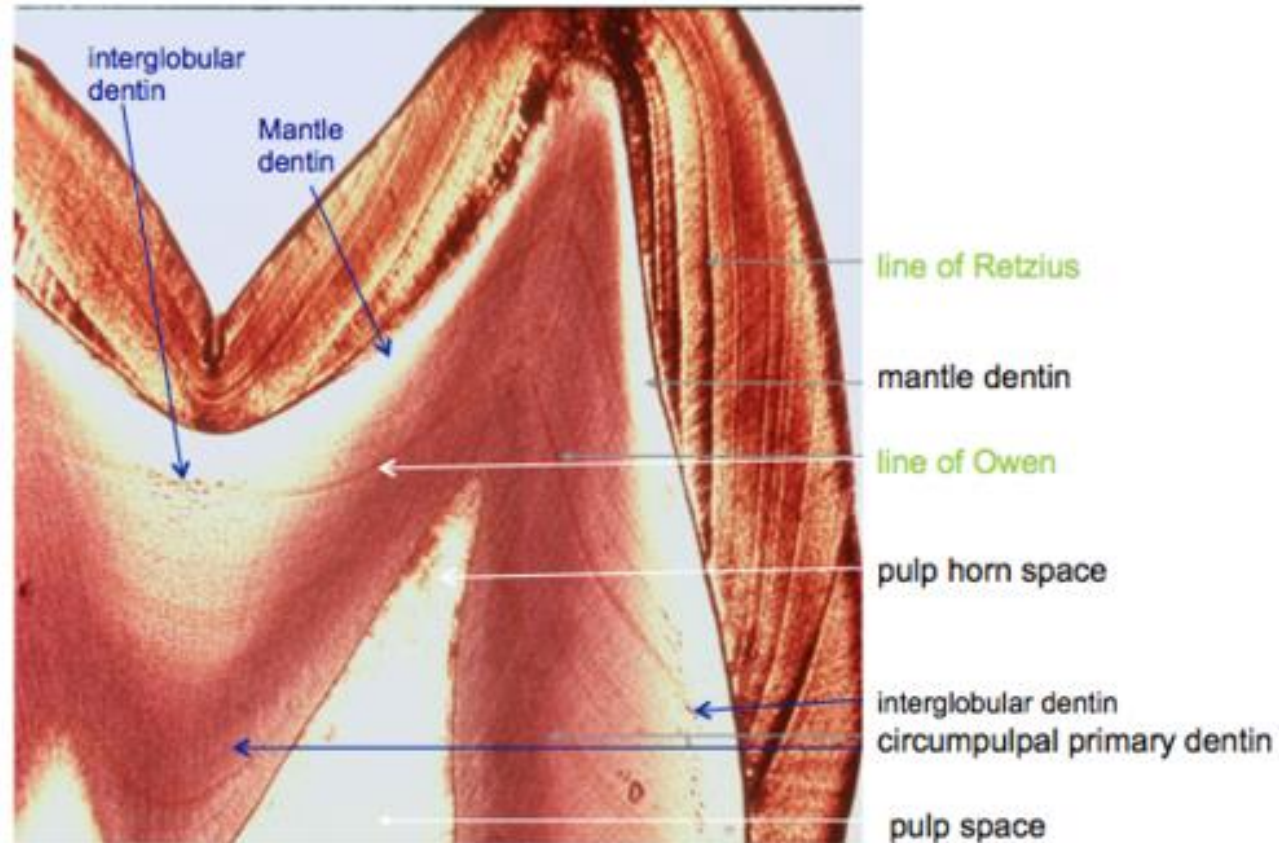
# Dentin types

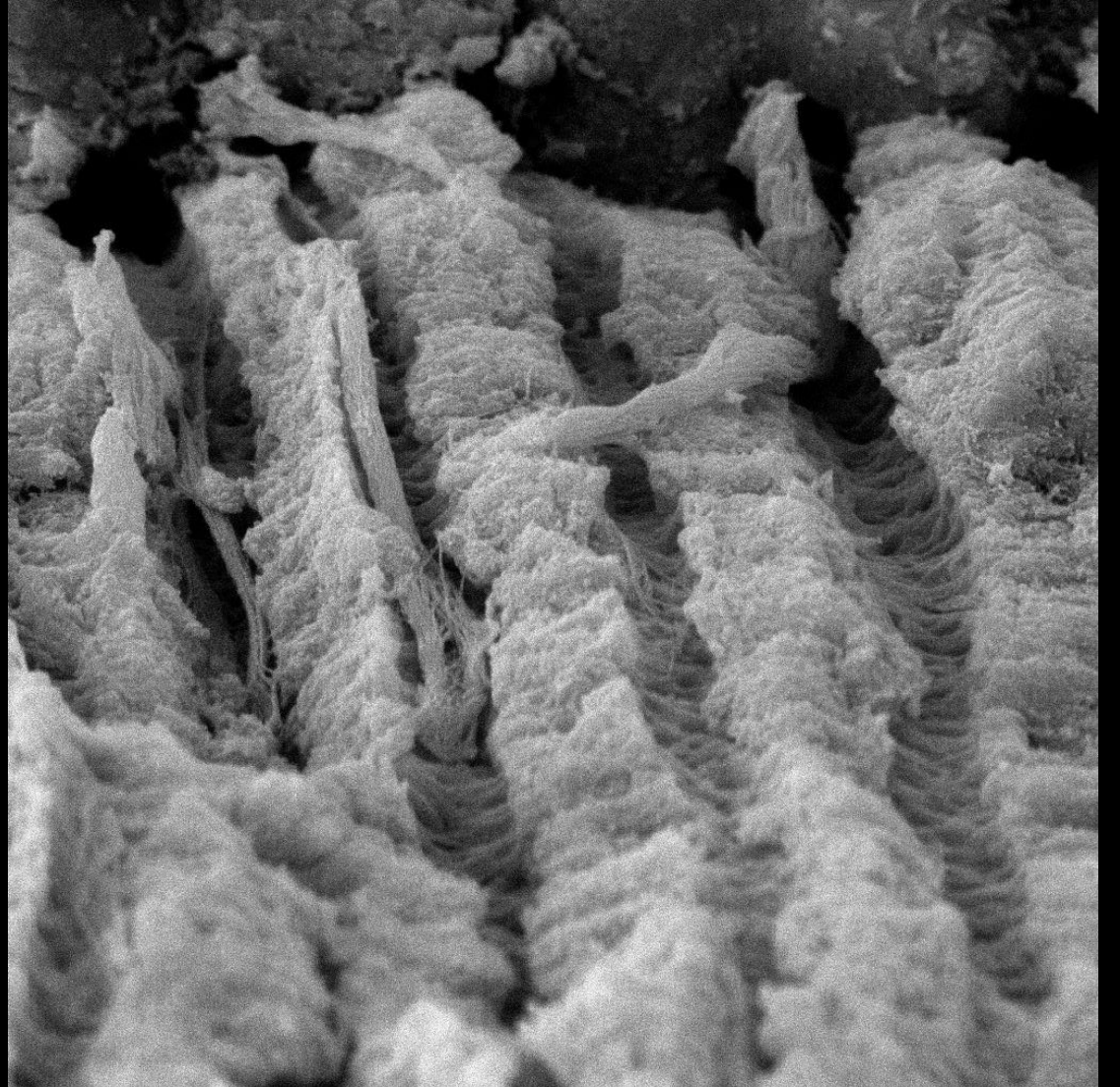
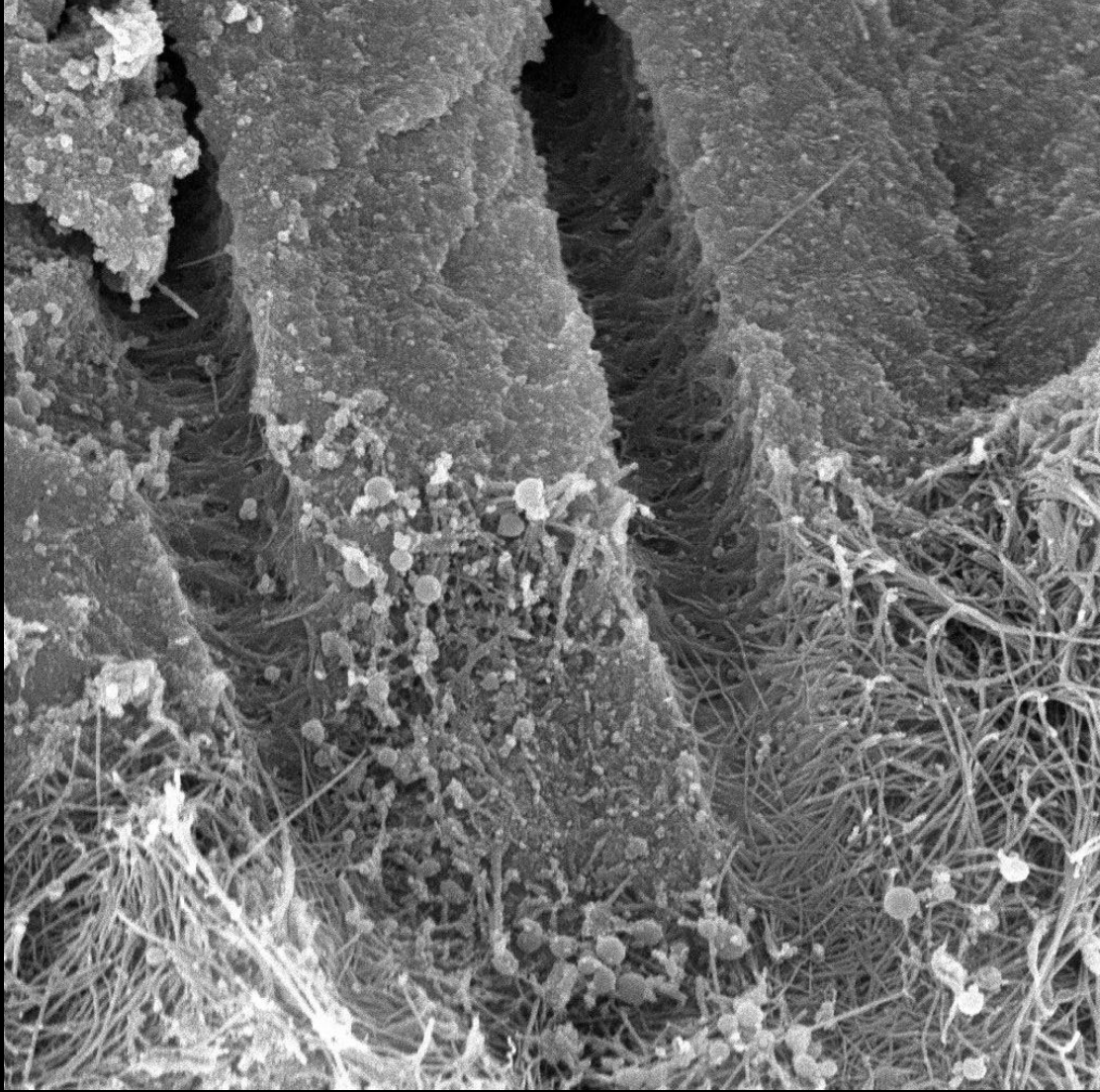


