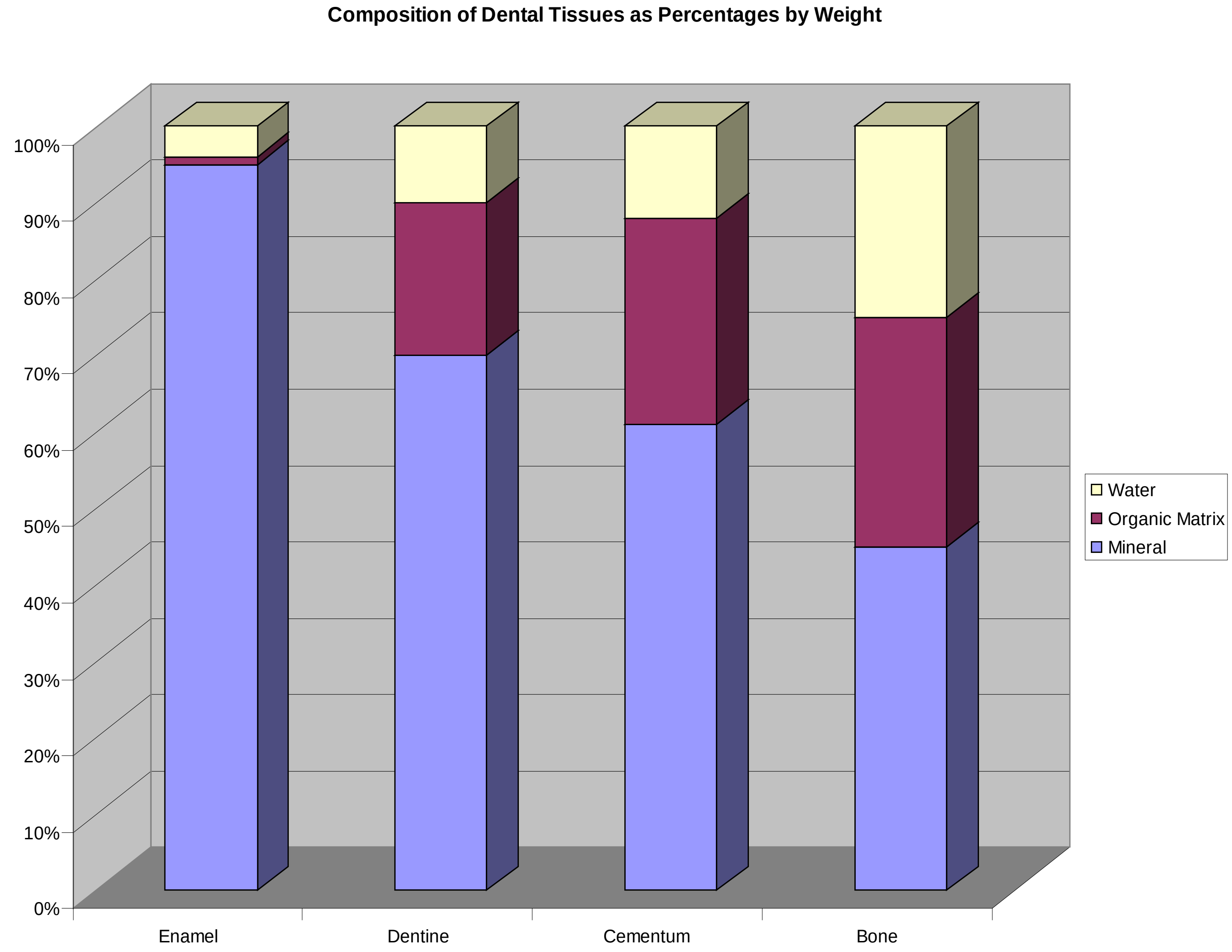
Lecture 2: Dentine and Cementum

General properties of dentine

Mesenchymal in origin, less mineralised than enamel



Chemical Composition of Dentine

- 20% organic
  - Most is type I collagen
  - Phosphorylated phosphoproteins (phosphophoryn – this is unique to dentine)
  - Osteocalcin, osteonectin
  - Proteoglycans – similar to those in bone
  - Growth factors, eg bone morphogenetic protein

Physical Properties of Dentine

- Less hard than enamel
- Has higher tensile strength than enamel
- More resilient (elastic) than enamel (supports brittle enamel)
- Sensitive (depends on nerves in pulp)
- Pulp-dentine complex is a living organ
- Can react to damage
- Increases in amount with age
- Porous
- Structure (and physical properties) change with age

Regions and Types of Dentine

- Dentine types based on region
  - Coronal dentine
    - Mantle dentine
    - Circumpulpal dentine
      - Globular dentine
      - Intertubular dentine
      - Peritubular or intratubular dentine
      - Sclerotic dentine
  - Root dentine
    - Includes intertubular and peritubular
    - Granular layer of Tomes
    - Hyaline layer

Regions and Types of Dentine

- Dentine types based on time of development
  - Predentine
  - Primary dentine
  - Secondary dentine
  - Tertiary dentine
    - Reparative dentine
    - Reactionary dentine

Dentinogenesis

- Begins at bell stage independently in each cusp
- Formed by odontoblasts
  - Mesenchymal
  - Differentiate from dental papilla
  - Papilla will become dental pulp
  - Differentiate when inner dental epithelium cells change polarity while becoming ameloblasts through cell signalling

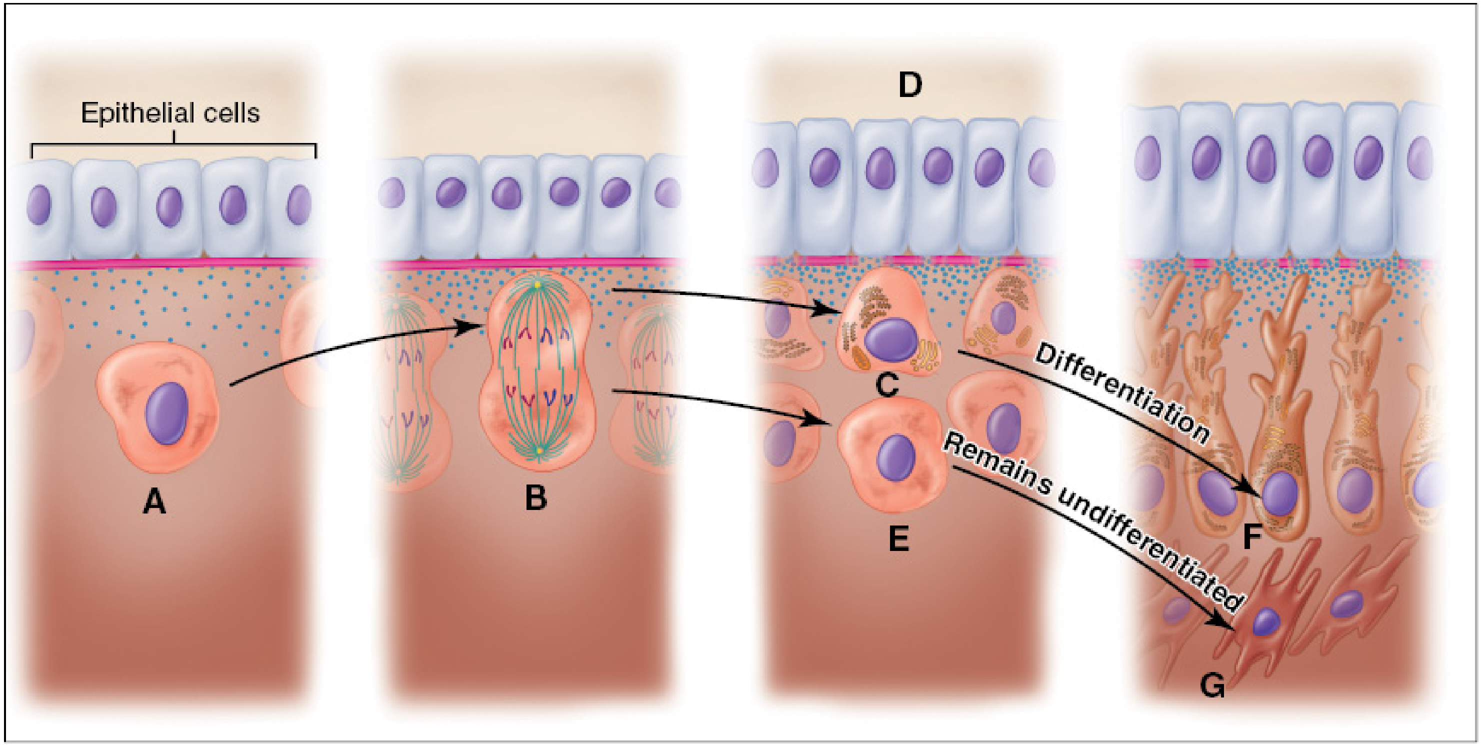


FIGURE 8-11 Odontoblast differentiation. The undifferentiated ectomesenchymal cell *(A)* of the dental papilla divides *(B)*, with its mitotic spindle perpendicular to the basal lamina *(pink line)*. A daughter cell *(C)*, influenced by the epithelial cells and molecules they produce *(D)*, differentiates into an odontoblast *(F)*. Another daughter cell *(E)*, not exposed to this epithelial influence, persists as a subodontoblast cell *(G)*. This cell has been exposed to all the determinants necessary for odontoblast formation except the last.

