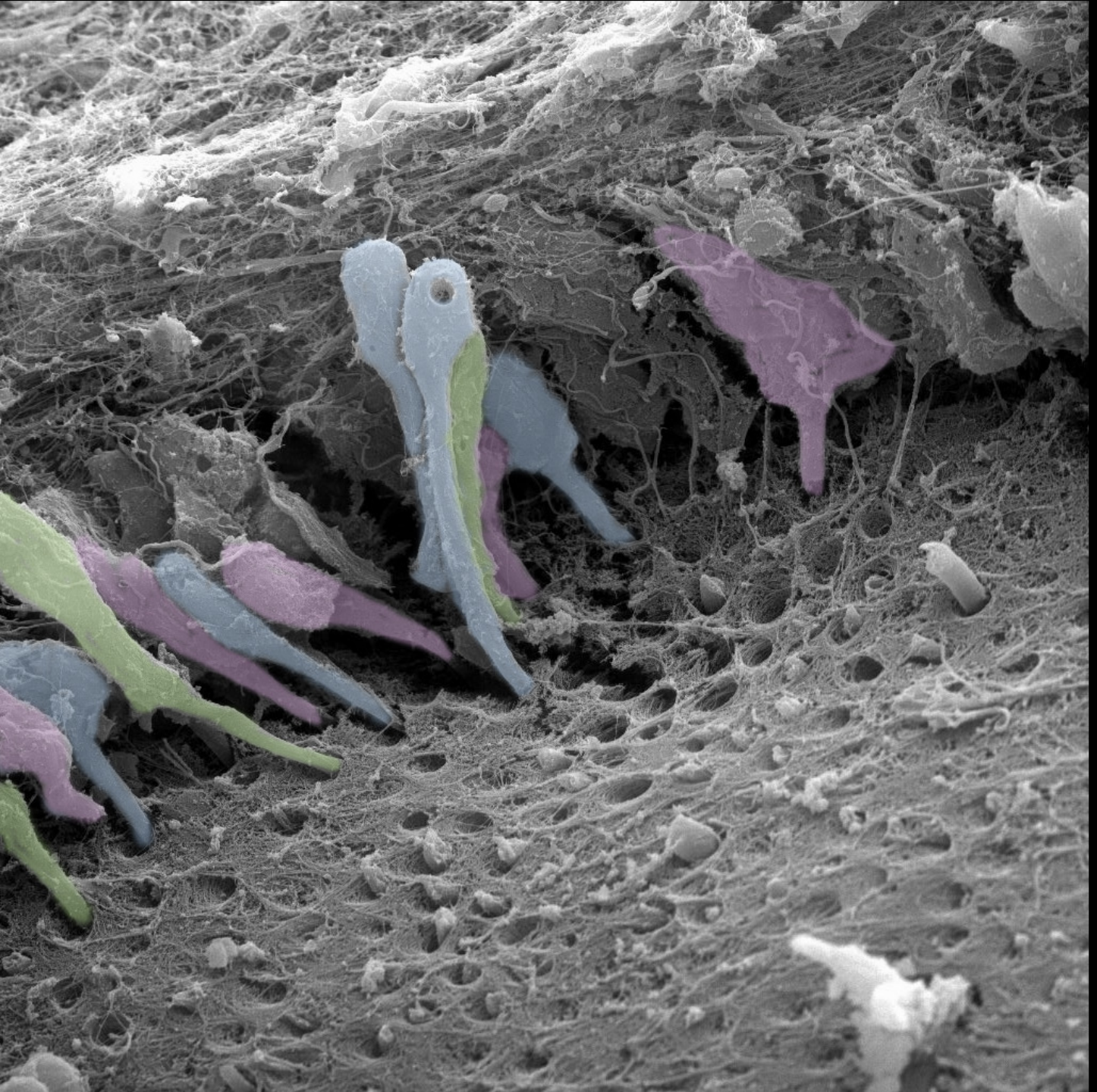
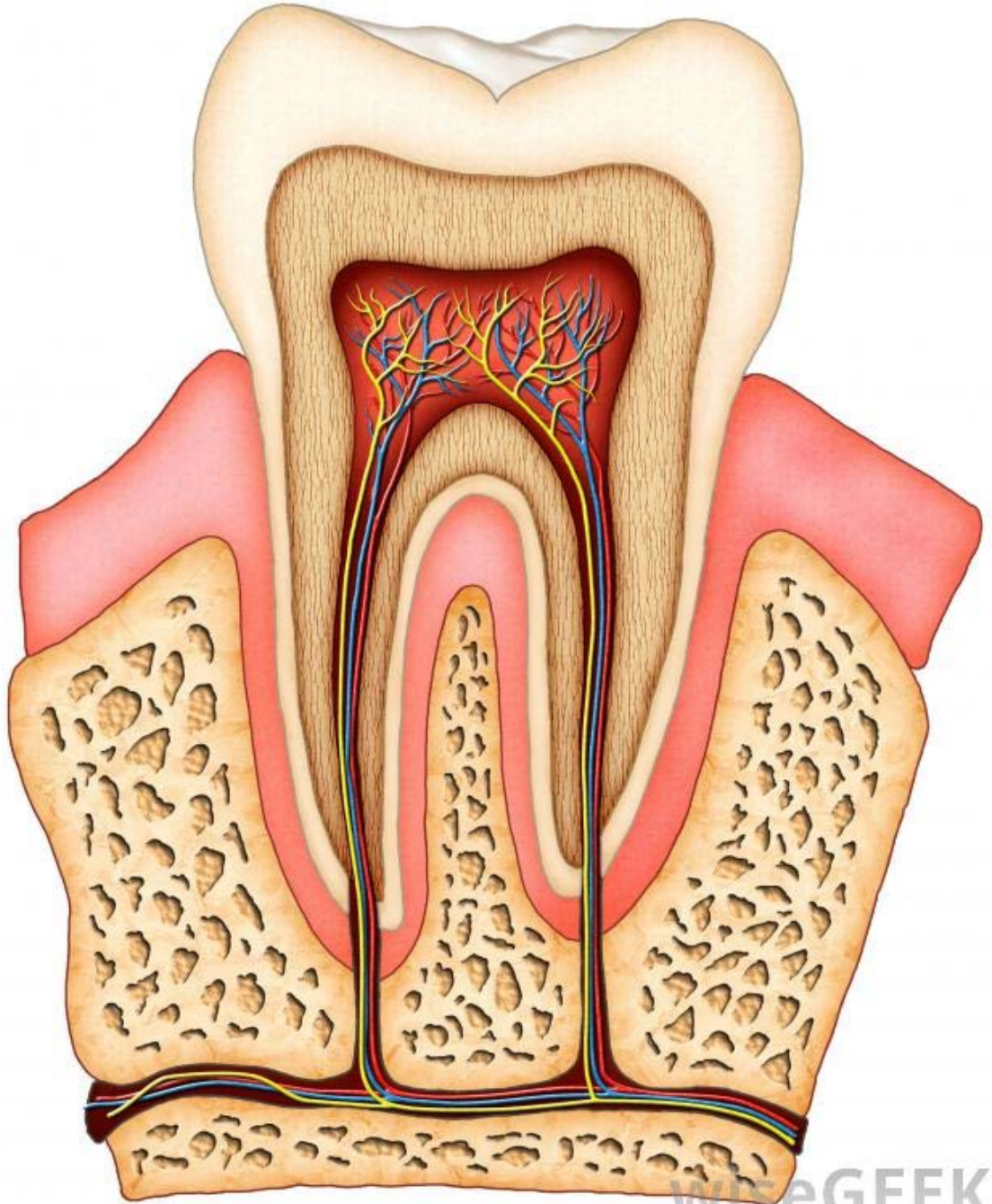
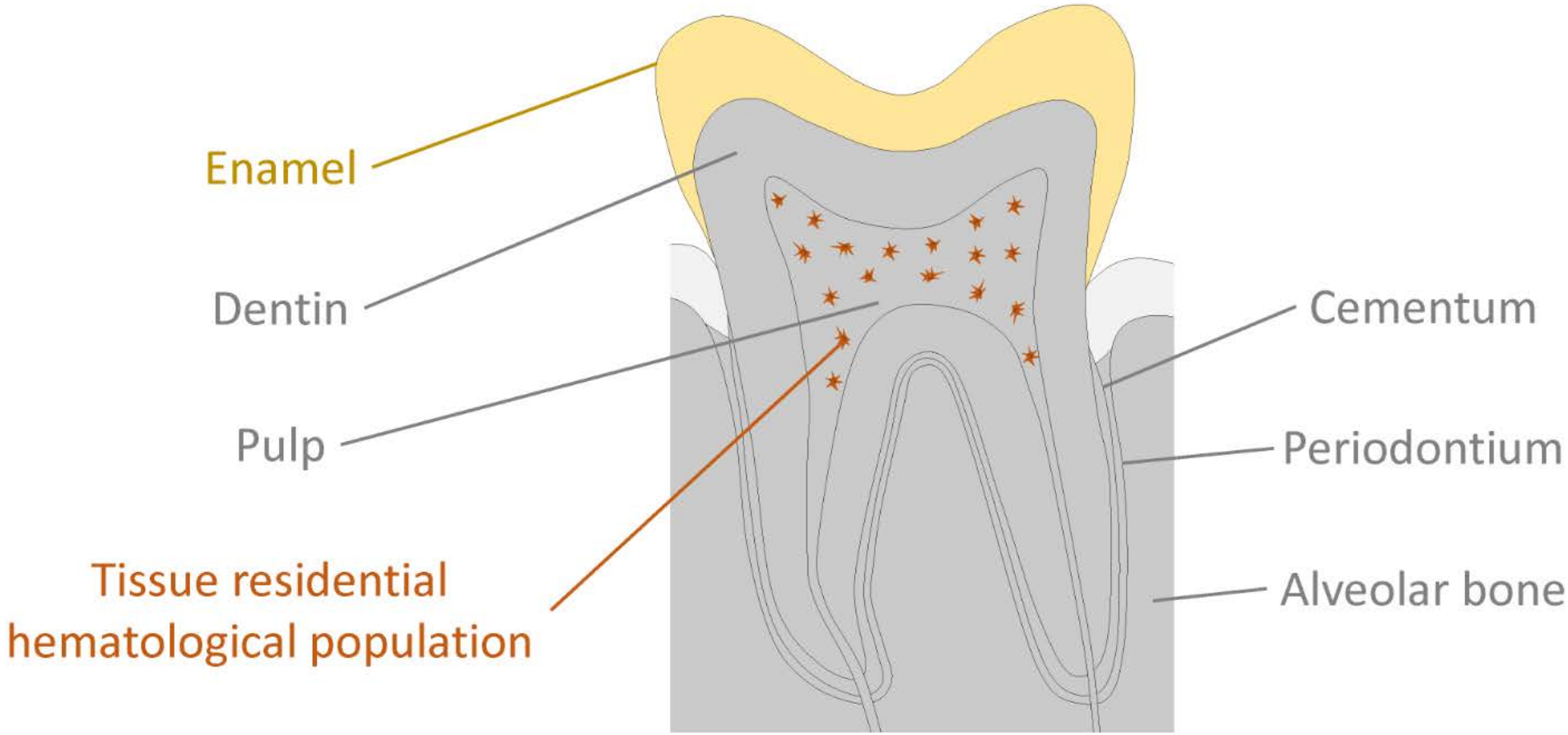


Dental pulp
Dentin

Jan Krivanek

28. 4. 2021

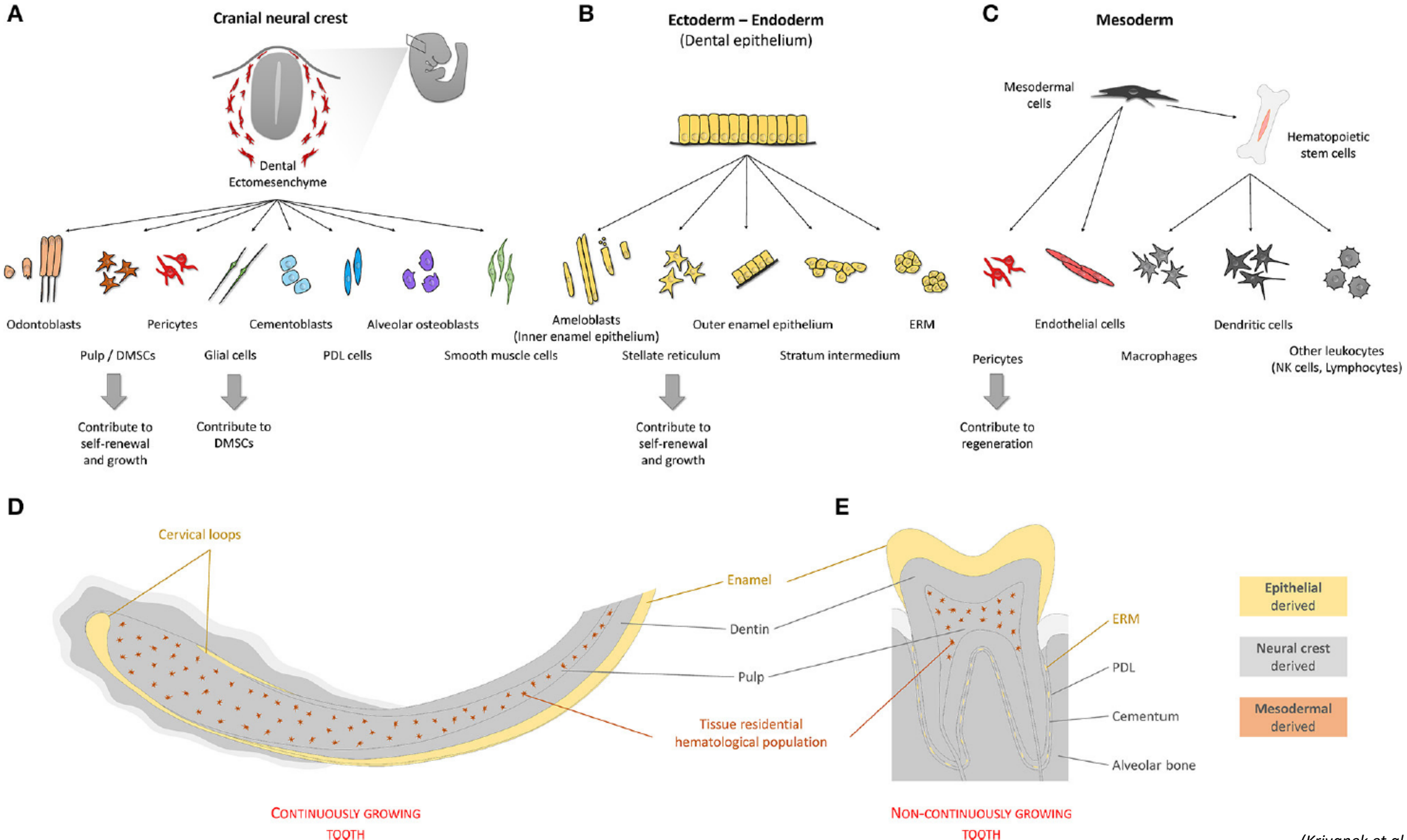

wiseGEEK



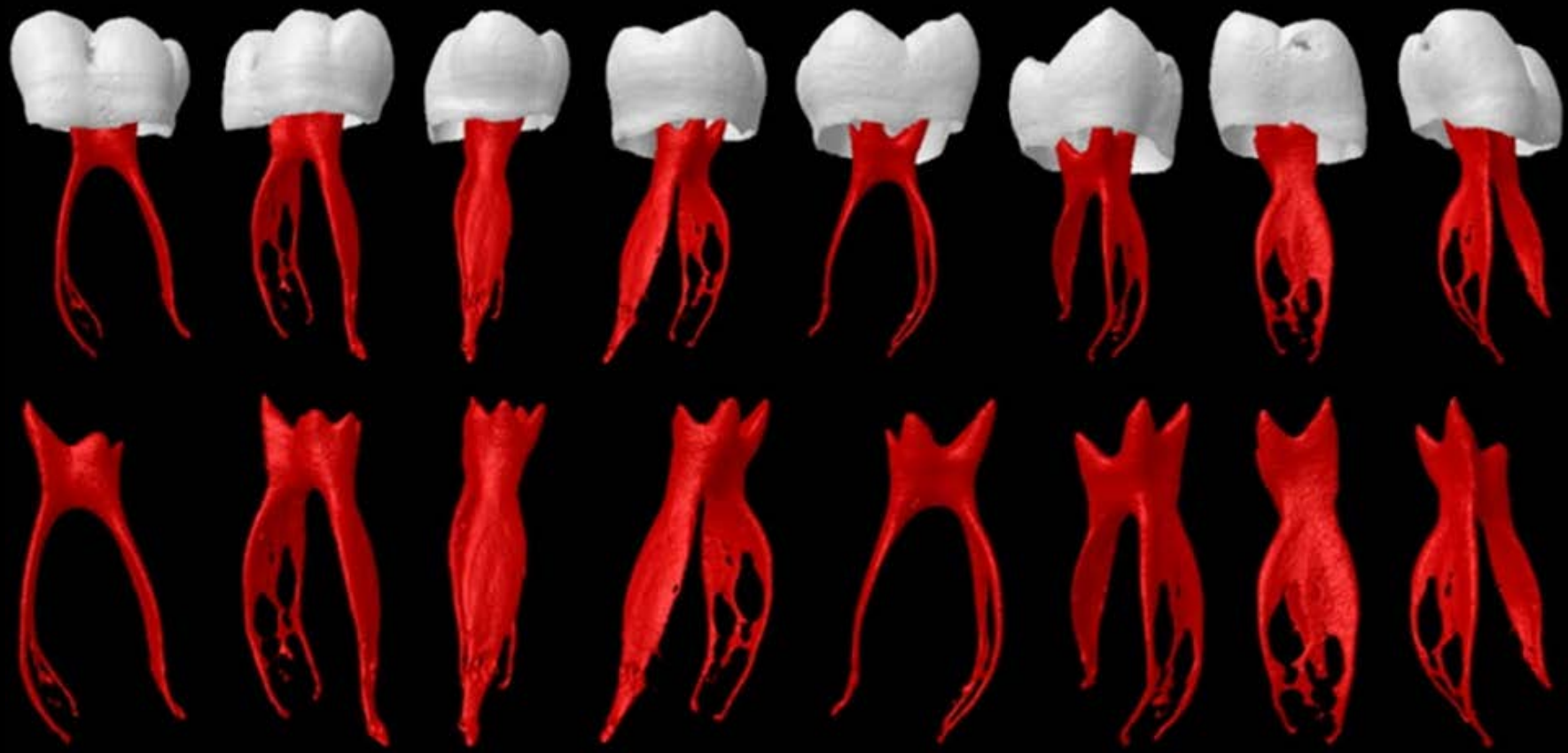
Neural crest - derived

Epithelial - derived

Mesodermal - derived



(Krivanek et al., 2017)



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

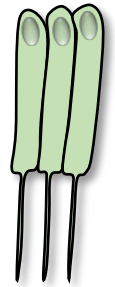
Tight developmental, histological and functional connections

Common development history (ectomesenchymal origin)

Dental pulp Fibroblasts

Interactions

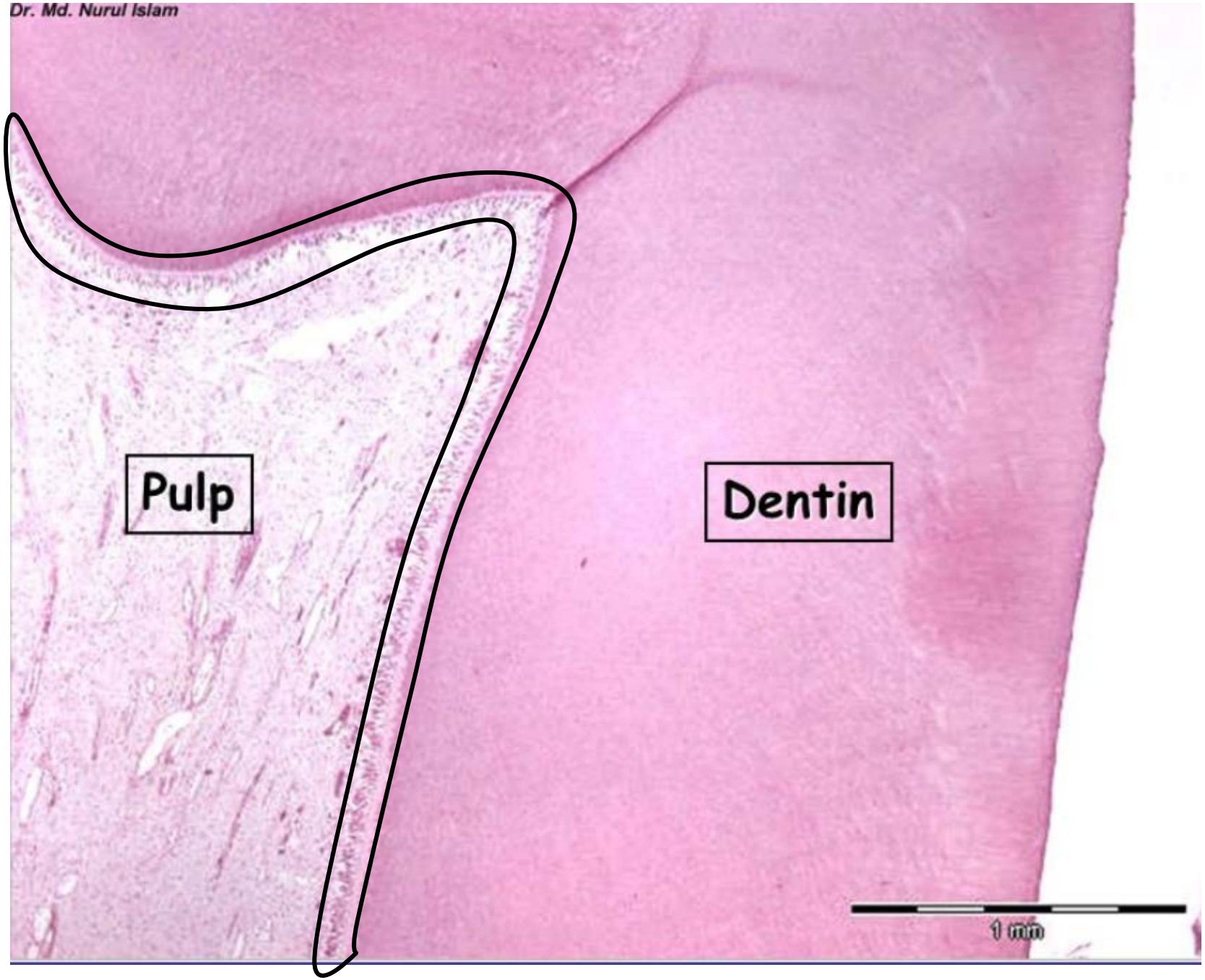
Odontoblasts



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

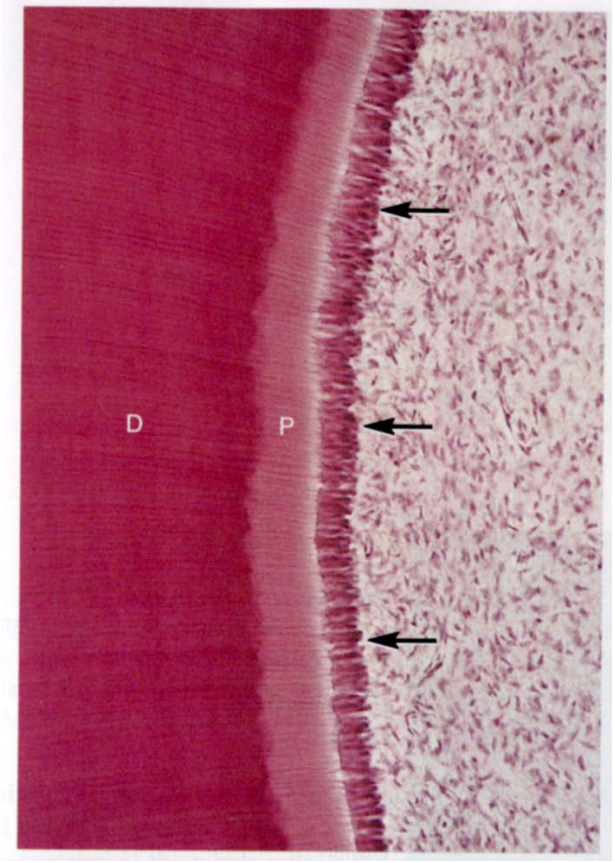
Dentin production
Living component of dentin
Reactions on tooth damage
(pain, immune response, reparative processes)

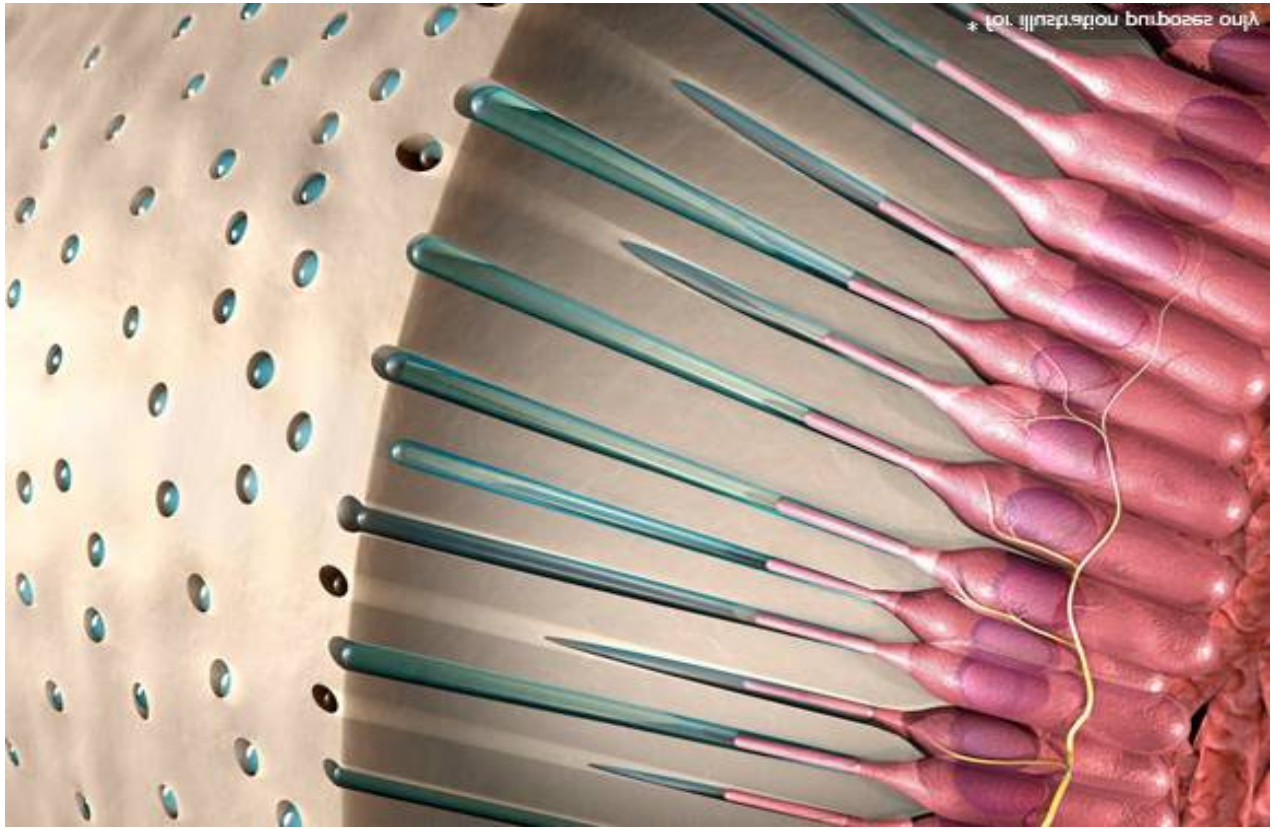
Dentin-pulp complex



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
- Odontoblats‘ processes involved in the pain perception
- Periodontoblastic space between the tubule wall and Tomes fibre, contains dentinal fluid and mucopolysaccharide material

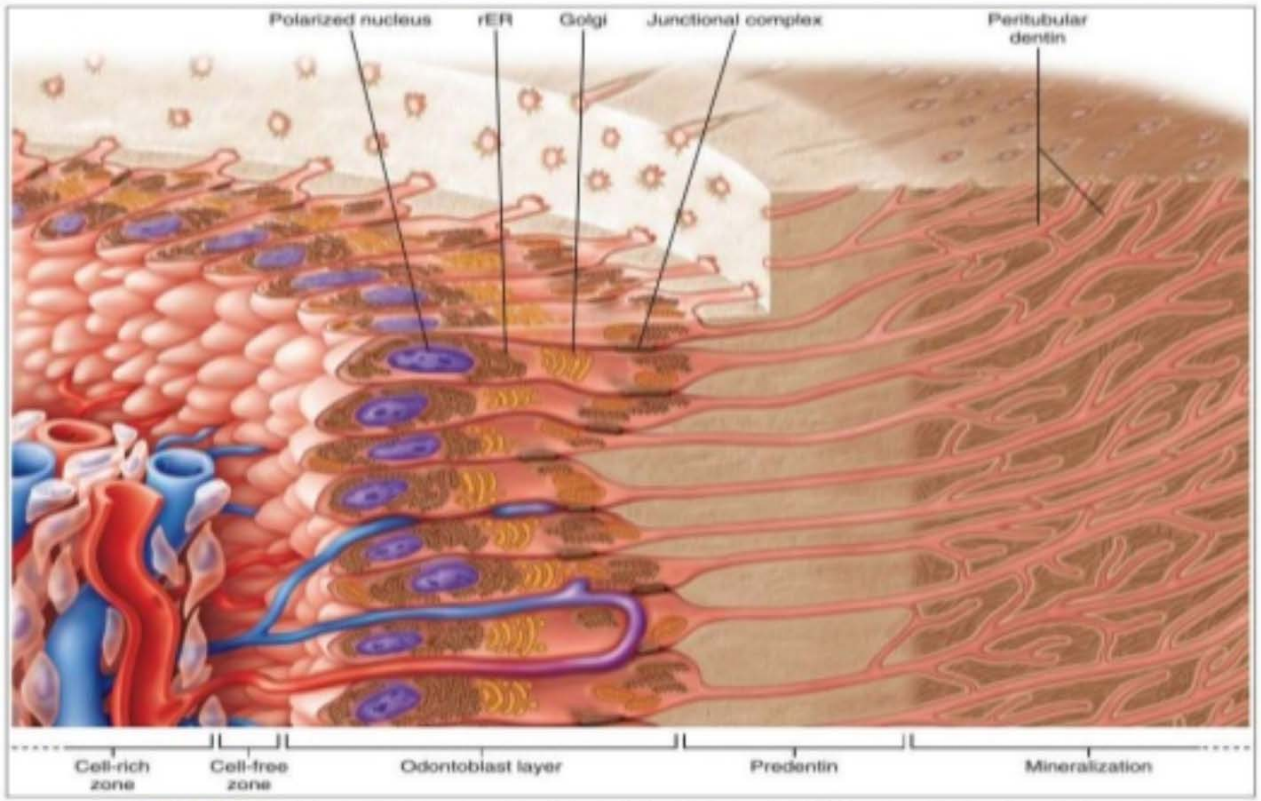
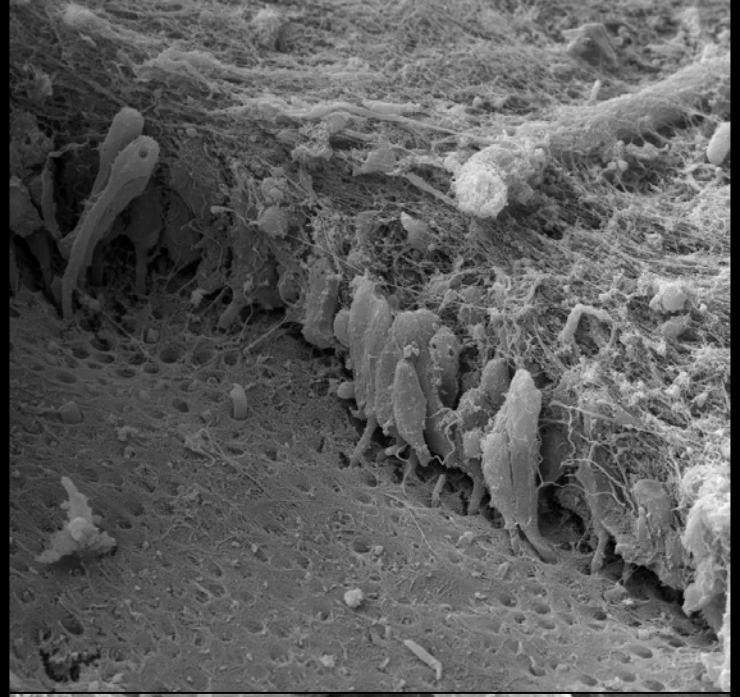
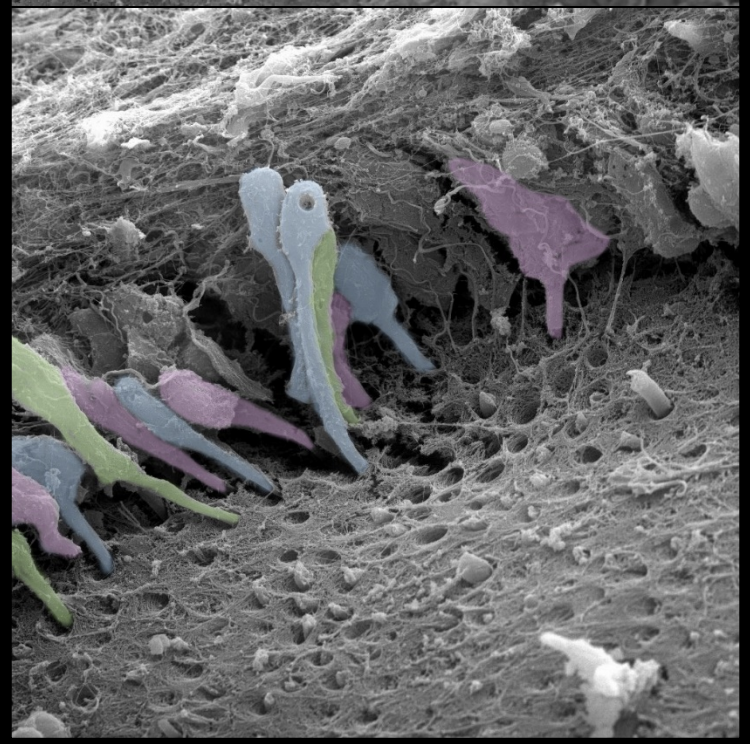
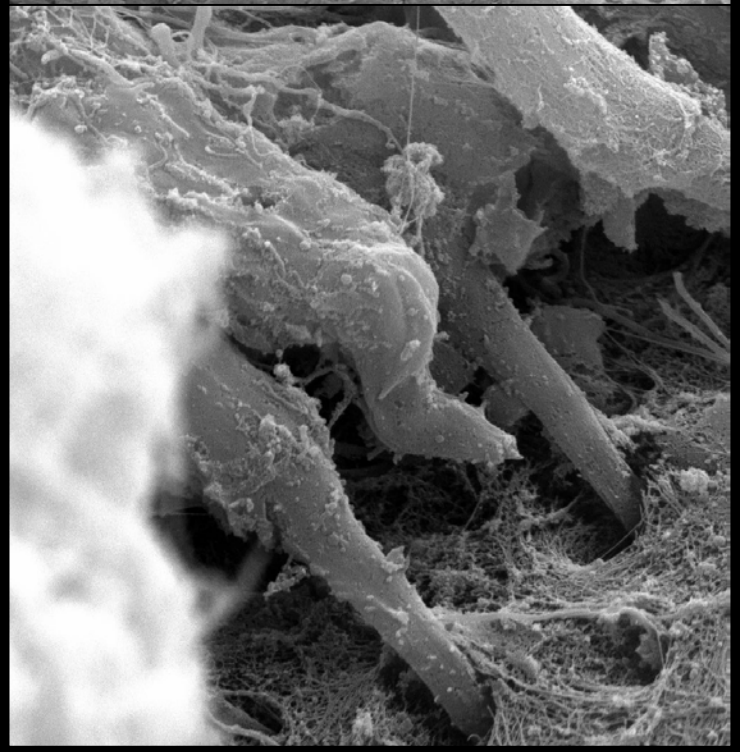


FIGURE 8-40 Schematic representation of the cells bordering pulp. *rER*, Rough endoplasmic reticulum.