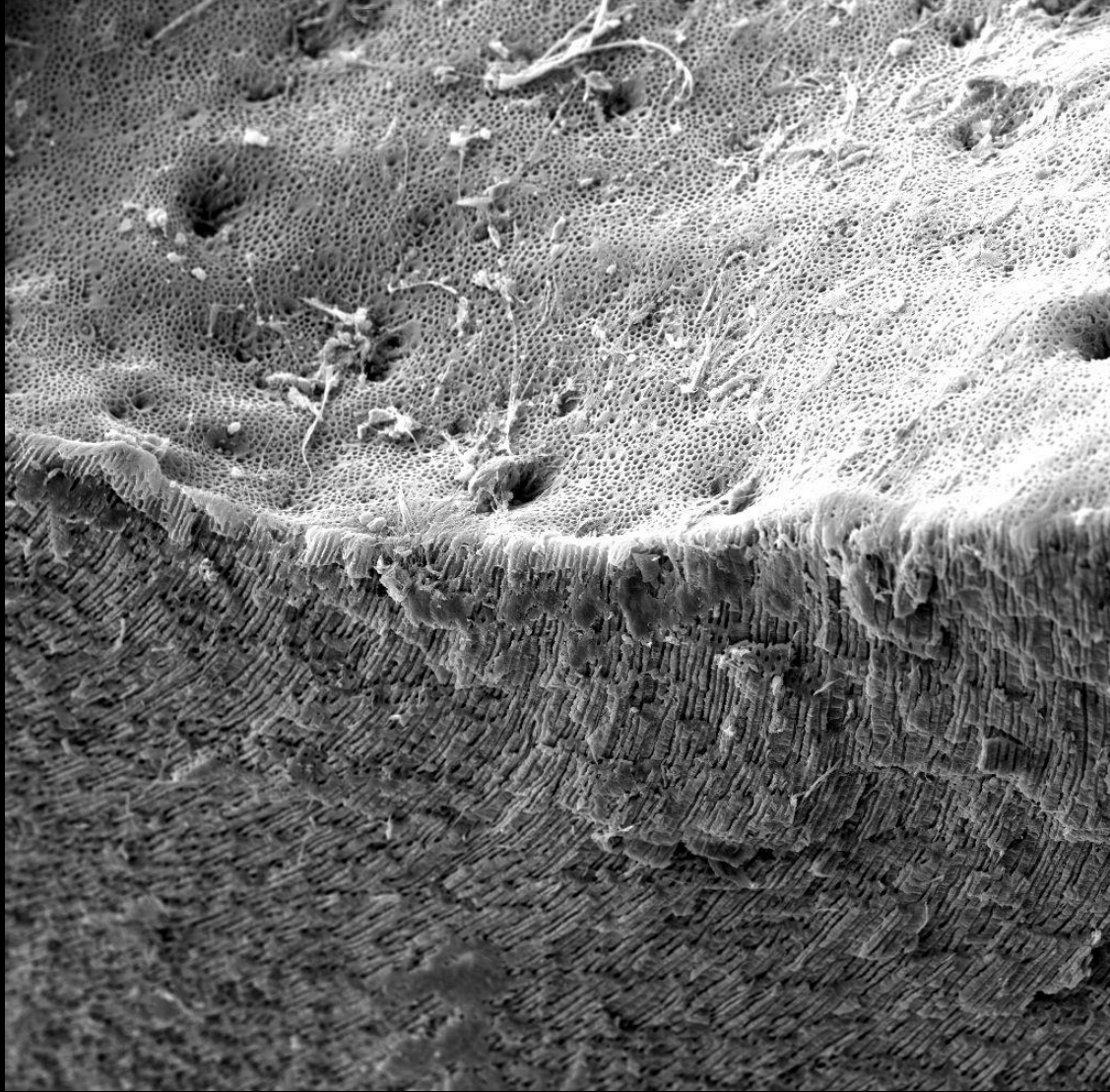
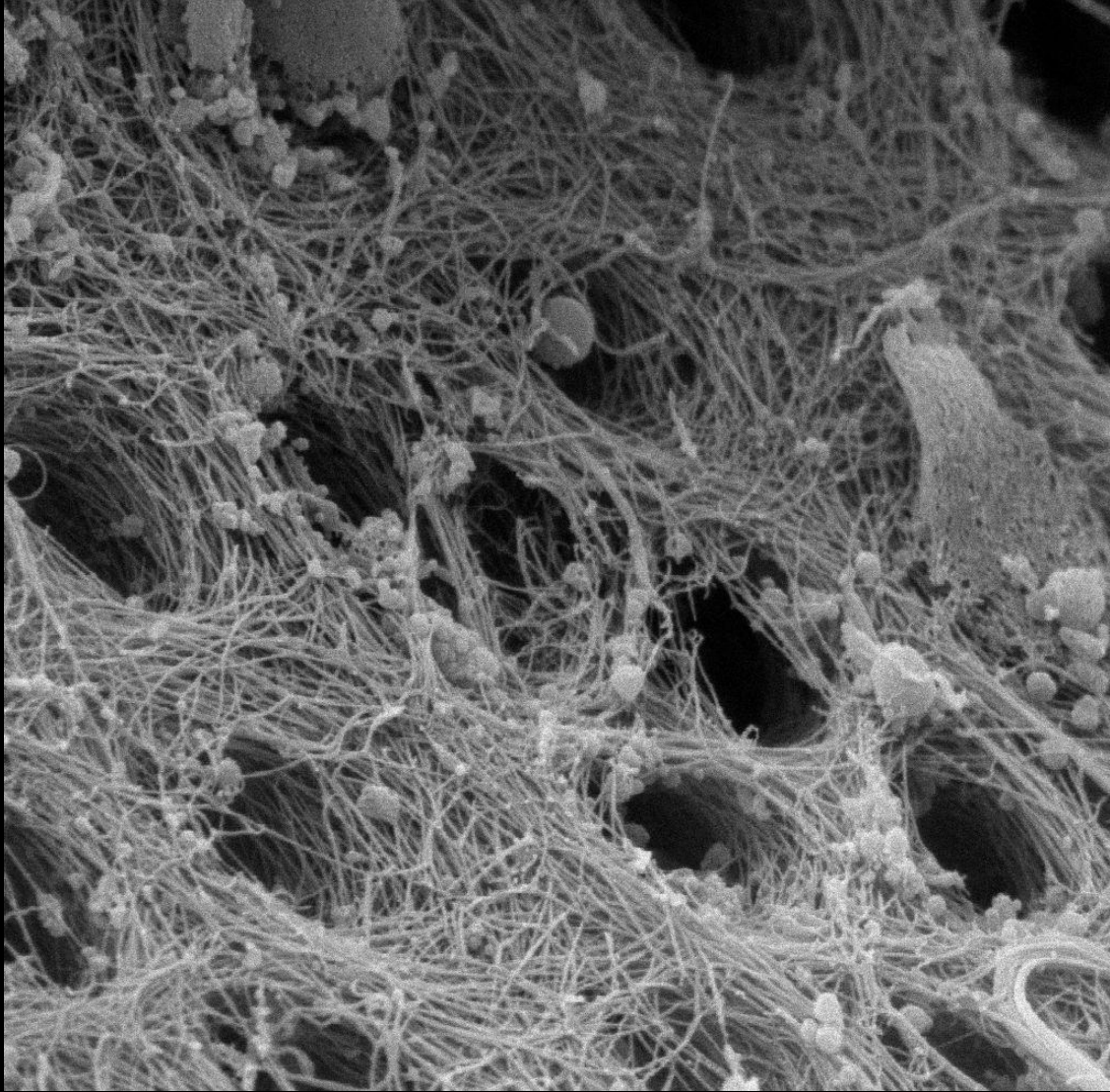


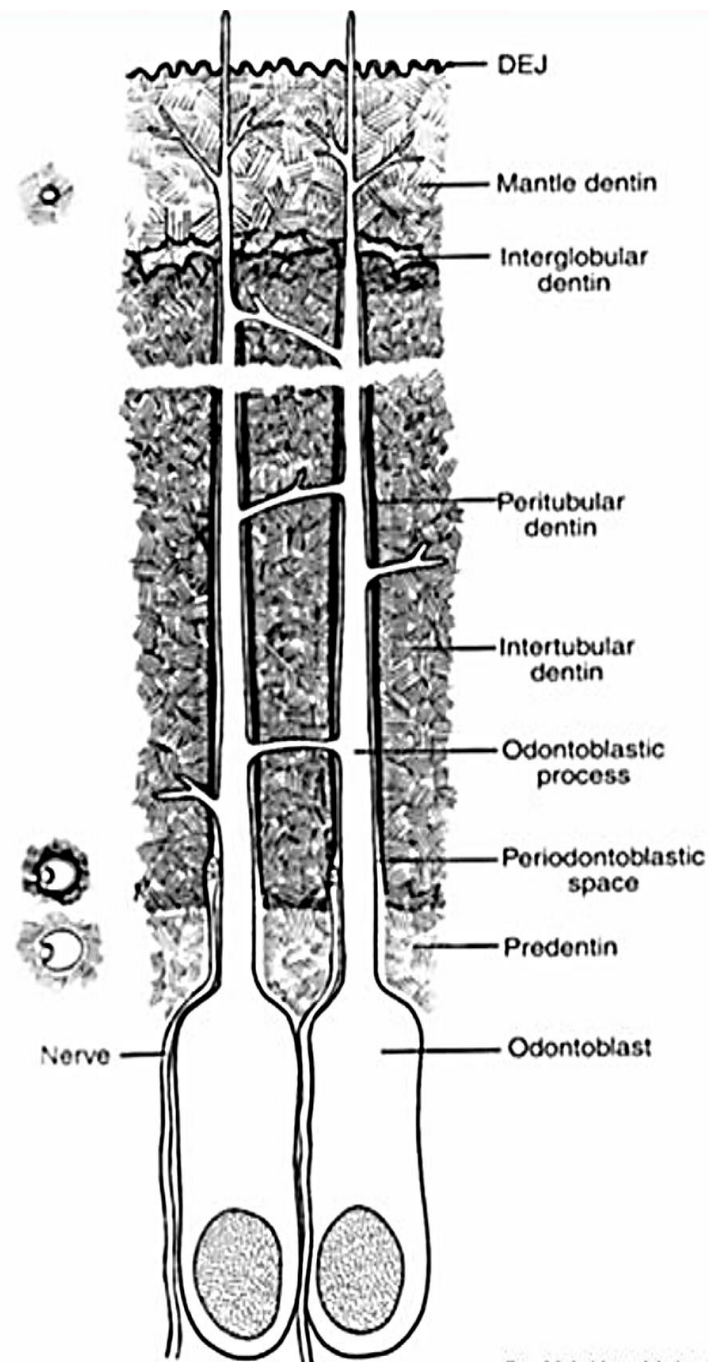
## Circumpulpal dentin (*von Ebner*)

- Collagen fibres run obliquely to perpendicular to the course of tubules
- Mineralization is globular.
- Only minor branching of the dentinal tubules here.

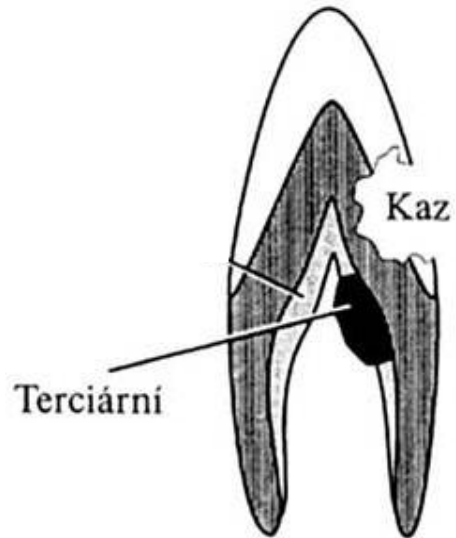
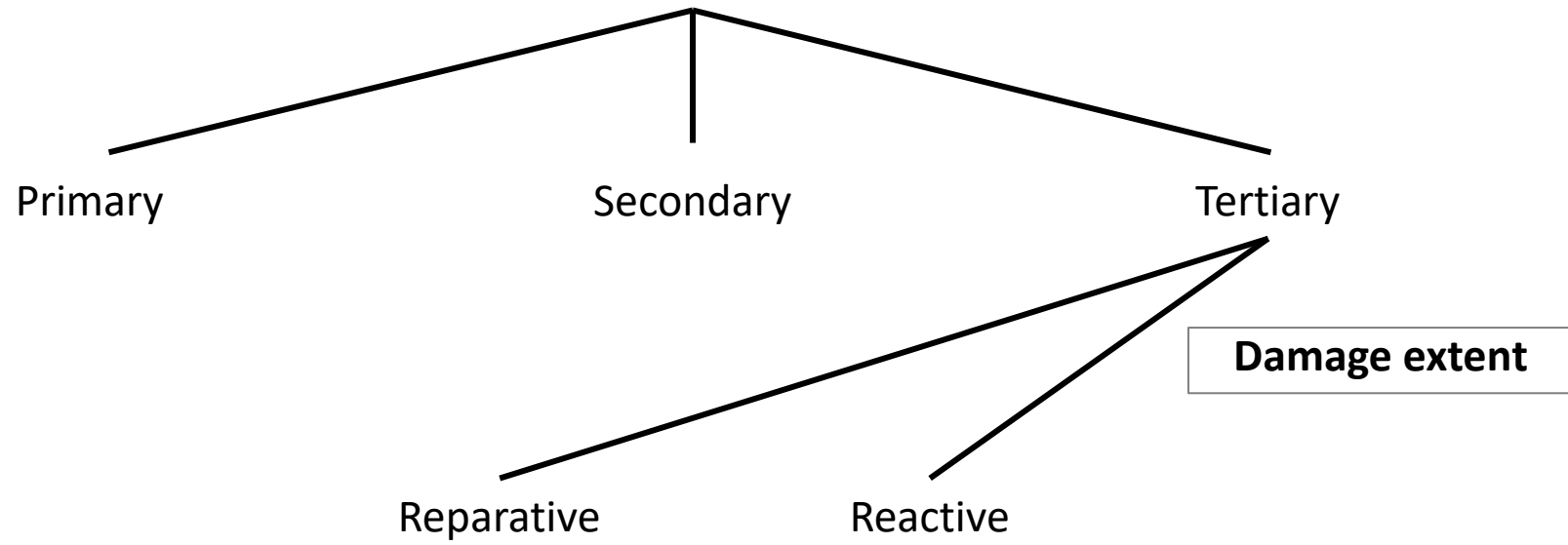