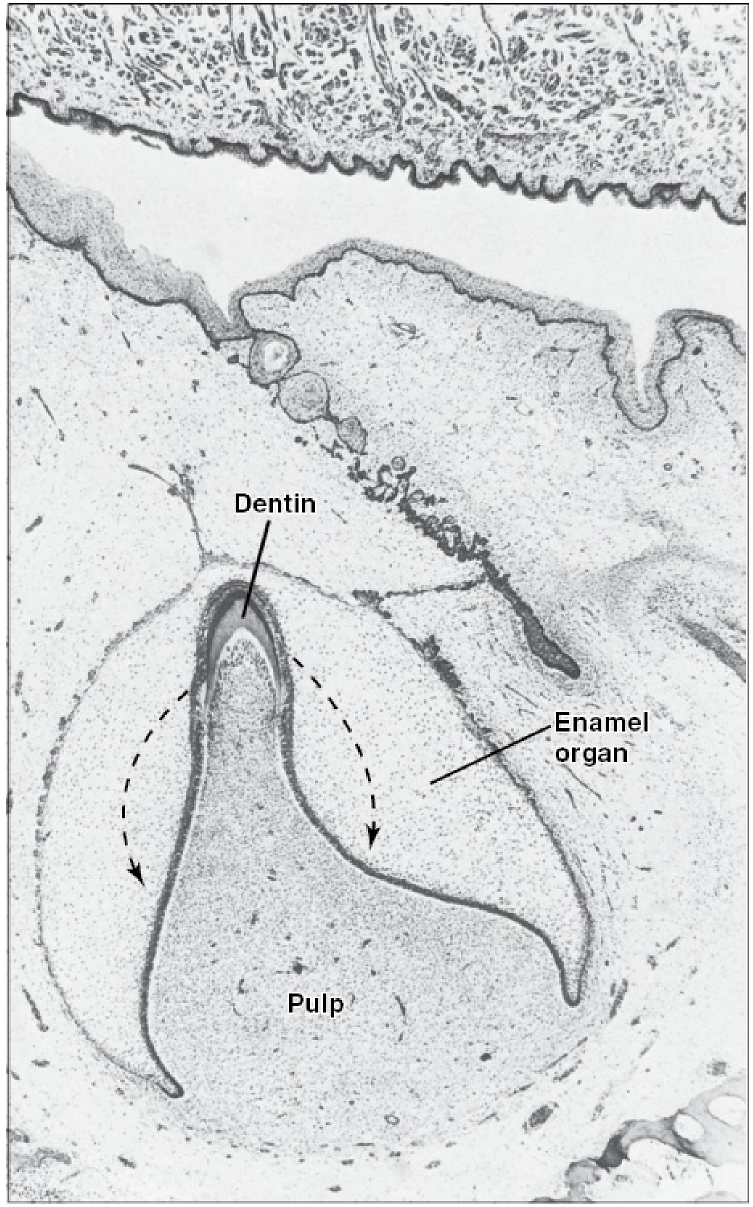
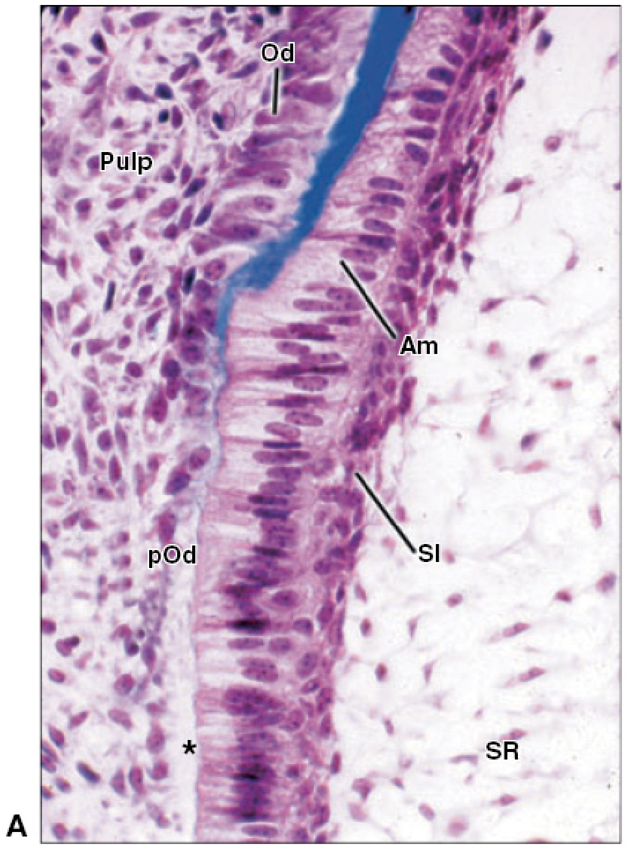


FIGURE 8-9 Dentin formation during the early bell stage of tooth development. From the apex of the tooth, dentin formation spreads down the slopes of the cusp.



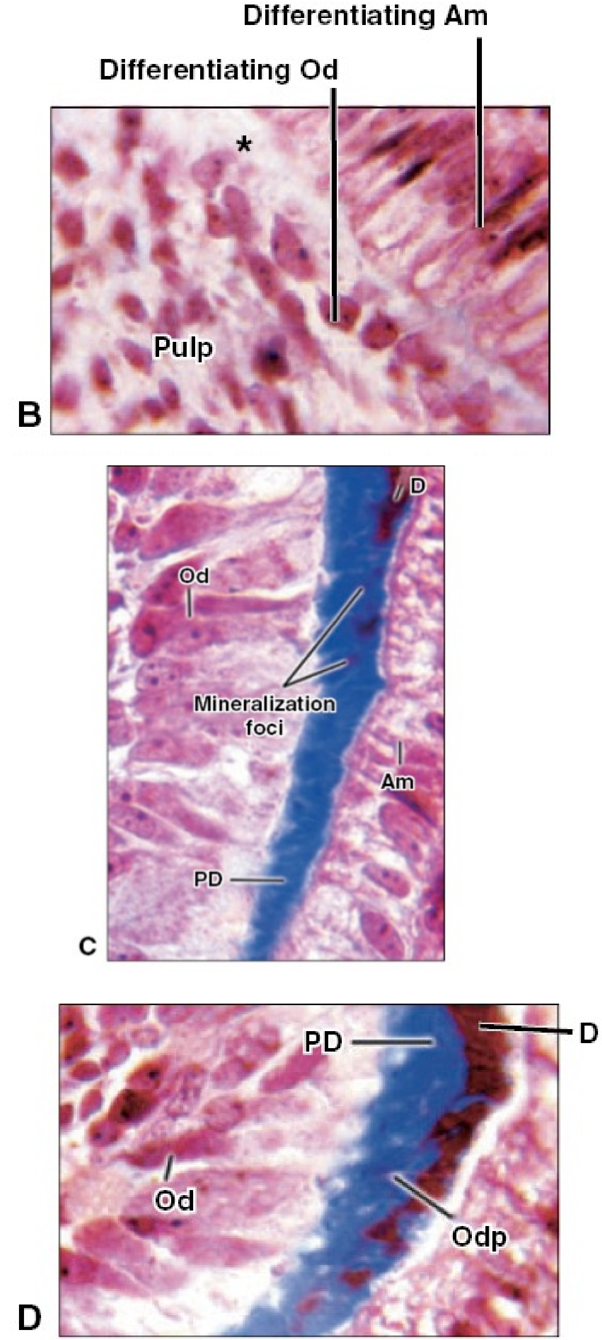


FIGURE 8-10A Changes in the dental papilla associated with initiation of dentin formation. **A,** An acellular zone *(*)* separates the undifferentiated cells of the dental papilla (preodontoblasts, *pOd*) from the differentiating inner enamel epithelium (ameloblasts, *Am*). **B** to **D,** Preodontoblasts develop into tall and polarized odontoblasts *(Od)* with the nucleus away from the matrix they deposit at the interface with ameloblasts. The matrix first accumulates as an unmineralized layer, predentin *(PD),* which gradually mineralizes to form mantle dentin *(D)*. *Odp,* Odontoblast process; *SI,* stratum intermedium; *SR,* stellate reticulum.