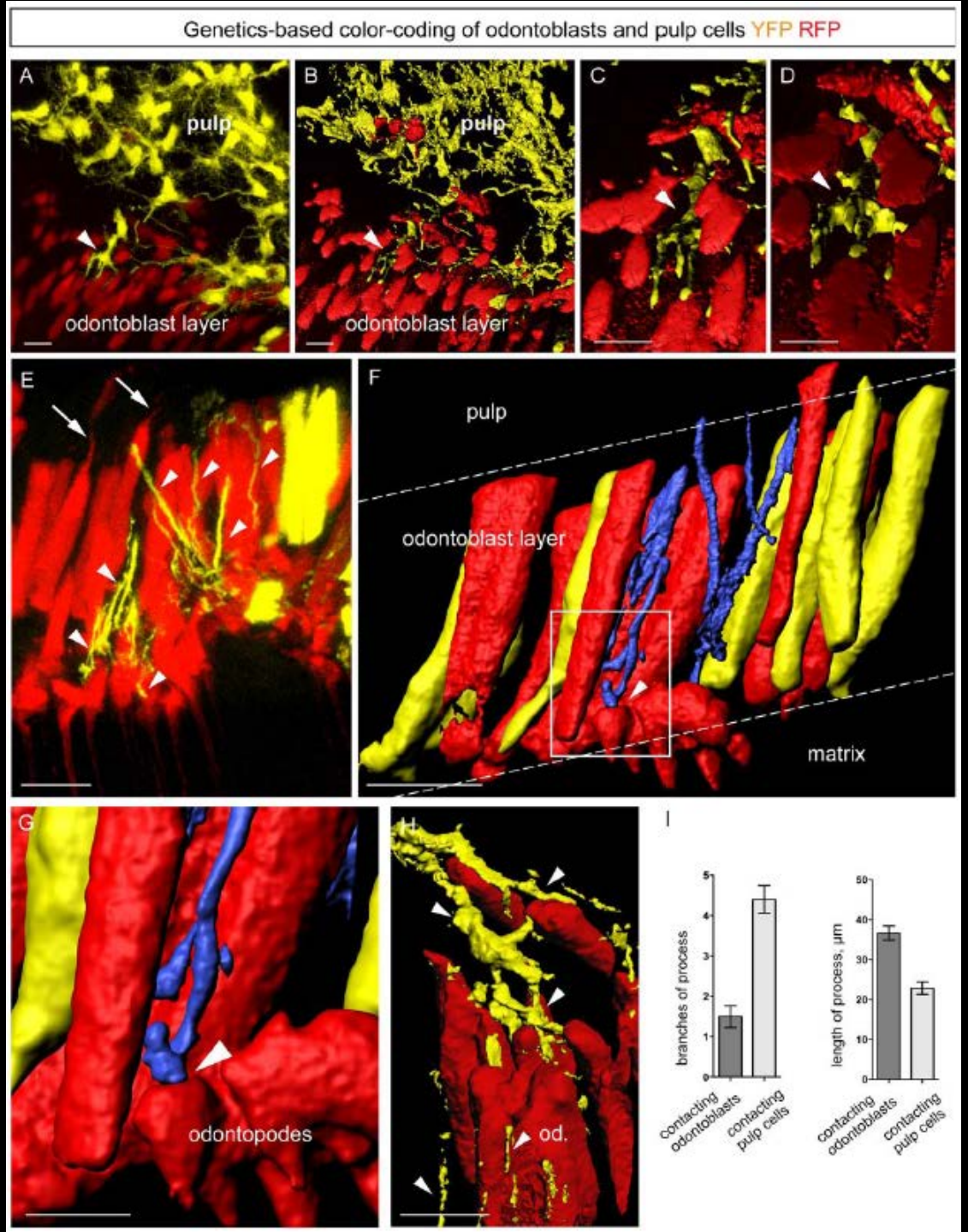
Odontoblasts



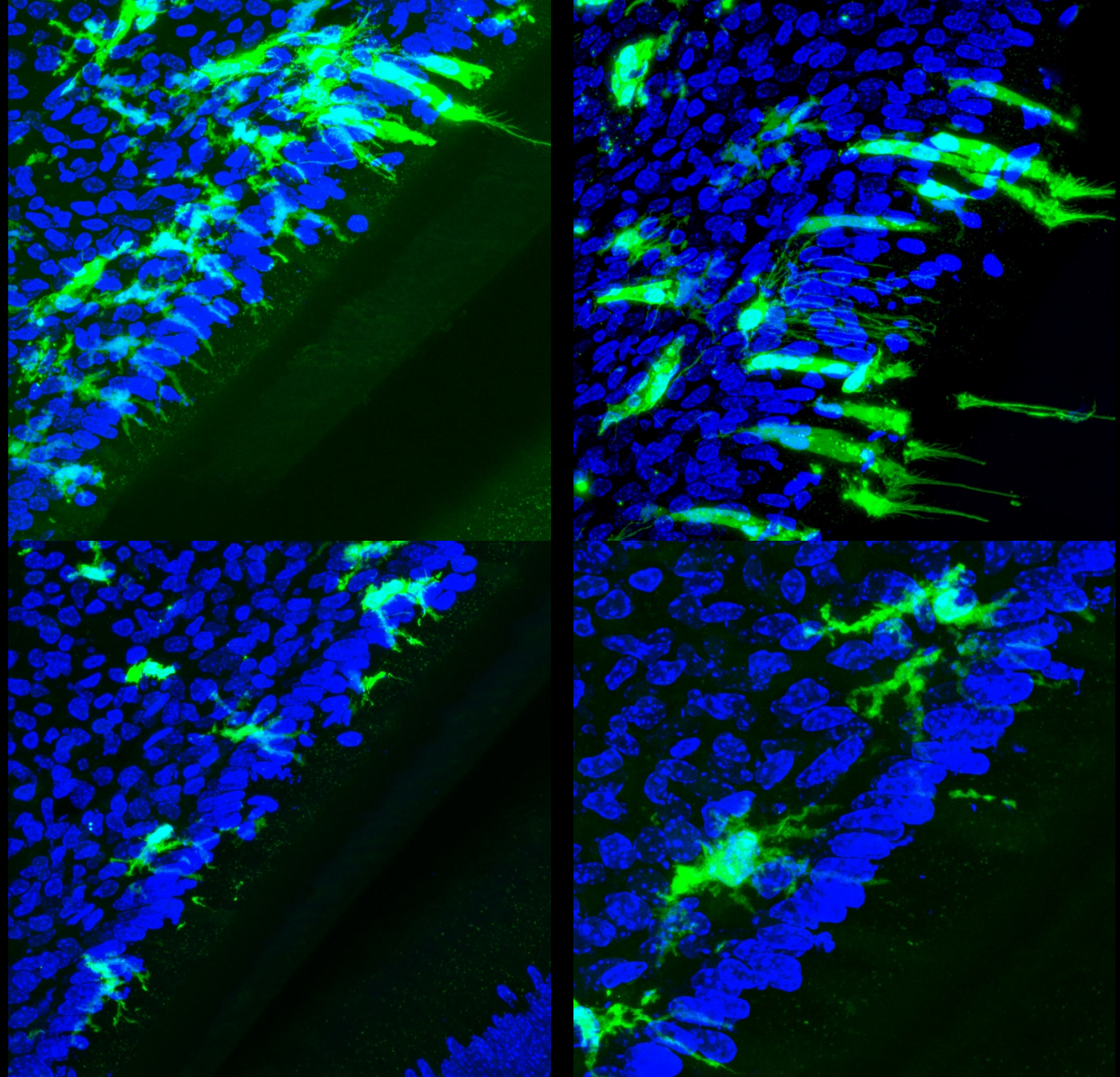




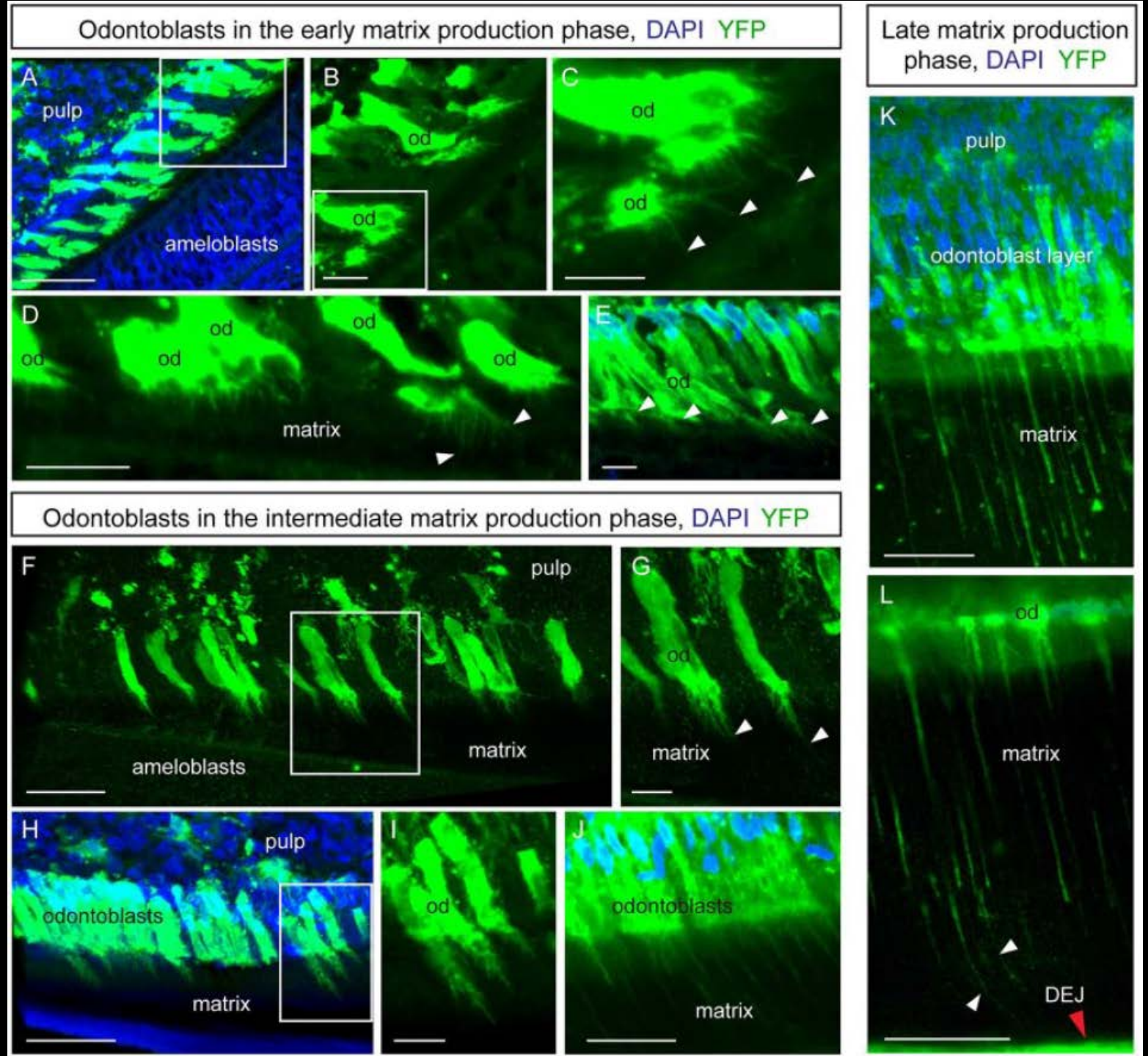
Odontoblasts



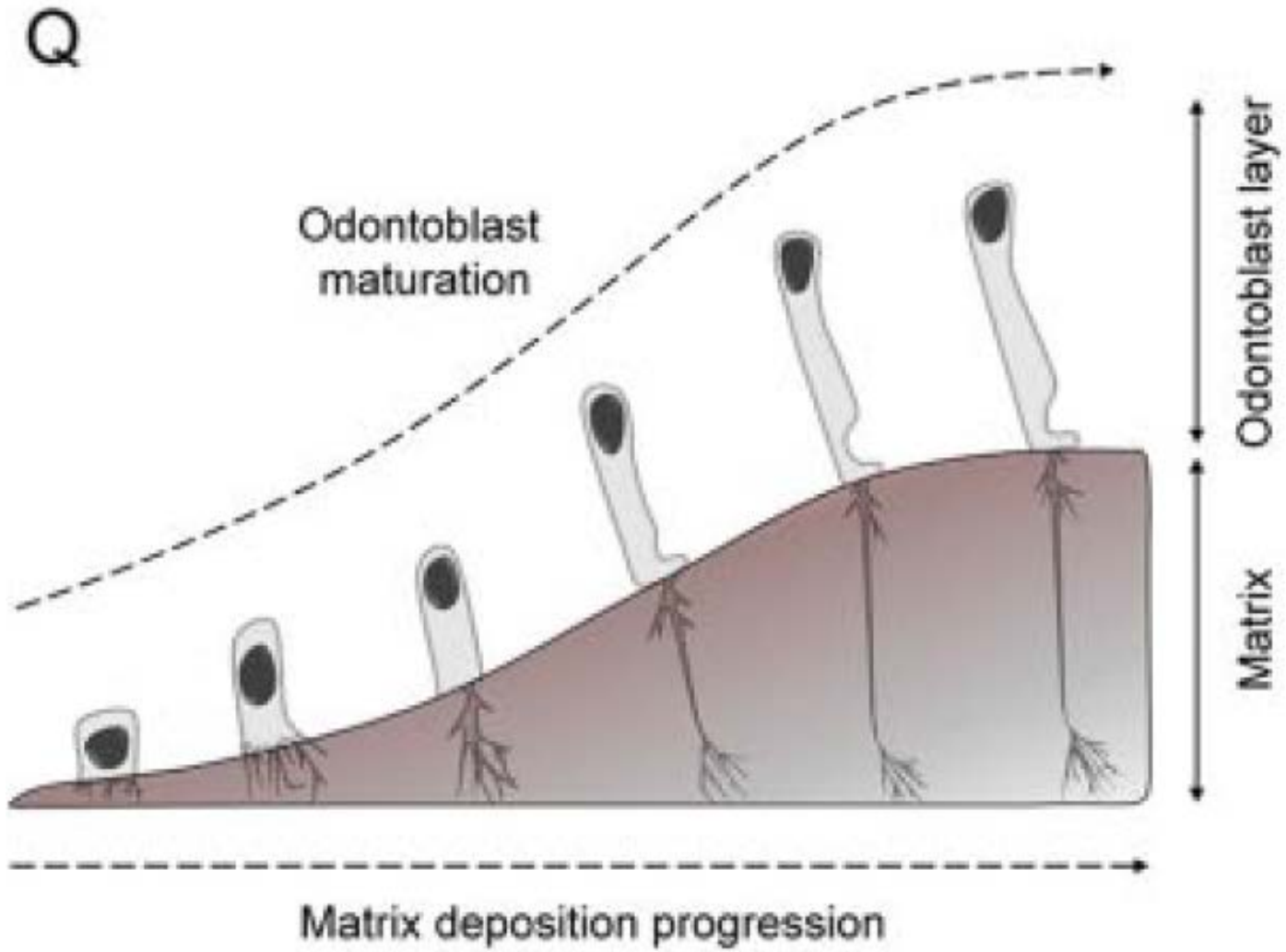
Odontoblasts /
Pulp cells

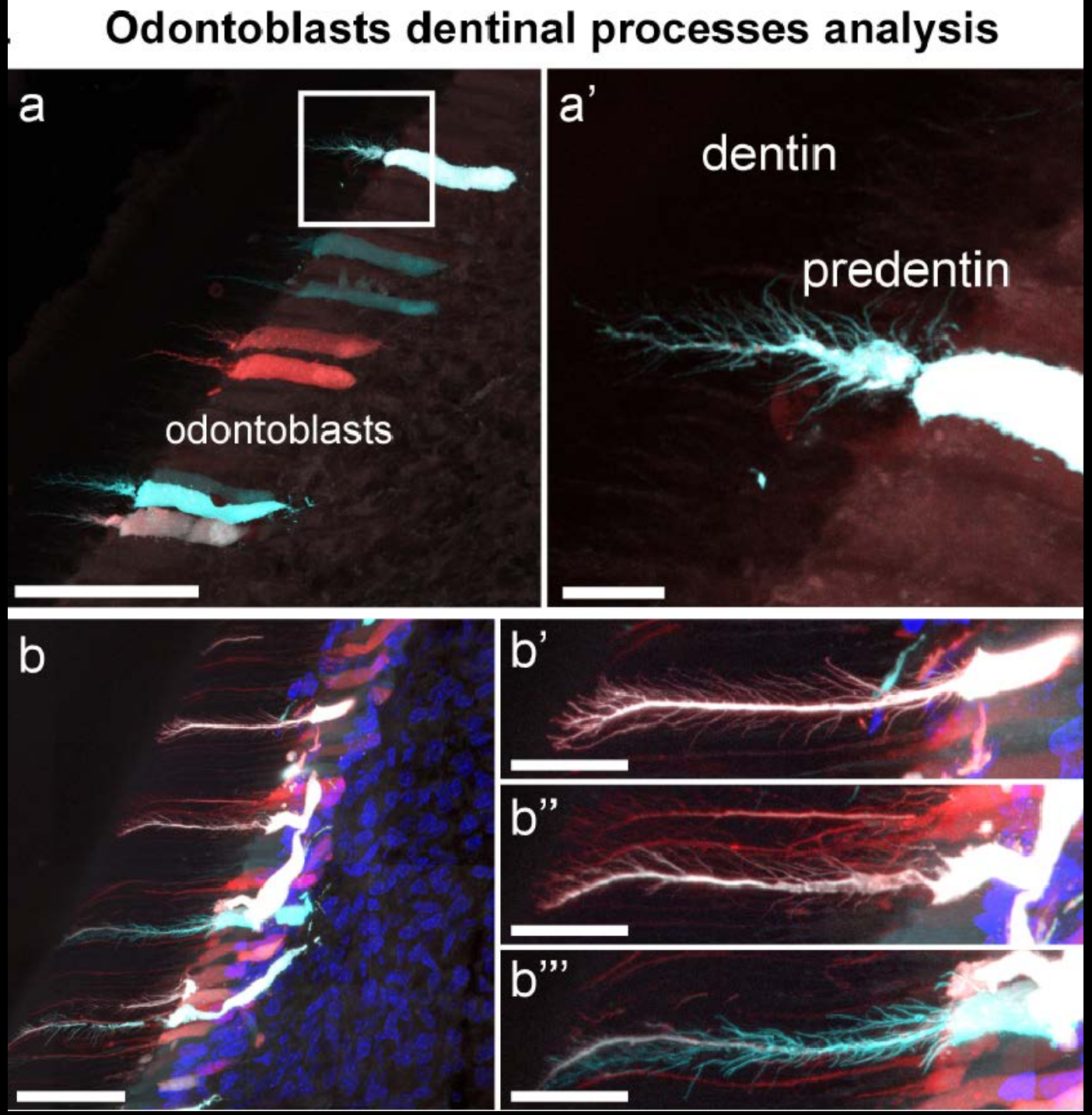


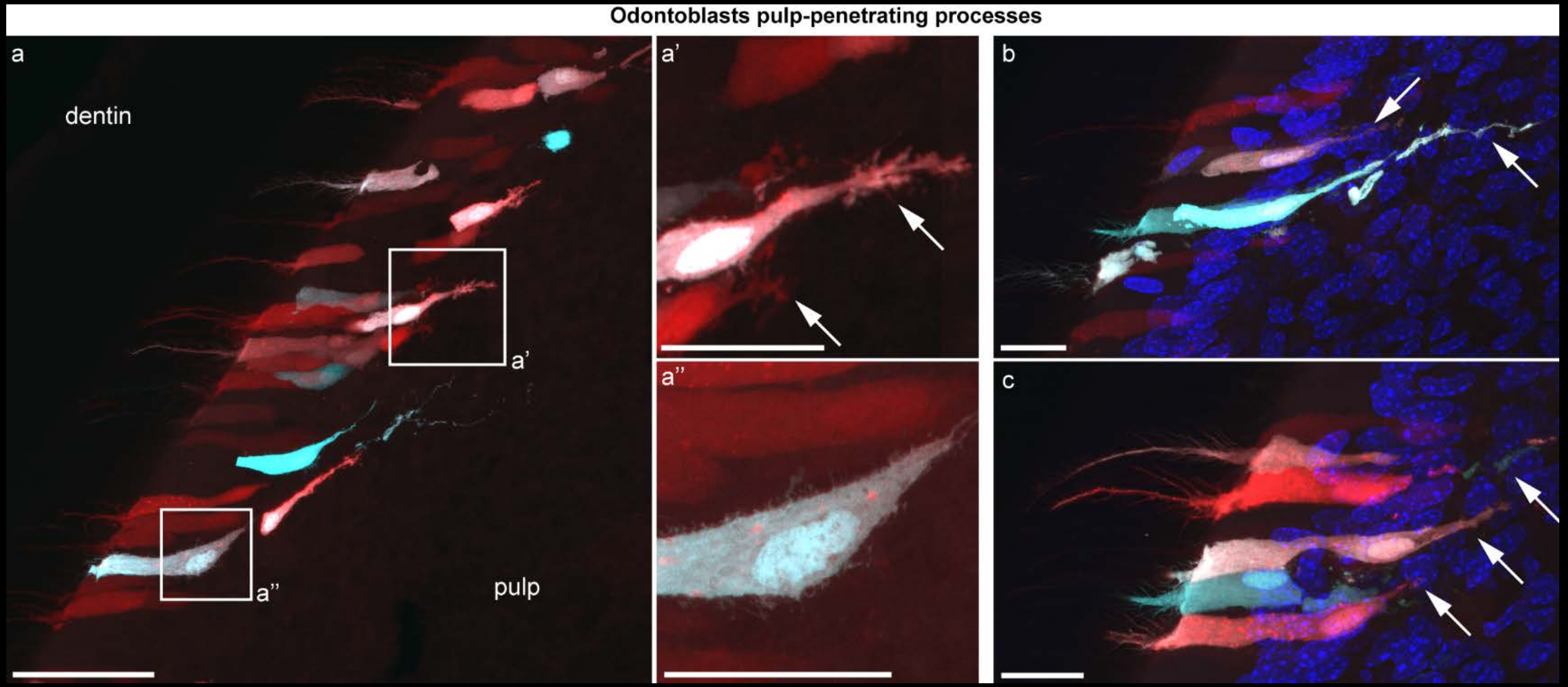
Development of odontoblasts



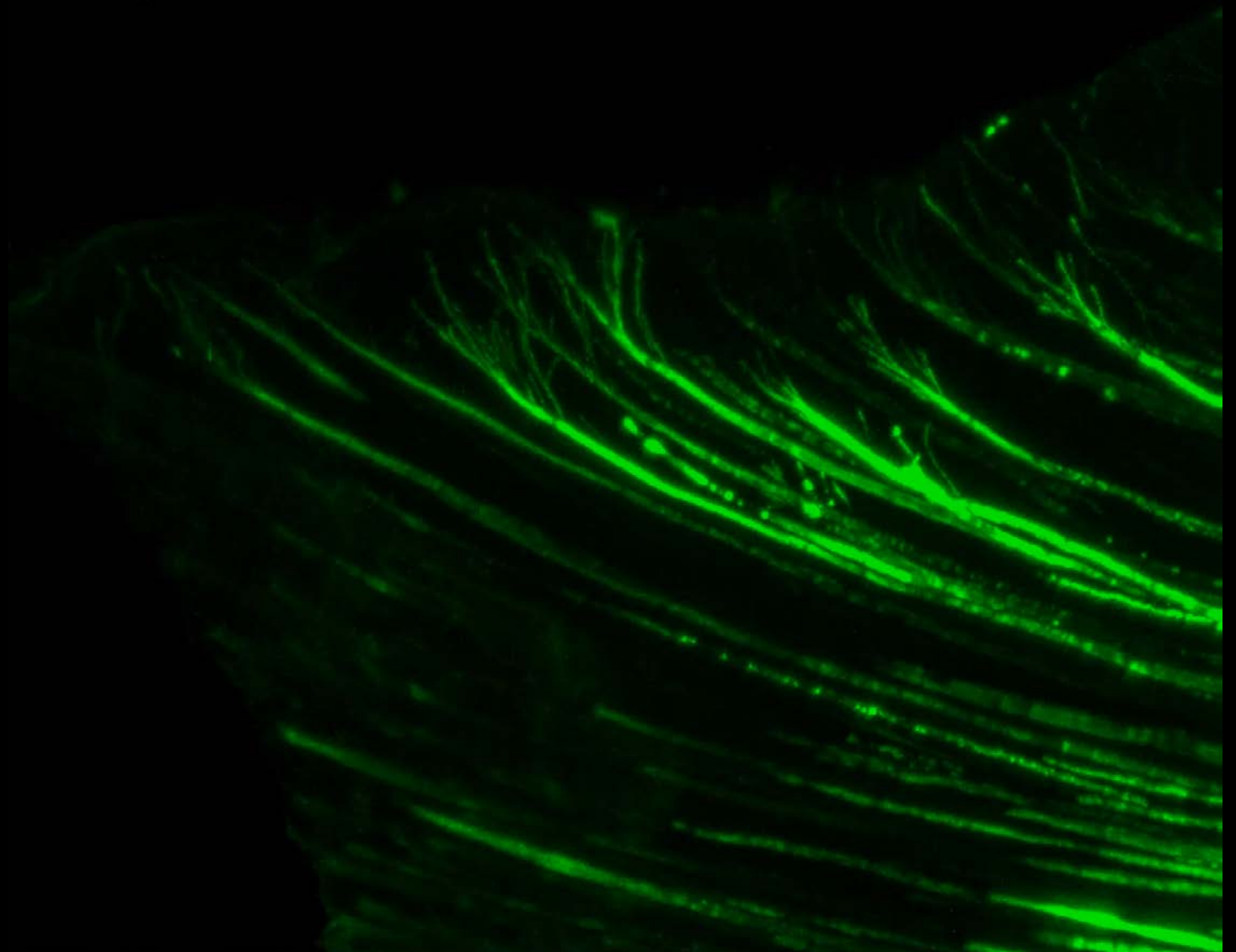
Development of odontoblasts



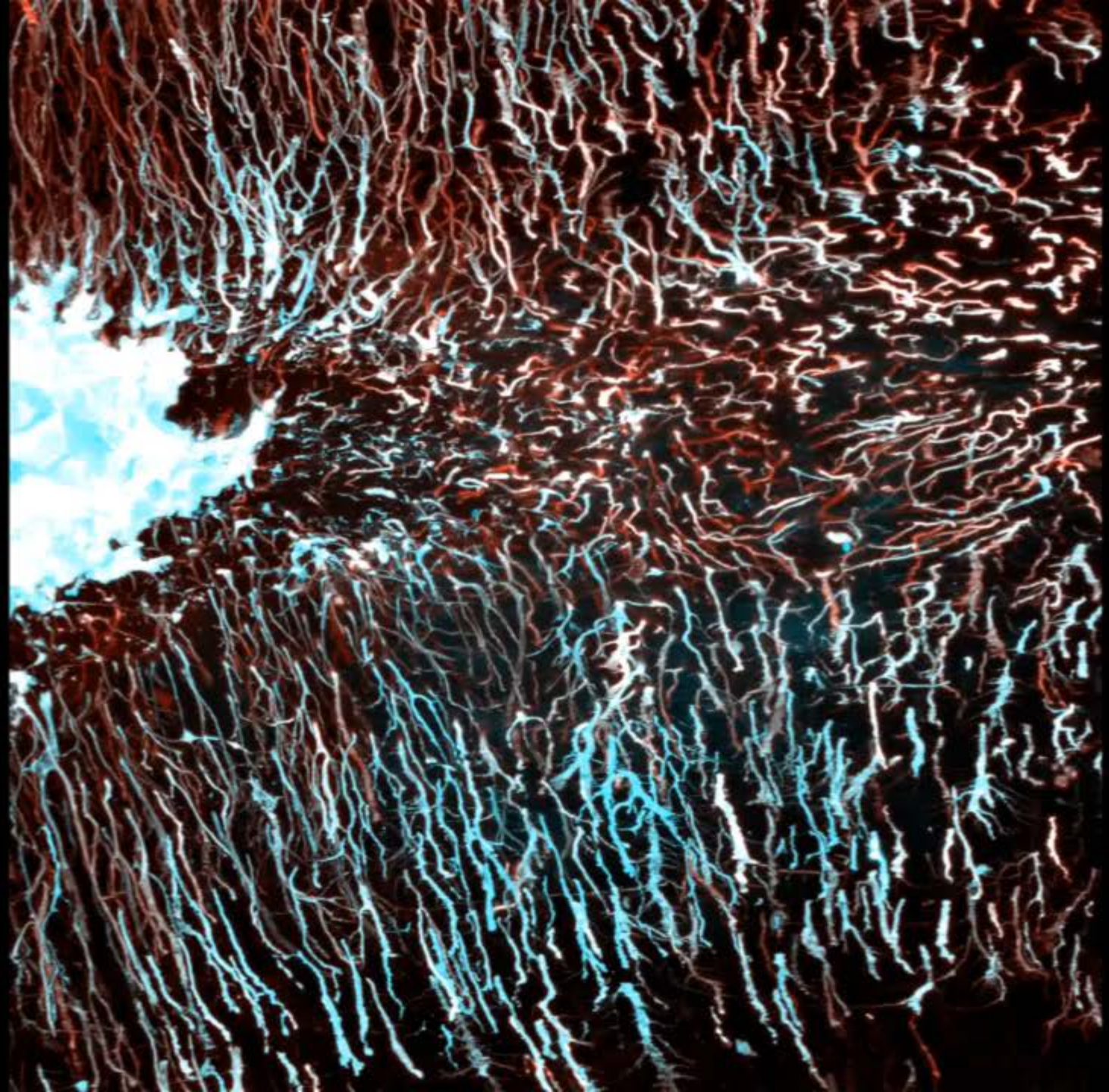

Odontoblasts dentinal processes analysis
a
odontoblasts
a'
dentin
predentin
b
b'
b''
b'''


Odontoblasts pulp-penetrating processes
a
dentin
a'
a''
pulp
a'
a''
b
c

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

Extracelular matrix (ECM)