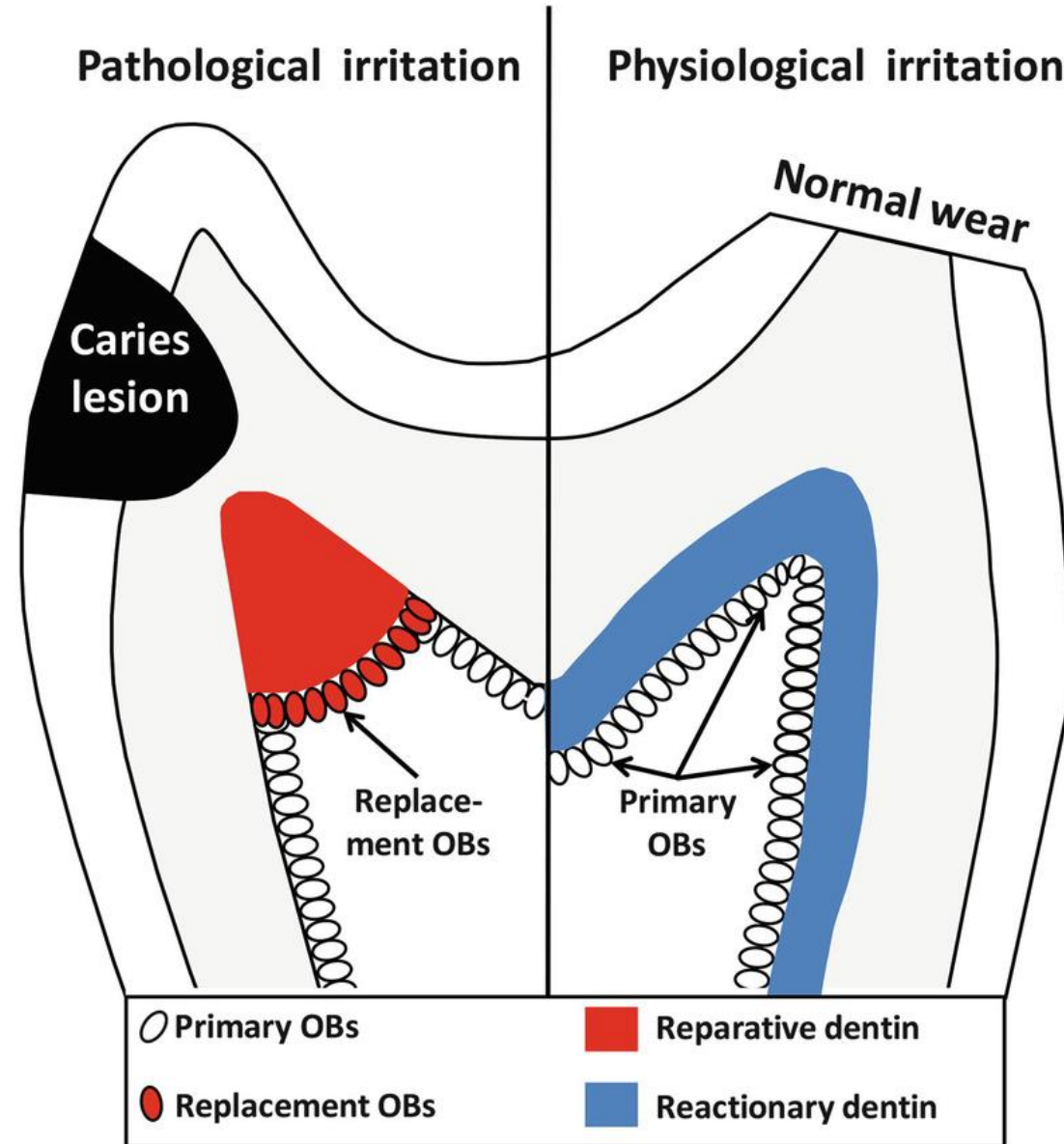




# Dentin types

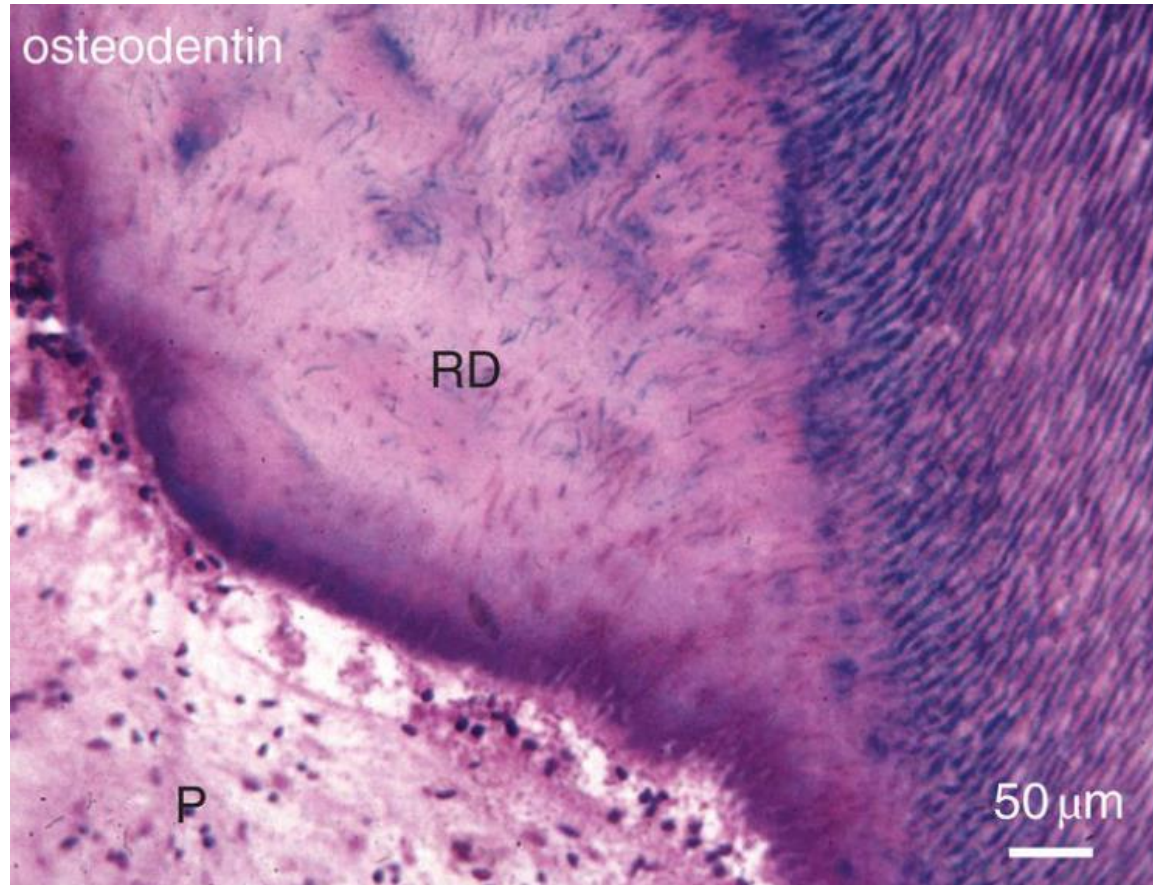


# Tertiary dentinogenesis



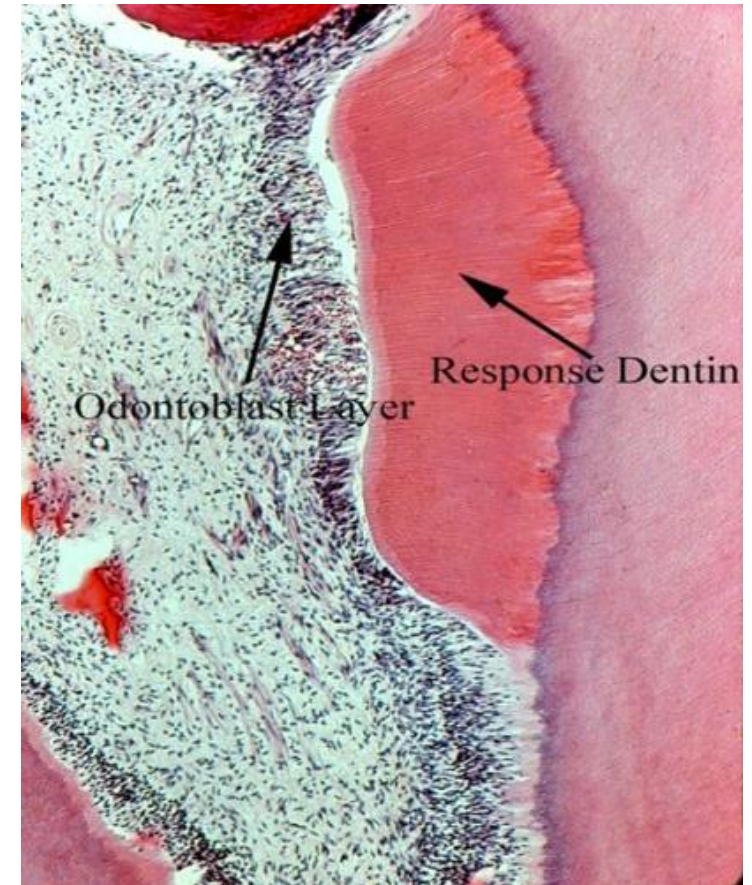
# Tertiary dentinogenesis

## Reparative<sup>?</sup> dentin



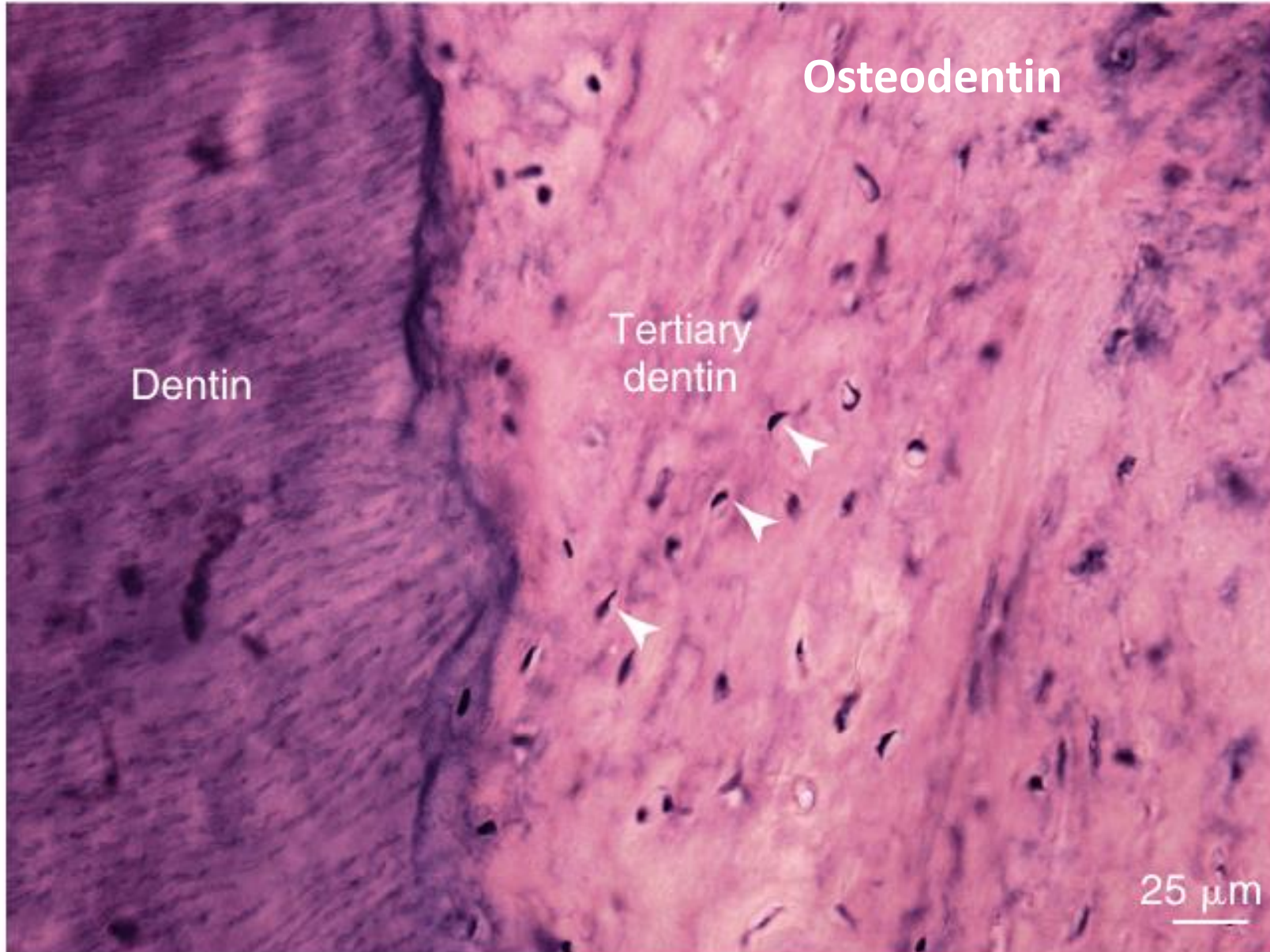
- Cause of formation:** Reaction to larger dentin damage
- Structure:** Amorphous structure
- Dentinal tubules:** NO
- Dentin-forming cells:** Newly differentiated from pulp
- Cell bodies:** May be present (osteodentin)
- Main function:** Protection from infection