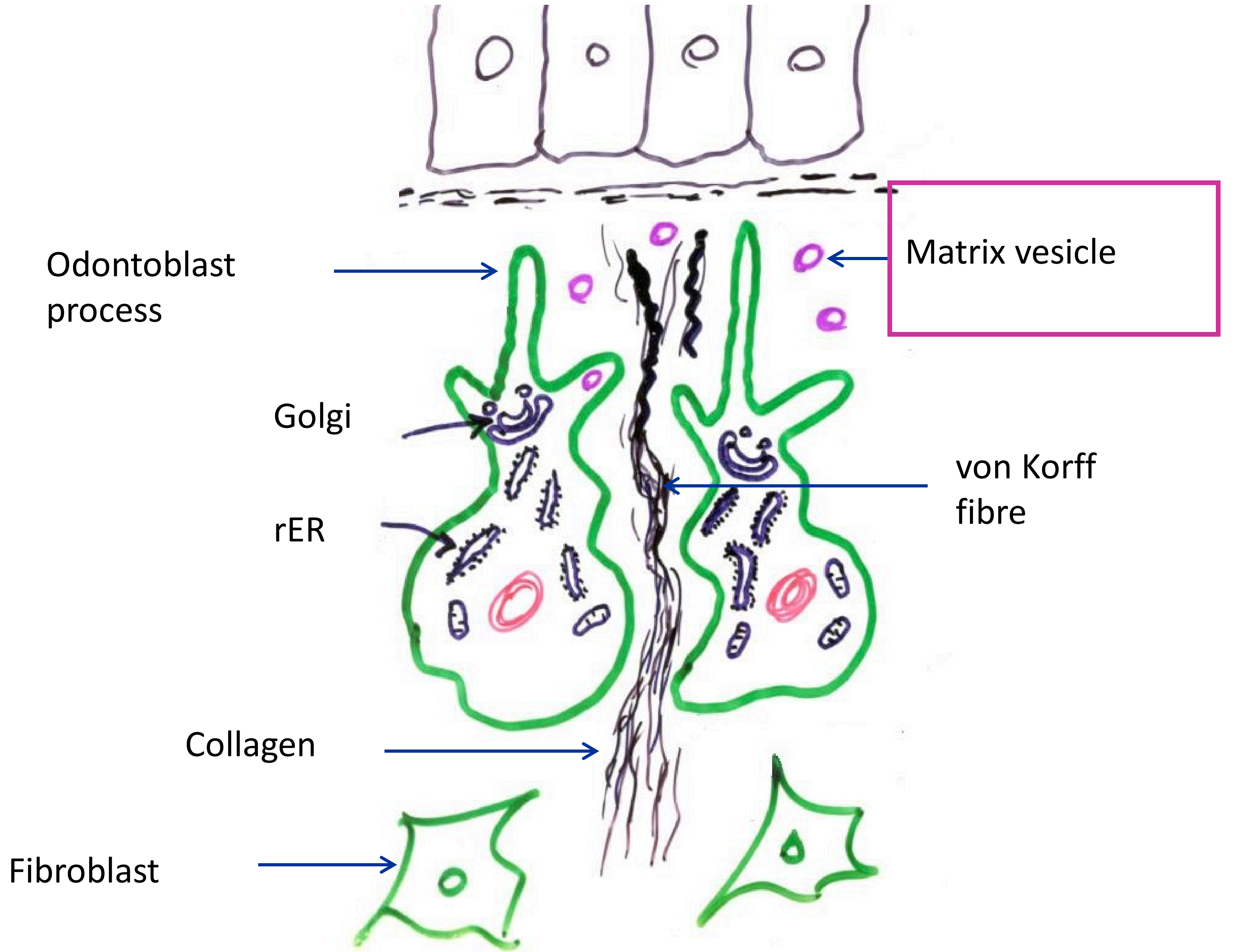
Dentinogenesis

- Odontoblast secrete collagen fibres (Type III) called von Korff's fibres at 90 degrees to edj
- Begin to secrete smaller Type 1 collagen fibres parallel to edj
- Odontoblast develops cell process
- Secretion of matrix vesicles
- Initiation of mineralisation within matrix vesicle
- Crystallites burst out of vesicle and form mineralising front
- Mineralising front is always behind collagen matrix front
- Unmineralised area between odontoblast layer and mineralising front is called predentine

Mineralisation by matrix vesicles

- Small (25 – 250 nm) membrane-bound vesicle produced by odontoblast
- Moves into matrix surrounding odontoblast (hence name)
- Contains phospholipids that bind to calcium
- Contains alkaline phosphatase that increases phosphate concentration *or* destroys inhibitor of mineralisation
- Matrix vesicles have only been seen during mineralisation of mantle dentine
- They may or may not be involved with mineralisation of circumpulpal dentine

Dentinogenesis: mineralisation (drawing courtesy of Doug Luke)