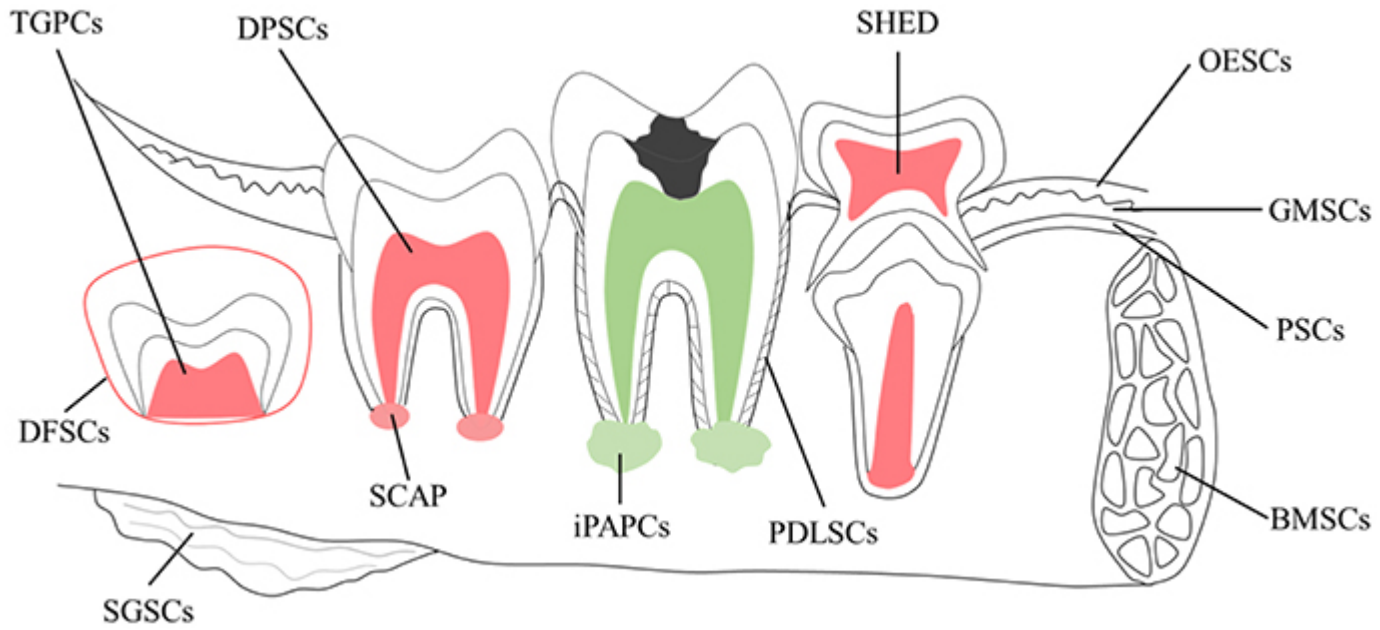
- **Fibres:**
  - Collagen
  - Reticular fibres

- **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

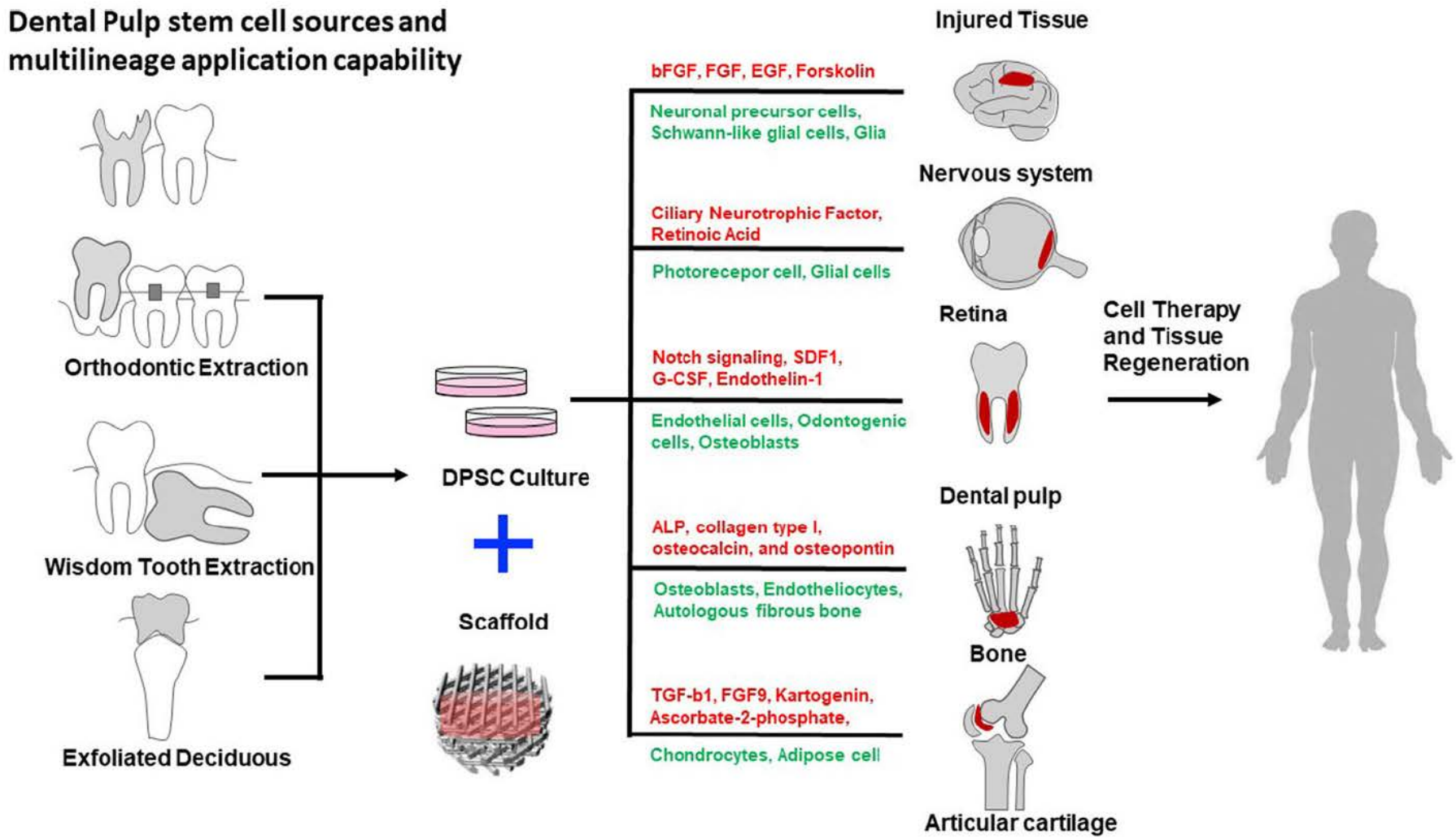
Stem Cells in (human) teeth



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

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

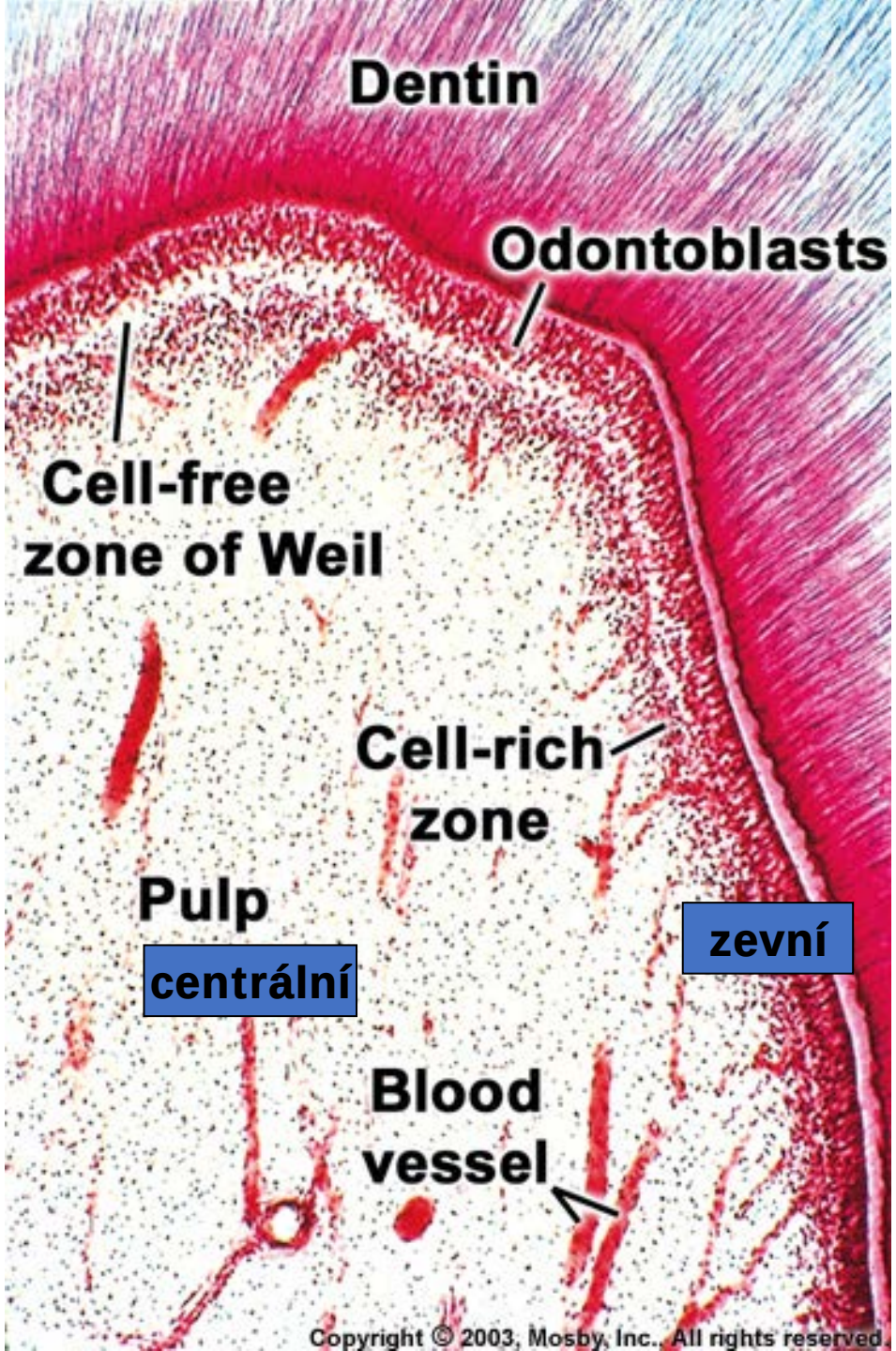
(Yang et al., 2017)

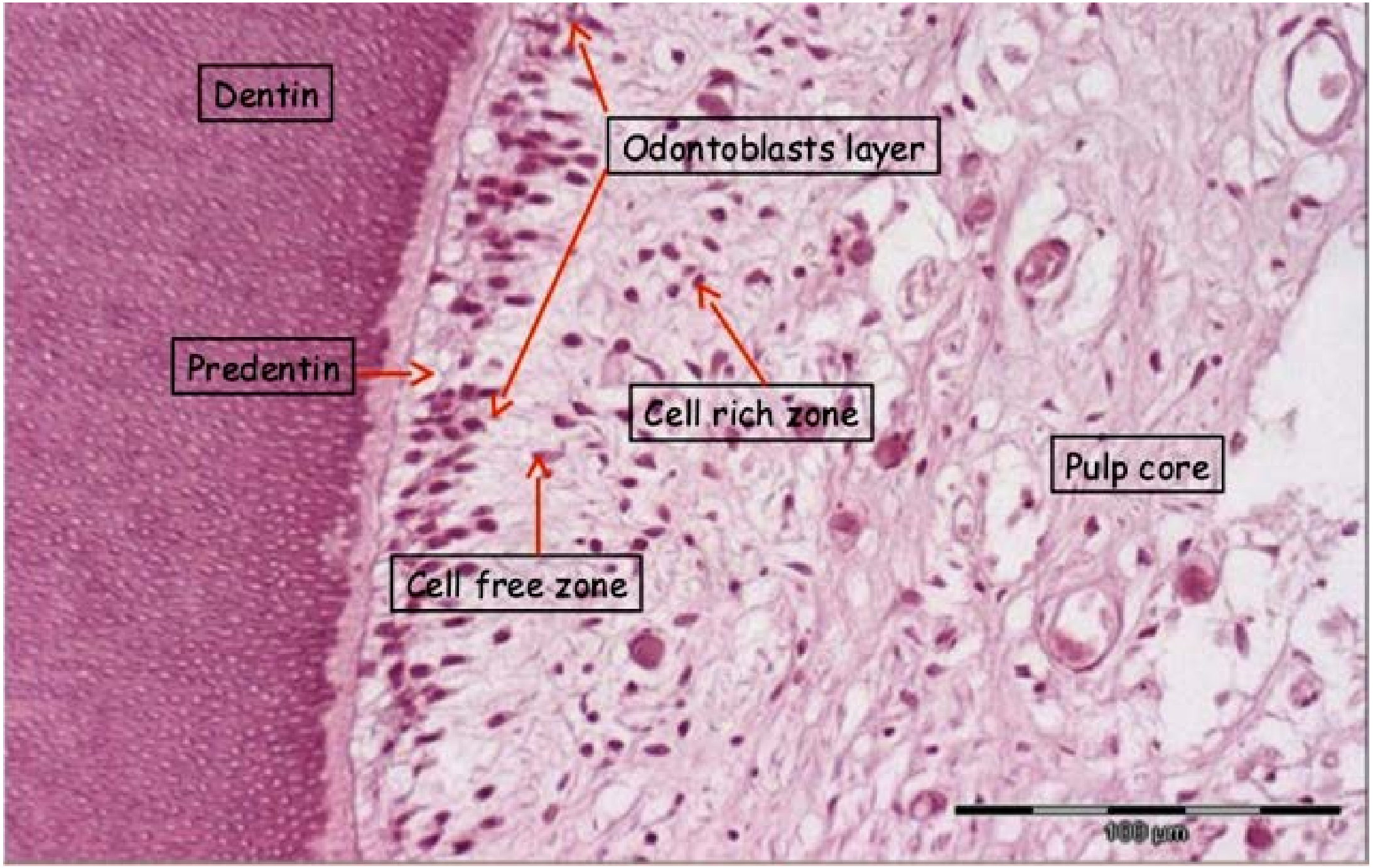

Dental Pulp stem cell sources and multilineage application capability
Orthodontic Extraction
Wisdom Tooth Extraction
Exfoliated Deciduous
DPSC Culture
Scaffold
bFGF, FGF, EGF, Forskolin
Neuronal precursor cells, Schwann-like glial cells, Glia
Ciliary Neurotrophic Factor, Retinoic Acid
Photorecepor cell, Glial cells
Notch signaling, SDF1, G-CSF, Endothelin-1
Endothelial cells, Odontogenic cells, Osteoblasts
ALP, collagen type I, osteocalcin, and osteopontin
Osteoblasts, Endotheliocytes, Autologous fibrous bone
TGF-b1, FGF9, Kartogenin, Ascorbate-2-phosphate,
Chondrocytes, Adipose cell
Injured Tissue
Nervous system
Retina
Dental pulp
Bone
Articular cartilage
Cell Therapy and Tissue Regeneration

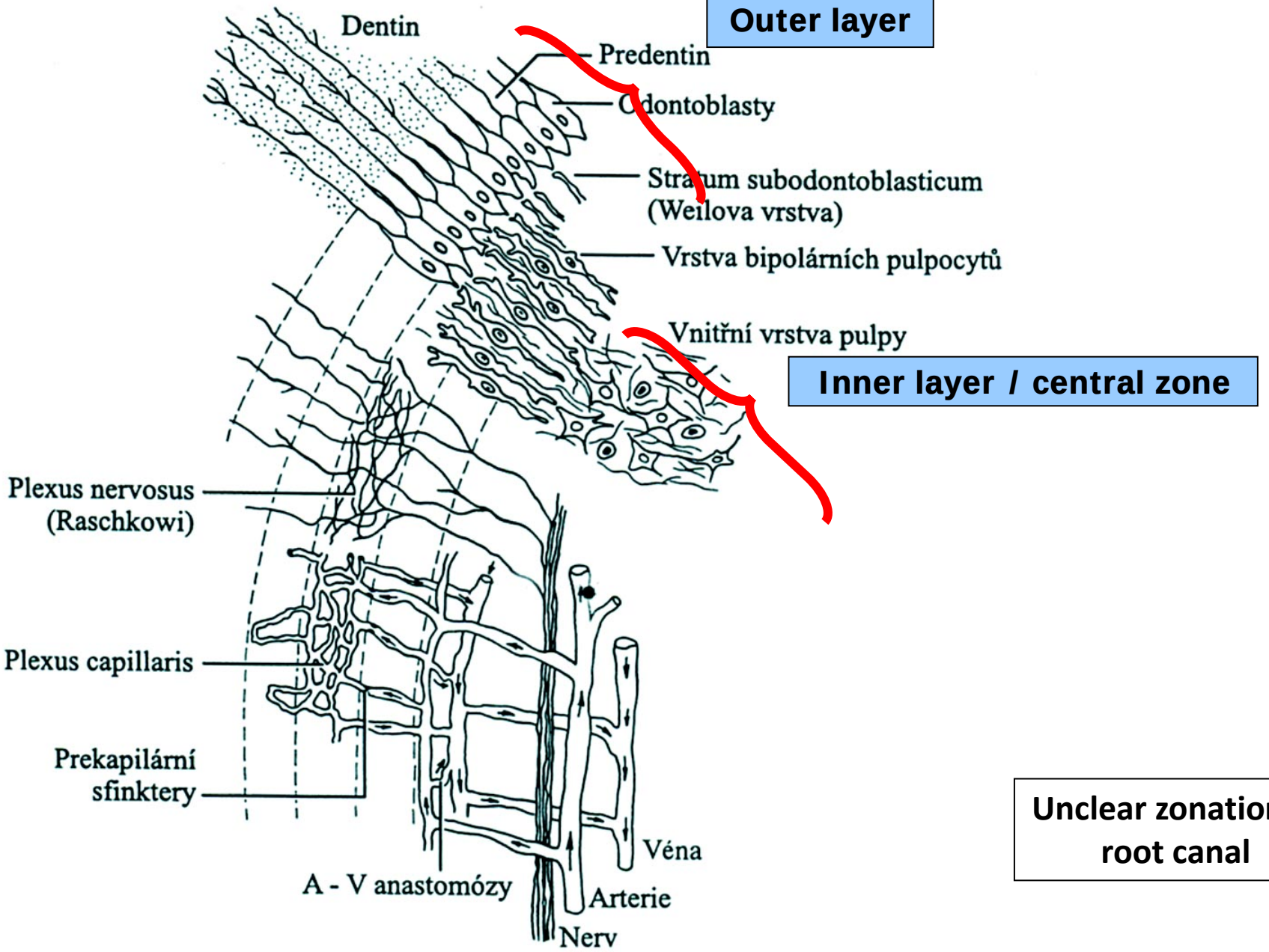
Dental pulp stratification

Two layers (crown part)

Outer - surface
Inner - central




Dentin
Odontoblasts layer
Predentin
Cell rich zone
Pulp core
Cell free zone
100 µm



Outer layer

Inner layer / central zone

Unclear zonation in root canal

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

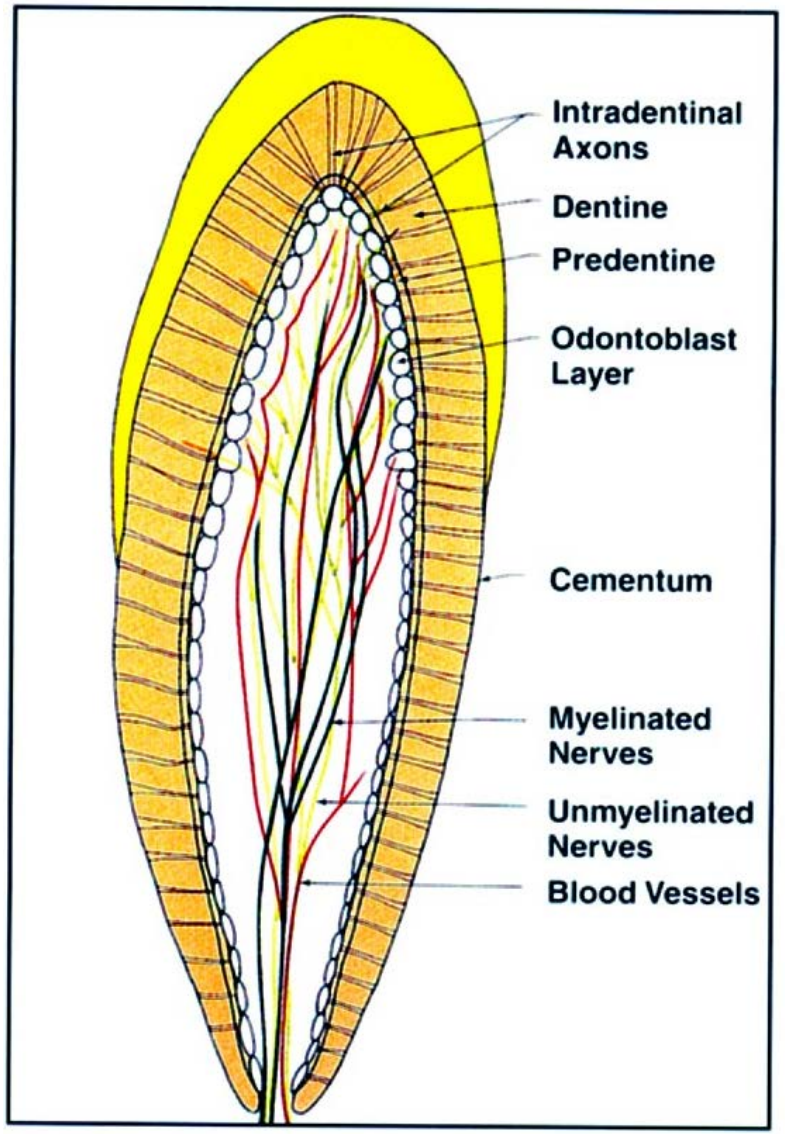
Blood and lymph vessels

Very rich blood supply (especially at a young age)

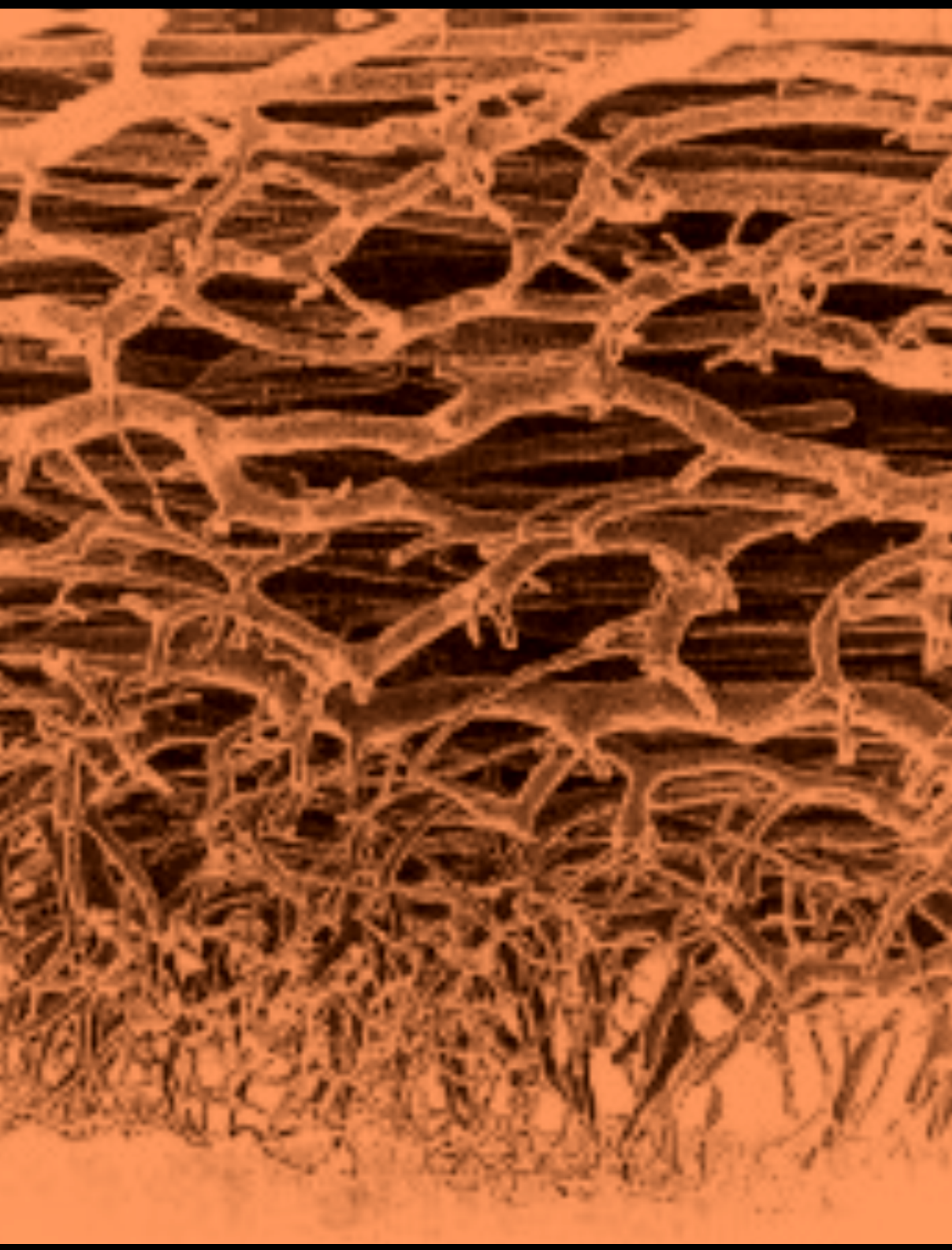
Arteries (2-10)
- Oriented longitudinally through the center of the pulp
- Numerous side branches
- They divide into terminal networks – odontoblasts supply

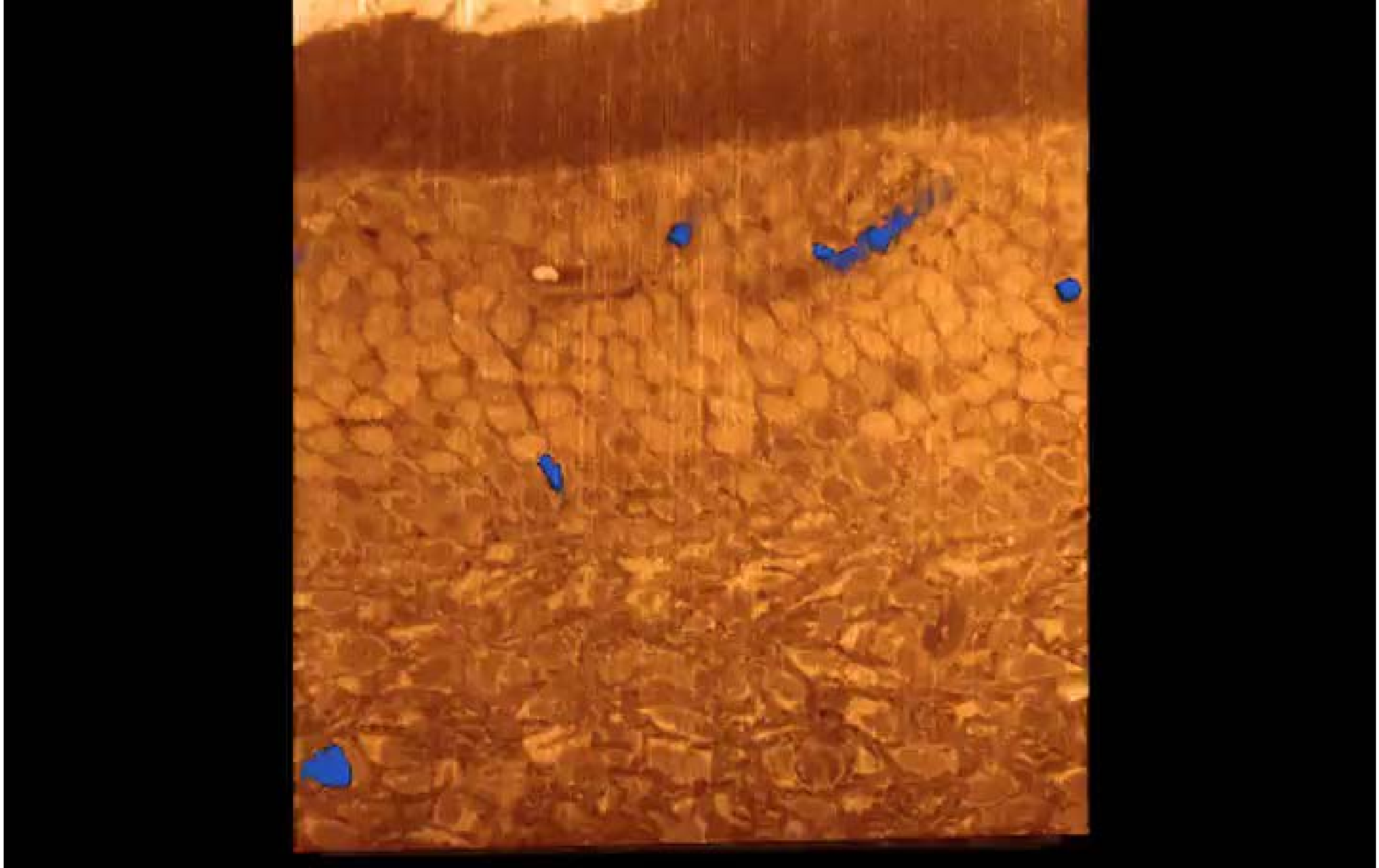
Subodontoblastic capillary network
- Arteries with narrow lumen, thick wall reinforced by several layers of smooth muscle cells
- Veins and venules wall very thin, which strikingly contrasts with their wide luminosity

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 radicis dentis



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





Pulp inervation

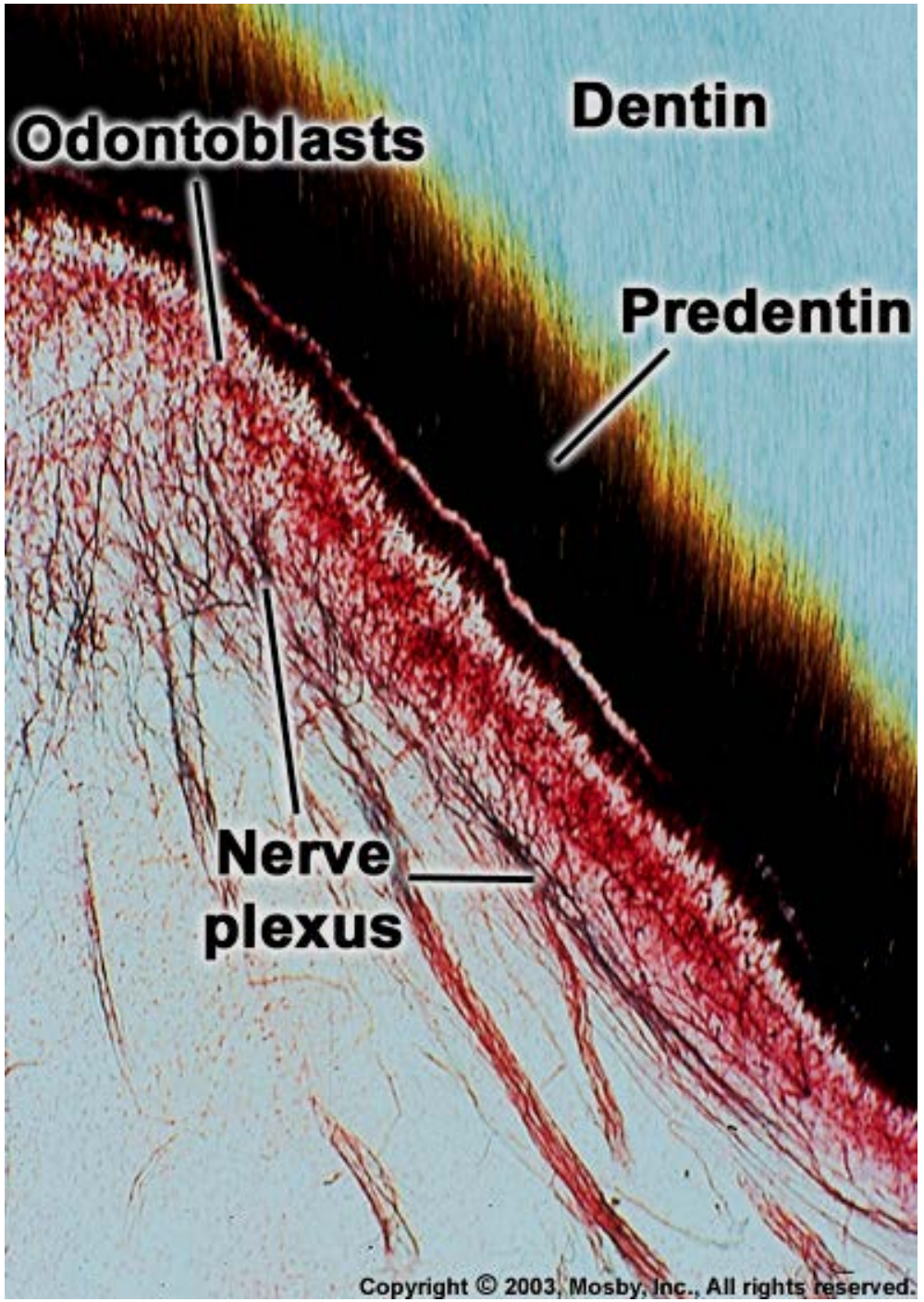
Both myelinated and non-myelinated

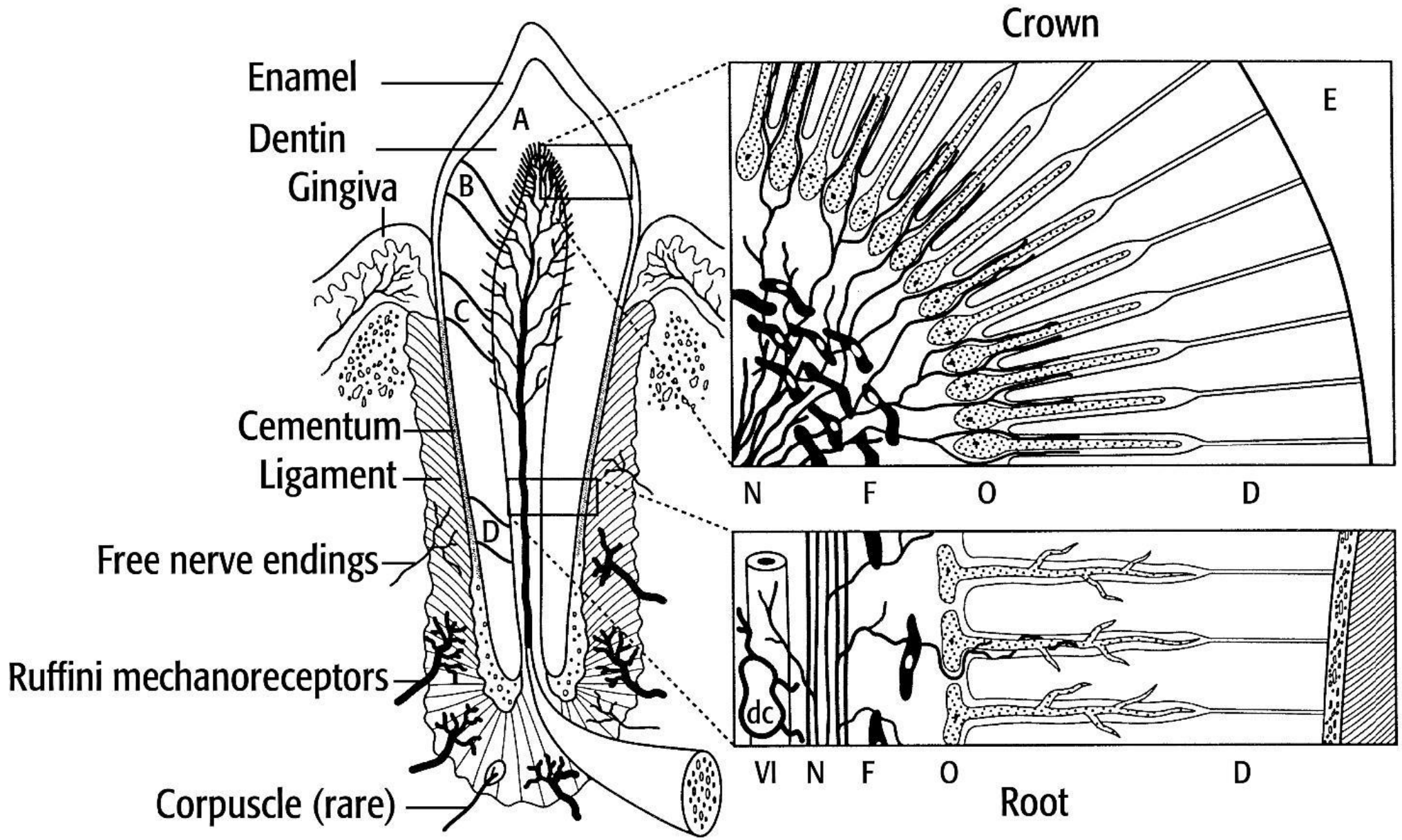
Myelinated nerve fibres in the dental pulp are rich in branches and reach up to the odontoblast bases under which they form a dense network:

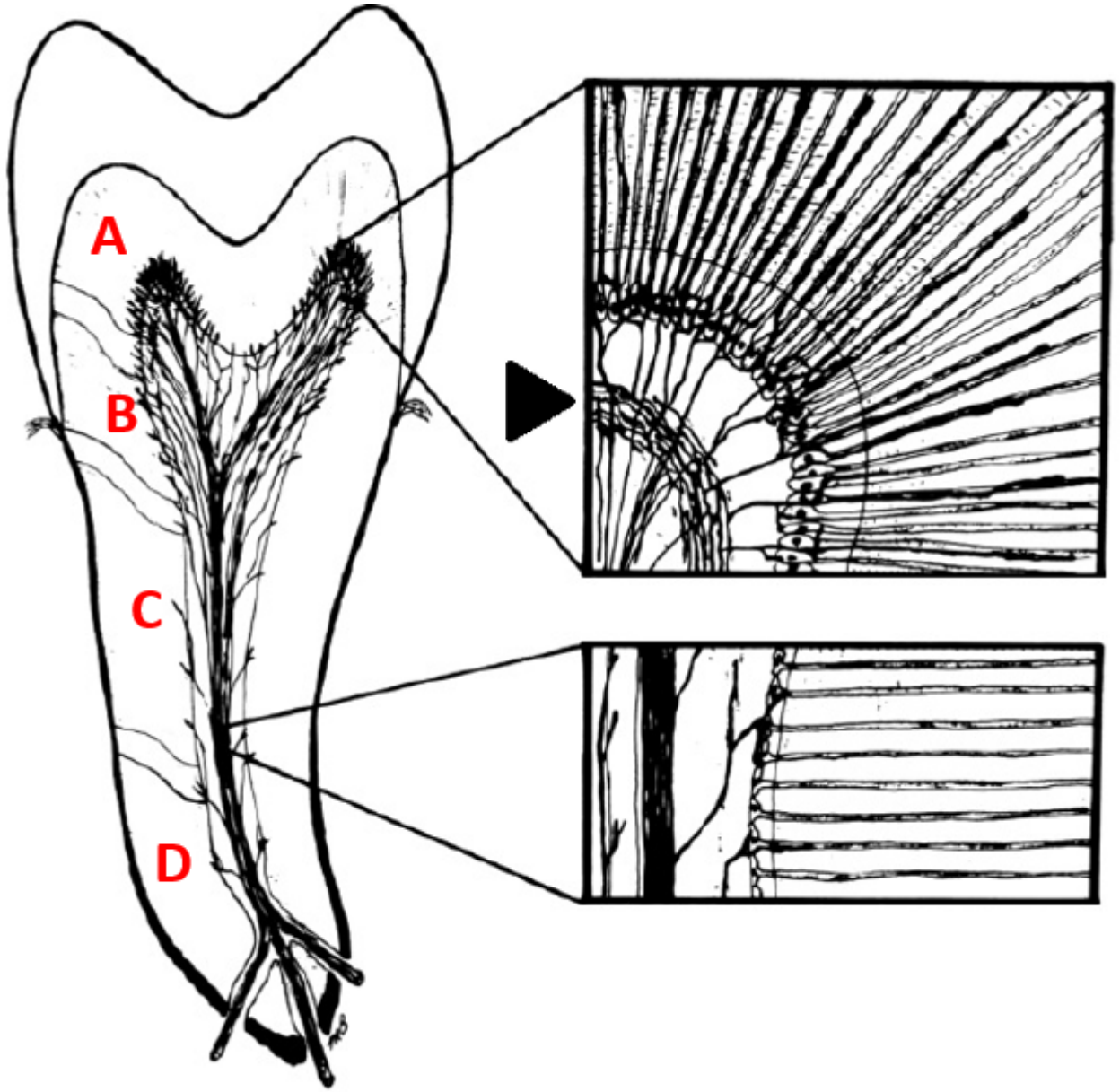
Plexus subodontoblasticus Raschkowi

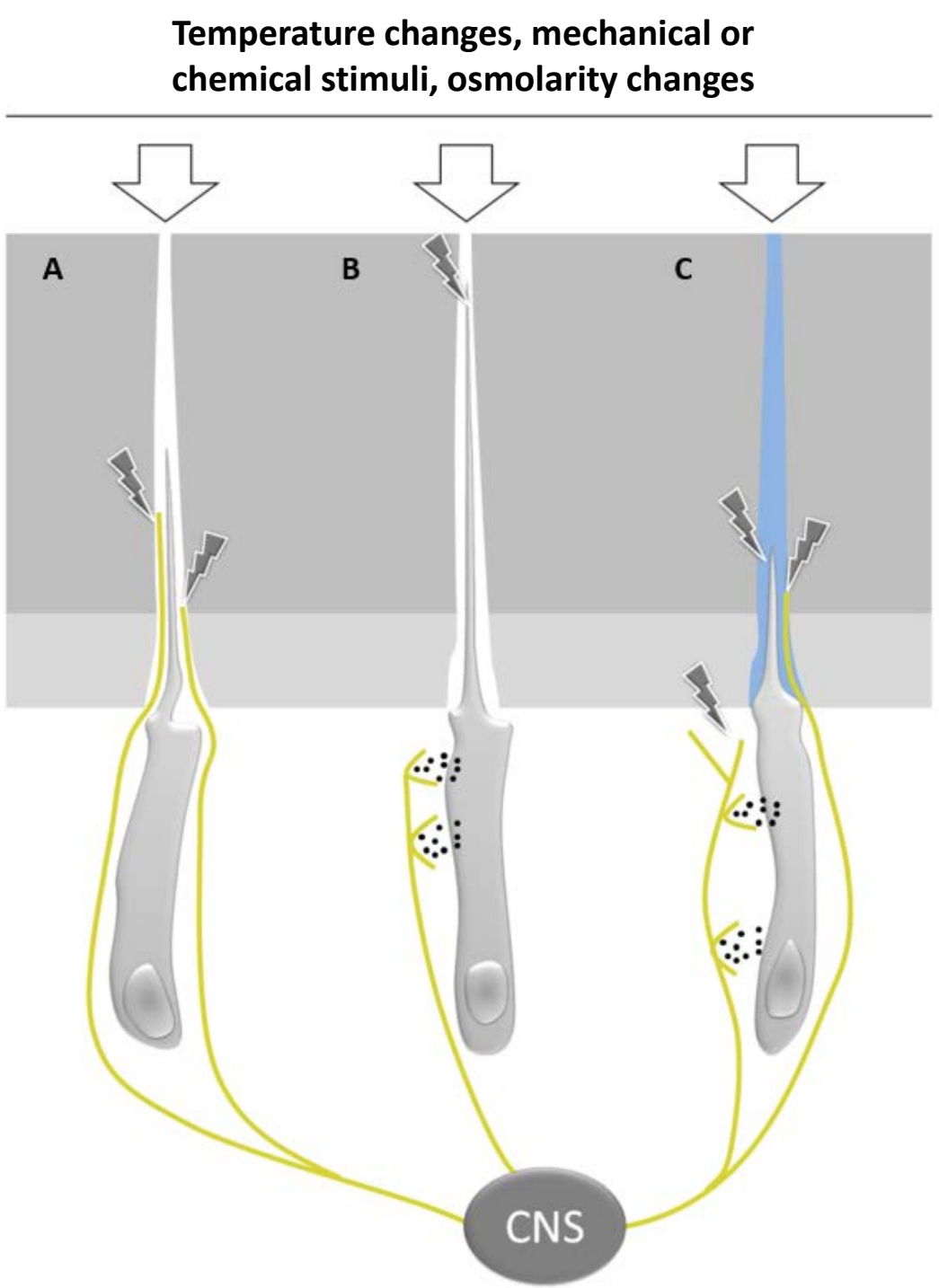
the nerve fibres ends on the bodies of the odontoblasts, some enters the predentin and dentin channels

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



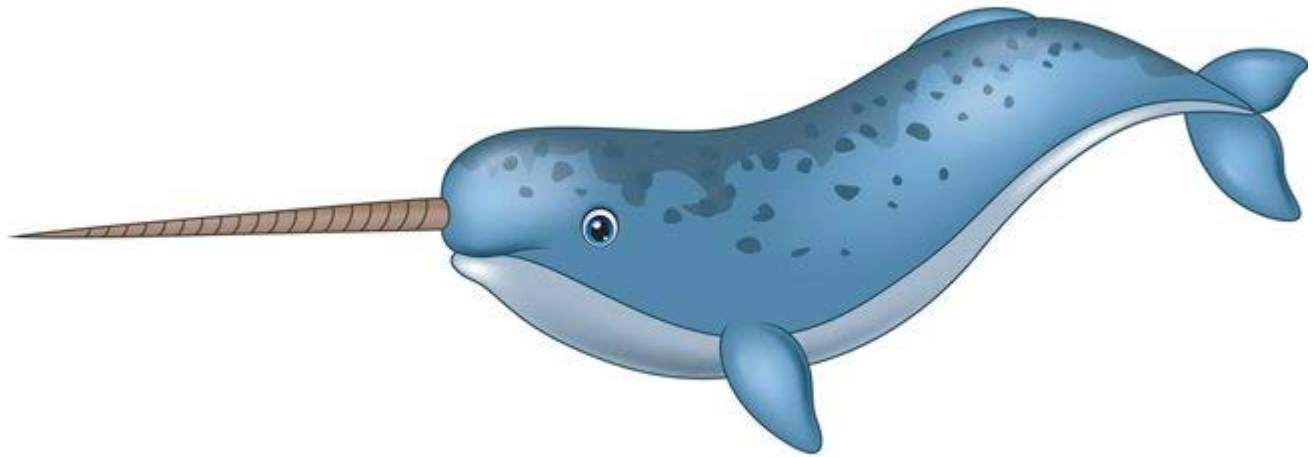

Crown
Enamel
Dentin
Gingiva
A
B
C
D
E
Cementum
Ligament
Free nerve endings
Ruffini mechanoreceptors
Corpuscle (rare)
N
F
O
D
dc
VI
N
F
O
D
Root

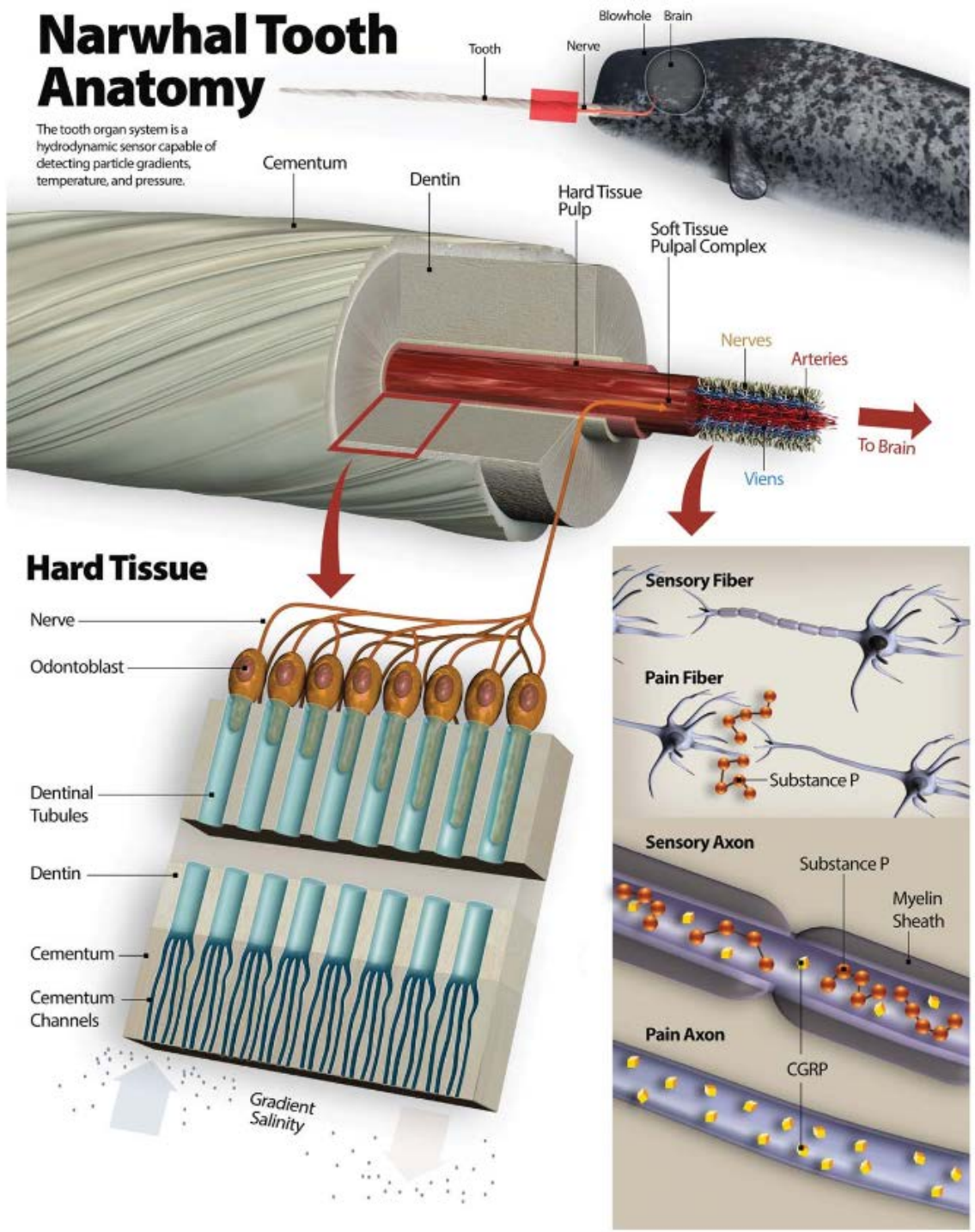

A
B
C
D



Theories of dental pulp perception

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



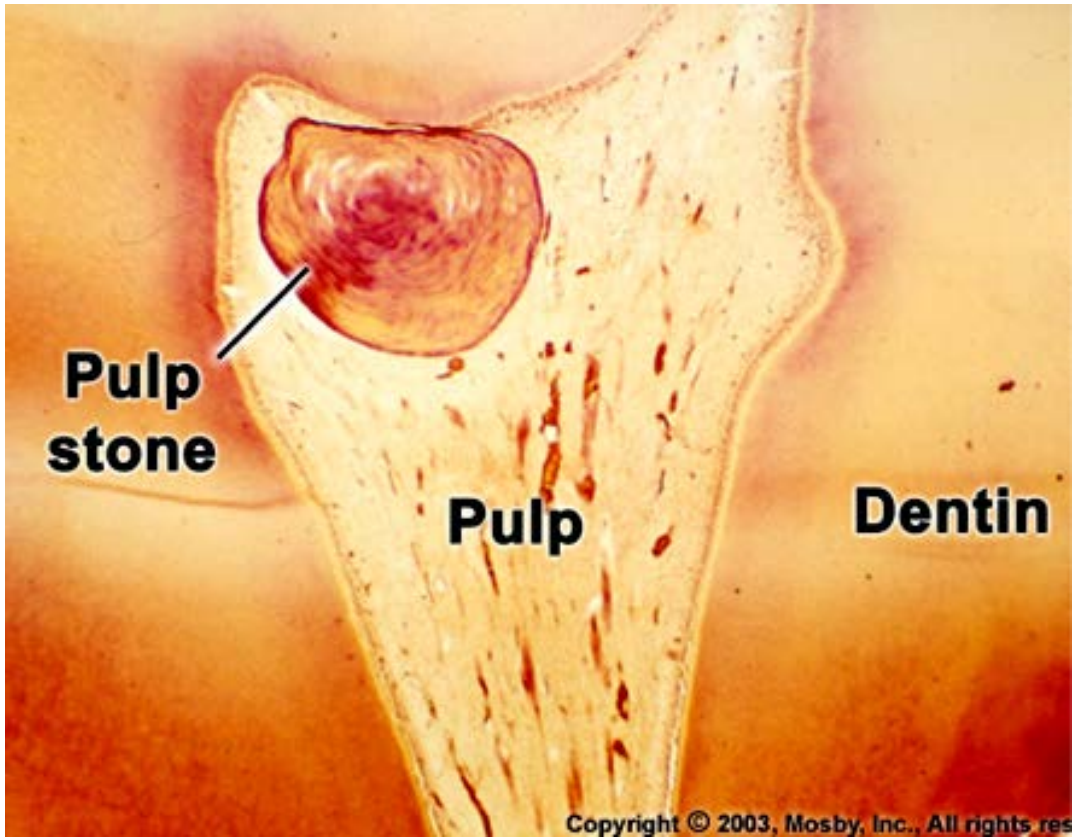


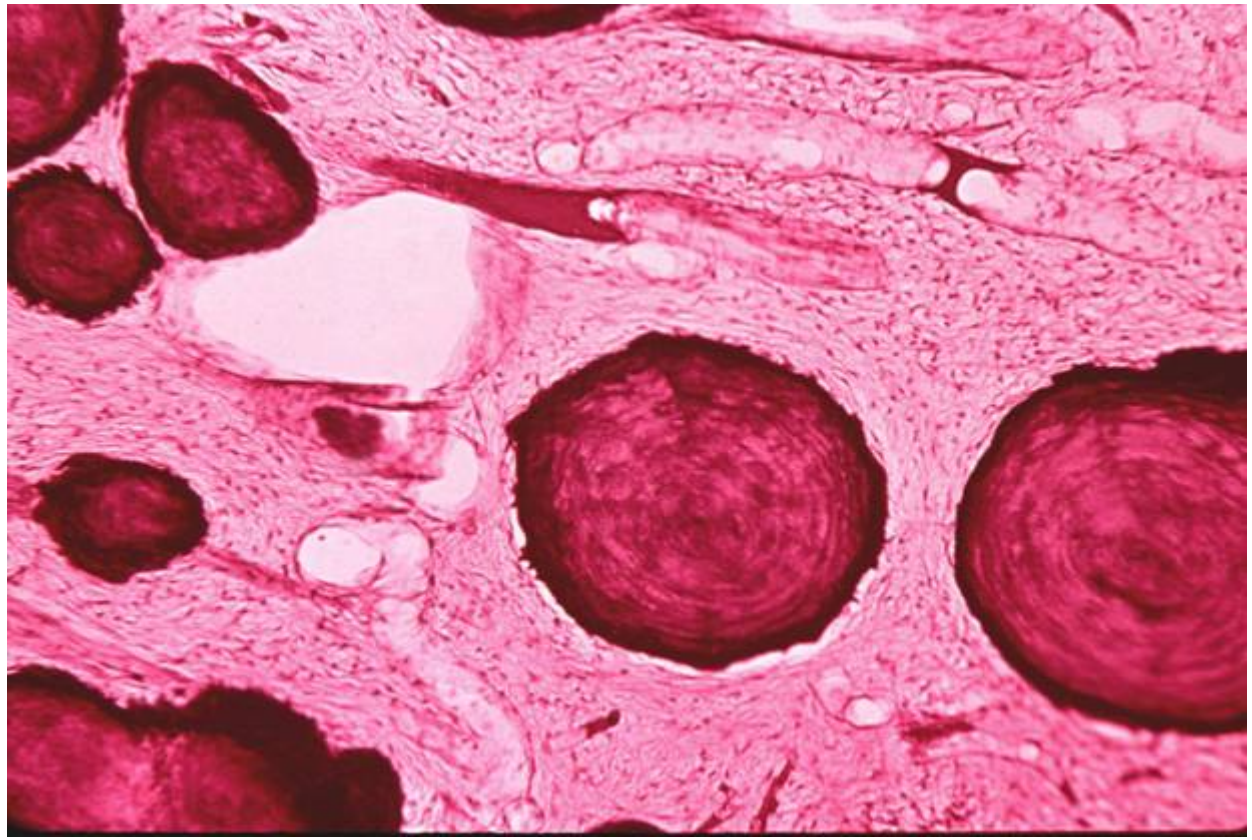
Nweeia et al., 2014

Pulp changes during aging

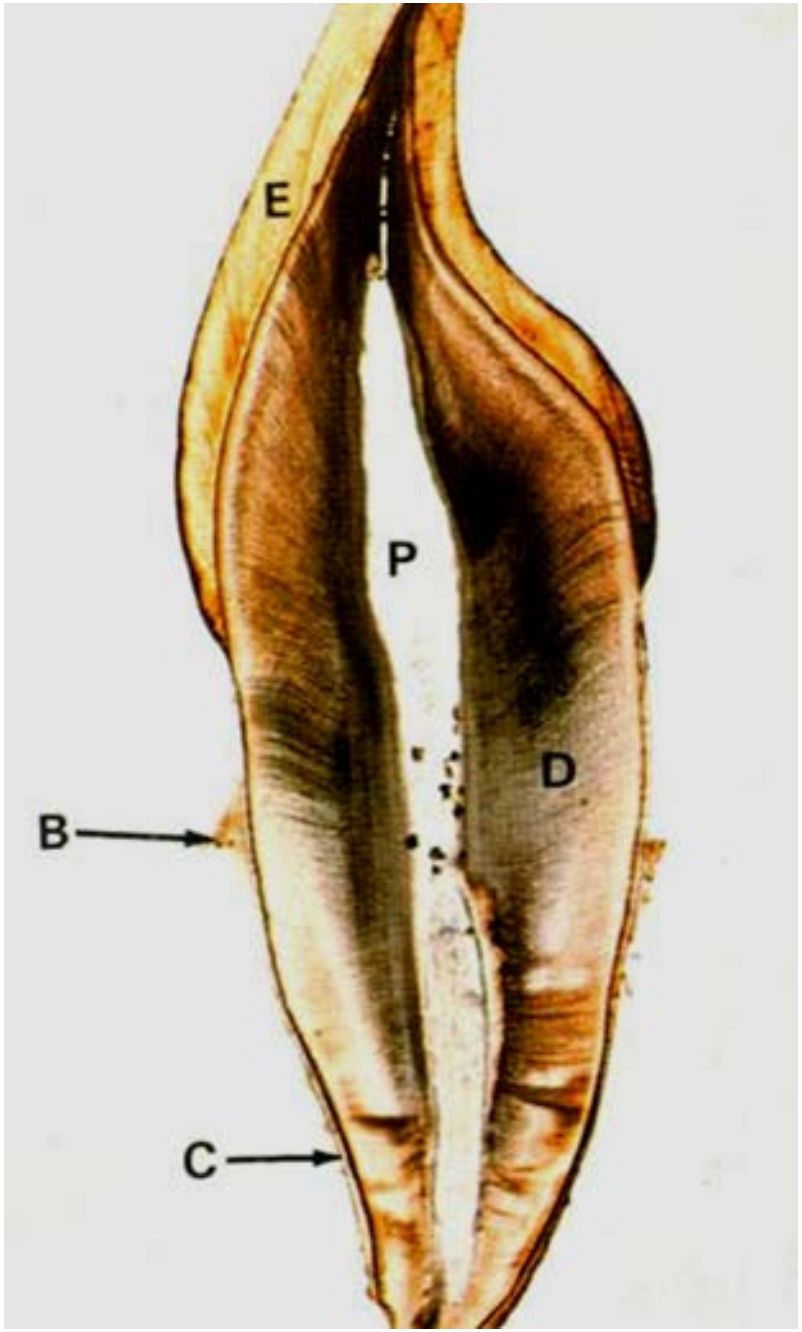
- Fastest development immediately after pruning
- Age-related changes: chemical composition, structure and volume

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

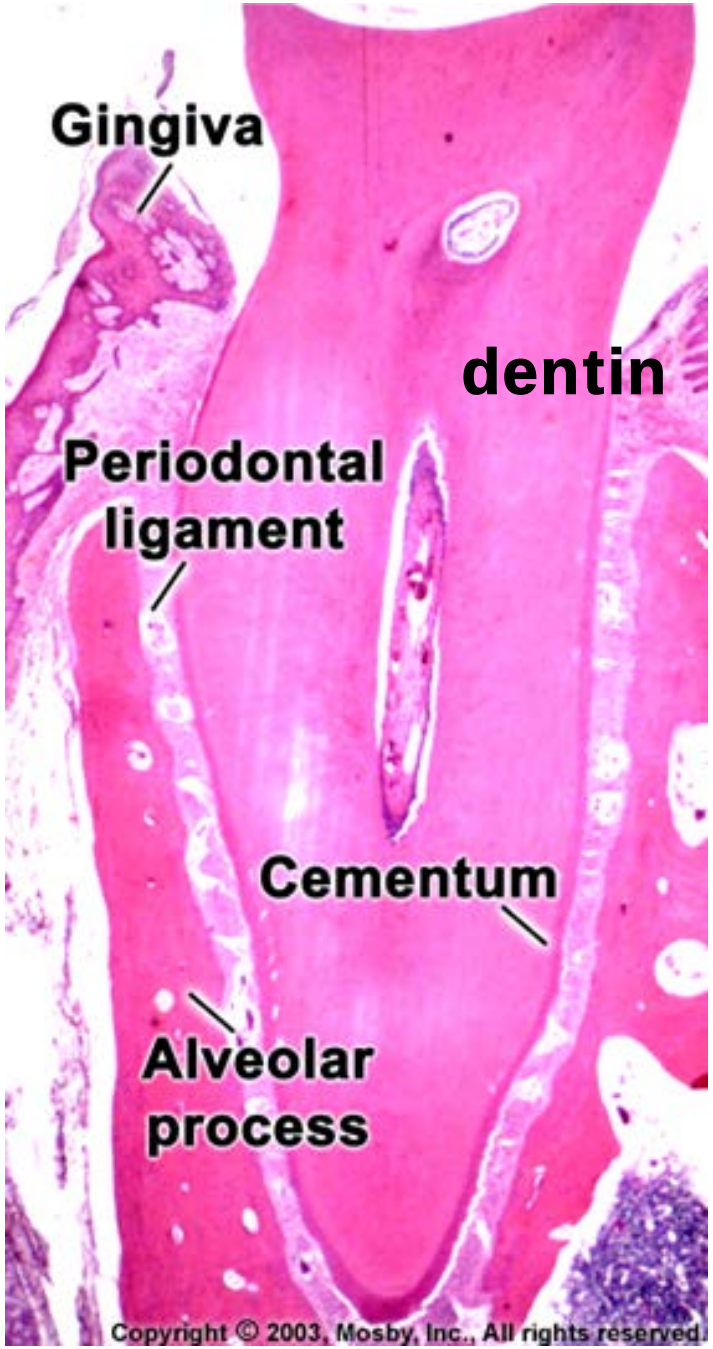




DENTIN

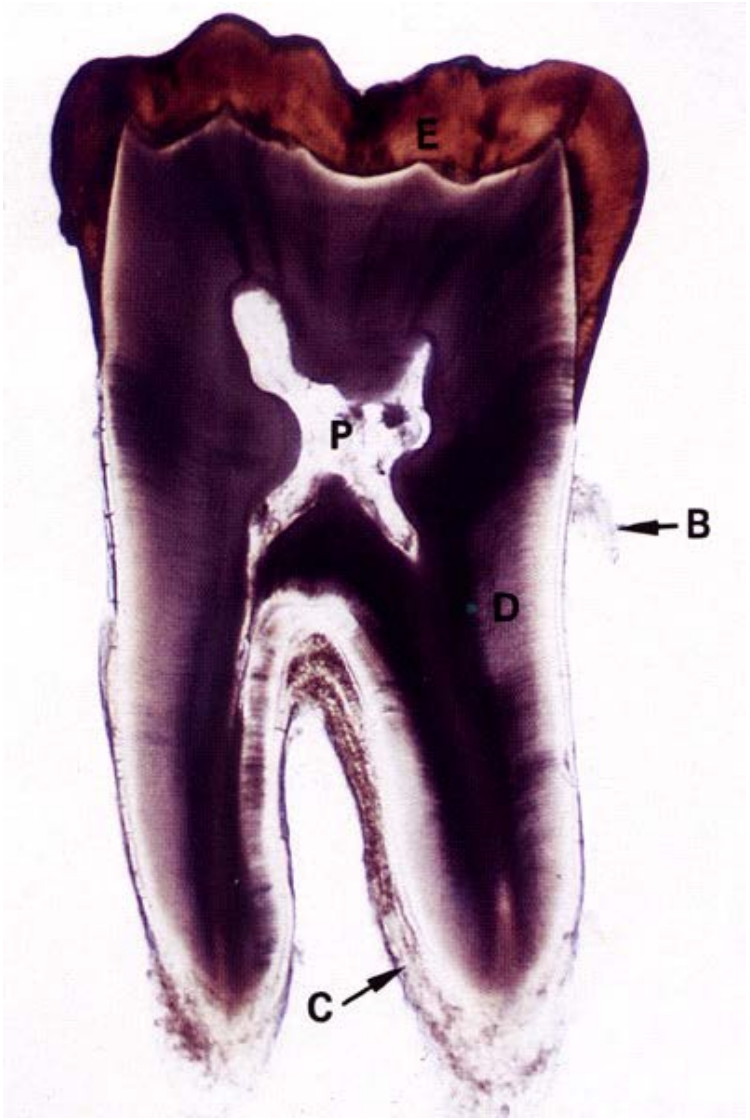


Podélný výbrus



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-lamelar structure
Derives from ectomesenchyme

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

<u>Physical properties</u>
Ivory color
Harder than bone or cementum, but softer than enamel
Refractive index 1.62 (same as enamel)
Specific weight 2.14 g/cm3 (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**
Colour	White (to light blue)	Ivory	Brown-yellow	Brown-yellow
Inorganic (%) **Organic (%)** **H_20 (%)**	96 (86) 1 (2) 3 (11)	70 (45) 20 (30) 10 (25)	61 (33) 27 (31) 12 (36)	45 (23) 30 (37) 25 (40)
Collagen fibres	NO	YES (perpendicular to the dentinal tubules)	YES (in all directions)	YES (same direction in lamellas)
Cells	**Ameloblasts** (missing in adults)	**Odontoblasts** (on the pulpal side of dentin)	**Cementoblasts** (cementocytes)	**Osteoblasts** osteocytes
Blood vessels	NO	NO	NO	YES (in Haversian canals)
Nerves	NO	YES (on entry of dentinal tubules)	NO	YES (in Haversian canals)