## Reactionary<sup>?</sup> dentin

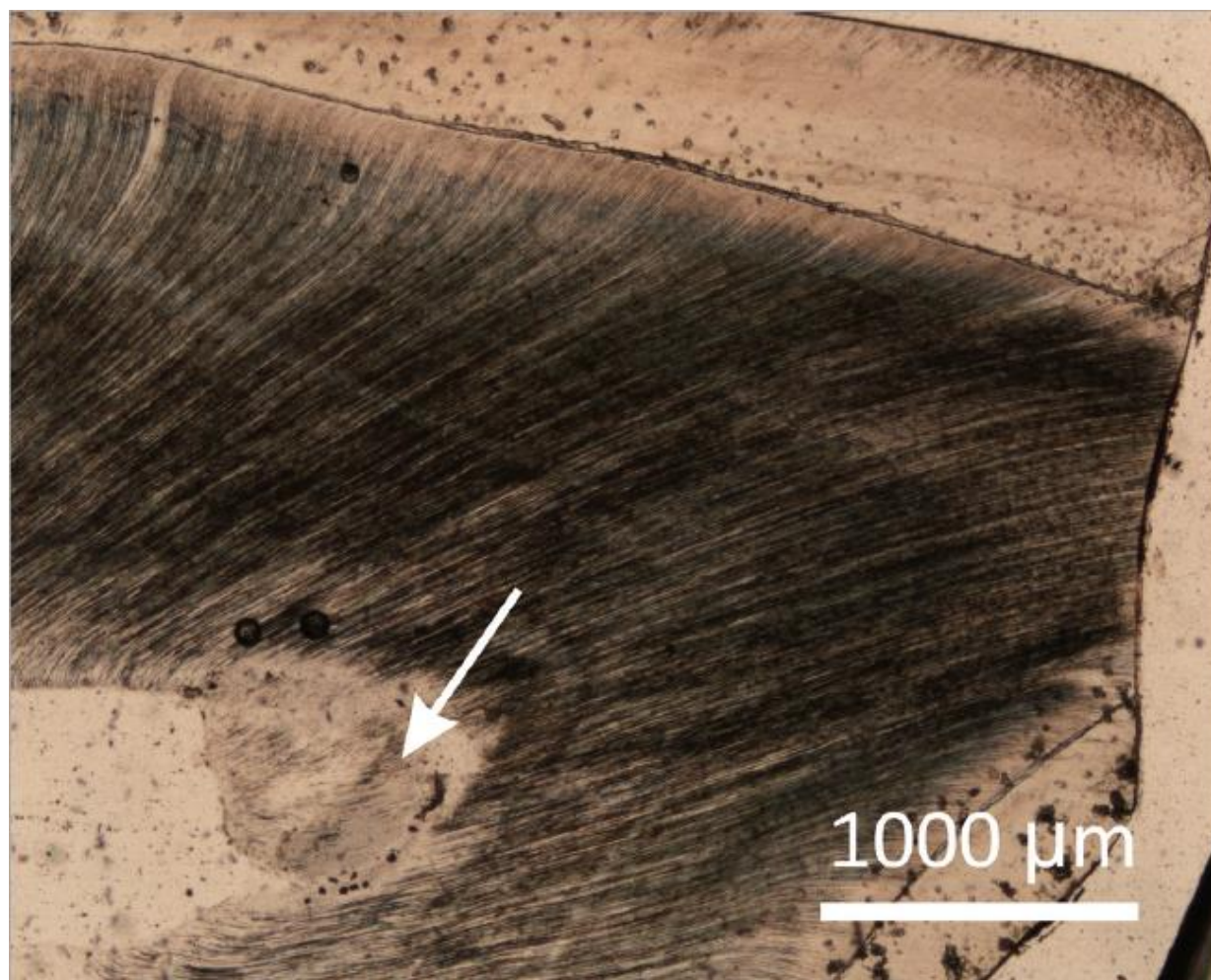


- Cause of formation:** Minor stimuli
- Structure:** Arranged
- Dentinal tubules:** YES
- Dentin-forming cells:** Odontoblasts
- Cell bodies:** NO
- Main function:** Increase of tooth wall

# Tertiary dentinogenesis







Histologický výbrus vysoce abradovaného horního dočasného špičáku v oblasti korunky a vrcholu dřevové dutiny, kde se pod vlivem vnějších stimulů ukládá *terciární dentin*. Šipka ukazuje na **reakční dentin**, formu terciárního dentinu, která vzniká jako pomalá reakce zubu na poškození atricí/abrazí. Jako rychlá odpověď při poškození zubu kazem se vytváří *dentin reparační*. Foto: AH

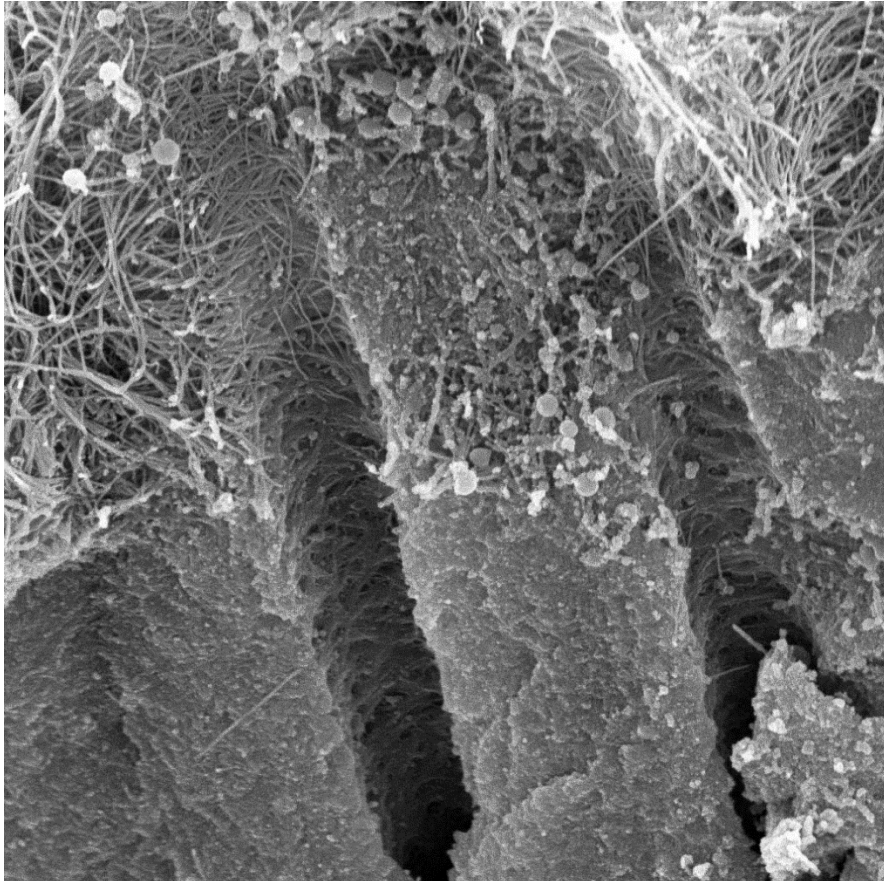
# Chemical composition

Inorganic  
70 %

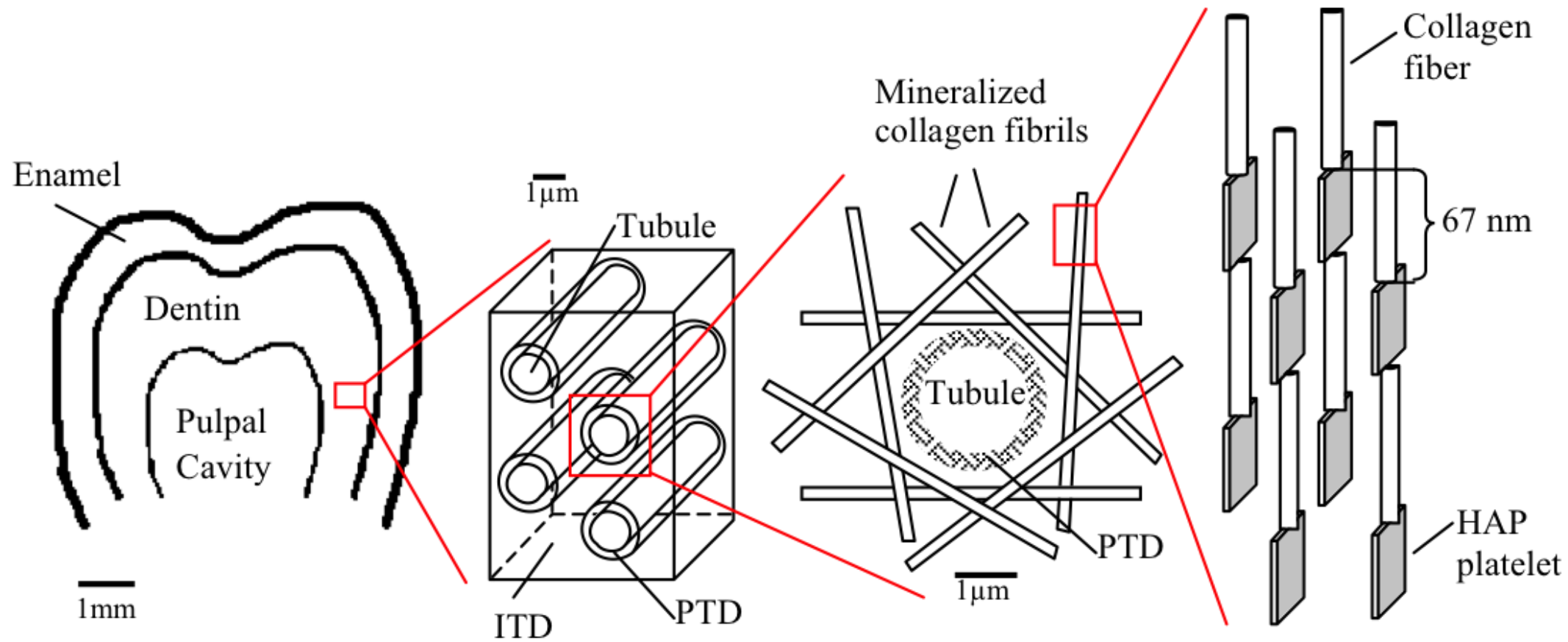
Water  
10 %

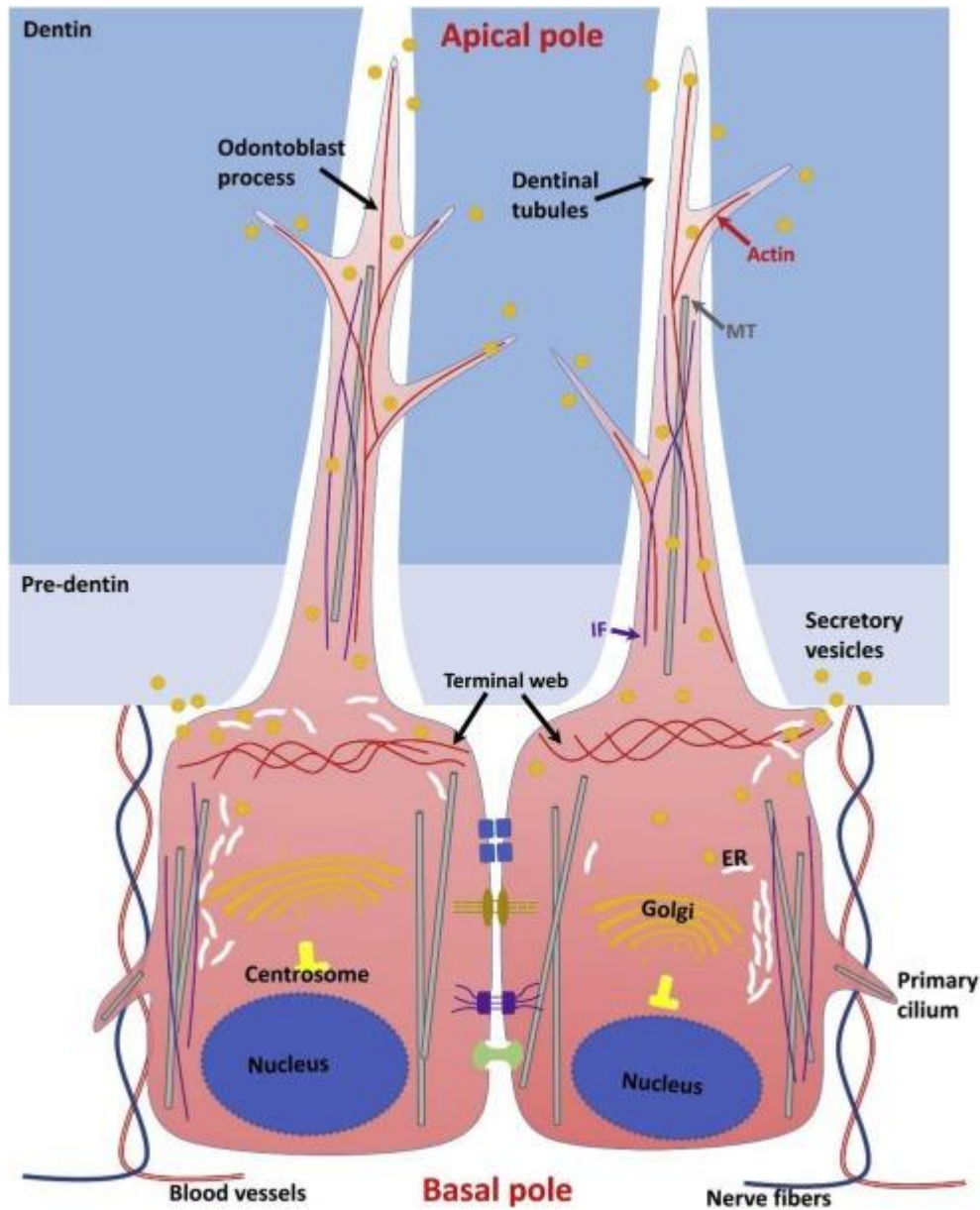
Organic  
20 %

- Hydroxylapatite crystals
- Crystals smaller than than in enamel
- Crystals attached to fibres