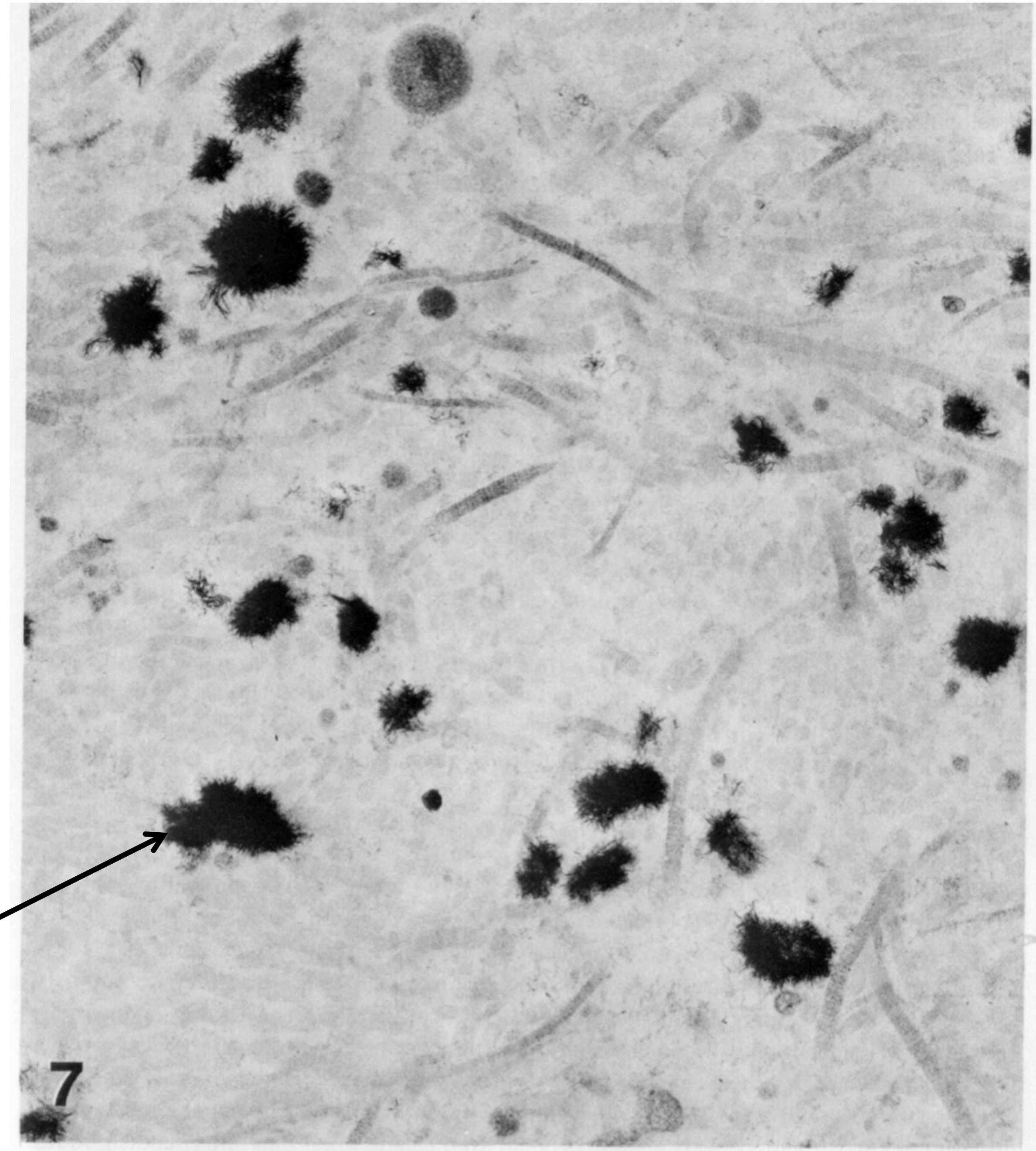


Matrix vesicles

Matrix vesicles – some calcified, some not calcified

Note there is no mineralisation in or near the collagen fibres, suggesting that collagen is not responsible for initiating mineralisation

Crystals in matrix vesicle

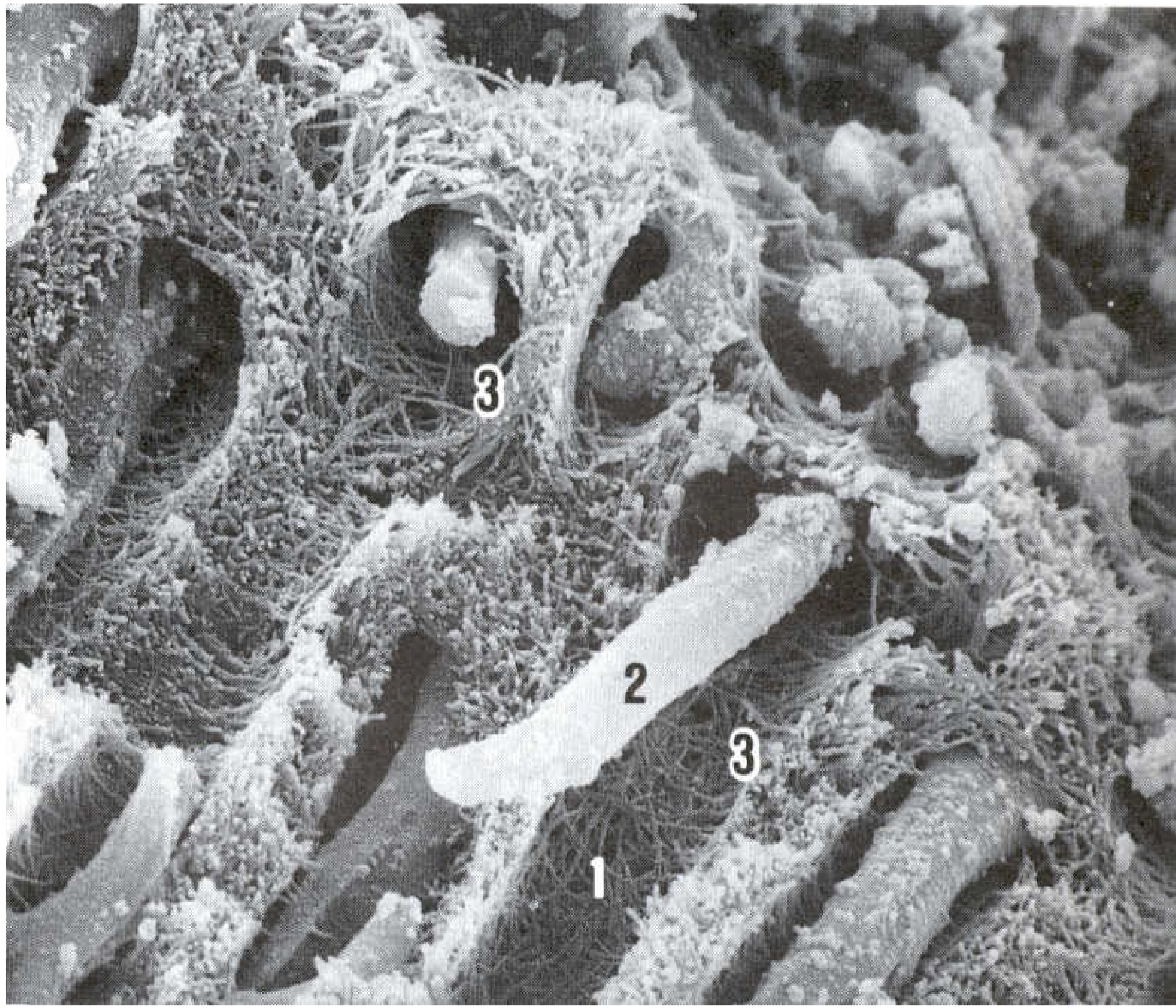


Dentine: oblique SEM of predentine

1 = Collagen fibres

2 = Odontoblast process

3 = Dentinal tubule



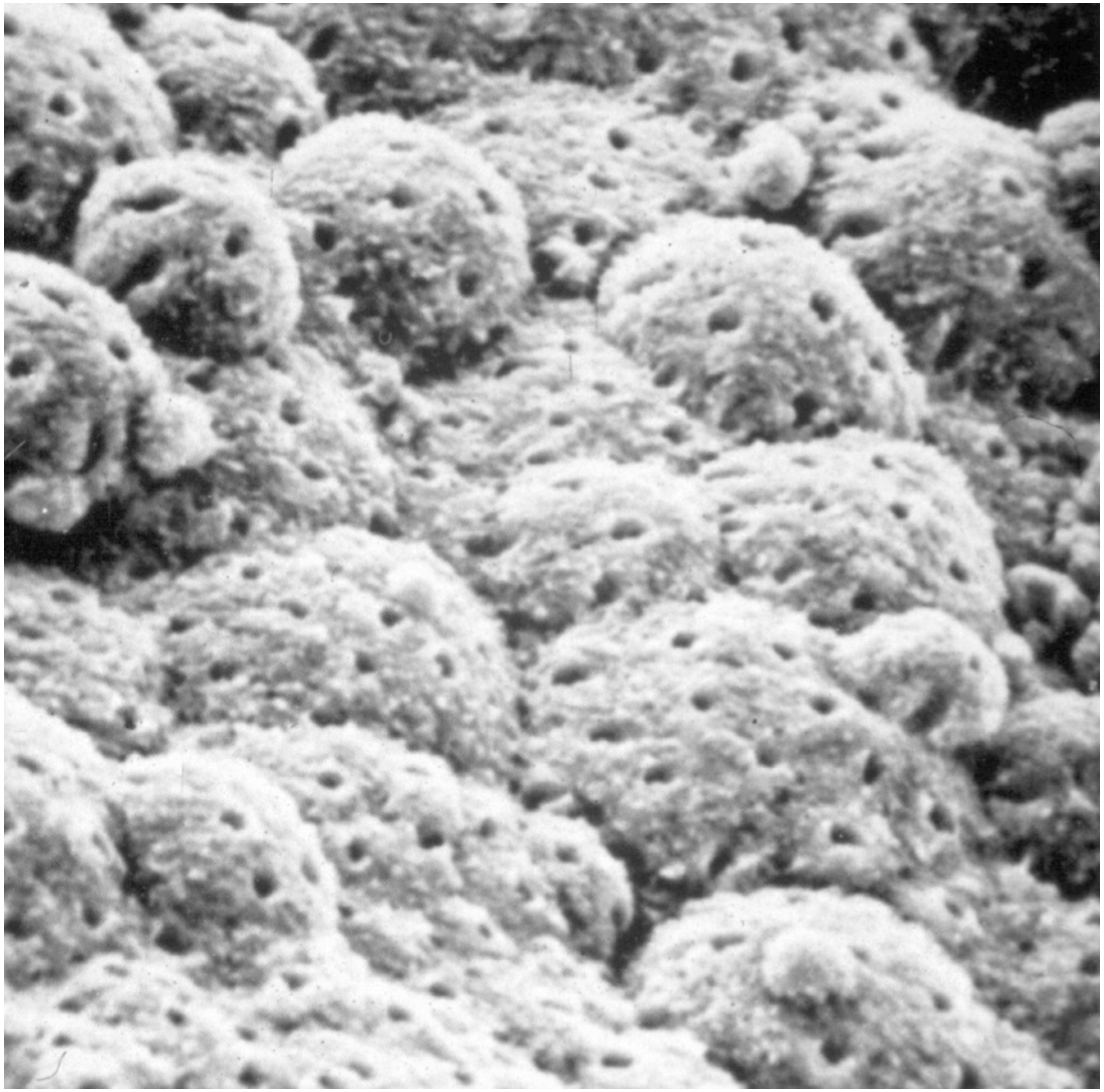
Linear and Globular Mineralisation

- Dentine mineralisation can be linear or globular, depending on speed of formation.
- Globular
  - Calcospherites (globular masses of mineralised dentine) form within collagen matrix and increase in size until they fuse – when fusion incomplete, interglobular dentine forms when formation is fast.
  - When formation slow, mineralisation occurs gradually and mineralising front looks straight.