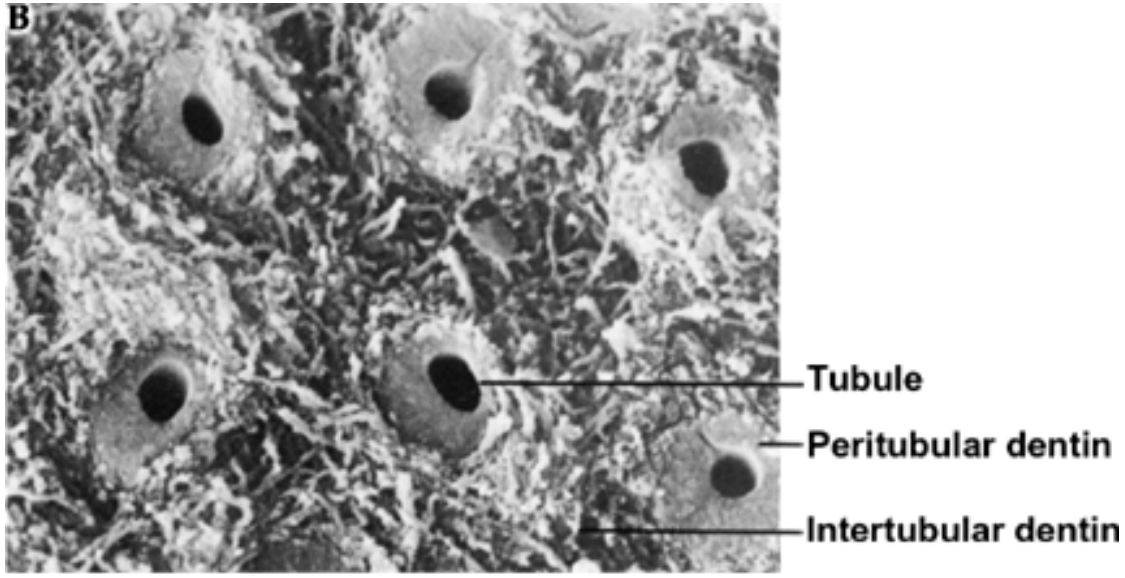
Dentin matrix

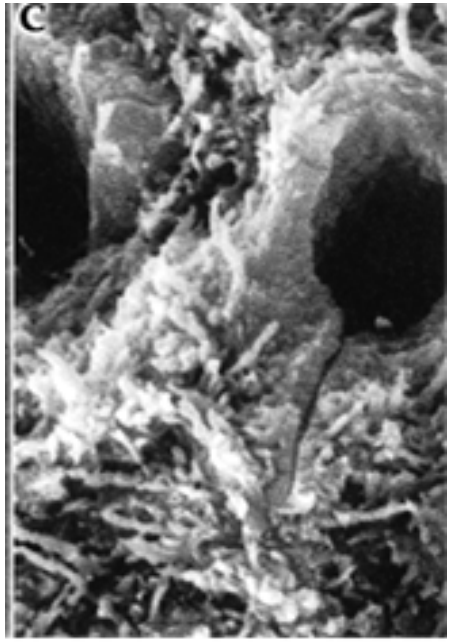
Consists of collagen fibrils (collagen type I) forming bundles

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

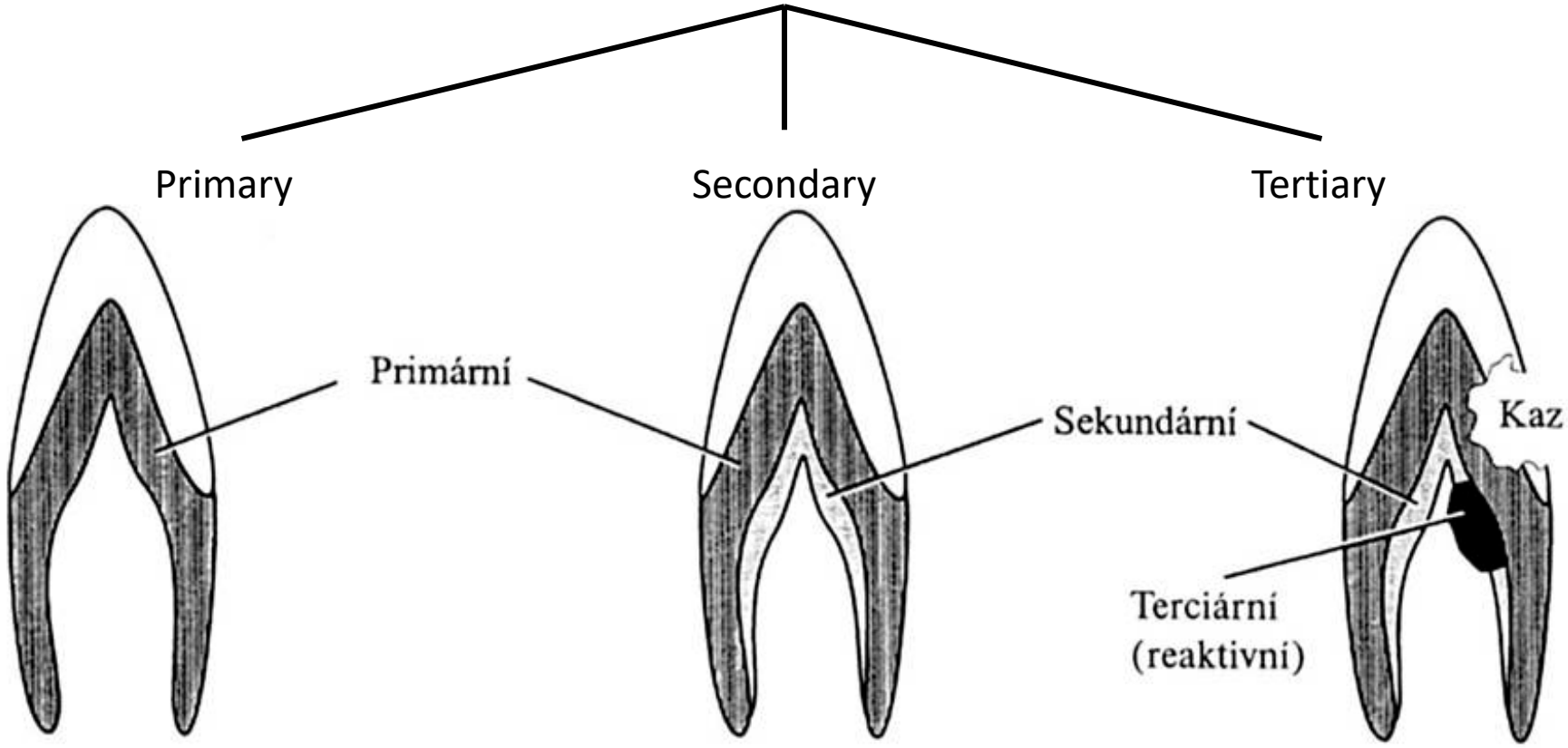
Amorphous matrix - glycosaminoglycans, proteoglycans and lipids, impregnated with hydroxylapatite crystals

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





Dentin types



Secondary dentin

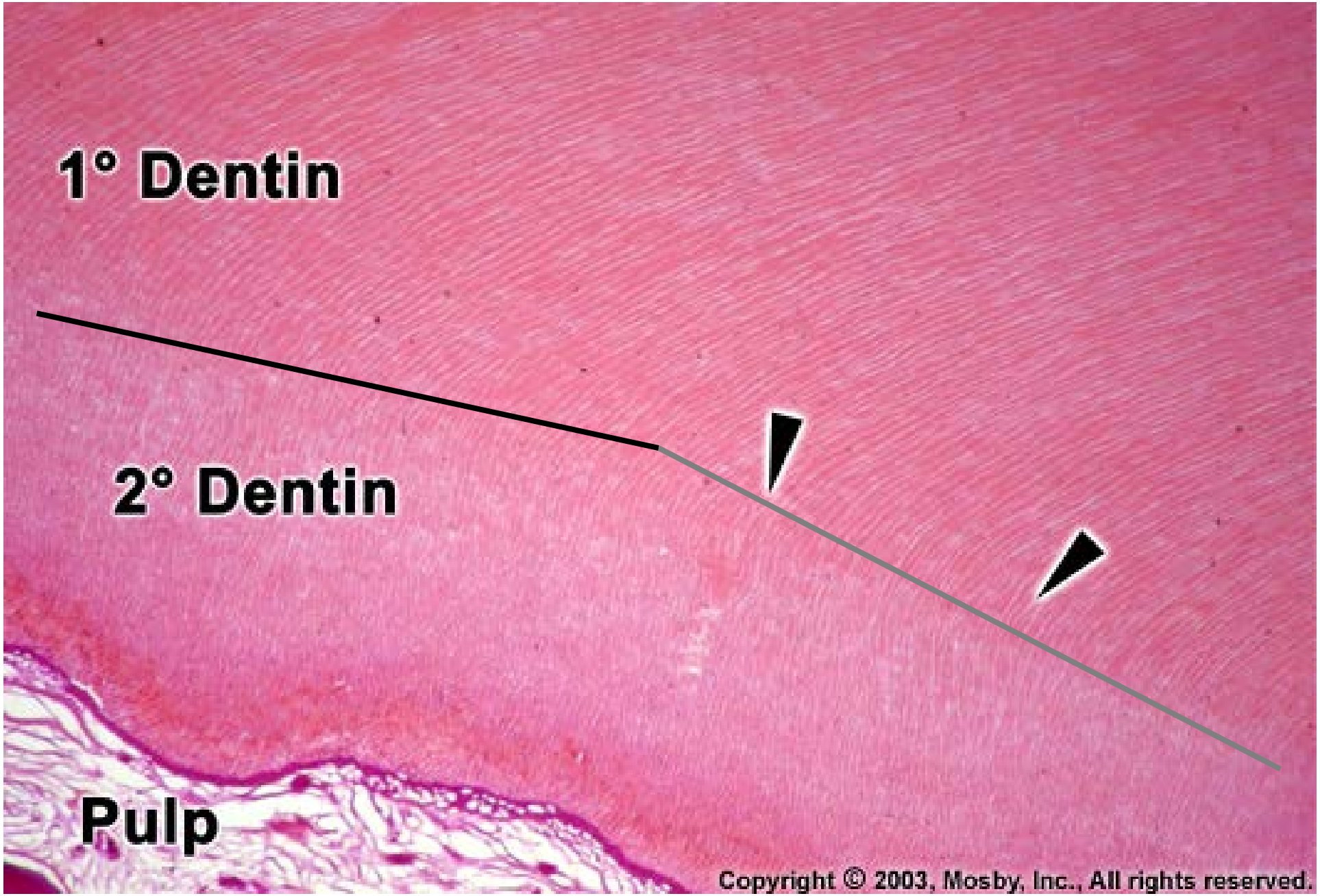
Laid down **after the root growth is finished**, when the crowns have reached the occlusal plane and the teeth are functionally loaded

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
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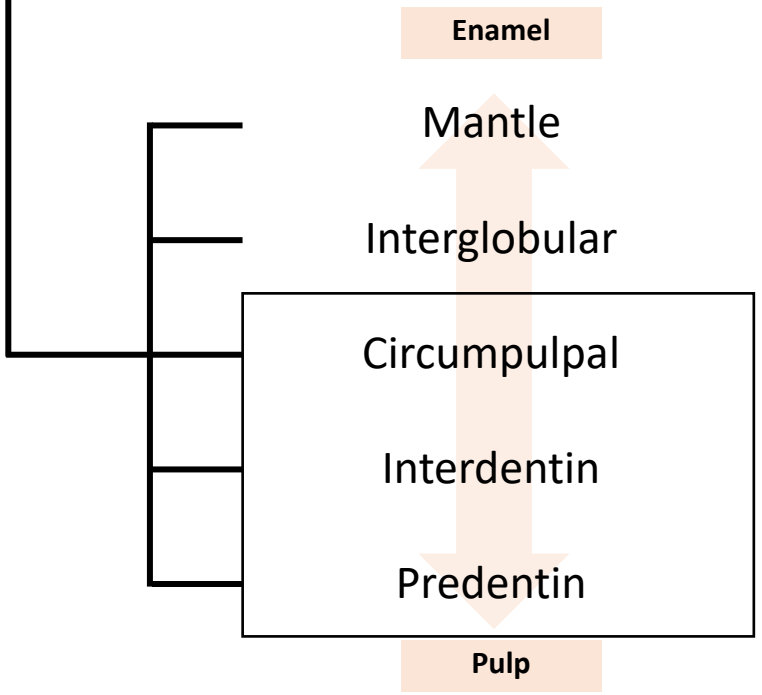
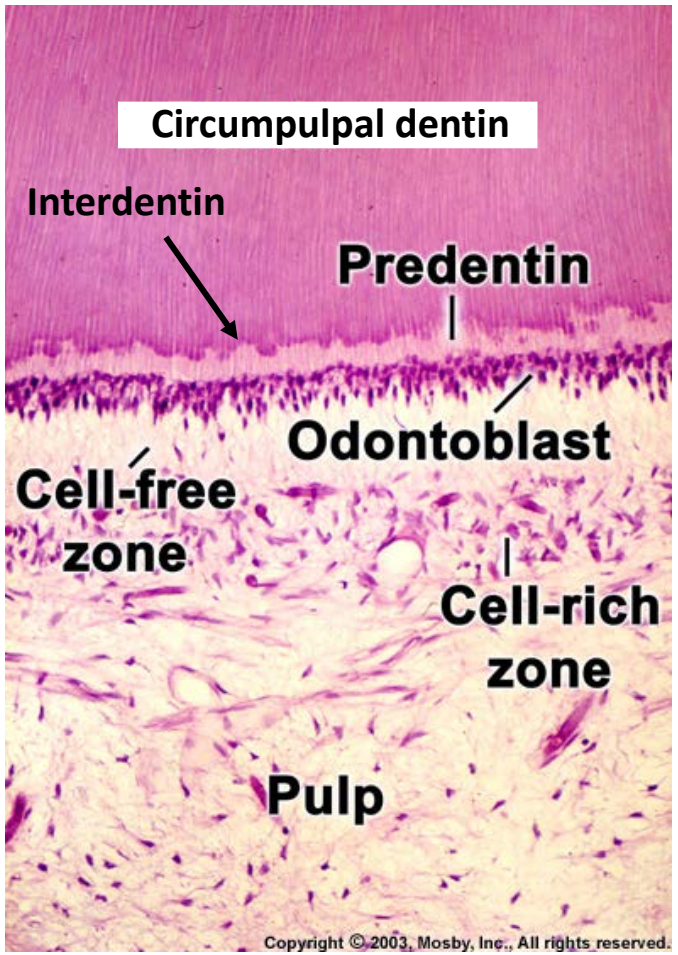
Dentin types

Primary

Secondary

Tertiary

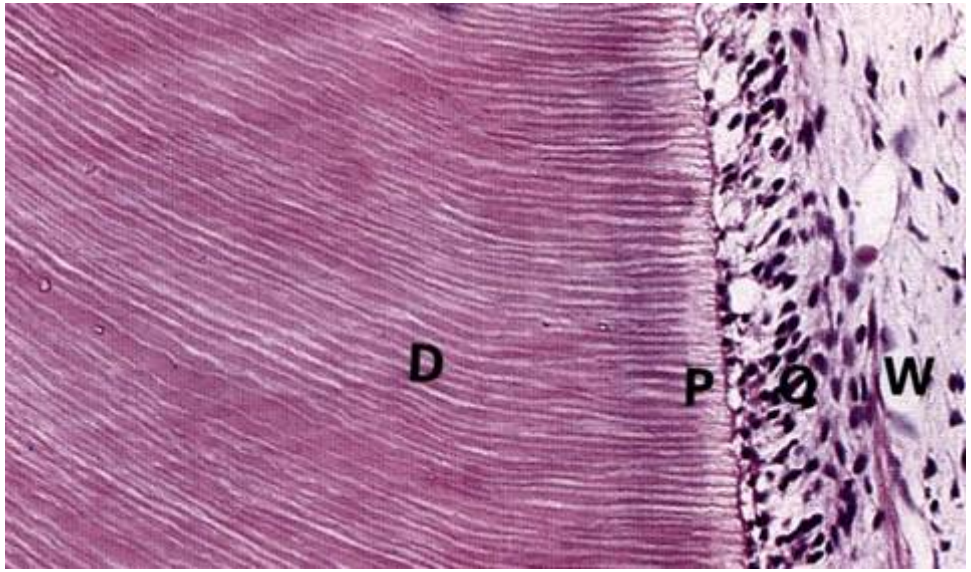


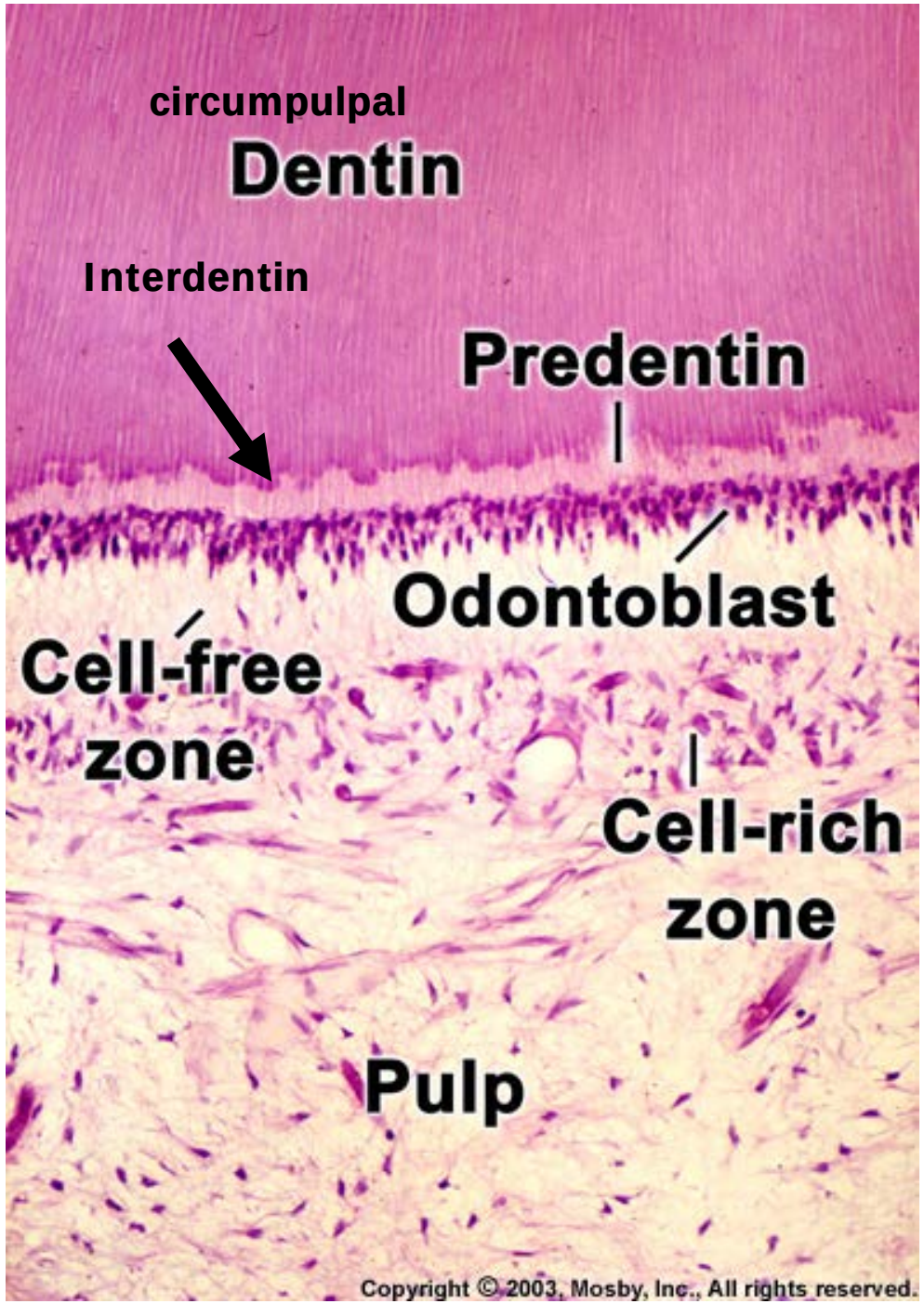


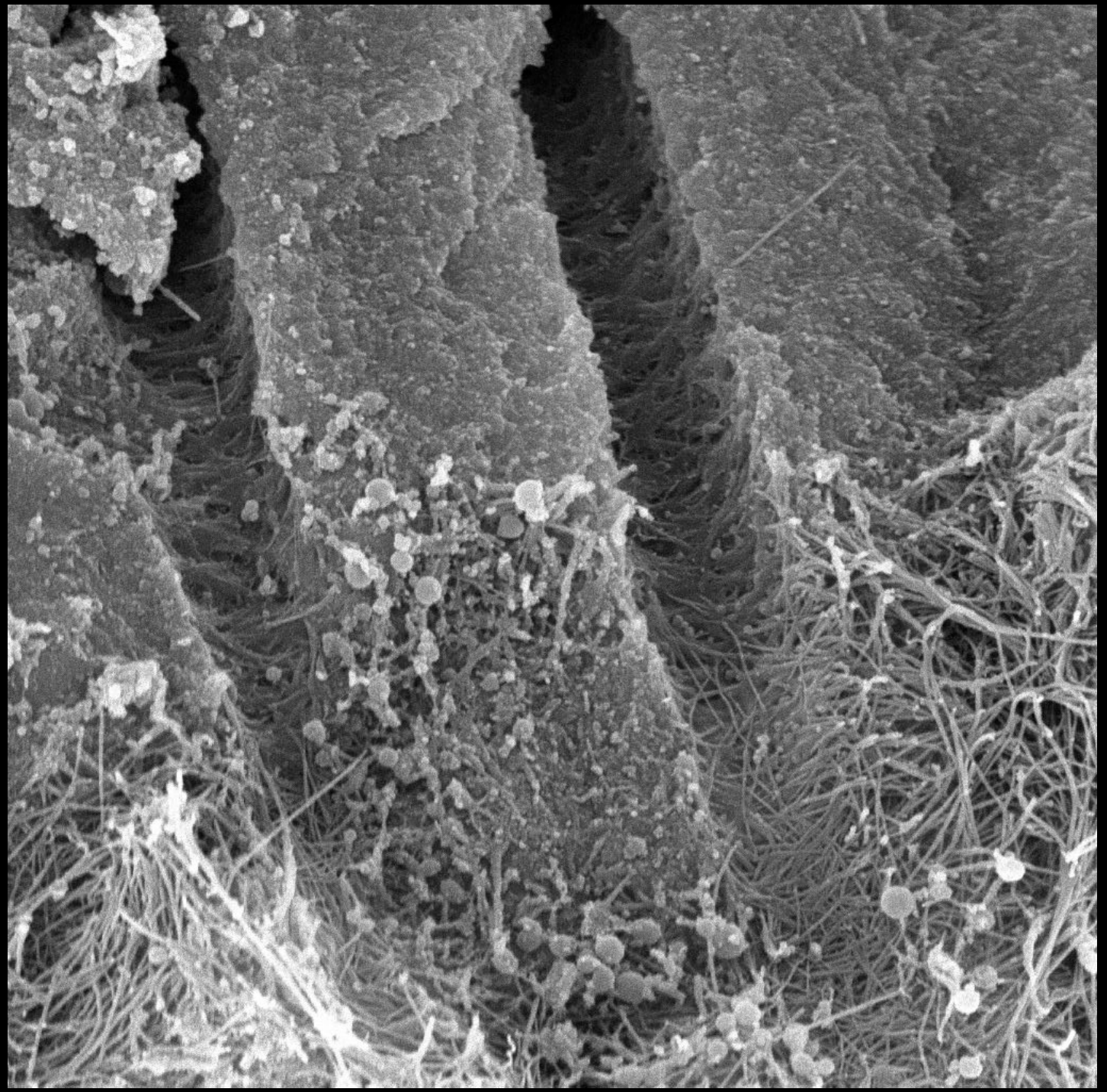
Circumpulpal dentin
90 % of all dentin
Contains dentinal tubules