- **Collagens** - collagen I (III a V) (90 %)
- **Non-Collagenous Proteins** (8%)
  - a) Phosphorins – Ca<sup>2+</sup> and phosphate donors, crystal growth control
  - b) Gla-proteins (gamma-carboxyglutamate proteins, acidic character) + glycoproteins (osteonectin, osteopontin, sialoprotein I and II) - calcium carriers, crystal growth
  - c) Proteoglycans - control of crystal growth
- **Phospholipids** (2%)



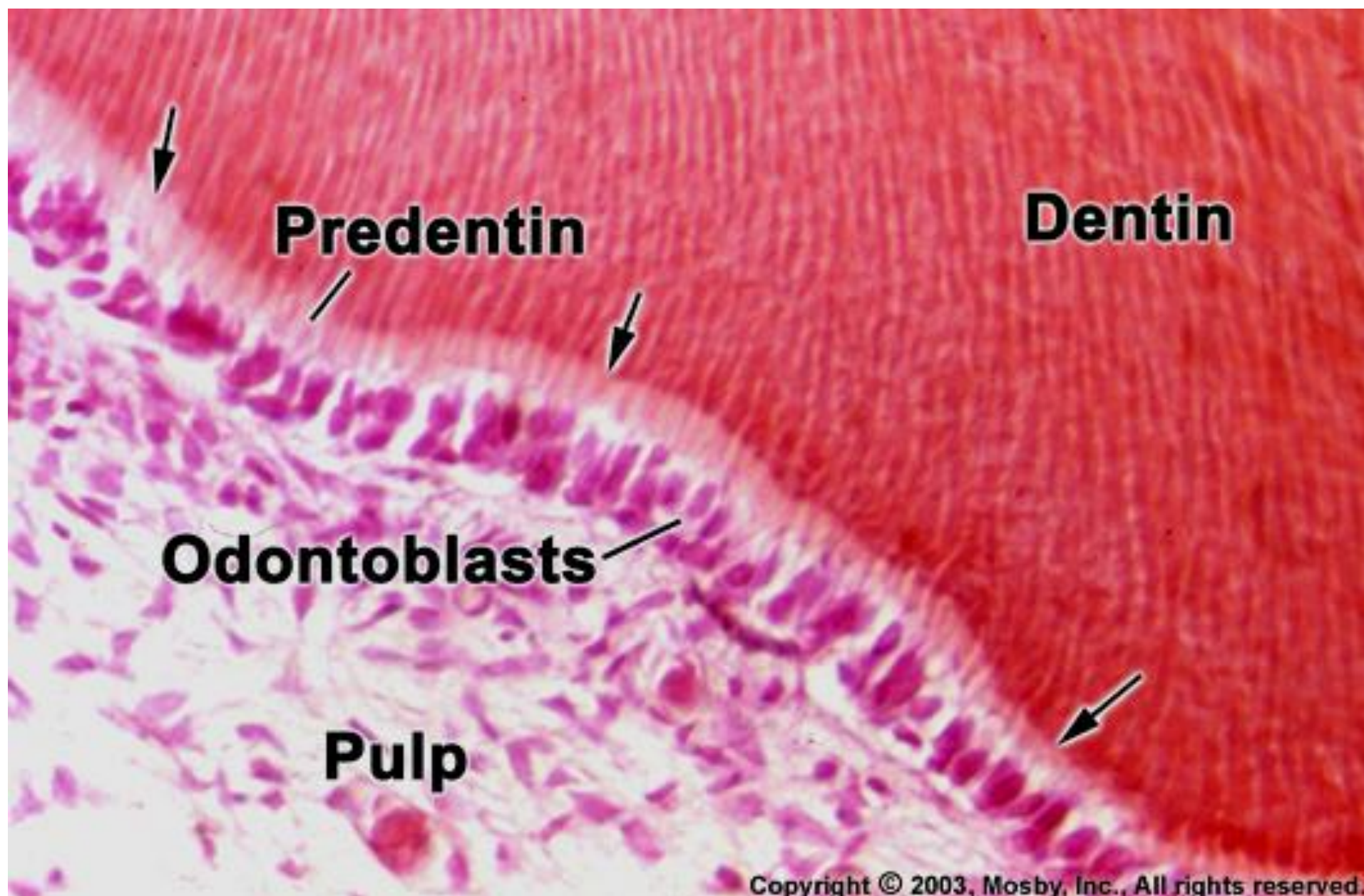


## Junctional complex

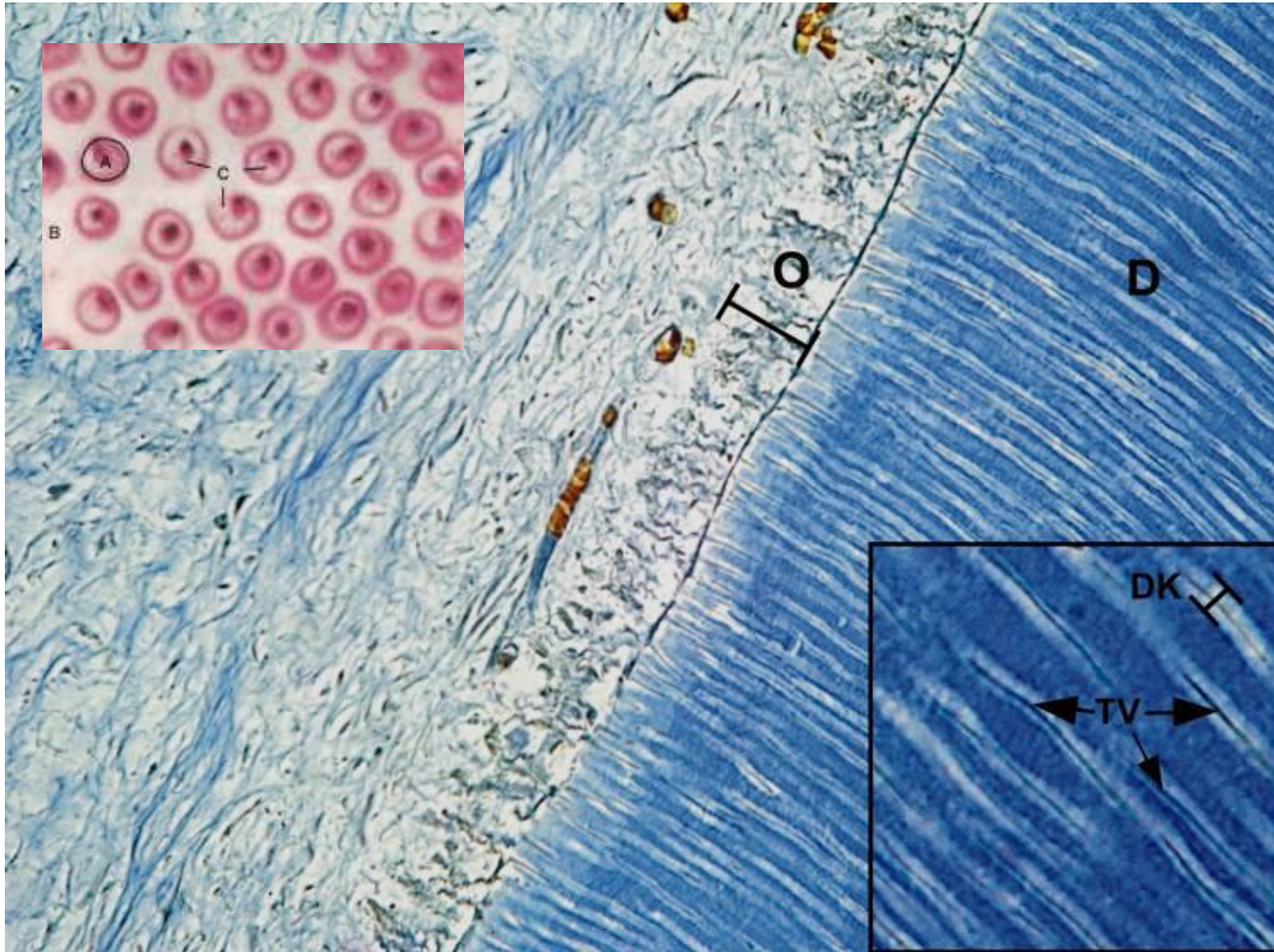
Numerous connecting complexes among the odontoblast apices:  
tight junctions, gap junctions, desmosomes -  
synchronization of odontoblasts

Above the connecting complexes, the apex slowly changes into a thin and long, short-sided branch -  
Tomes fiber

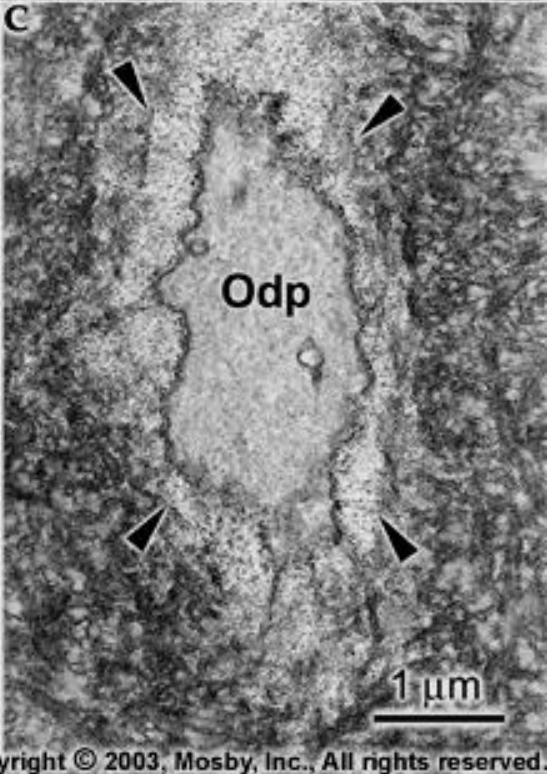
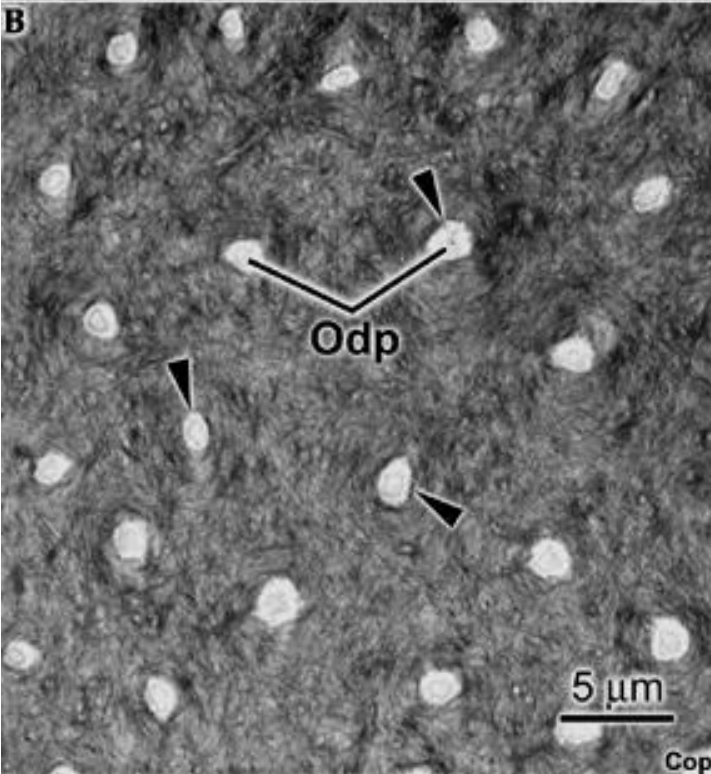
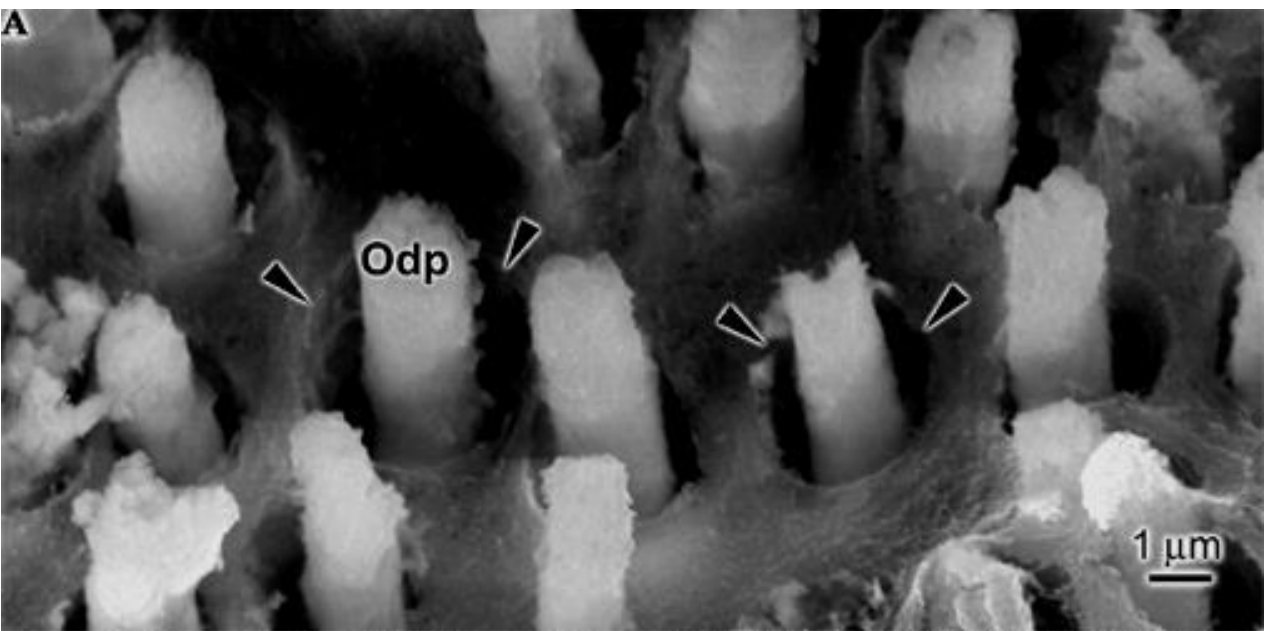
A basal process may be present