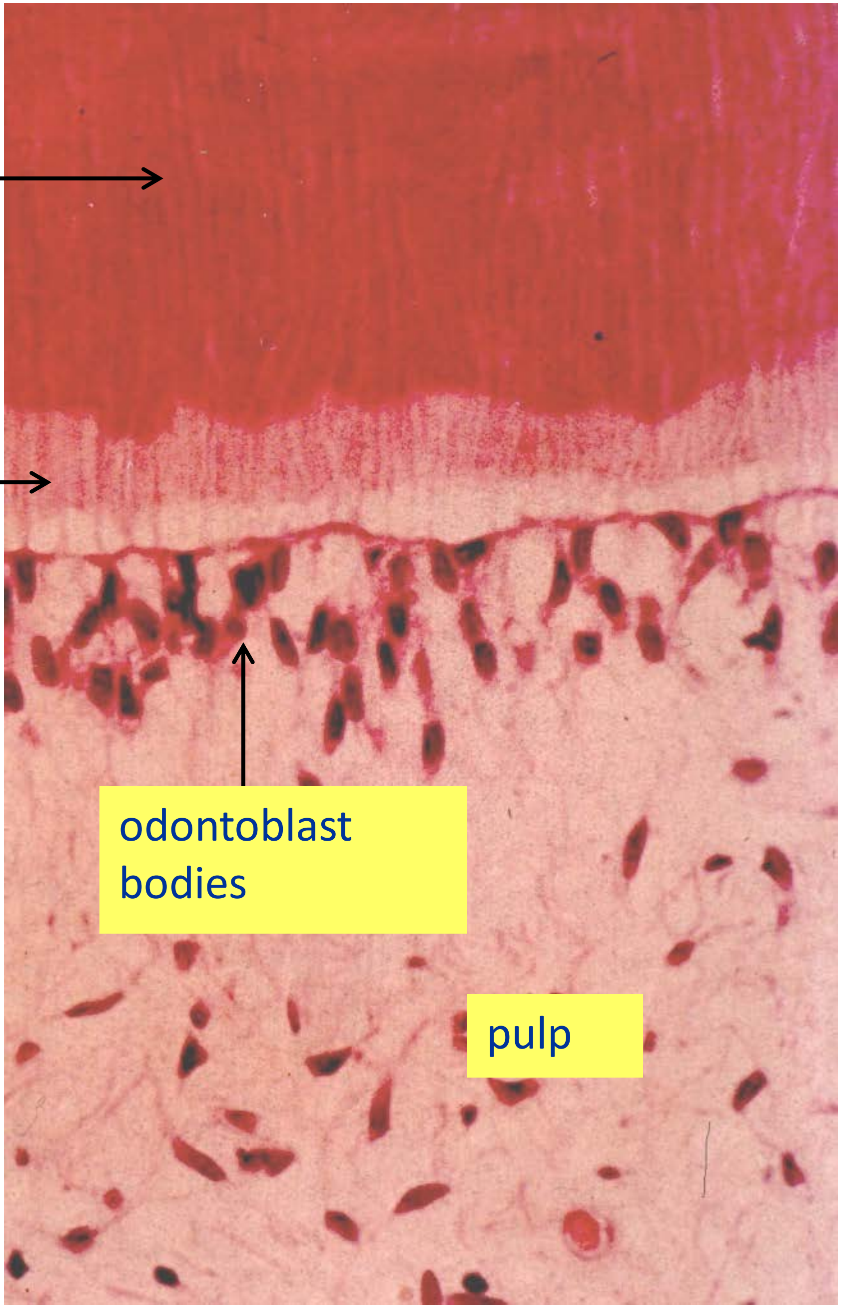
Dentine/predentine junction

Predentine has been removed and growing surface of mineralised dentine is seen using SEM

Note calcospherites with dentinal tubules passing through



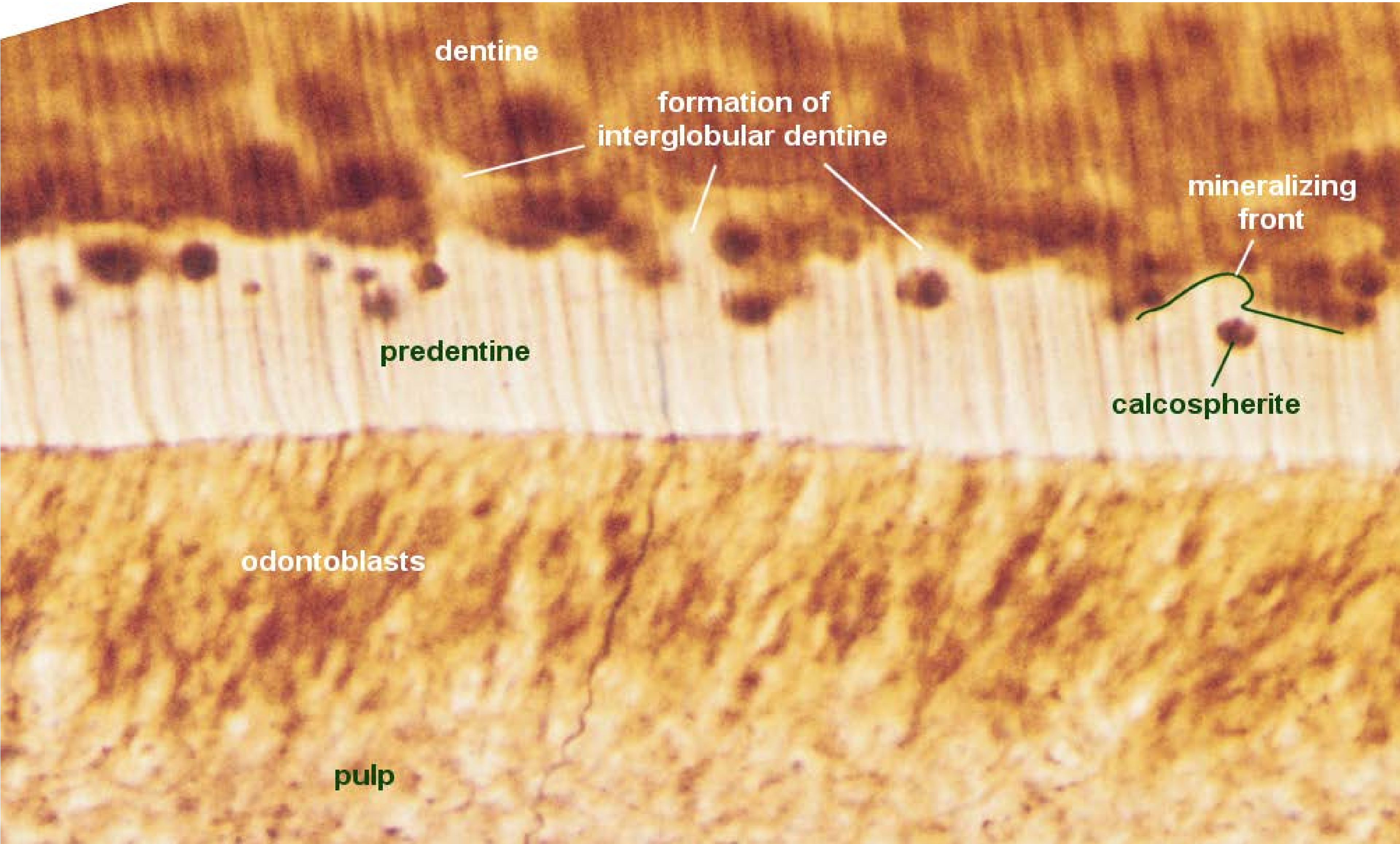
Dentine: predentine



•Predentine is unmineralised dentine found on the growing surface of dentine

•Calcospherites (mineral spheres) grow into the predentine so the predentine/dentine junction is scalloped