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

Primary

Secondary

Tertiary

Enamel

Mantle

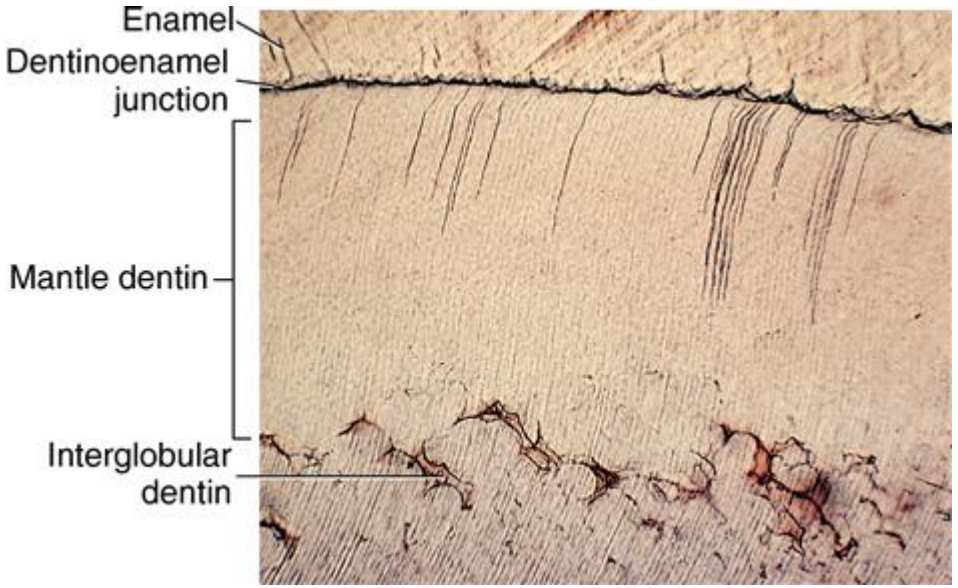
Interglobular

Circumpulpal

Interdentin

Predentin

Pulp



Distance from enamel

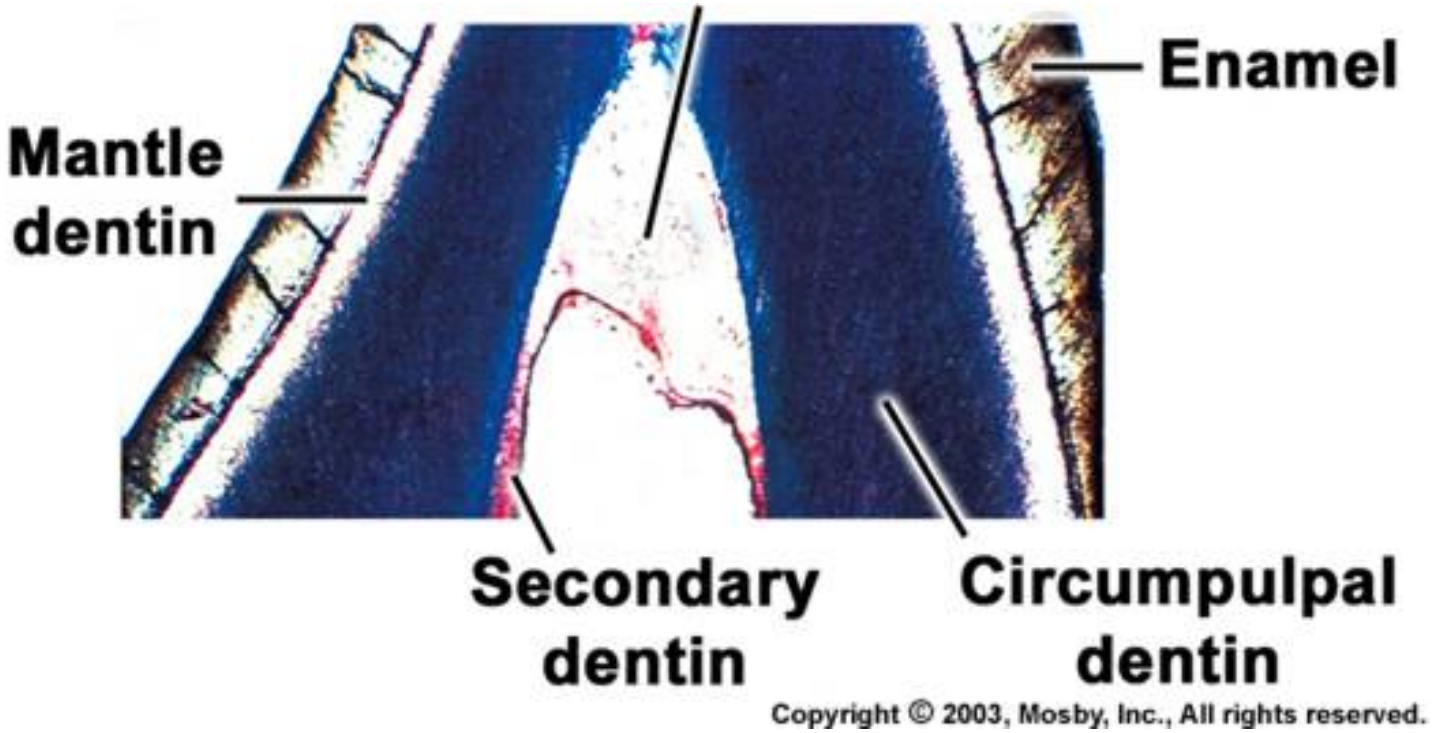
Mantle dentin

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



Interglobular dentin

Imperfectly calcified dentin at the interface of mantle and circumpulpal dentin

Fusion of dentin globules is impaired

Dentin types

Primary

Secondary

Tertiary

Enamel

Mantle

Interglobular

Circumpulpal

Interdentin

Predentin

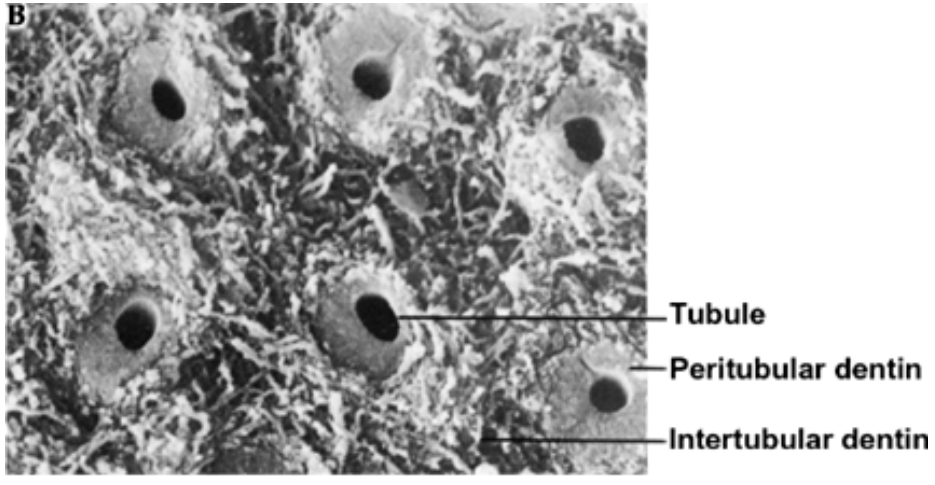
Pulp

Distance from enamel

Peritubular

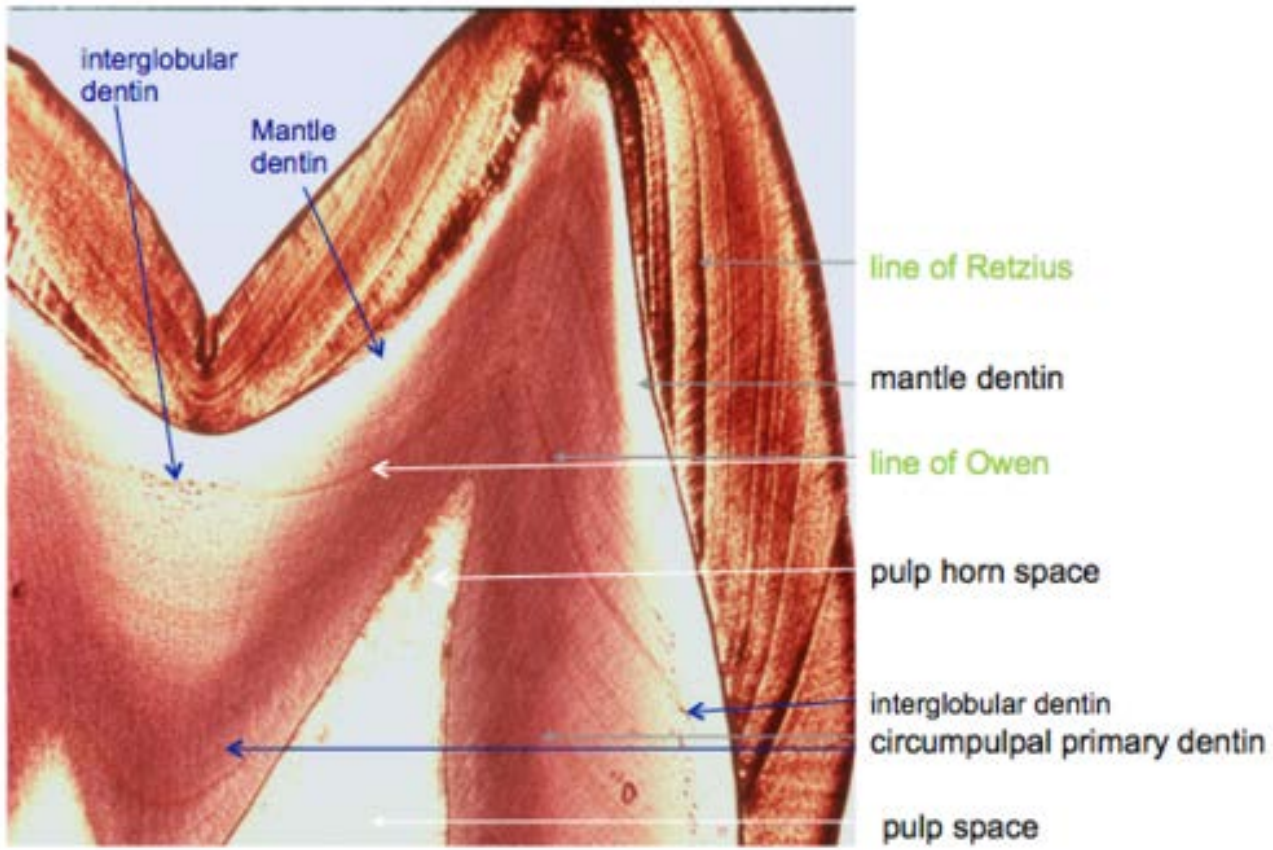
Intertubular

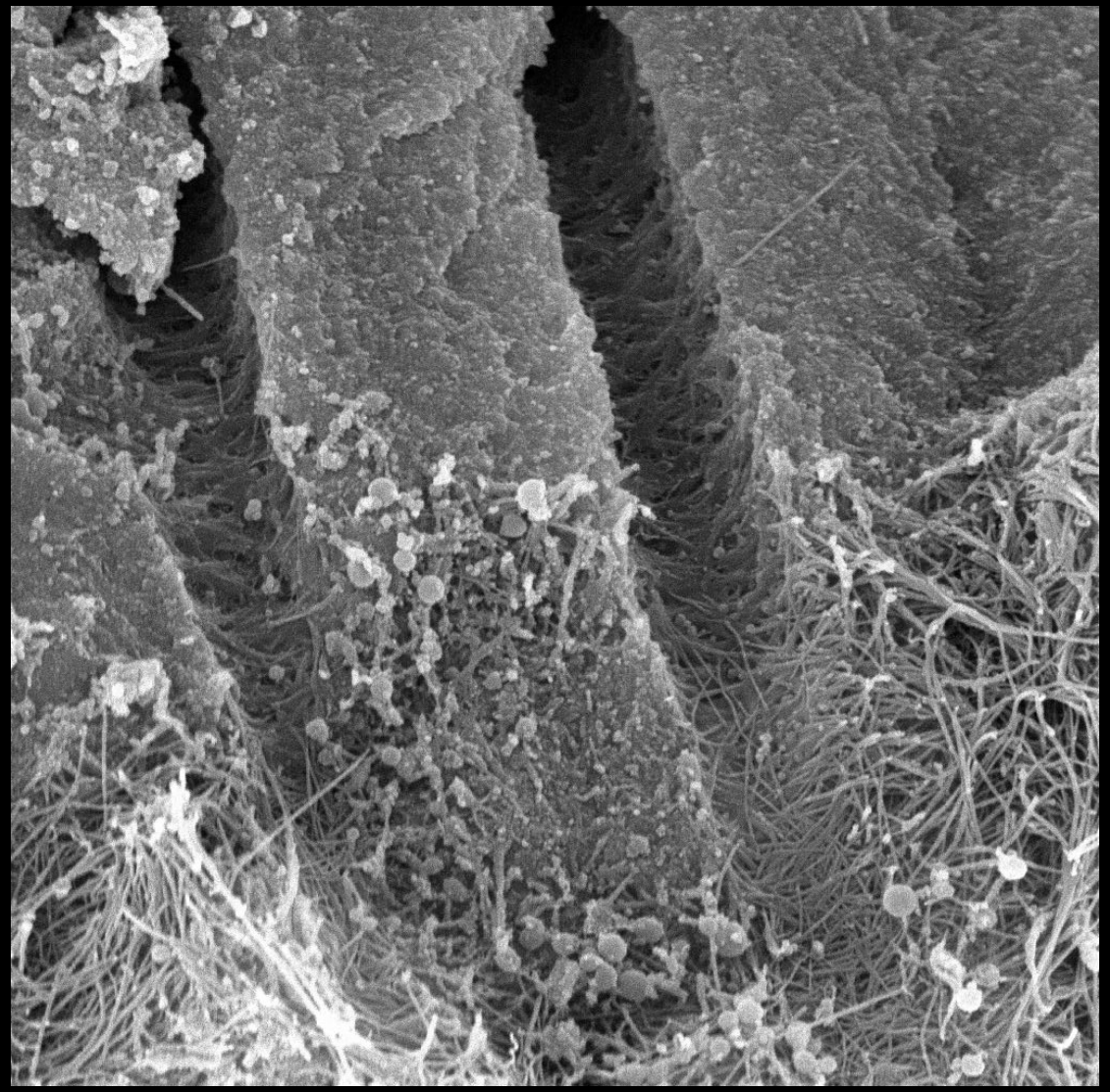
Relation of odontoblast processes

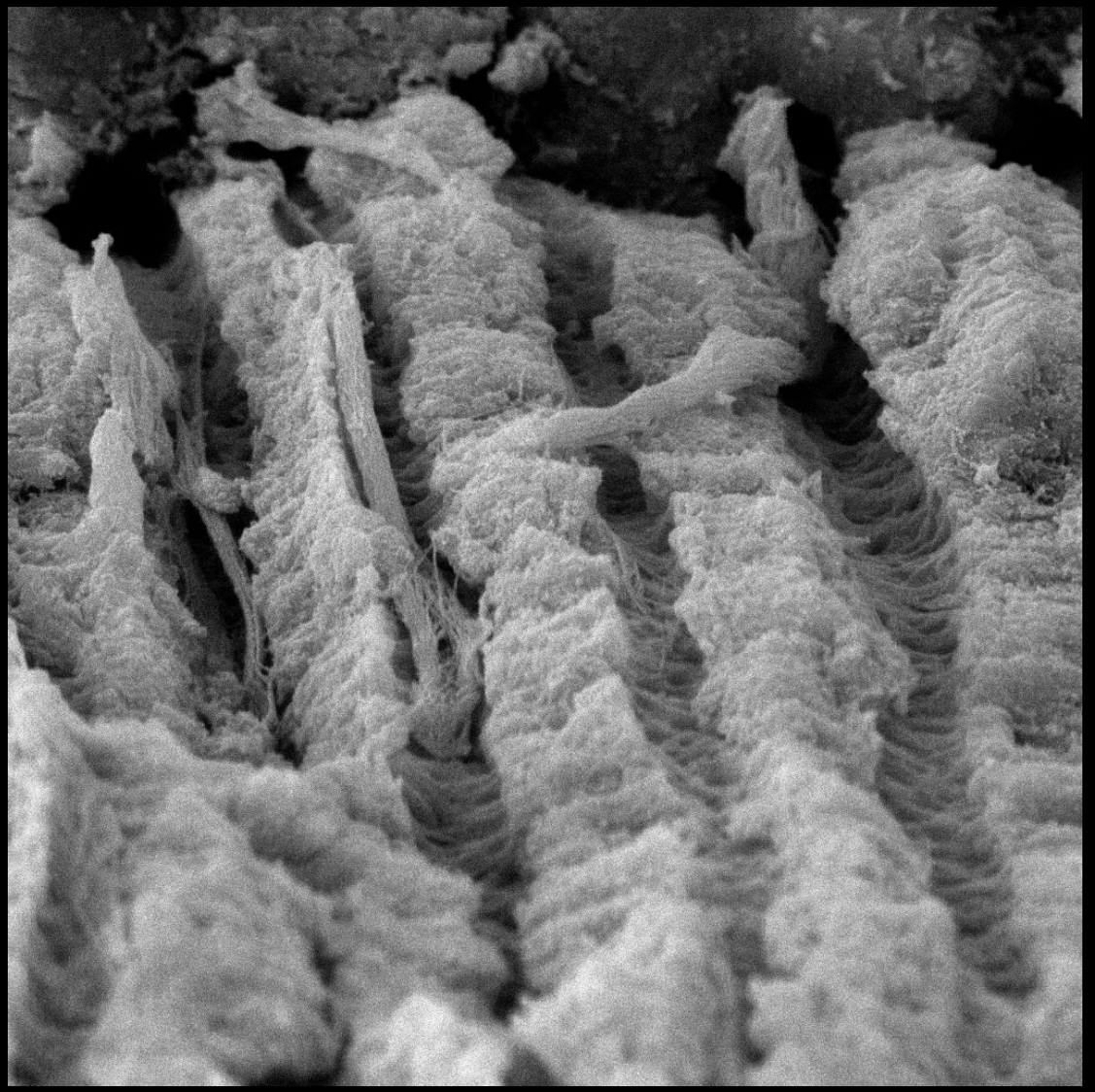


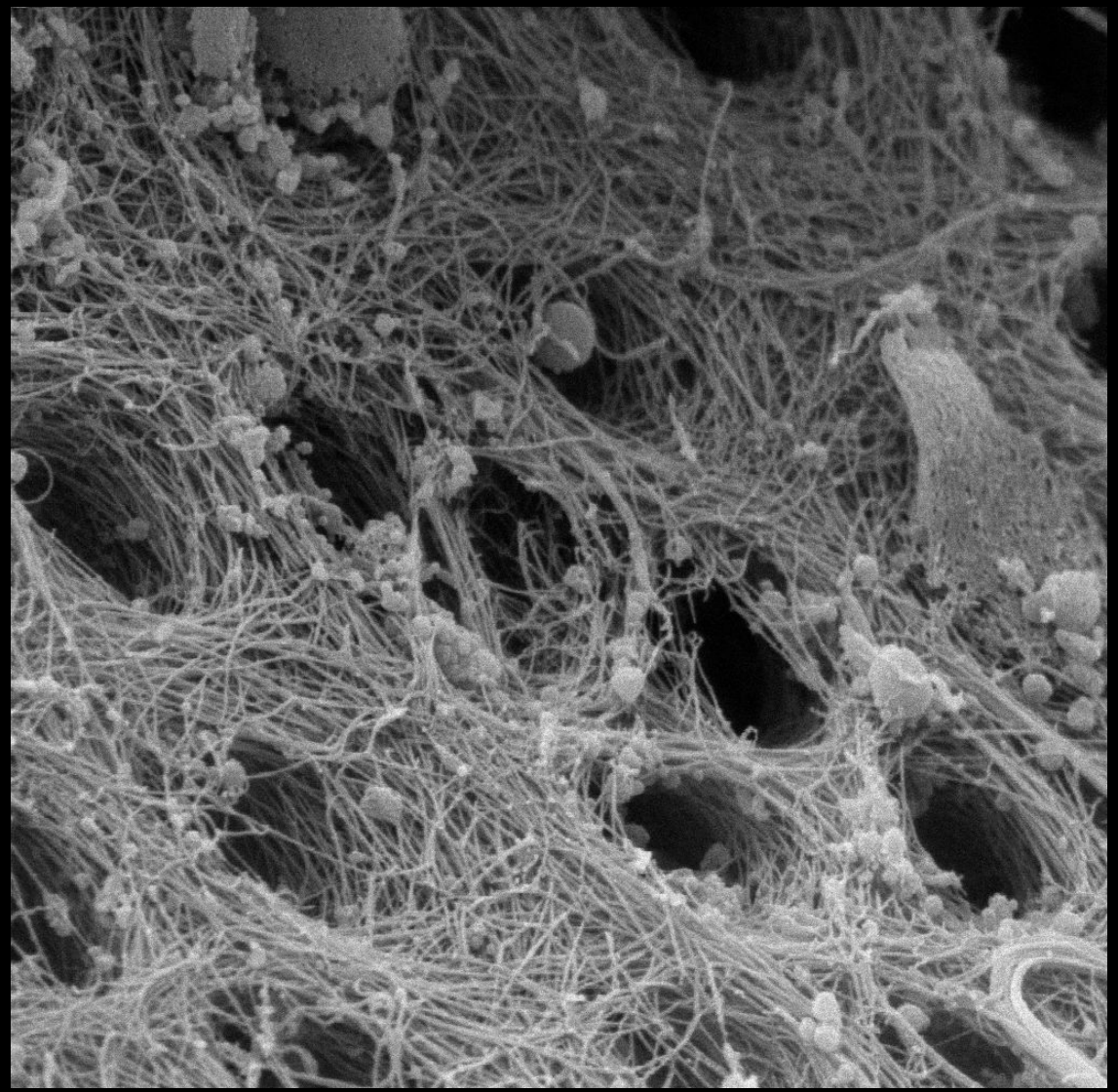
Circumpulpal dentin (*von Ebner*)

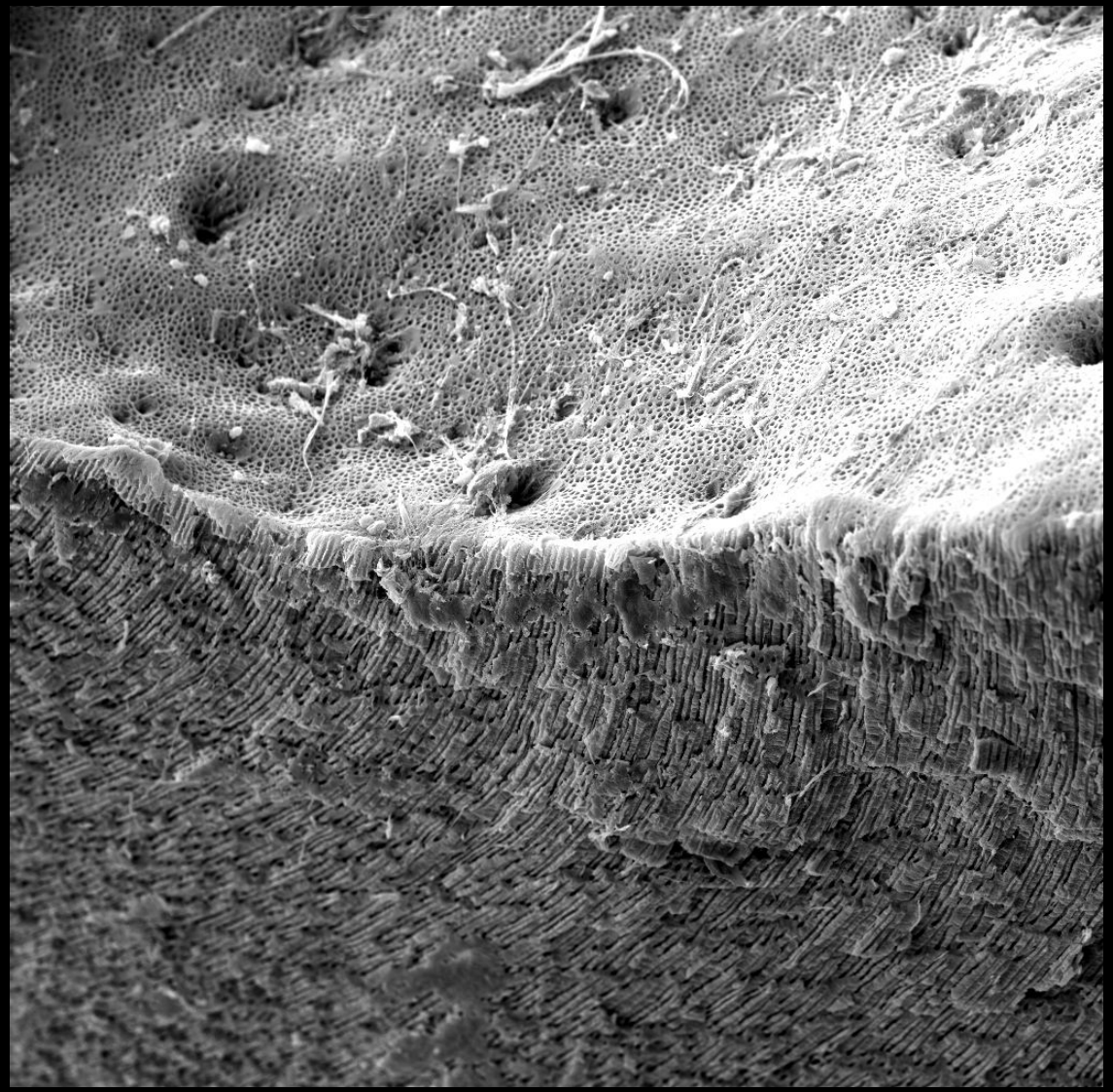
- Collagen fibres run obliquely to perpendicular to the course of tubules
- Mineralization is globular.
- Only minor branching of the dentinal tubules here.

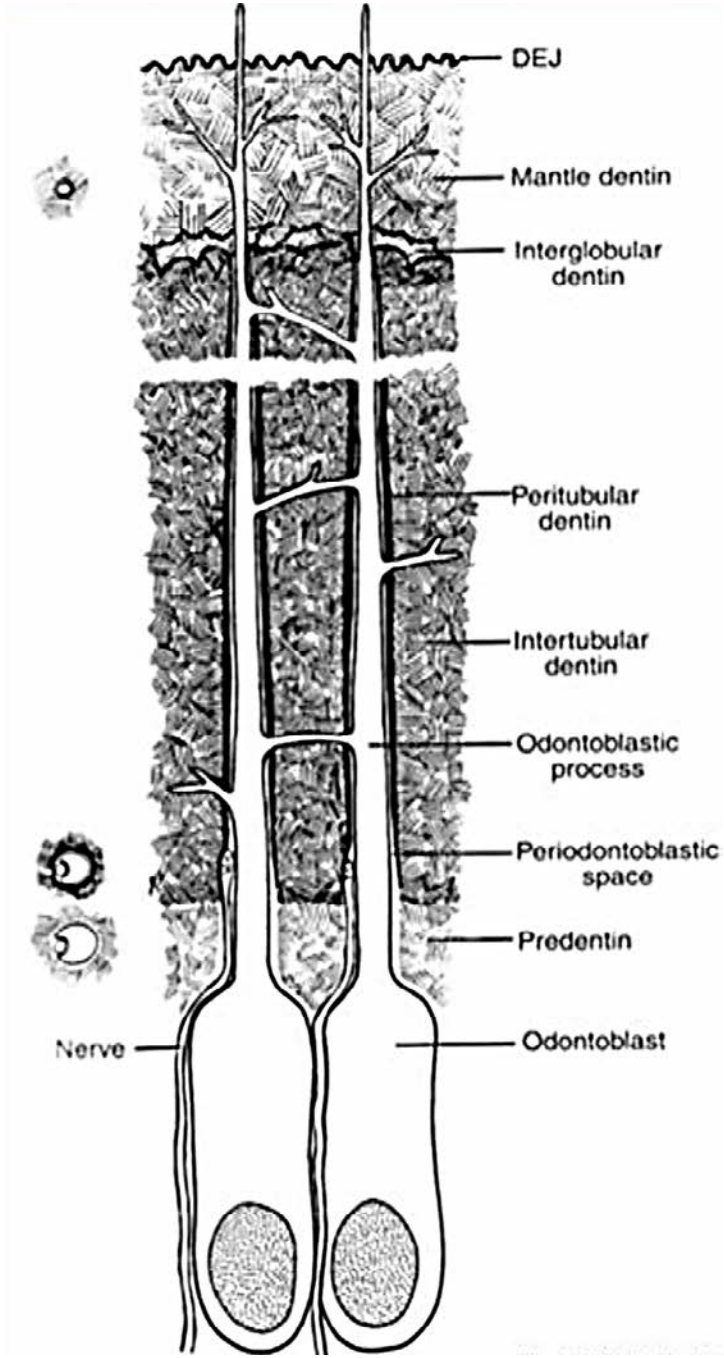











DEJ
Mantle dentin
Interglobular dentin
Peritubular dentin
Intertubular dentin
Odontoblastic process
Periodontoblastic space
Predentin
Odontoblast
Nerve

Dentin types

Primary

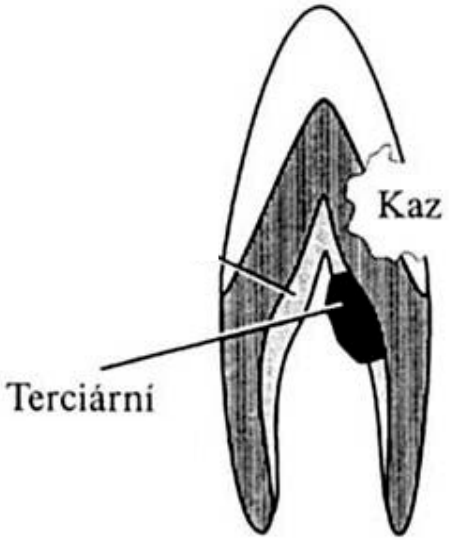
Secondary

Tertiary

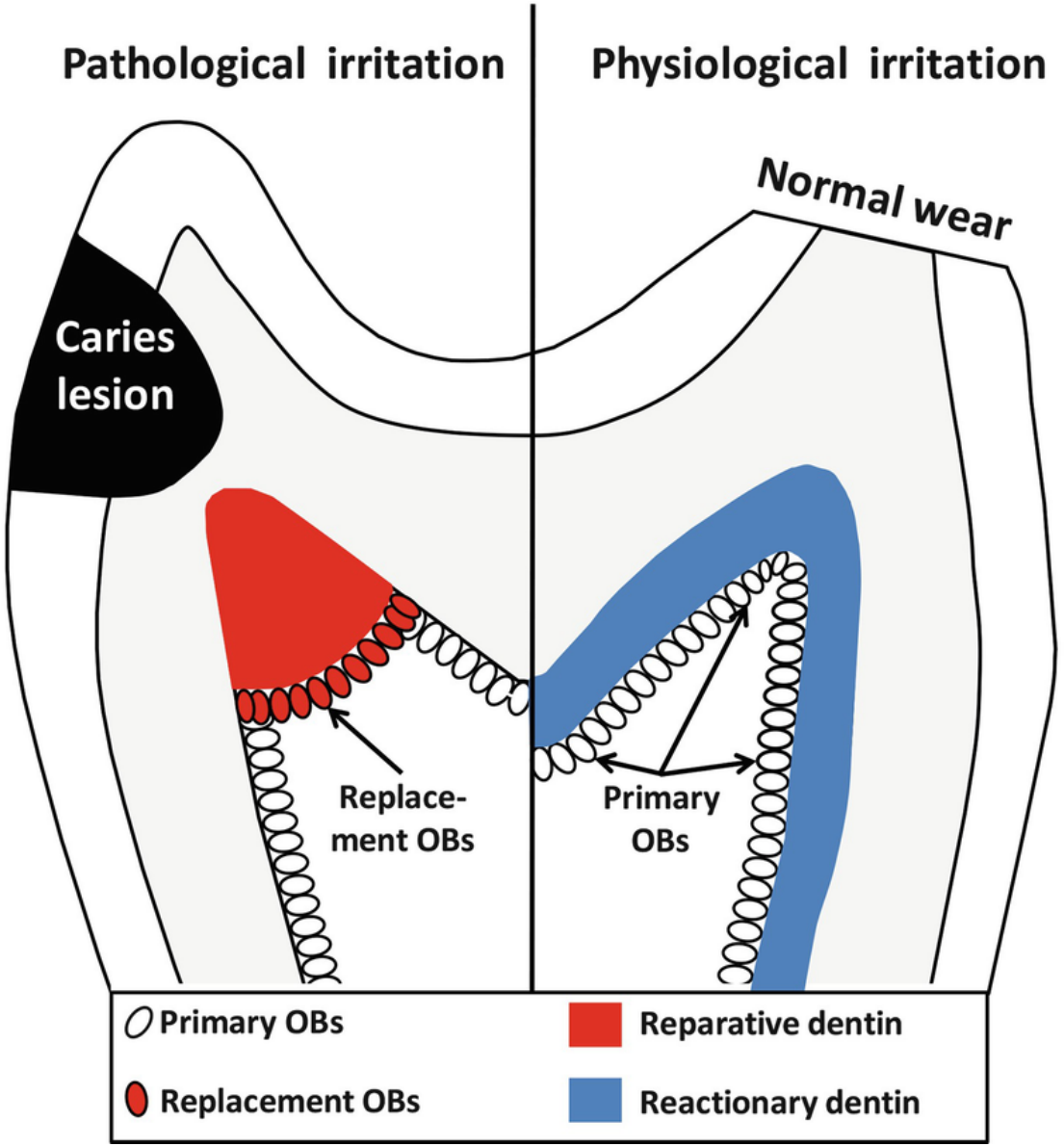
Damage extent

Reparative

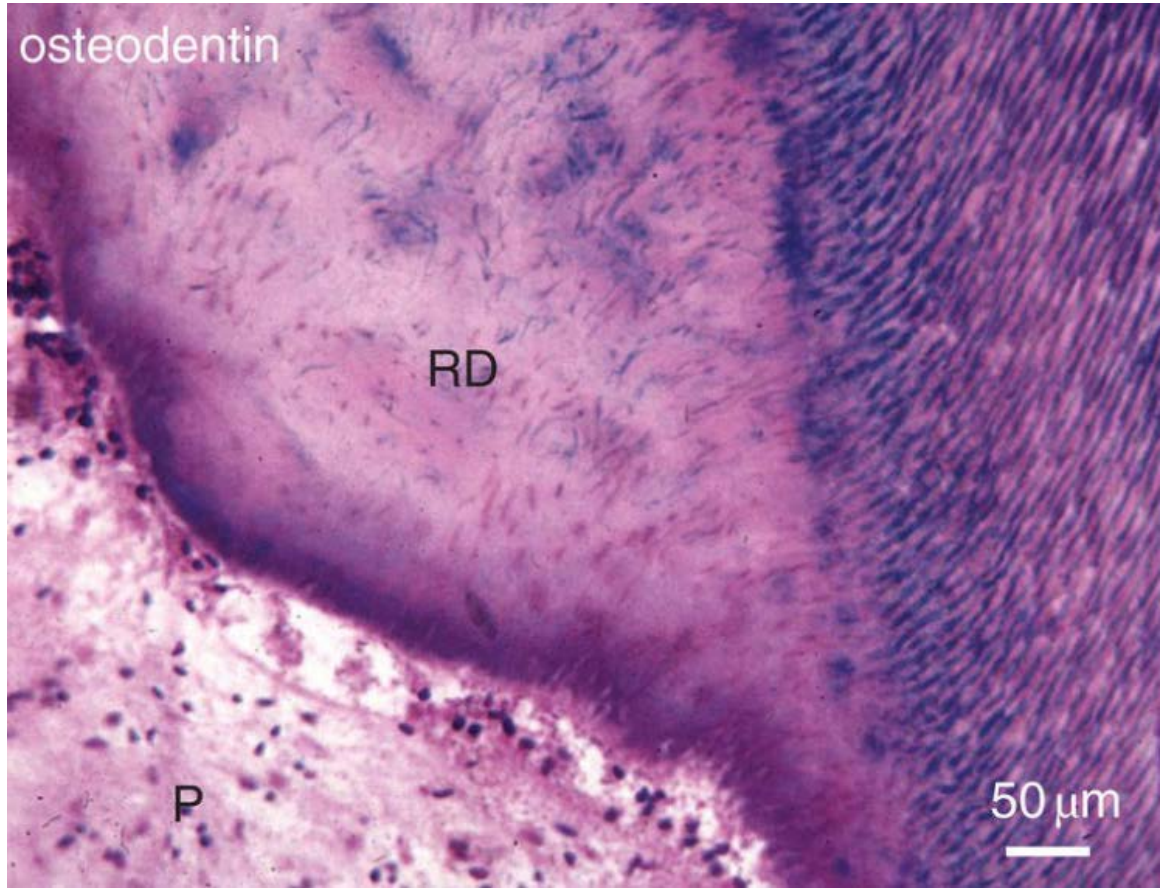
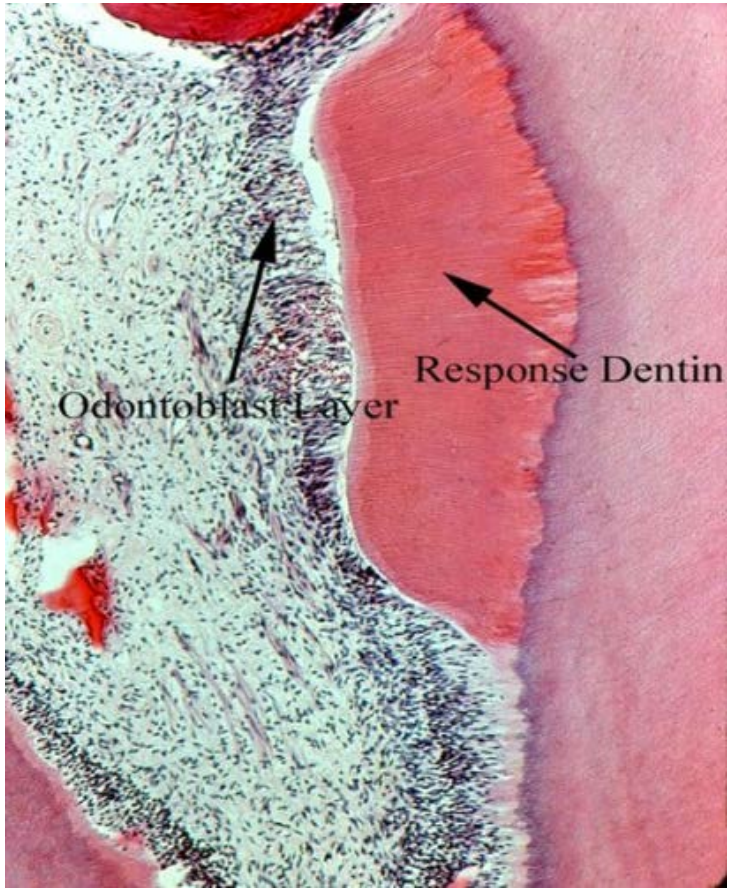
Reactive



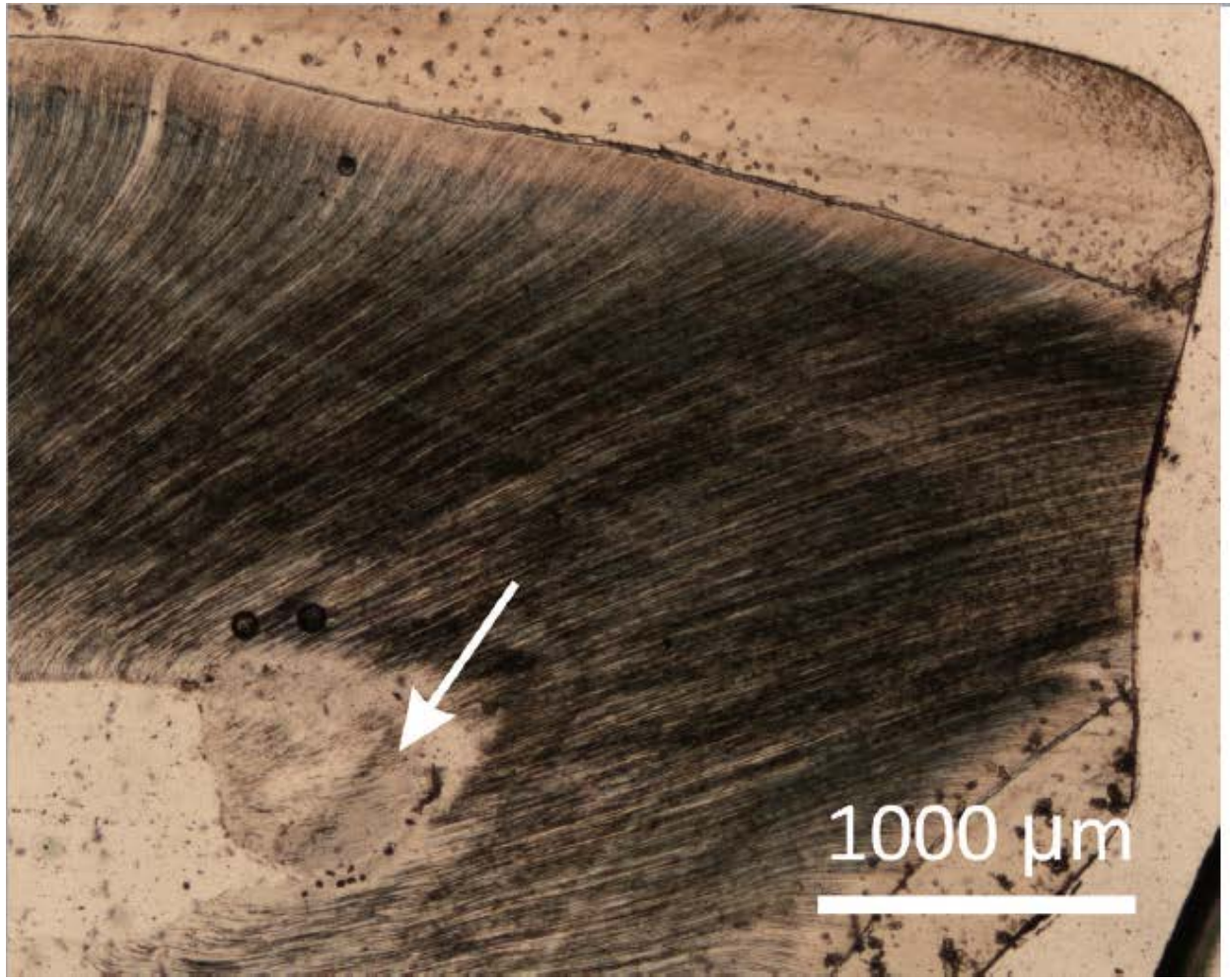
Tertiary dentinogenesis



Tertiary dentinogenesis

? Reparative dentin	Reactionary dentin ?
	