Each fiber is has its own canal - **Dentinal Canal** (tubulus)

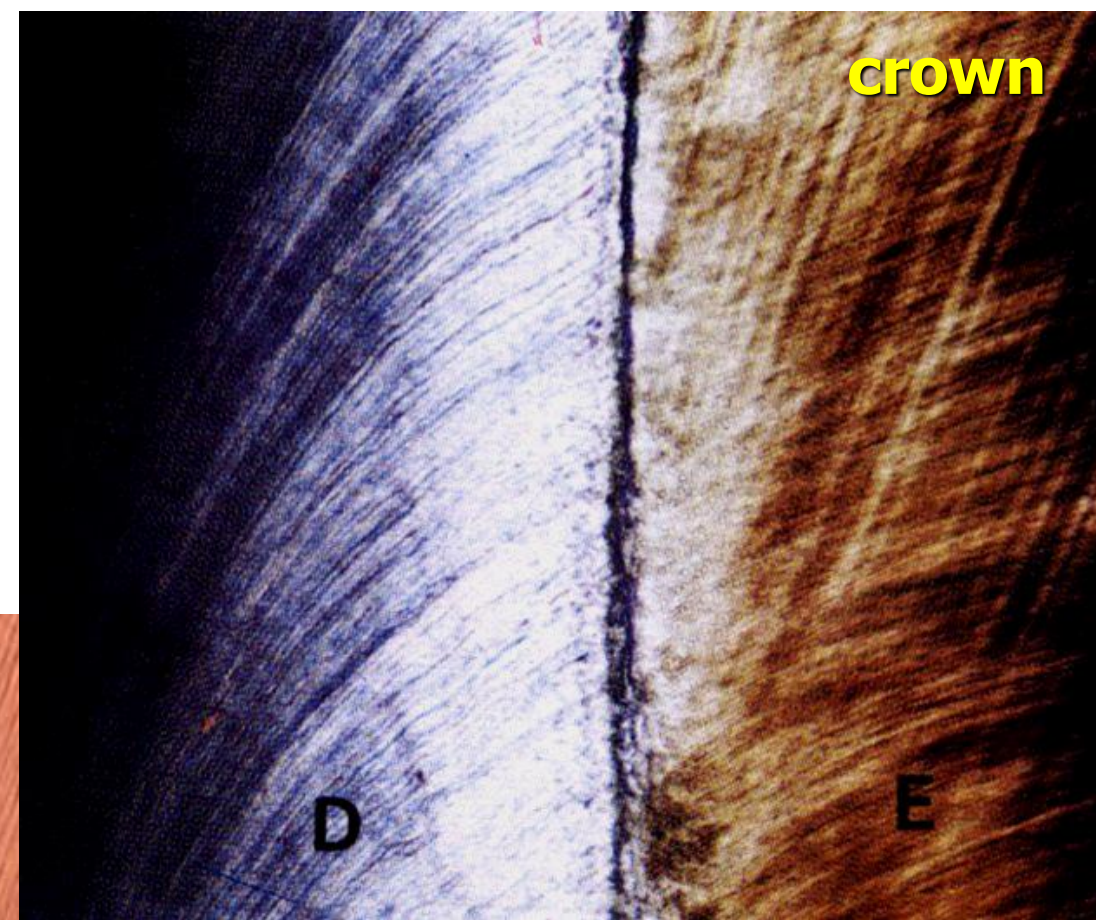


Tomes fibres

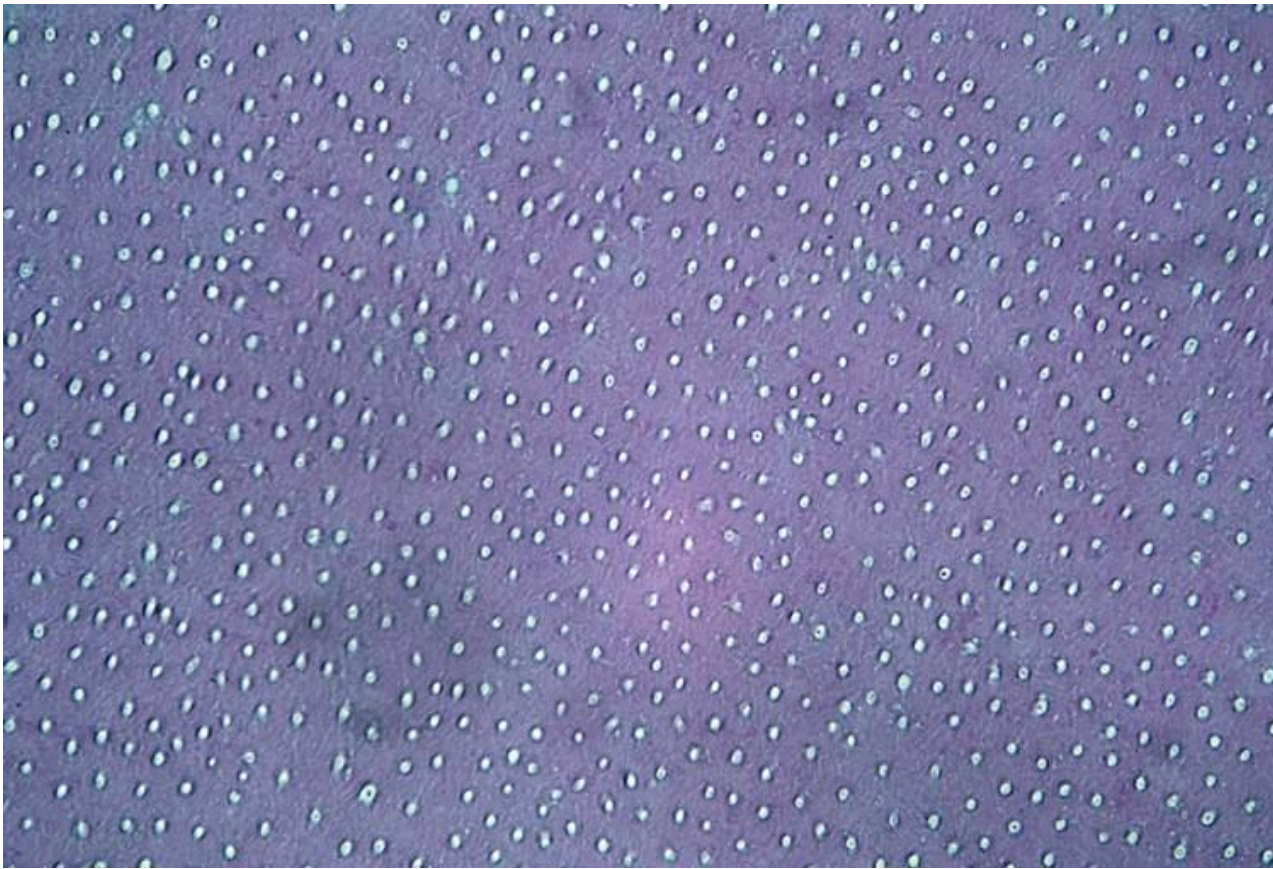


Channels with Tomes fibres penetrate the entire dentin and cause the dentinal stripes

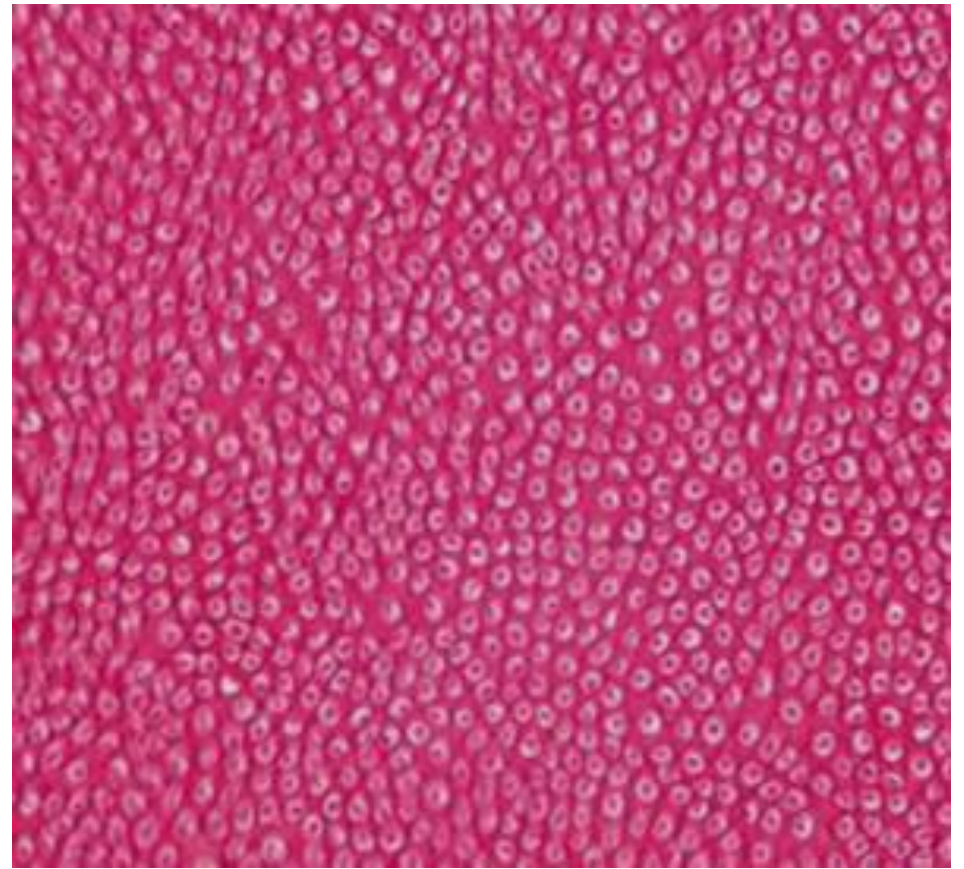
visible on stained sections as well as ground sections







**Dentinal tubules**  
(transversal section)



**Dentinal tubules with Tomes fibres**  
(transversal section)

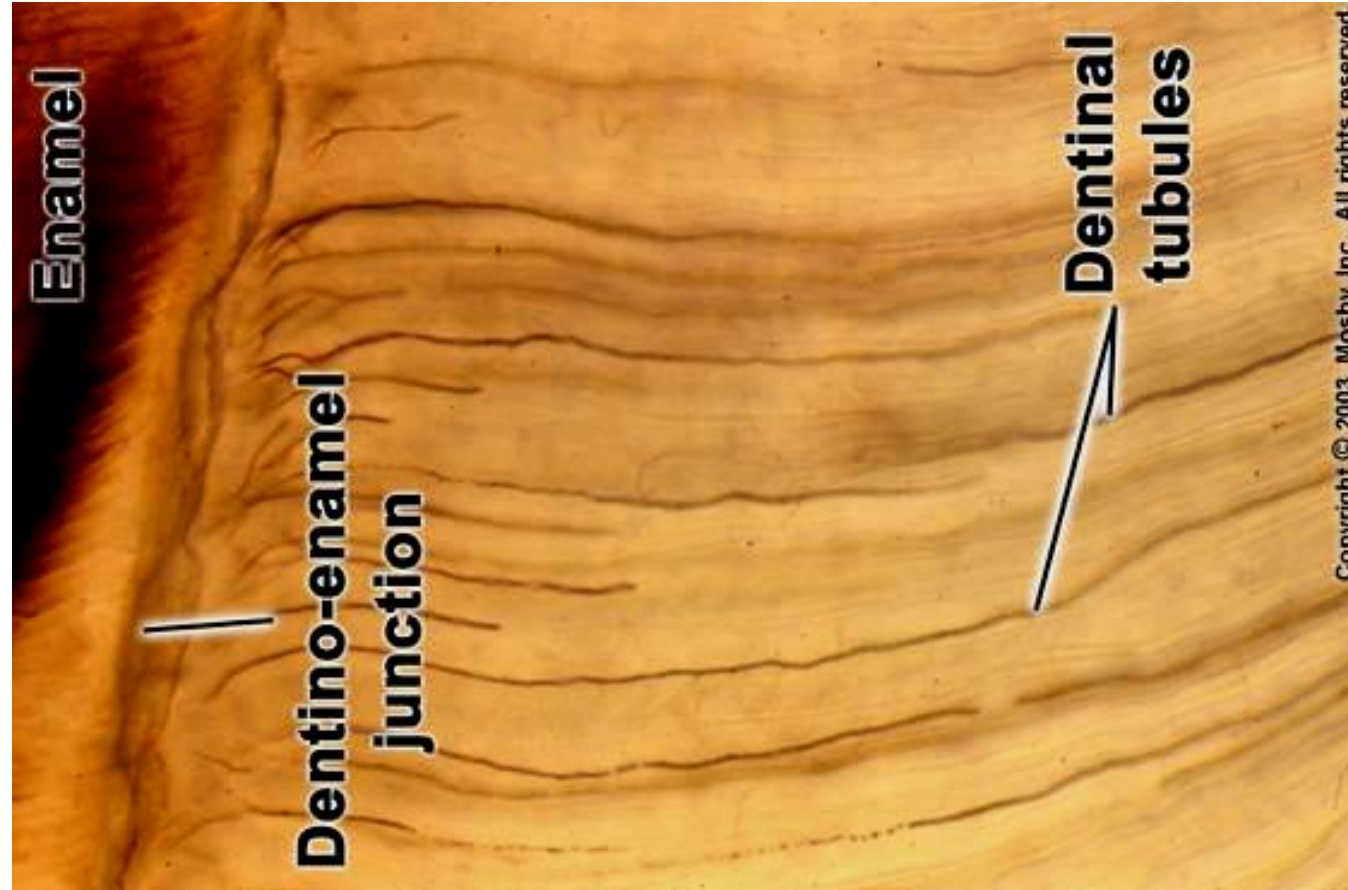
1 mm<sup>2</sup> surface can contain around 50 000 tubules