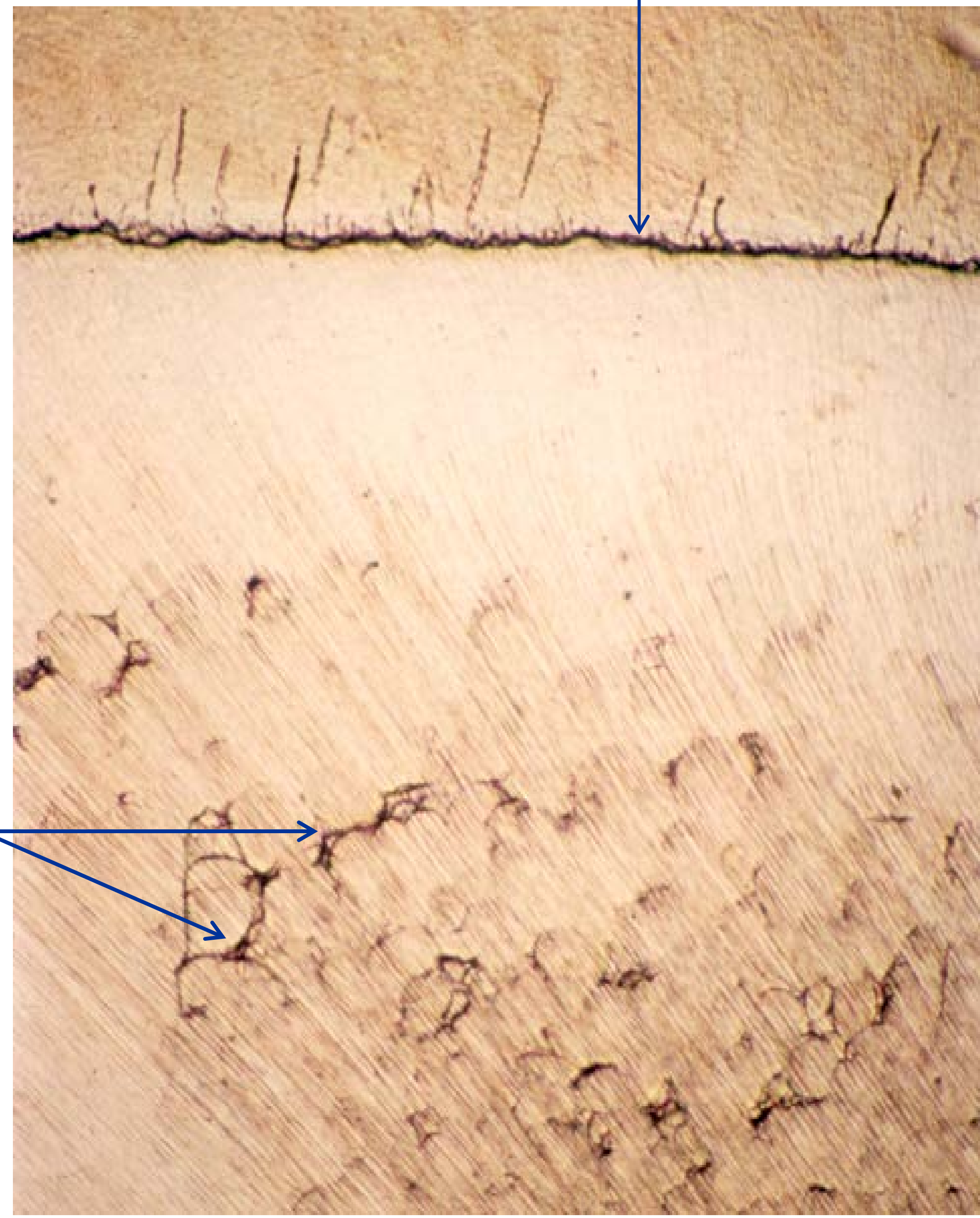
- **Globular mineralisation of dentine**.
- Faster rate of secretion of predentine results in calcospherite formation in advance of the mineralising front, leading to interglobular dentine formation



Dentine: interglobular dentine

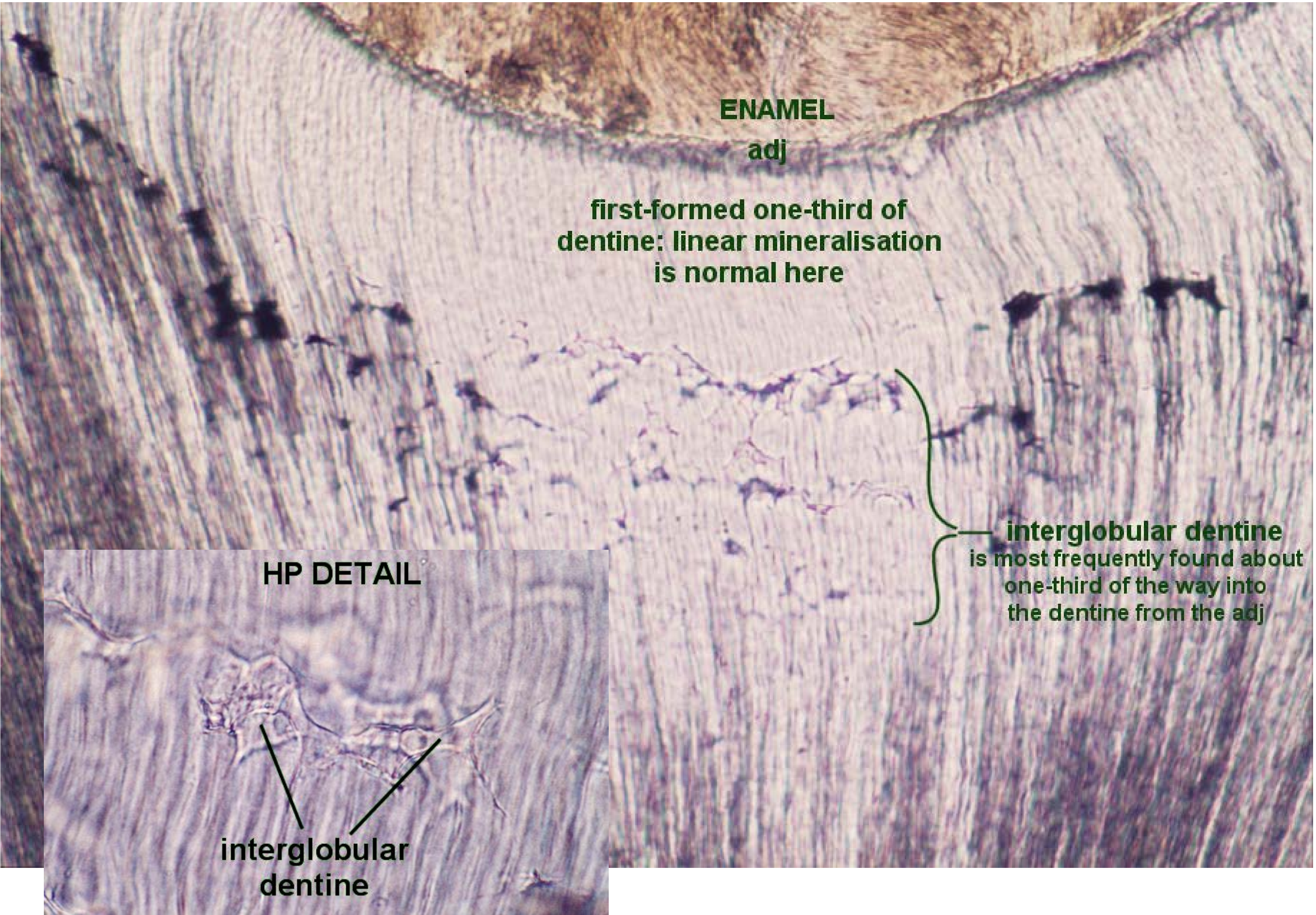
- In a region of the crown about 0.2 mm from the EDJ is usually interglobular dentine:
- Leaf-like areas between spheres or globules of mineral