Cause of formation:	Reaction to larger dentin damage	Minor stimuli
Structure:	Amorphous structure	Arranged
Dentinal tubules:	NO	YES
Dentin-forming cells:	Newly differentiated from pulp	Odontoblasts
Cell bodies:	May be present (osteodentin)	NO
Main function:	Protection from infection	Increase of tooth wall

Tertiary dentinogenesis



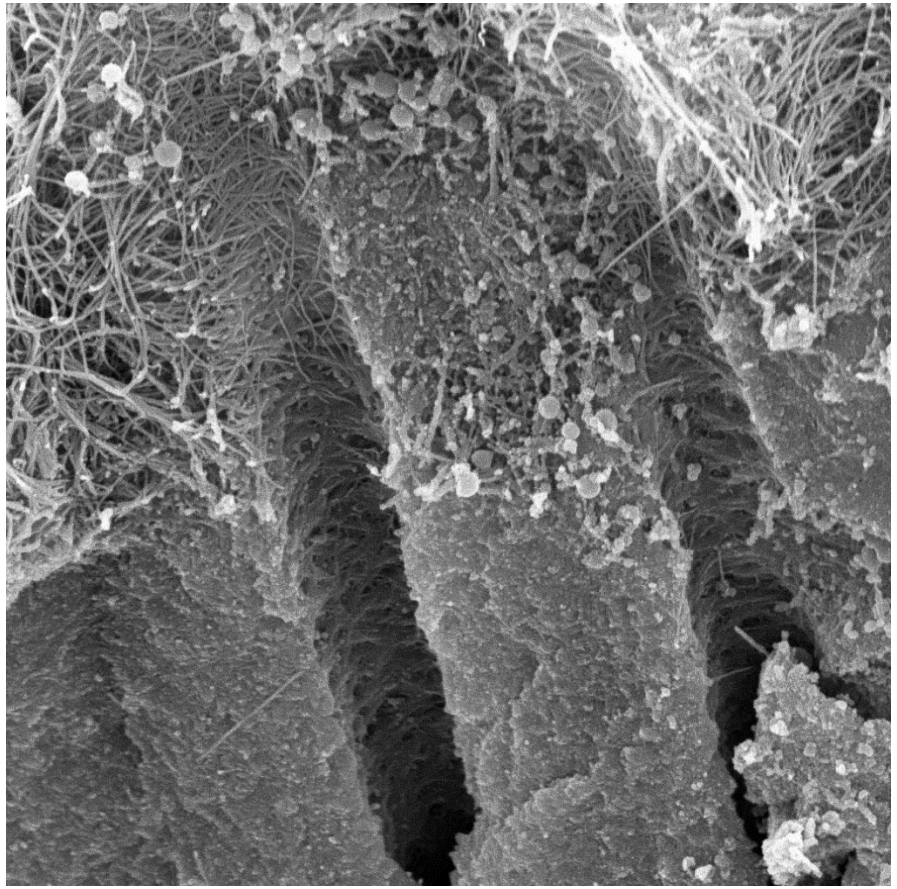
Histologický výbrus vysoce abradovaného horního dočasného špičáku v oblasti korunky a vrcholu dřeňové dutiny, kde se pod vlivem vnějších stimulů ukládá *terciární dentin*. Šipka ukazuje na ***reakční dentin***, formu terciárního dentinu, která vzniká jako pomalá reakce zubu na poškození atricí/abrazí.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

Adela Hupková et. Miroslav Králík, 2015

Chemical composition

Inorganic	Water	Organic
70 %	10 %	20 %

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



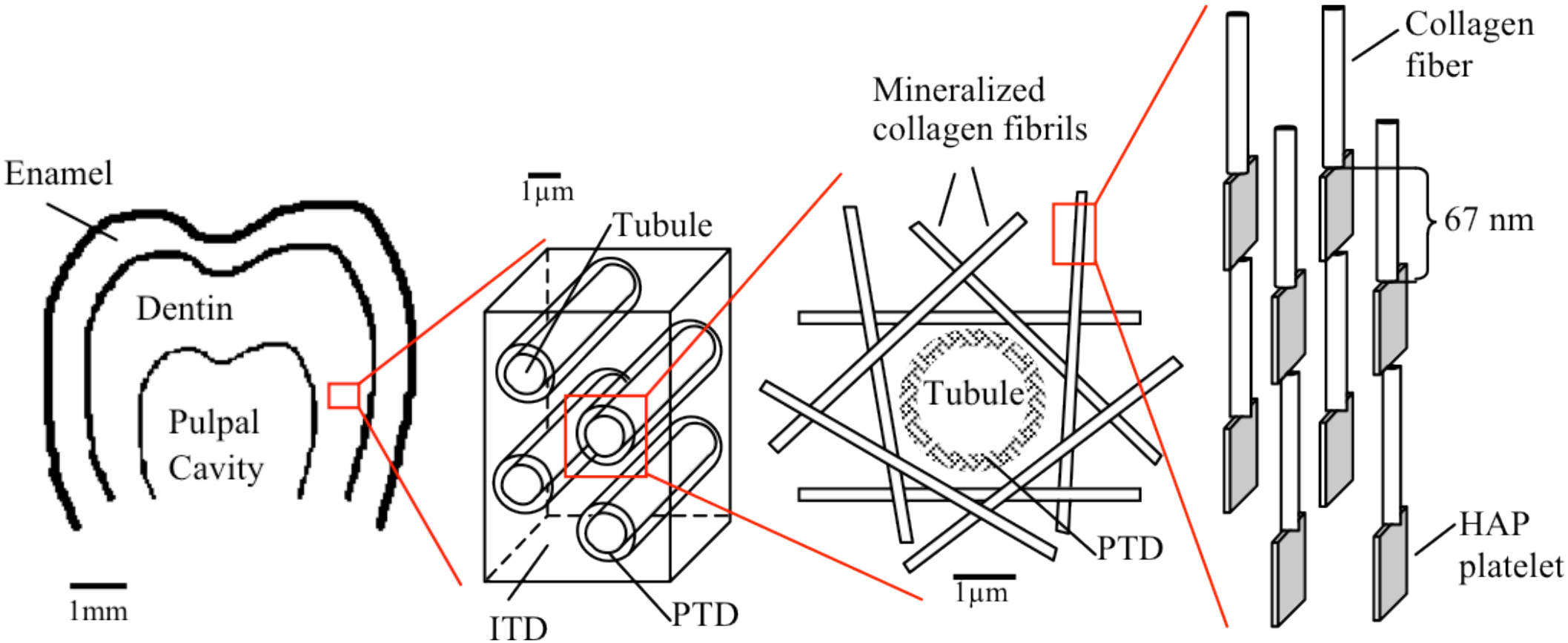
- **Collagens** - collagen I (III a V) (90 %)
- **Non-Collagenous Proteins** (8%)

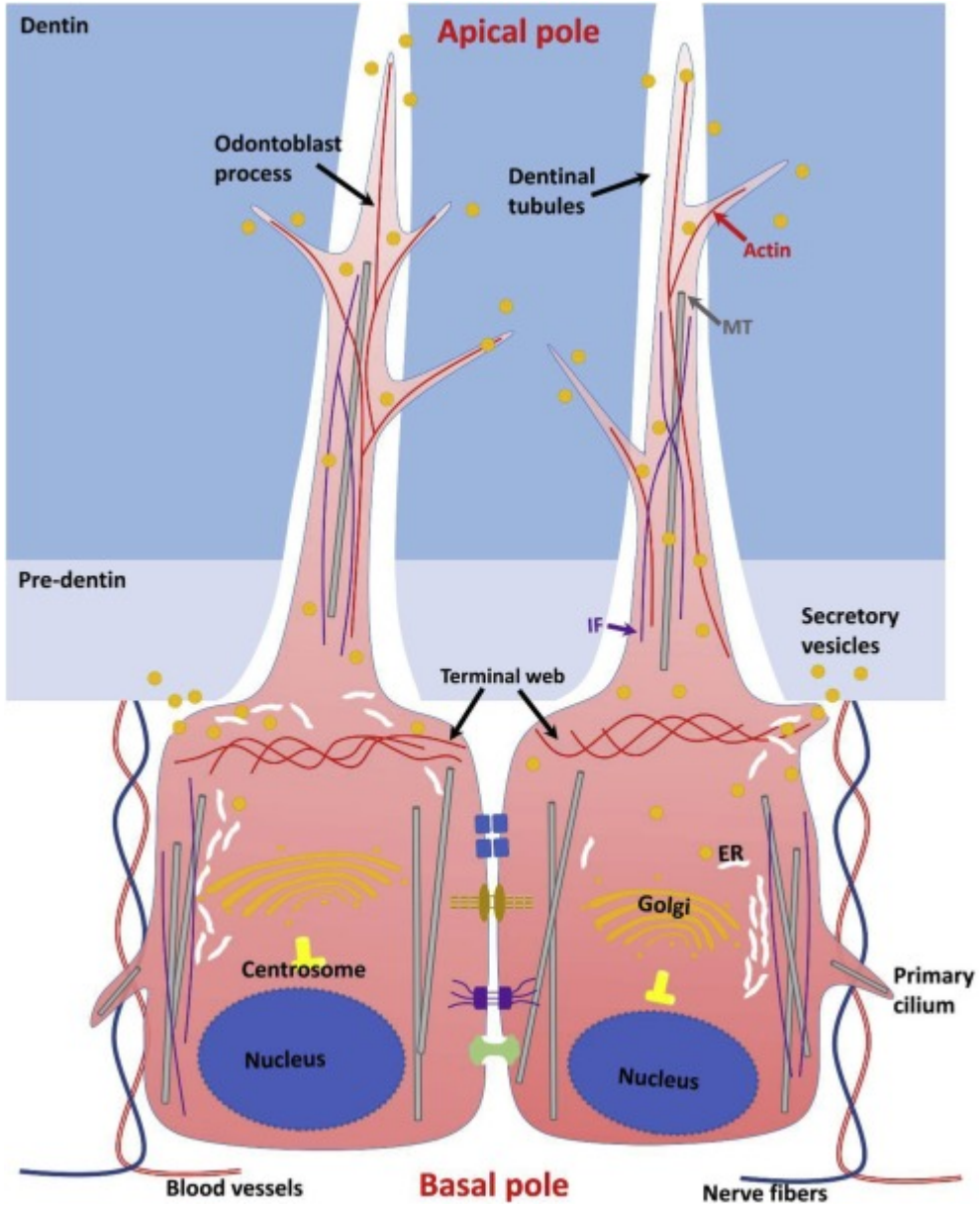
a) Phosphorins – Ca2+ and phosphate donors, crystal growth control

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%)


Enamel
Dentin
Pulpal
Cavity
1mm
1μm
Tubule
ITD
PTD
Mineralized
collagen fibrils
Tubule
PTD
1μm
Collagen
fiber
67 nm
HAP
platelet

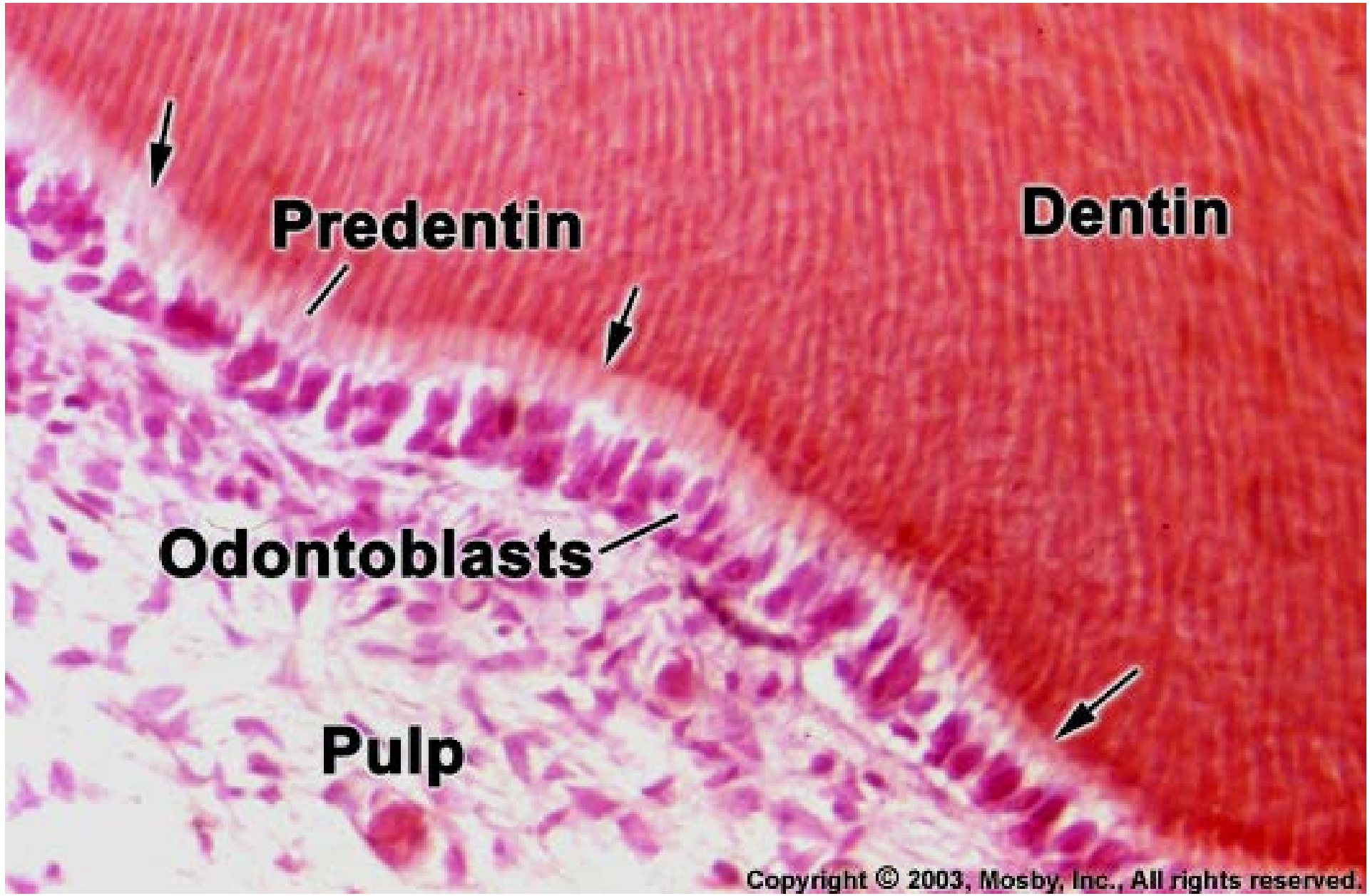


Junctional complex

Numerous connecting complexes among the odontoblast apexes:
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


Predentin
Dentin
Odontoblasts
Pulp
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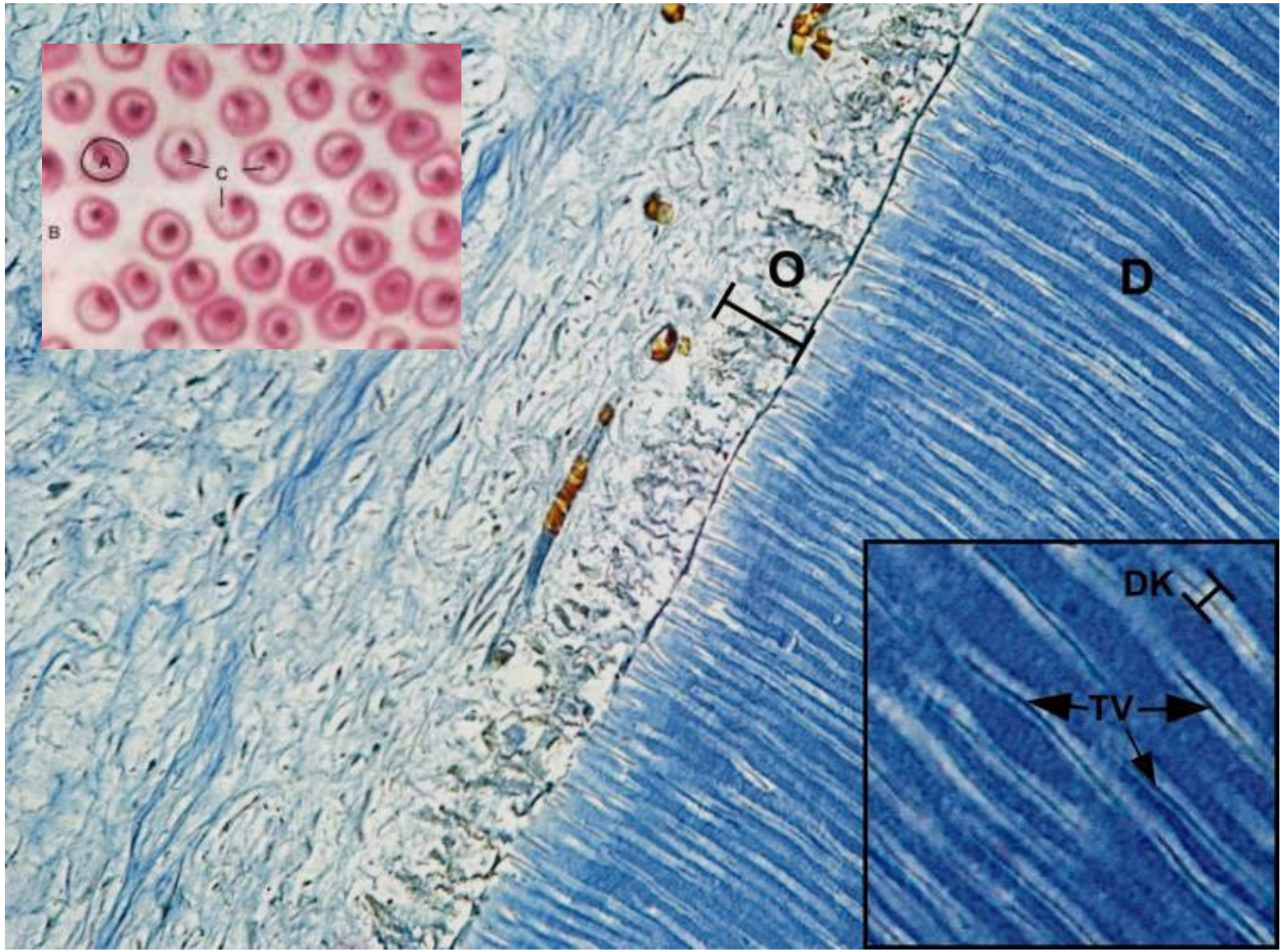
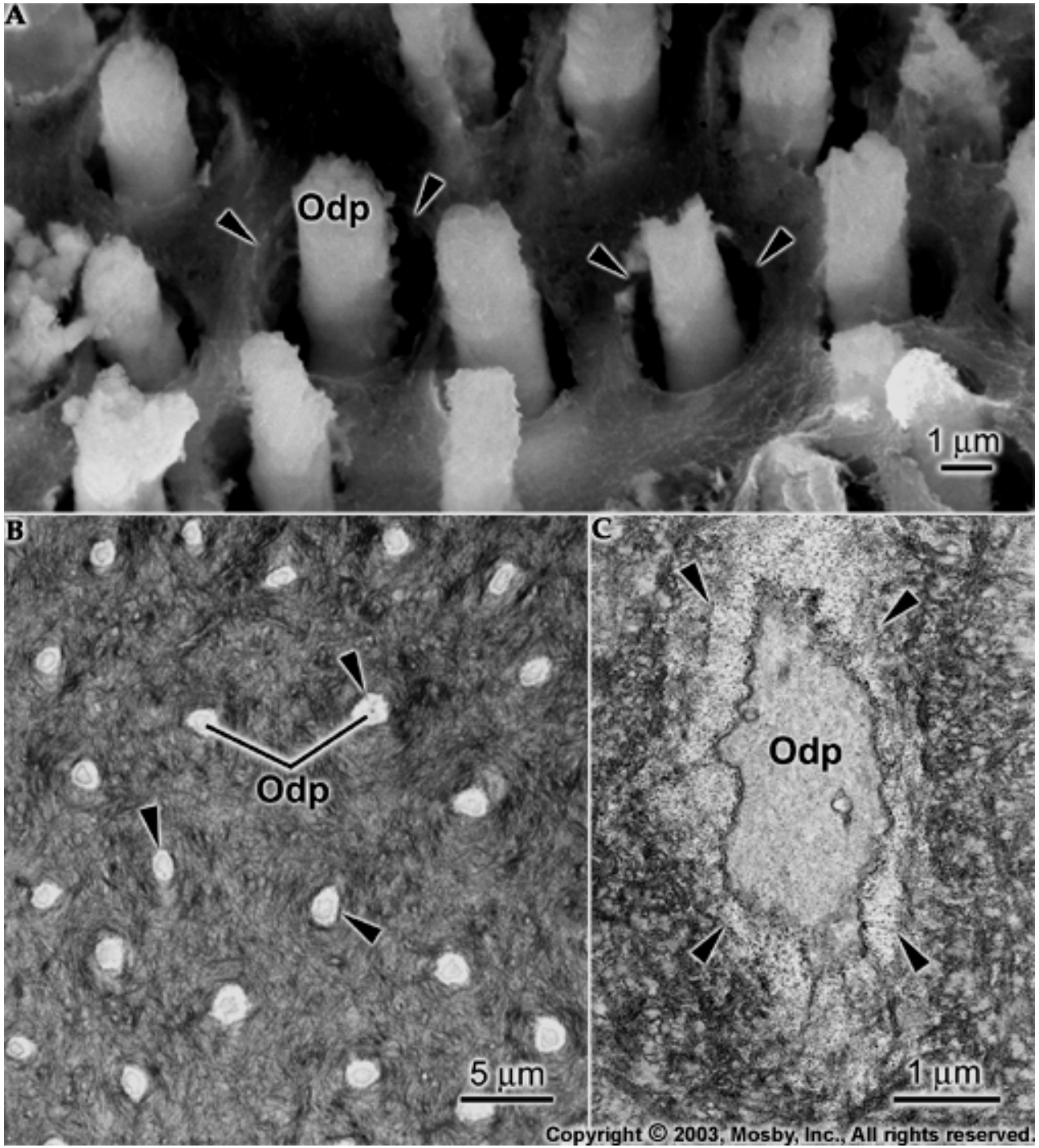
Each fiber is has its own canal - **Dentinal Canal** (tubulus)

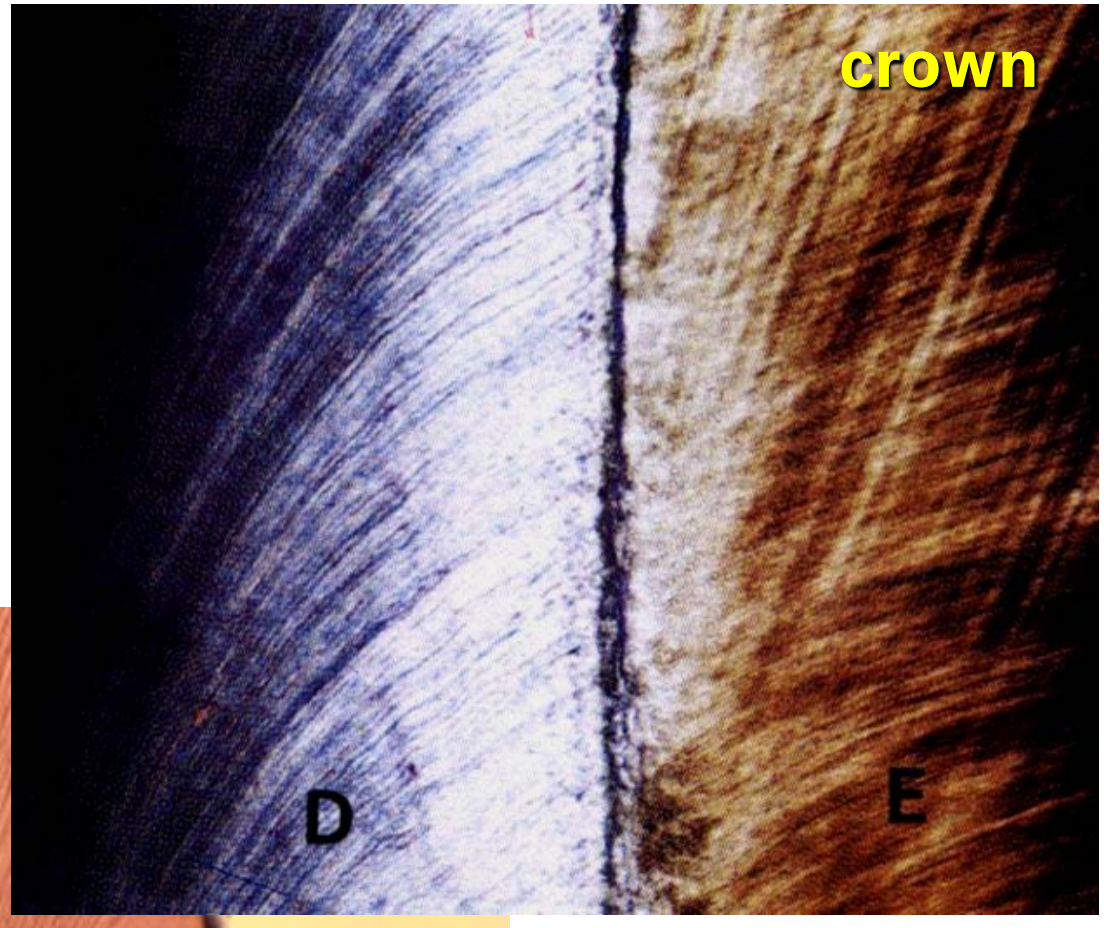


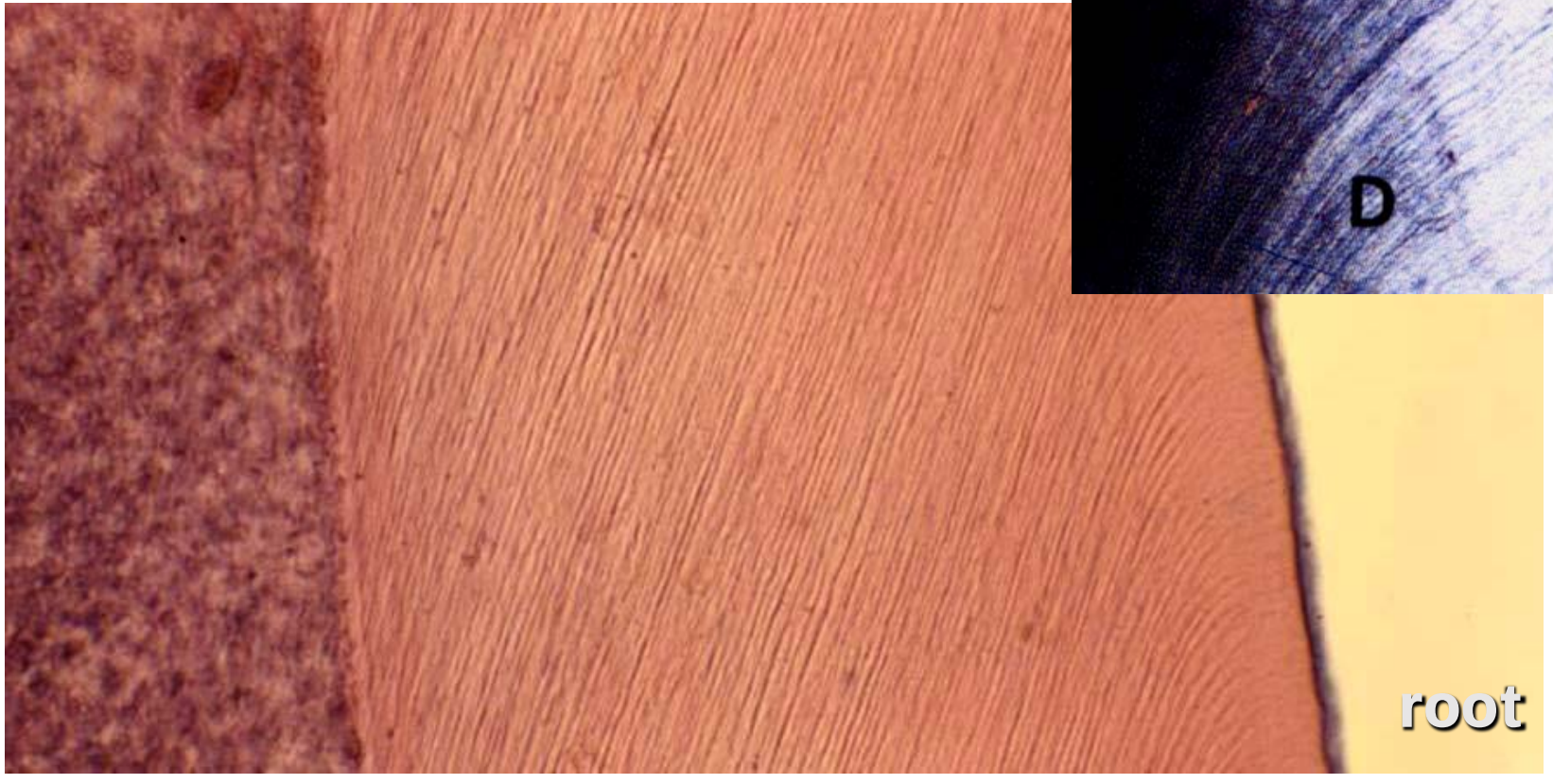
Tomes fibres

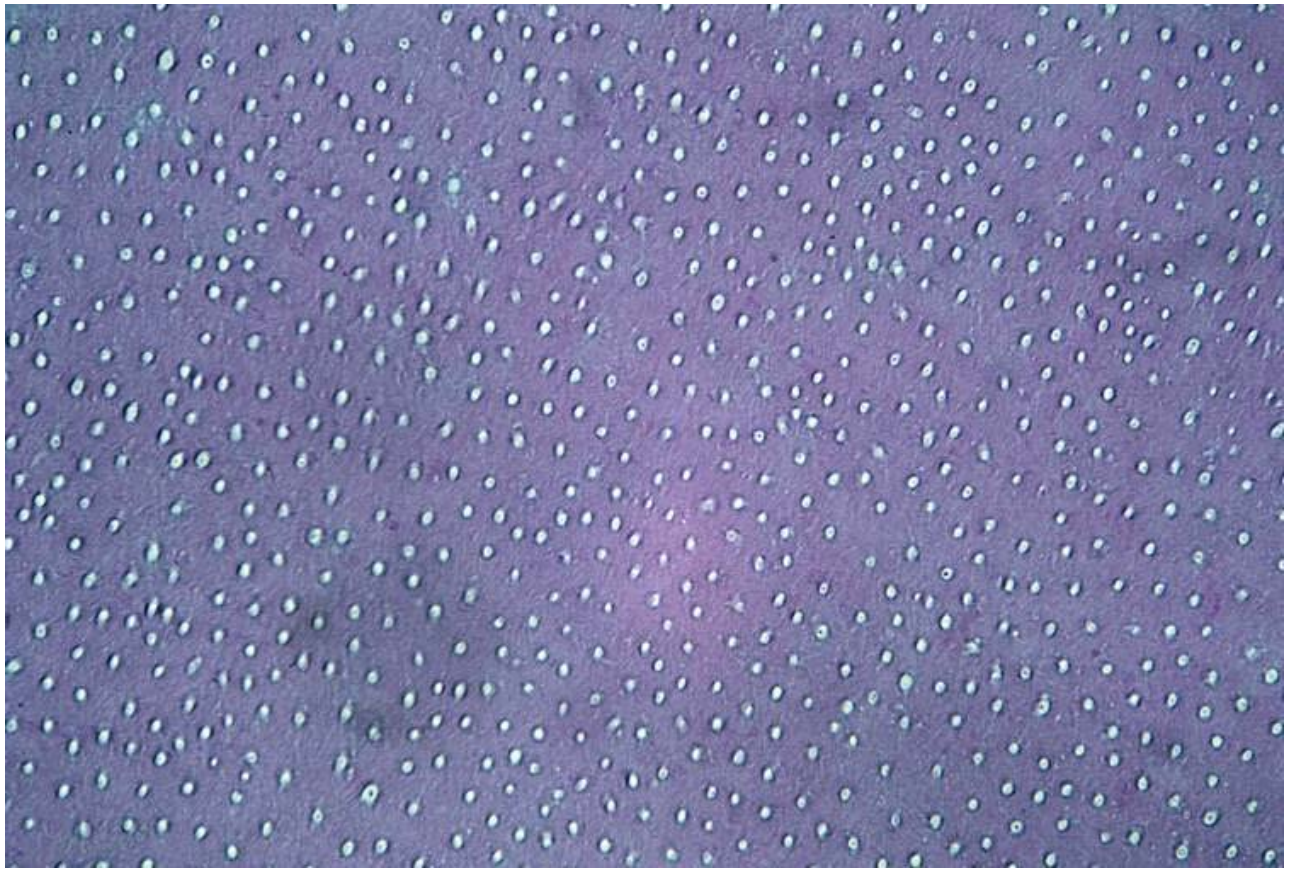


Channels with Tomes fibres penetrate the entire dentin and cause the dentinal stripes