# Dentinal tubules shape

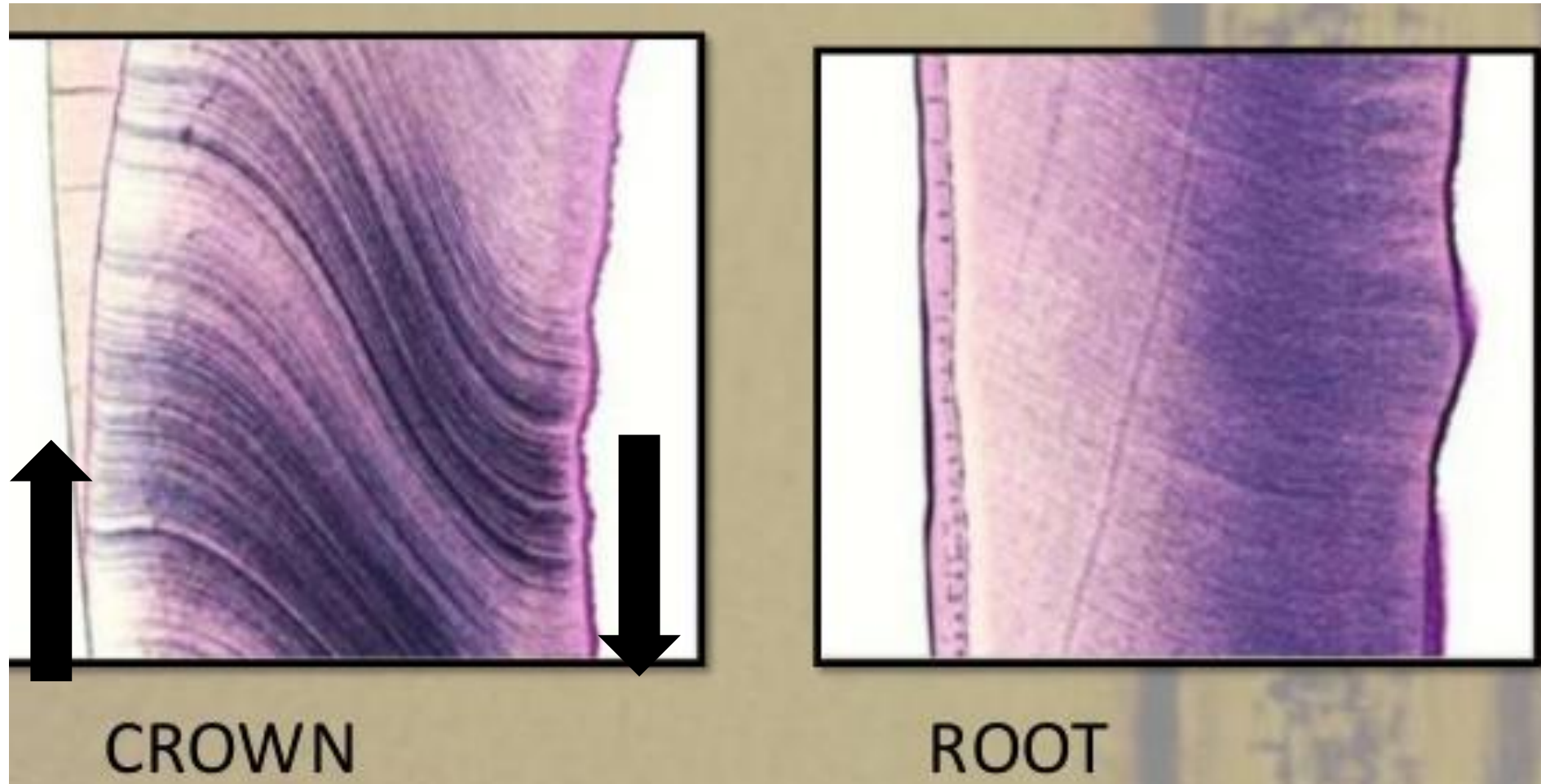
**S-shaped** (2 bends - primary bending) towards DEJ (or cemento-dentinal junction)



**Schreger shapes**  
(Crown part of dentin)



## Primary dential bending



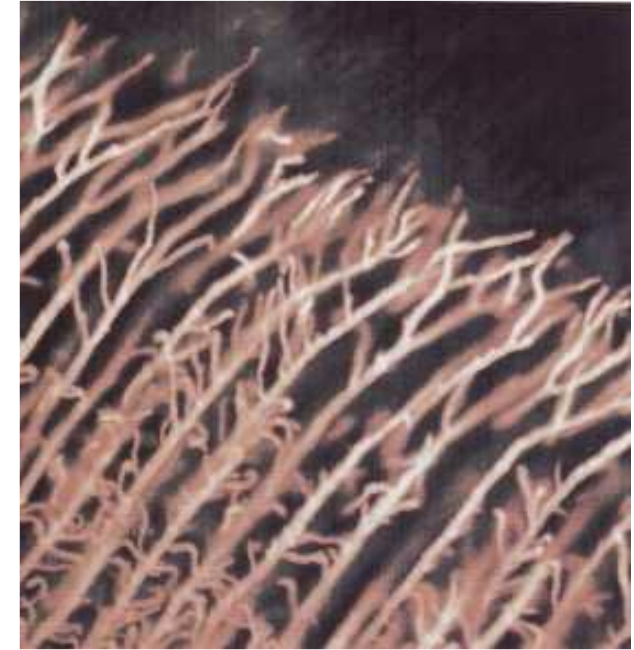
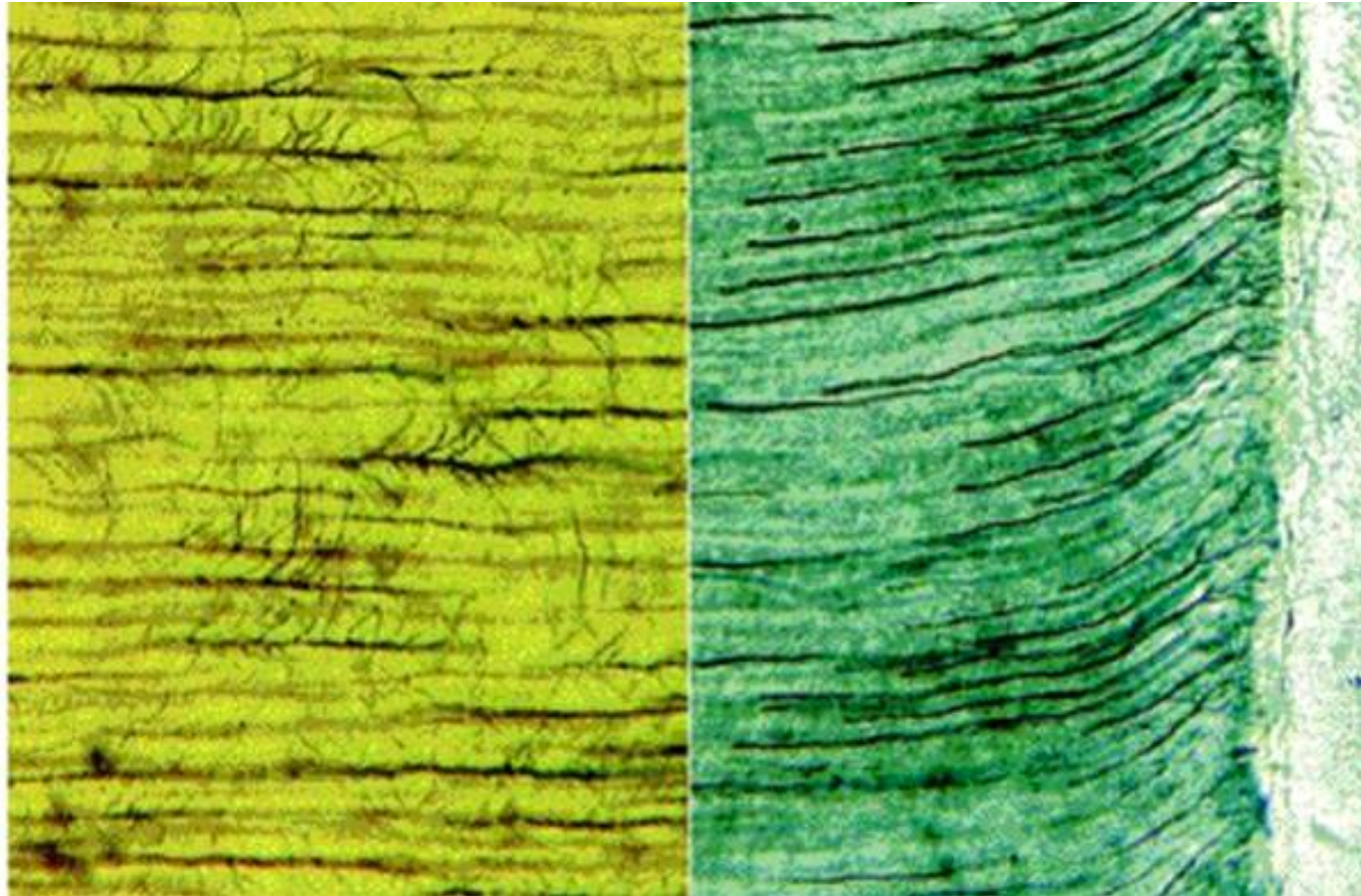
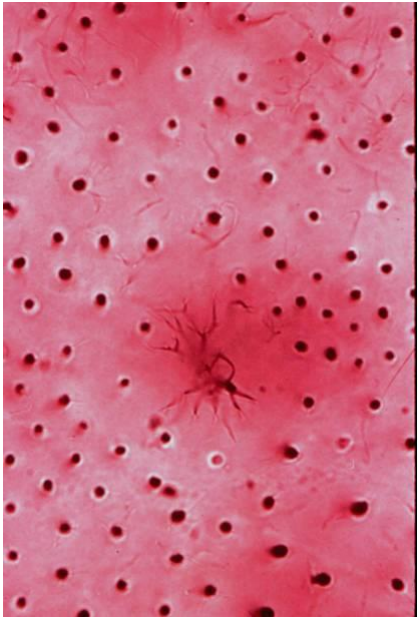
In addition to S-shape primary bending, up to another 200 secondary bends -

Primary and secondary tubular bending caused by migration movements of odontoblasts during dentinogenesis