edj



interglobular dentine

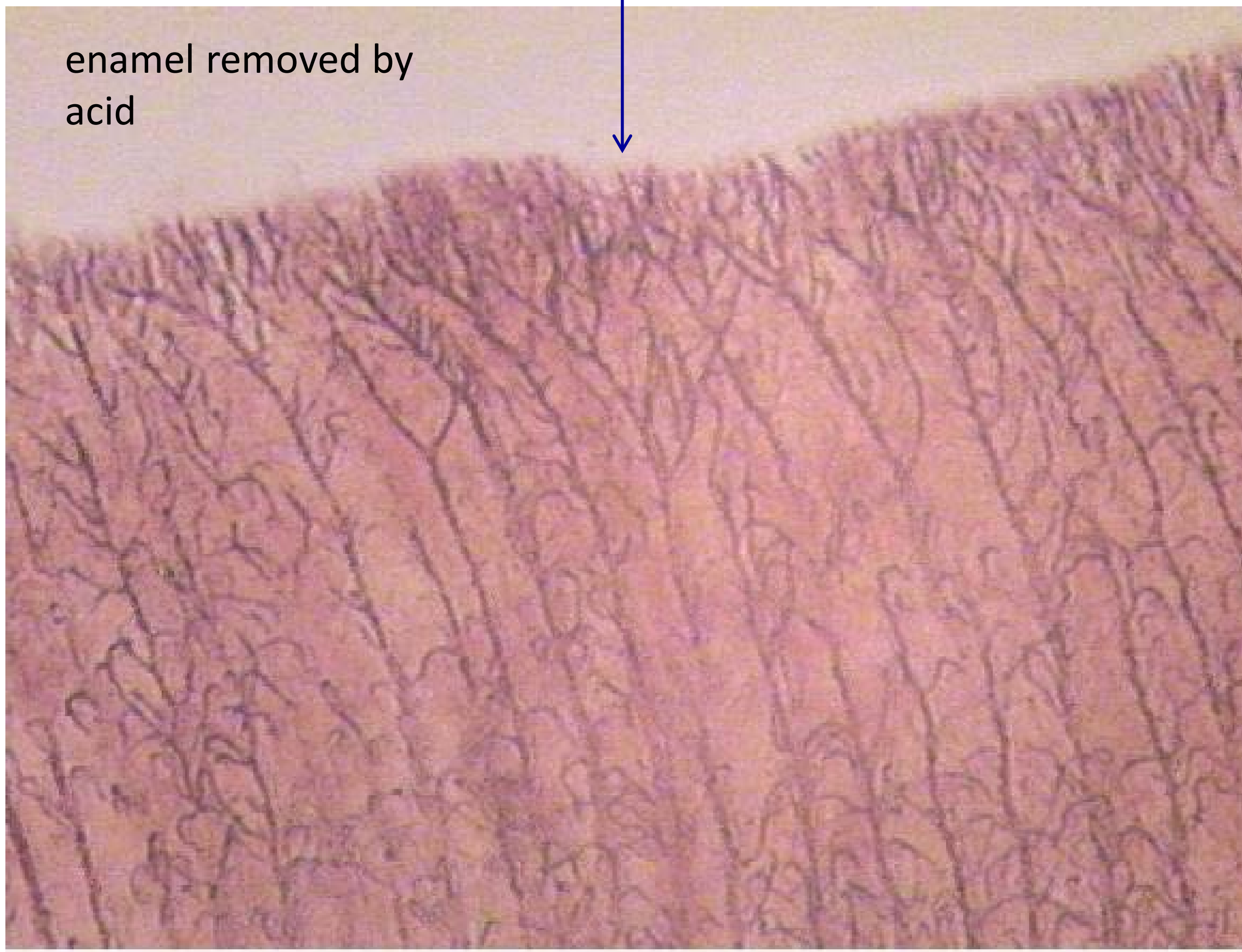
- Enamel and dentine showing **zone of interglobular dentine** where secretion rate was fastest



Dentine: contains tubules with branches

This is a part of a decalcified section of a tooth

enamel-dentine junction (picture courtesy of Doug Luke)