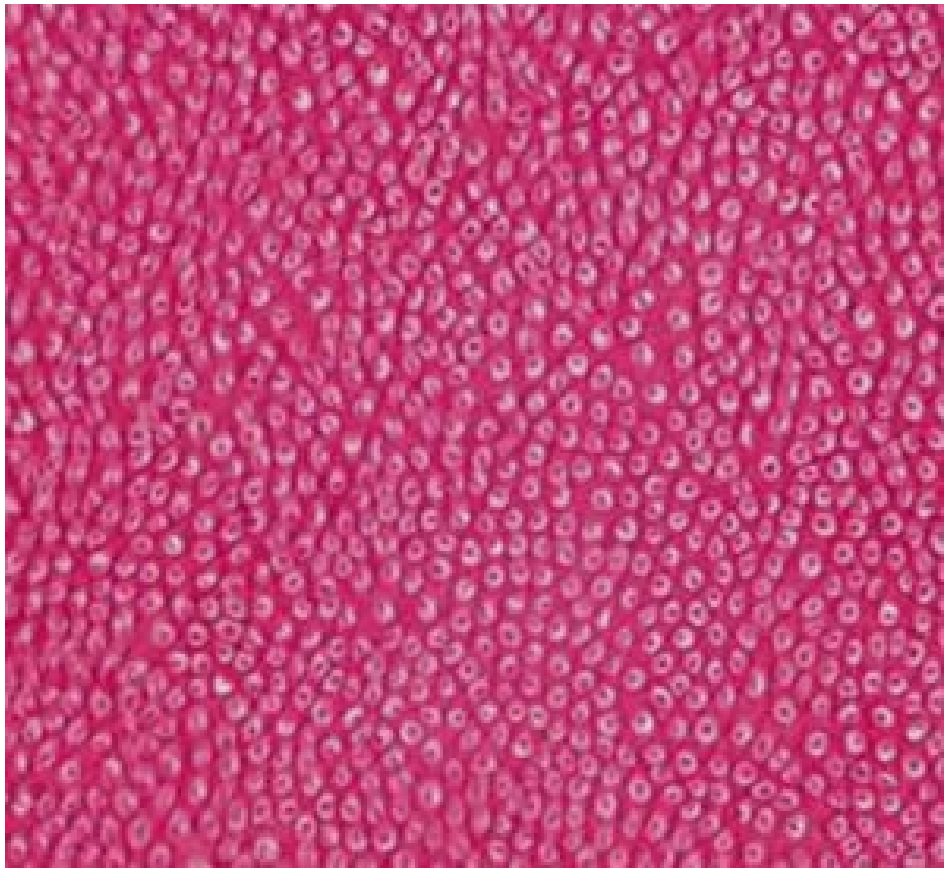
visible on stained sections as well as ground sections







Dentinal tubules
(transversal section)



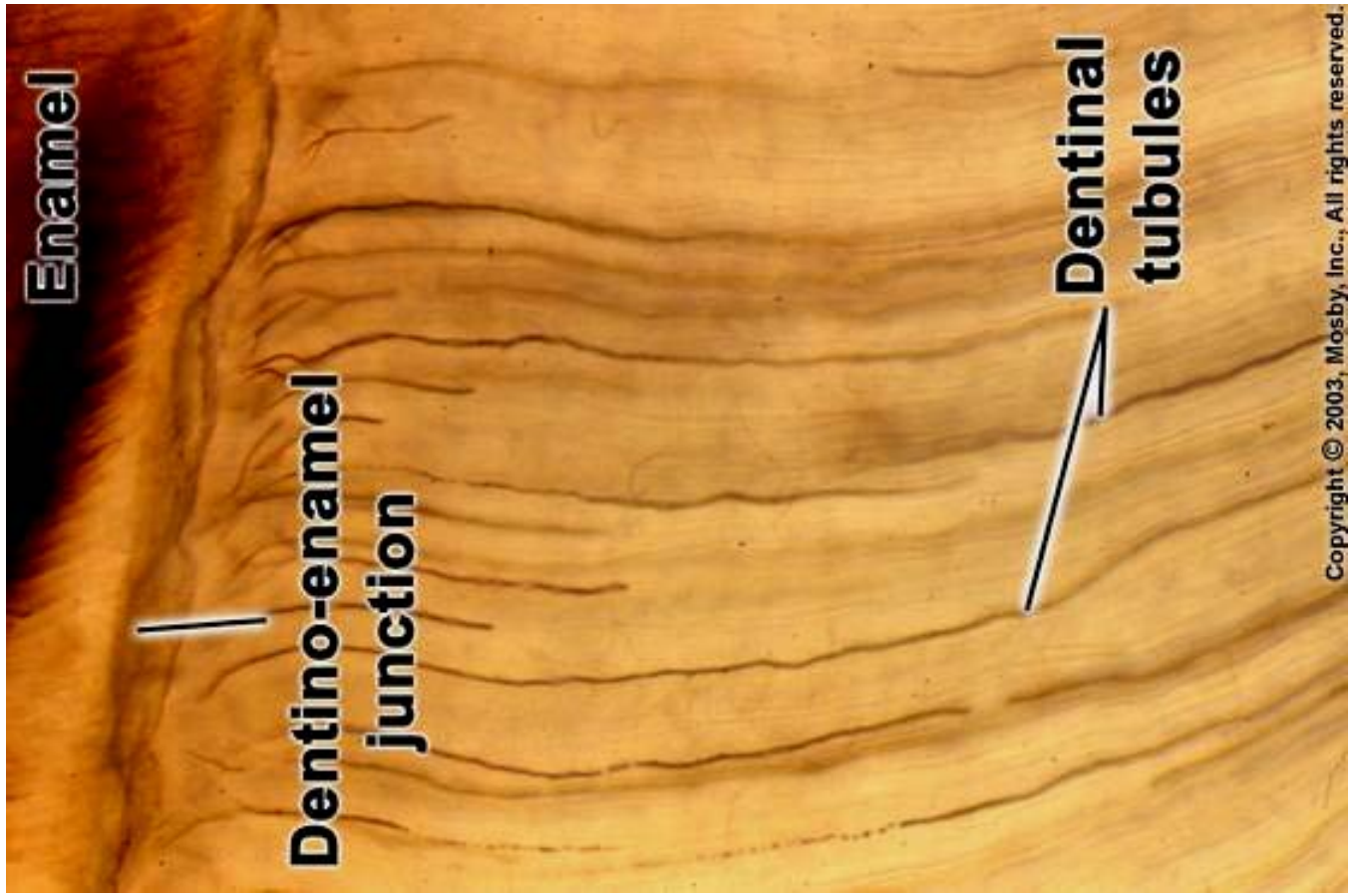
Dentinal tubules with Tomes fibres
(transversal section)

1 mm^2 surface can contain around 50 000 tubules

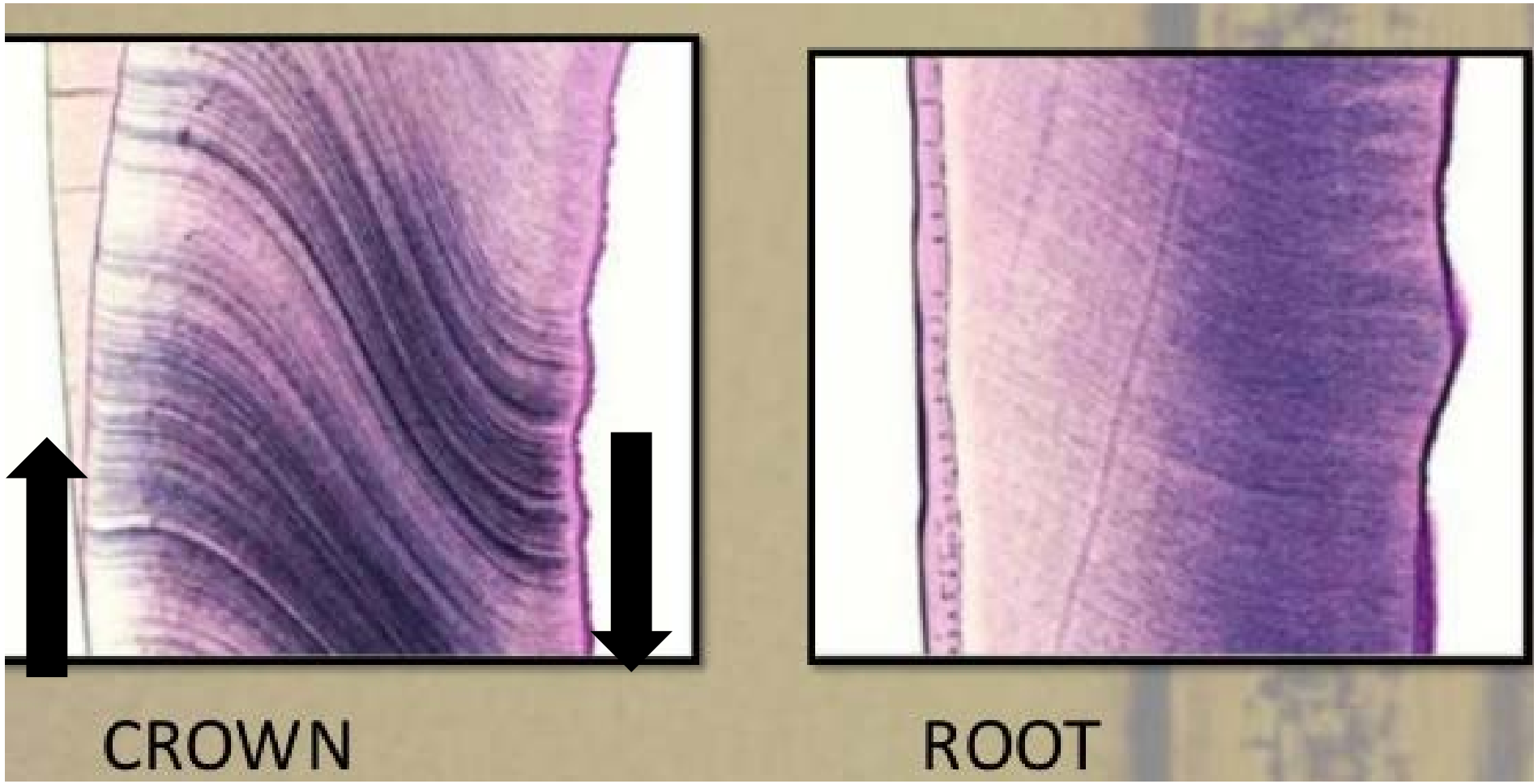
Dentinal tubules shape

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

Schreger shapes
(Crown part of dentin)



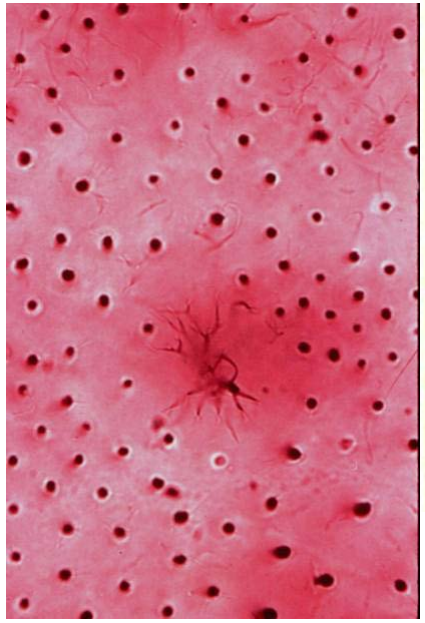
Primary dential bending

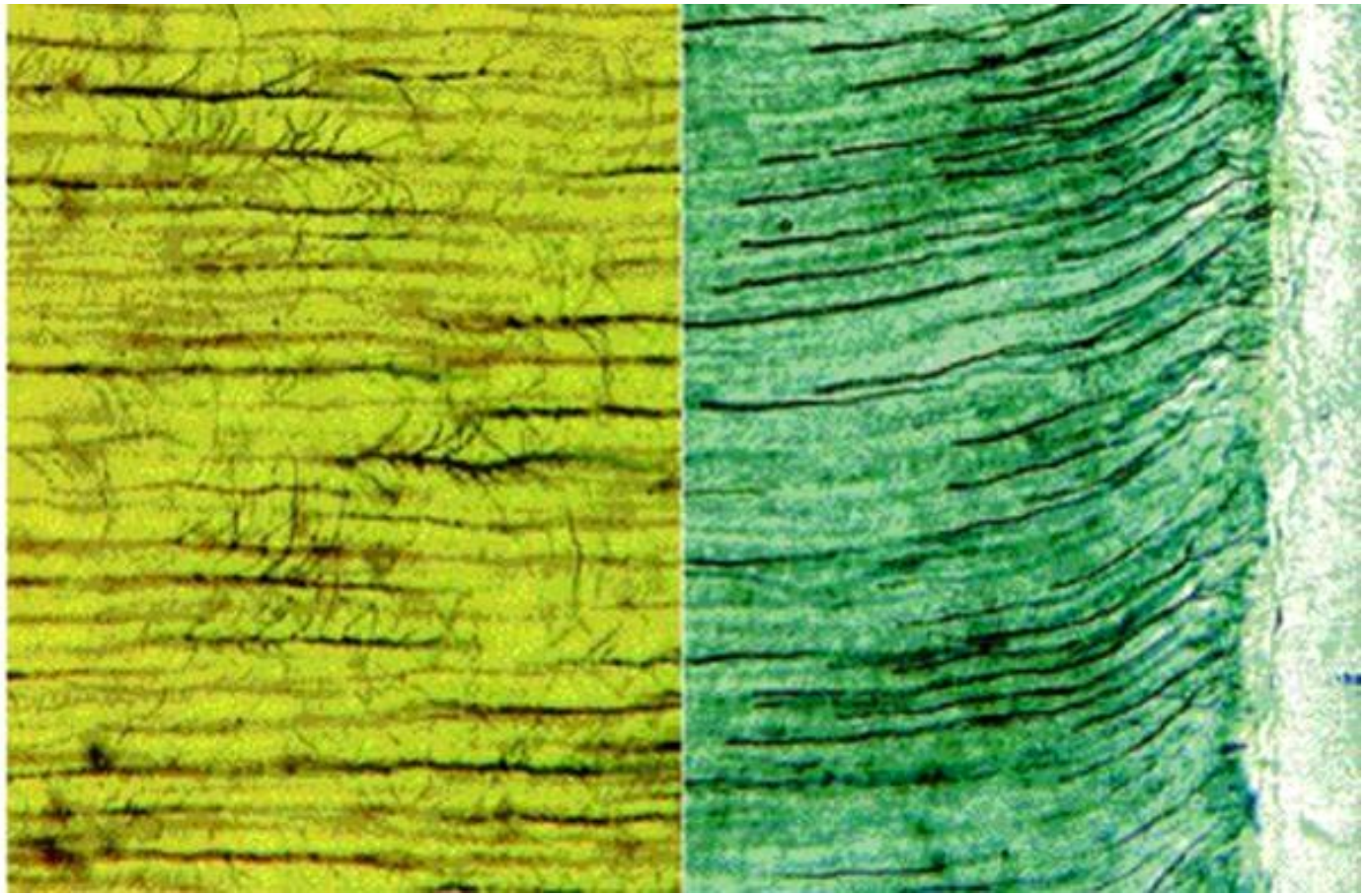


In addition to S-shape primary bending, up to another 200 secondary bends -

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

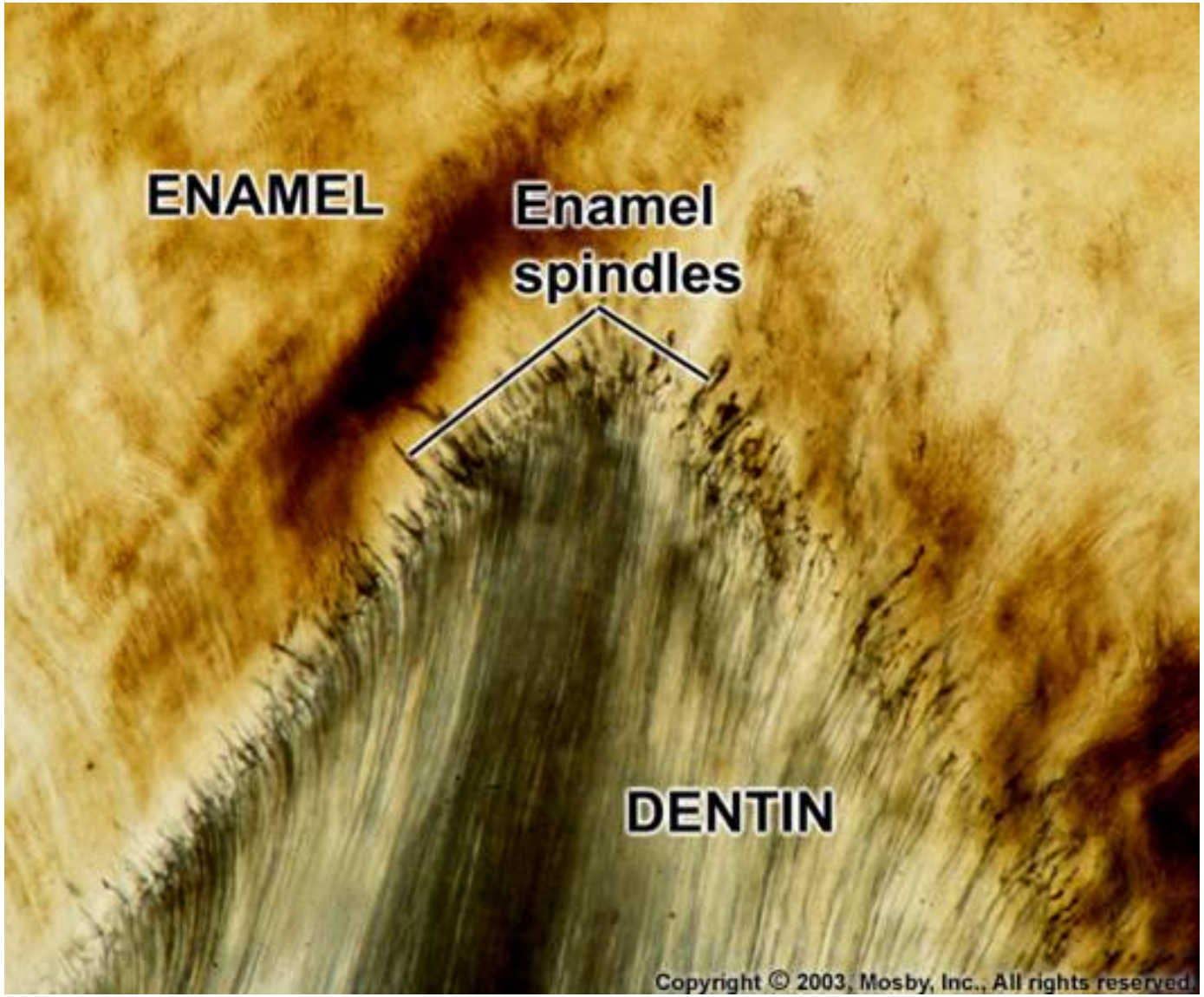
Diameter of the dentin tubules is around **1–4 um**
Decreasind towards DEJ (or cemento-dentinal junction)
Neighboring tubules can be interconnected by anastomoses (tubicles)

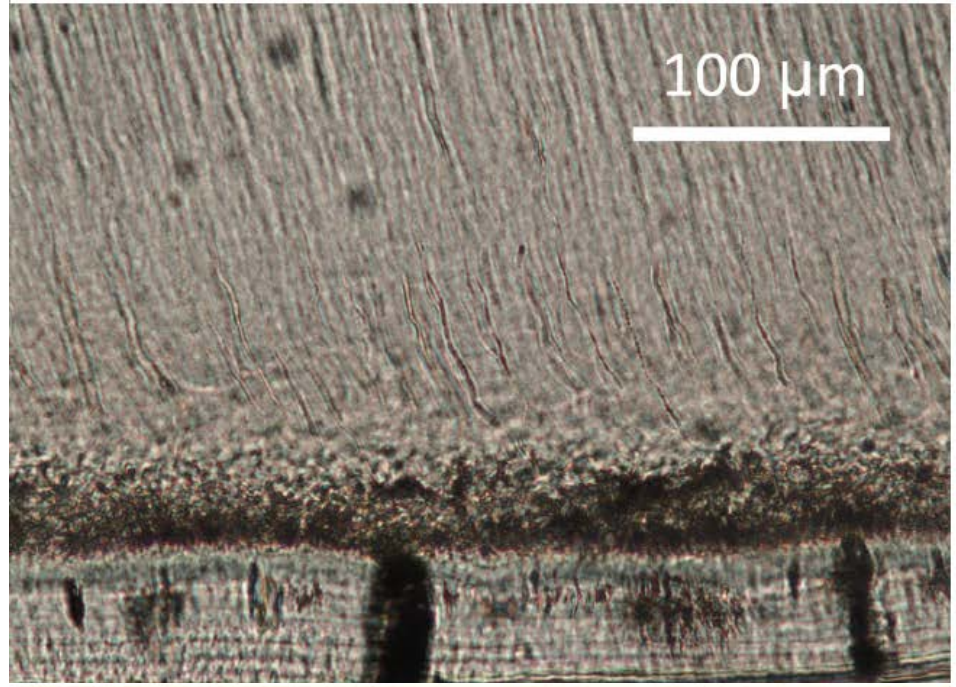




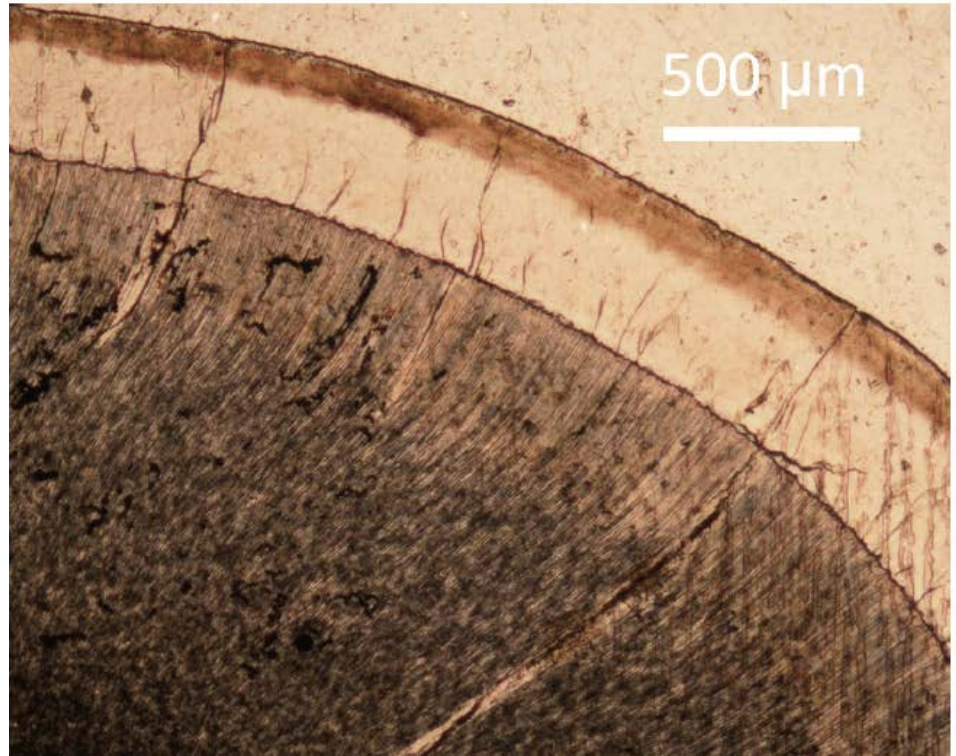
Enamel spindles *(fusus enameli)*

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

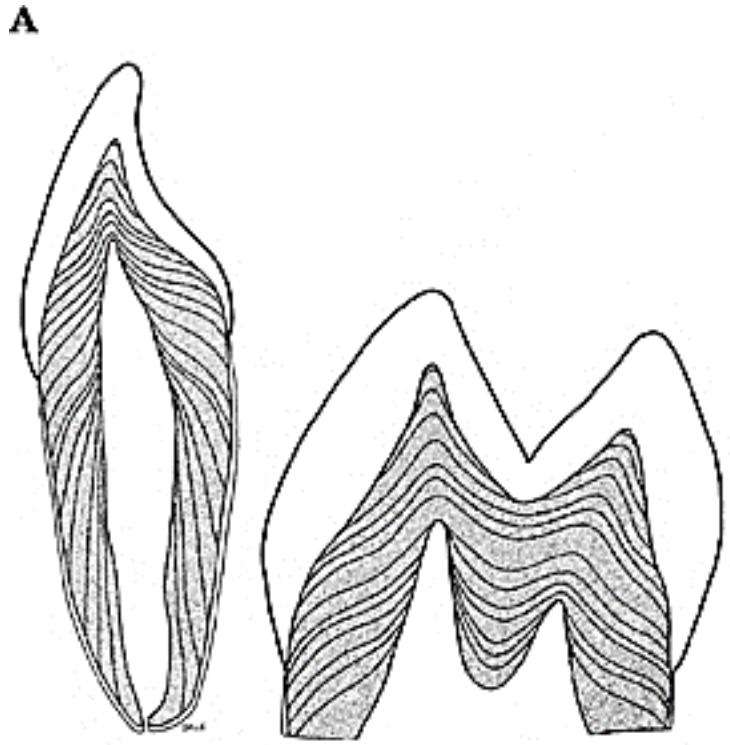


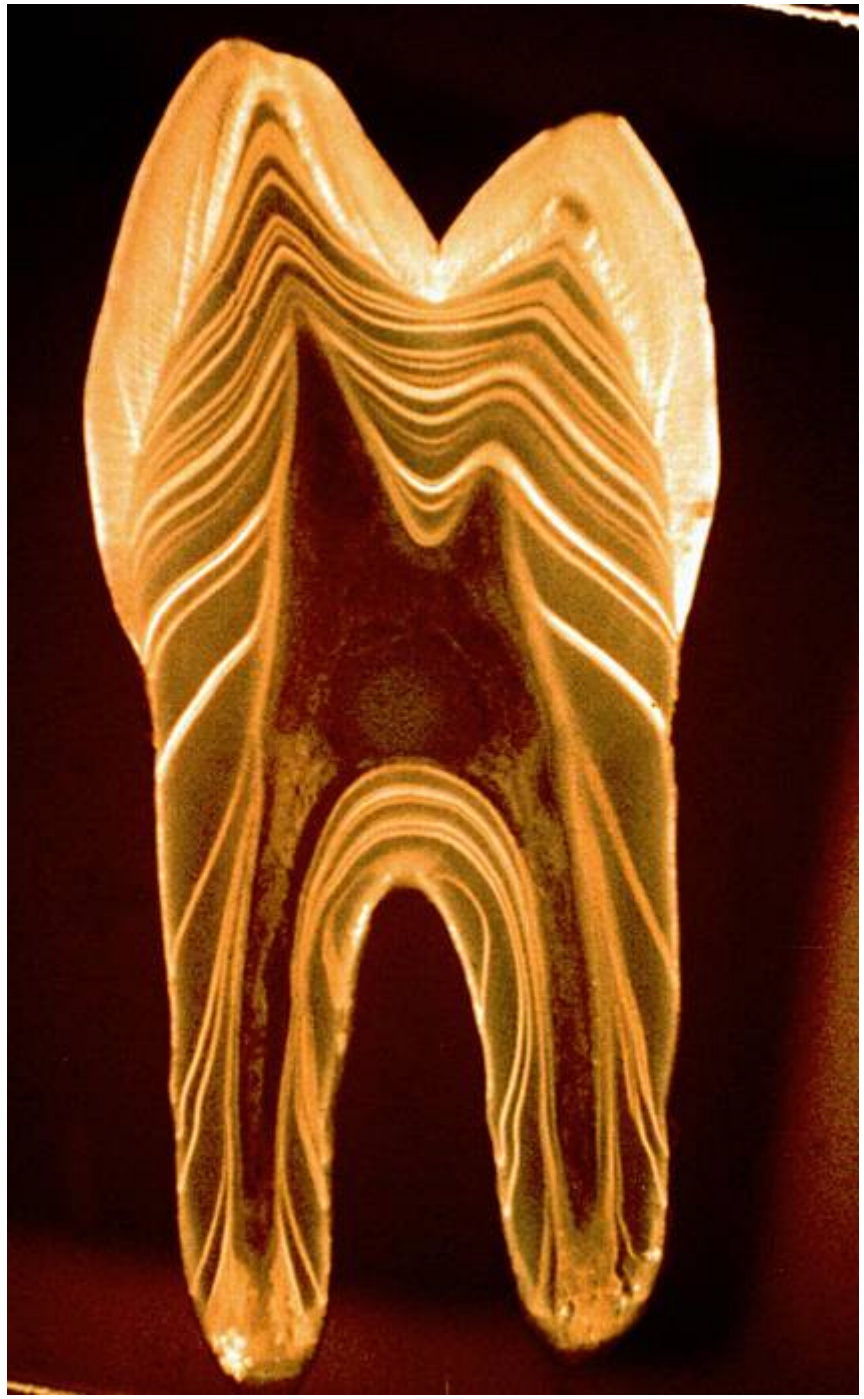
Dentino-sklovinné spojení na transverzálním výbrusu trvalého zubu, zobrazeno v procházejícím světle. Dentin je dole, sklovina nahoře. Ve vnitřní třetině skloviny jsou patrné *sklovinné trsy (enamel tufts)*, podobné trsům trávy a prasklinky probíhající celou její tloušťkou, tzv. *sklovinné lamely (enamel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

Dentin incremental lines

Caused by gradual deposition and mineralization of dentin

- **von Ebner** lines - **4-8 um** distance - daily increments
- **Owen's** lines - **15-30 µm** distance - joint calcification of 4-5 day increments
- **Neonatal** line - Owen line in temporary teeth - separates fetal and postnatal dentine

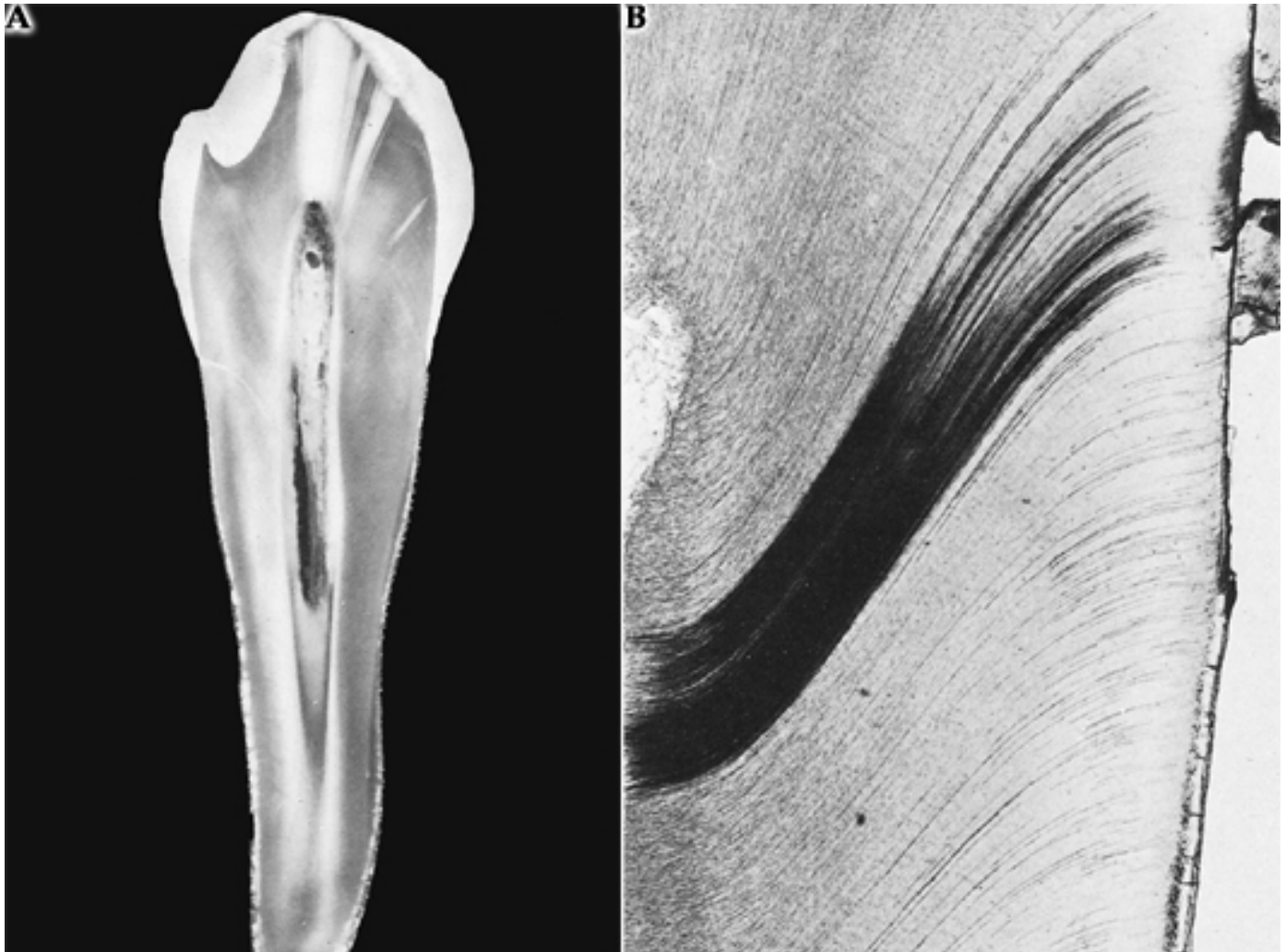




Circular pattern on cross section

Sclerotic dentin

"Dead Dentin", more resistant to dental caries, color of amber
Origin of **dentin tubule closure** by the thicknessing 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)



Thank you for your attention