Diameter of the dentin tubules is around **1–4  $\mu\text{m}$**

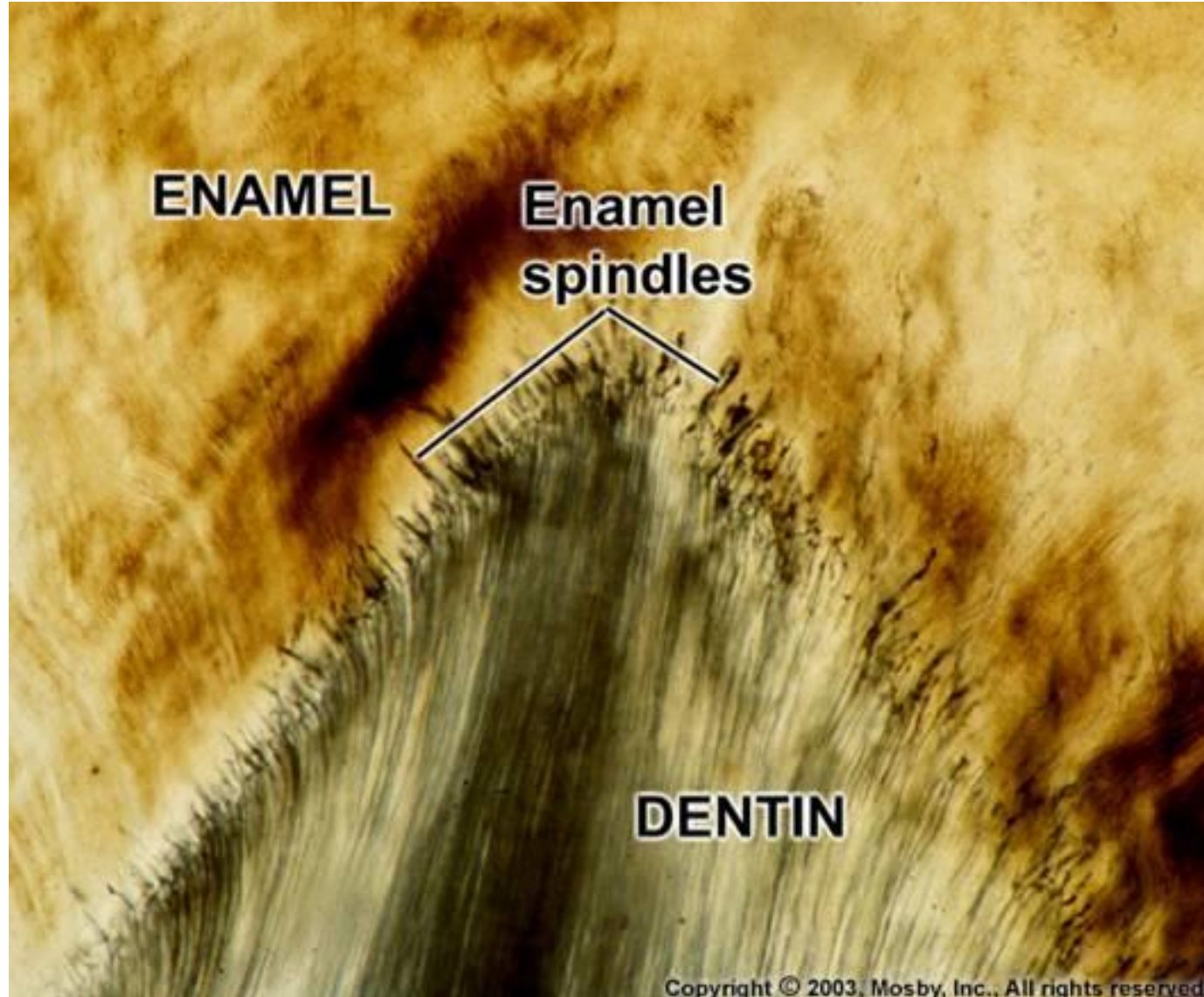
Decreasing towards DEJ (or cemento-dentinal junction)

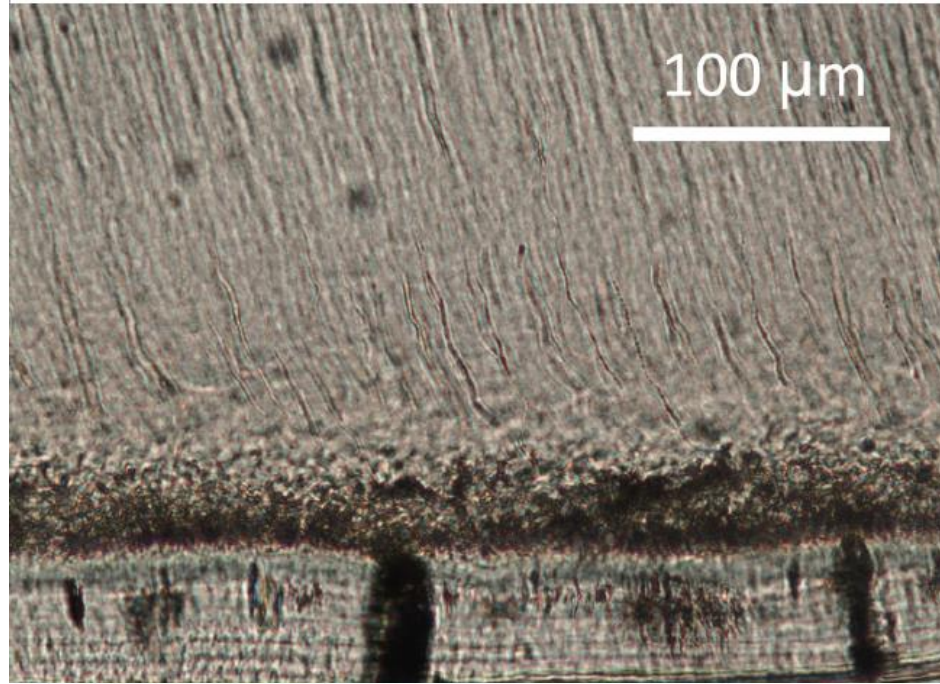
Neighboring tubules can be interconnected by anastomoses (tubicles)



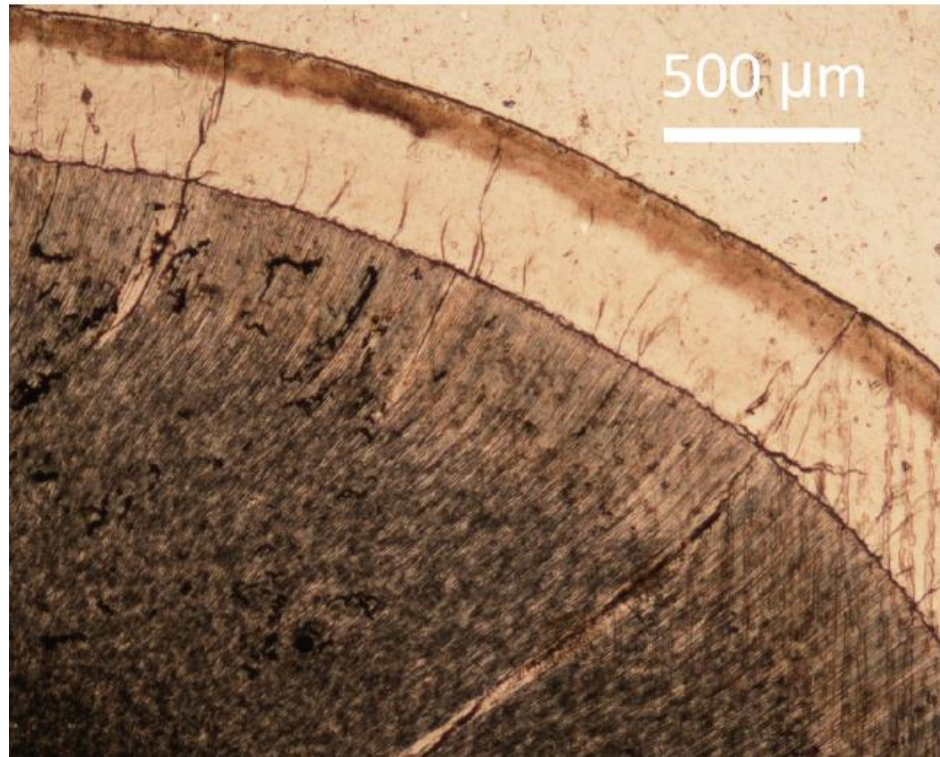
## Enamel spindles (*fuscus enameli*)

Dentine tubules extension into enamel





Detail **dentino-cementového spojení** na longitudinálním výbrusu trvalého zubu, zobrazeno v procházejícím světle. Dentin je nahoře; cement dole, je patrné jeho vrstevnaté přirůstání (vodorovné linie). Foto: AH

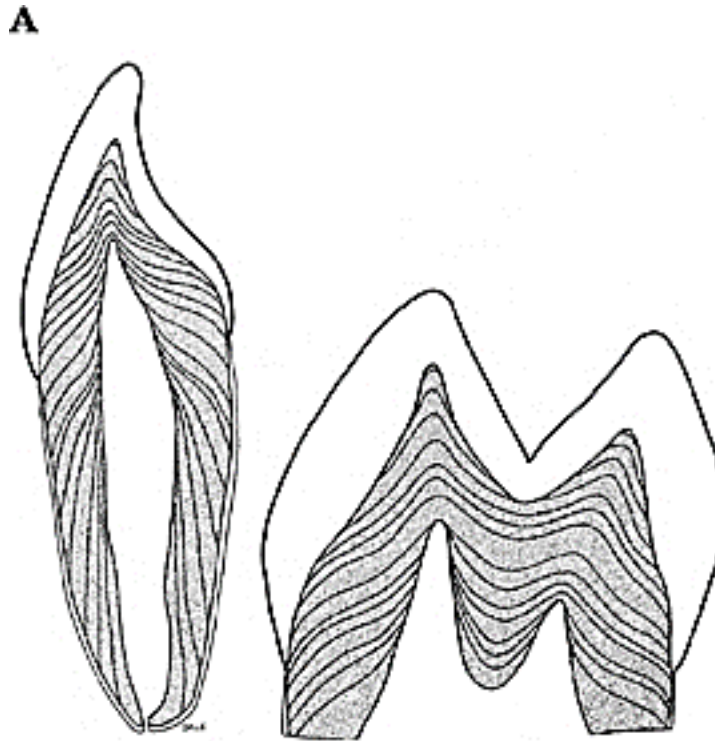


**Dentino-sklovinné spojení** na transverzálním výbrusu trvalého zubu, zobrazeno v procházejícím světle. Dentin je dole, sklovina nahoře. Ve vnitřní třetině skloviny jsou patrné *sklovinné trsy (enamel tufts)*, podobné trsům trávy a prasklinky probíhající celou její tloušťkou, tzv. *sklovinné lamely (enamel lamellae)*. Foto: AH

# Dentin incremental lines

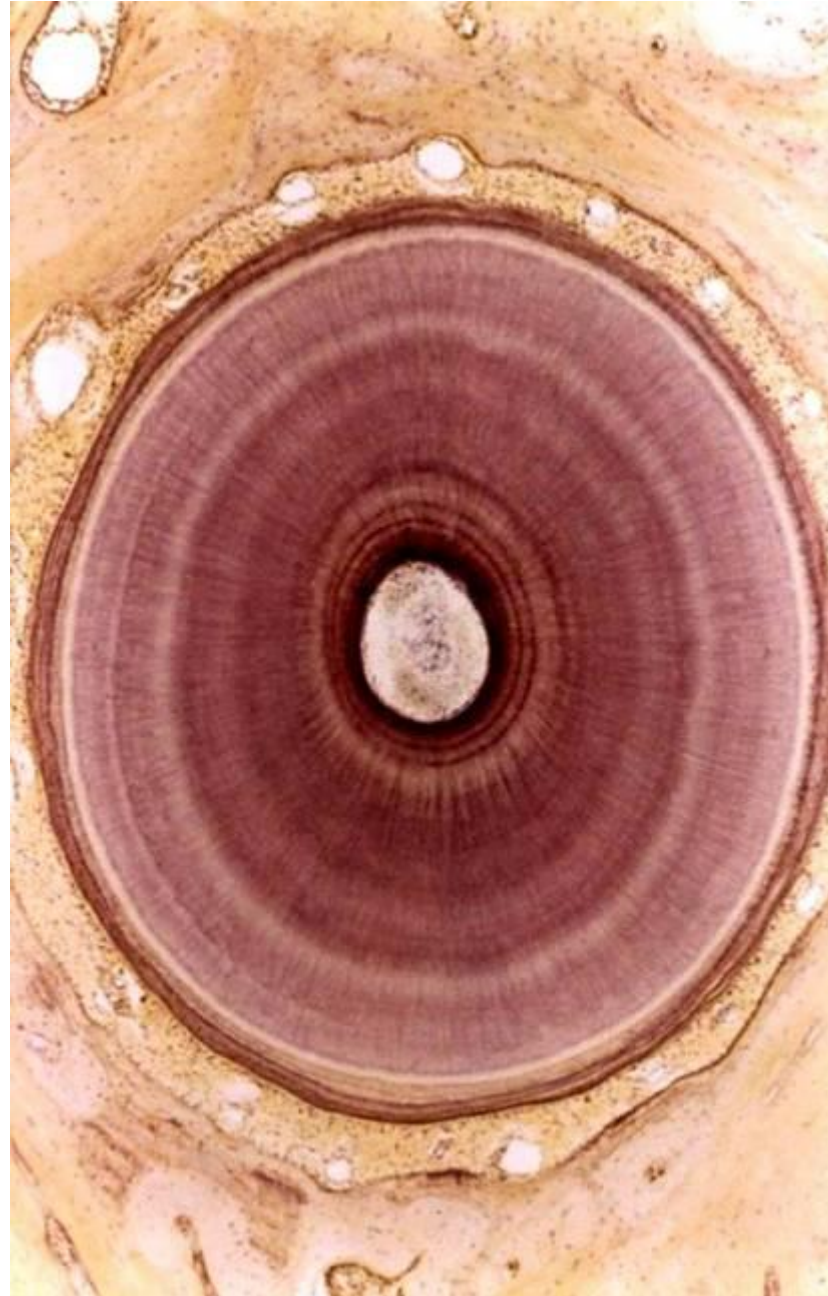
Caused by gradual deposition and mineralization of dentin

- **von Ebner lines** - **4-8  $\mu\text{m}$**  distance - daily increments
- **Owen's lines** - **15-30  $\mu\text{m}$**  distance - joint calcification of 4-5 day increments
- **Neonatal line** - Owen line in temporary teeth - separates fetal and postnatal dentine





**Circular pattern on cross section**





# Sclerotic dentin

"**Dead Dentin**", more resistant to dental caries, color of amber

Origin of **dentin tubule closure** by the thickening of peritubular dentin until complete tubules termination

**Formed in the crown part** and increases with age - a sign of aging

According to its amount, the age of the individual is determined (forensic)