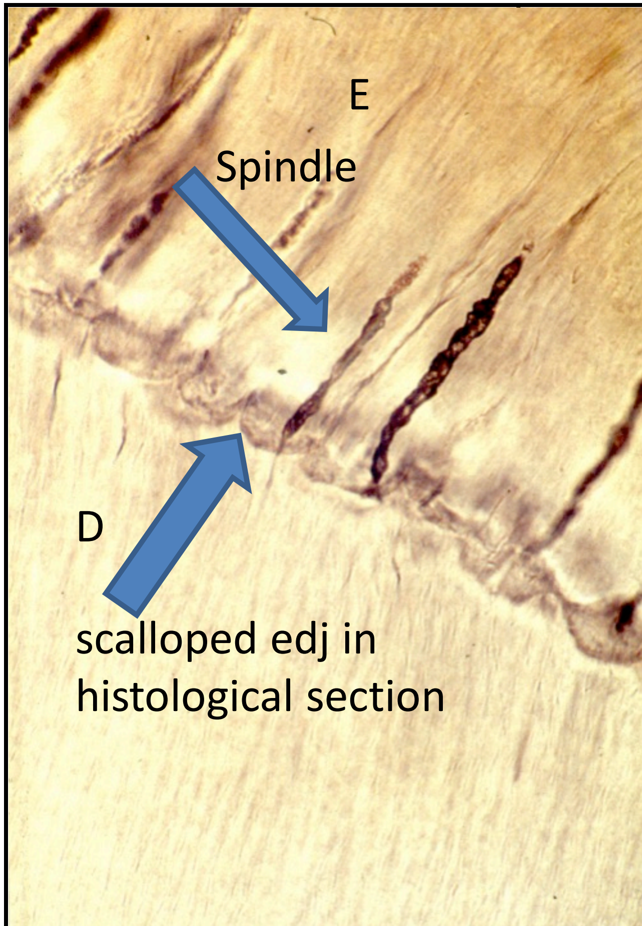


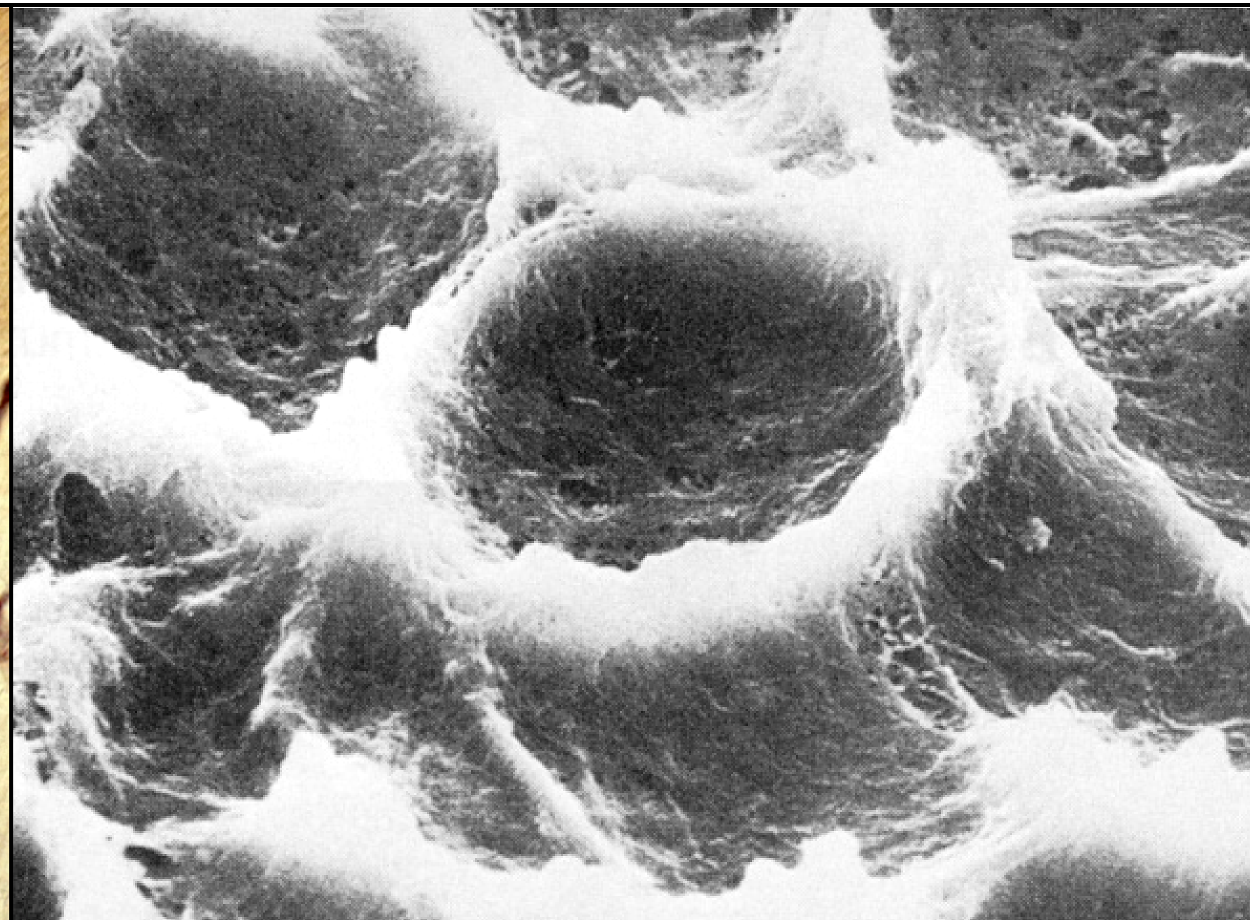
mantle dentine

circumpulpal dentine

Enamel-dentine junction

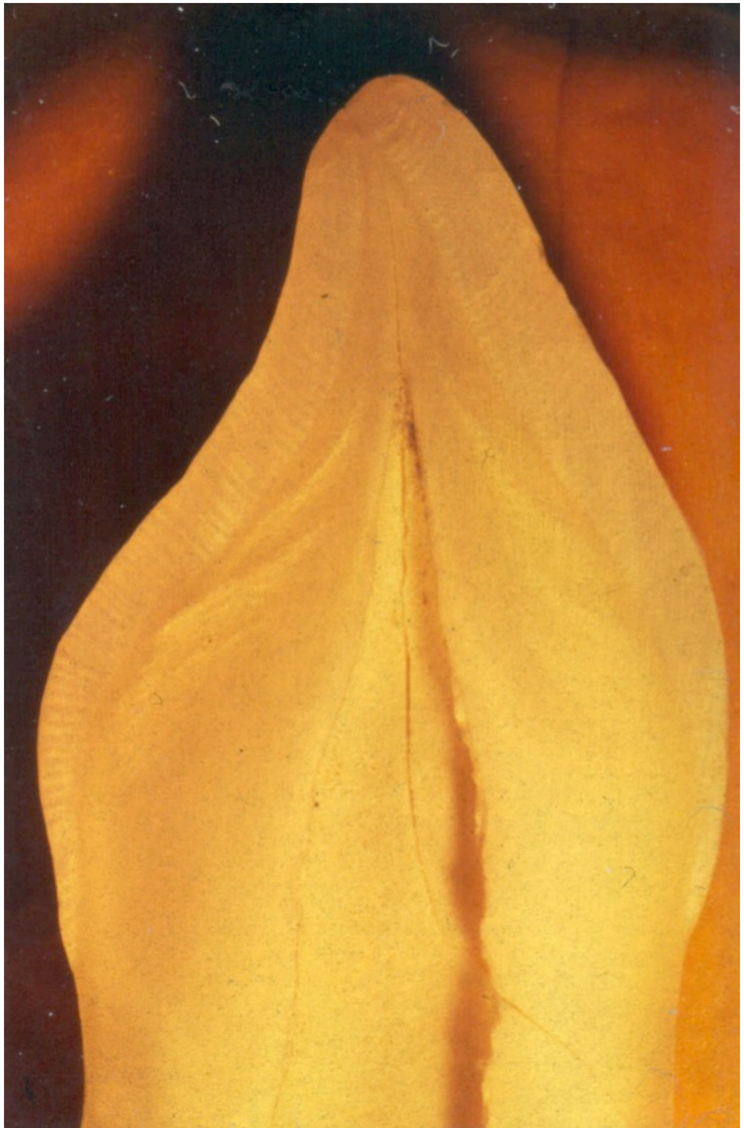
On right, the enamel has been removed and this is a high-power SEM 3D view of the edj: crater-like depressions increase the surface area of the edj and sharp edges help attachment of enamel to dentine





Dentine is much more permeable than enamel

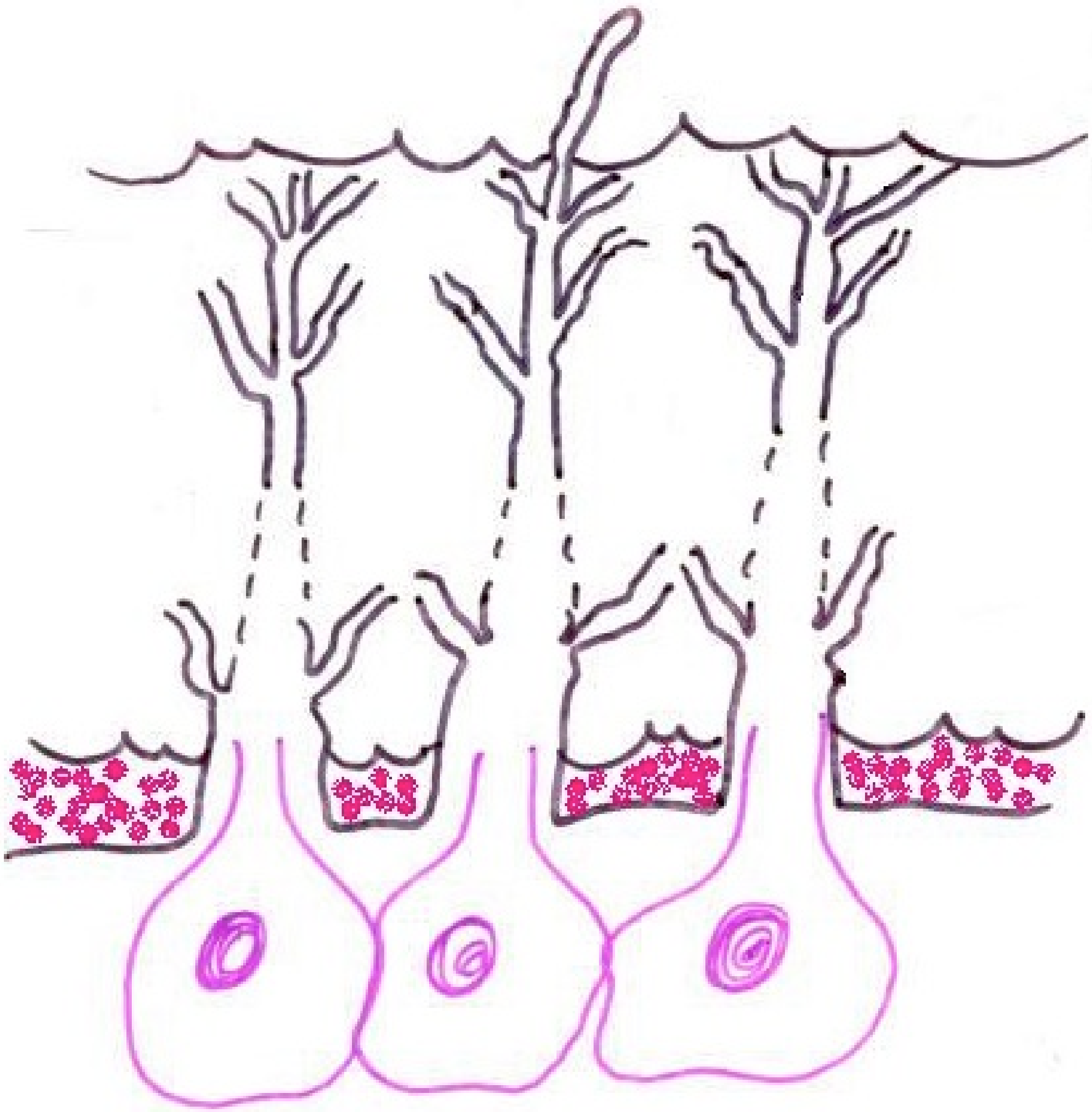
Flow of red dye placed in pulp (pictures courtesy of Doug Luke)

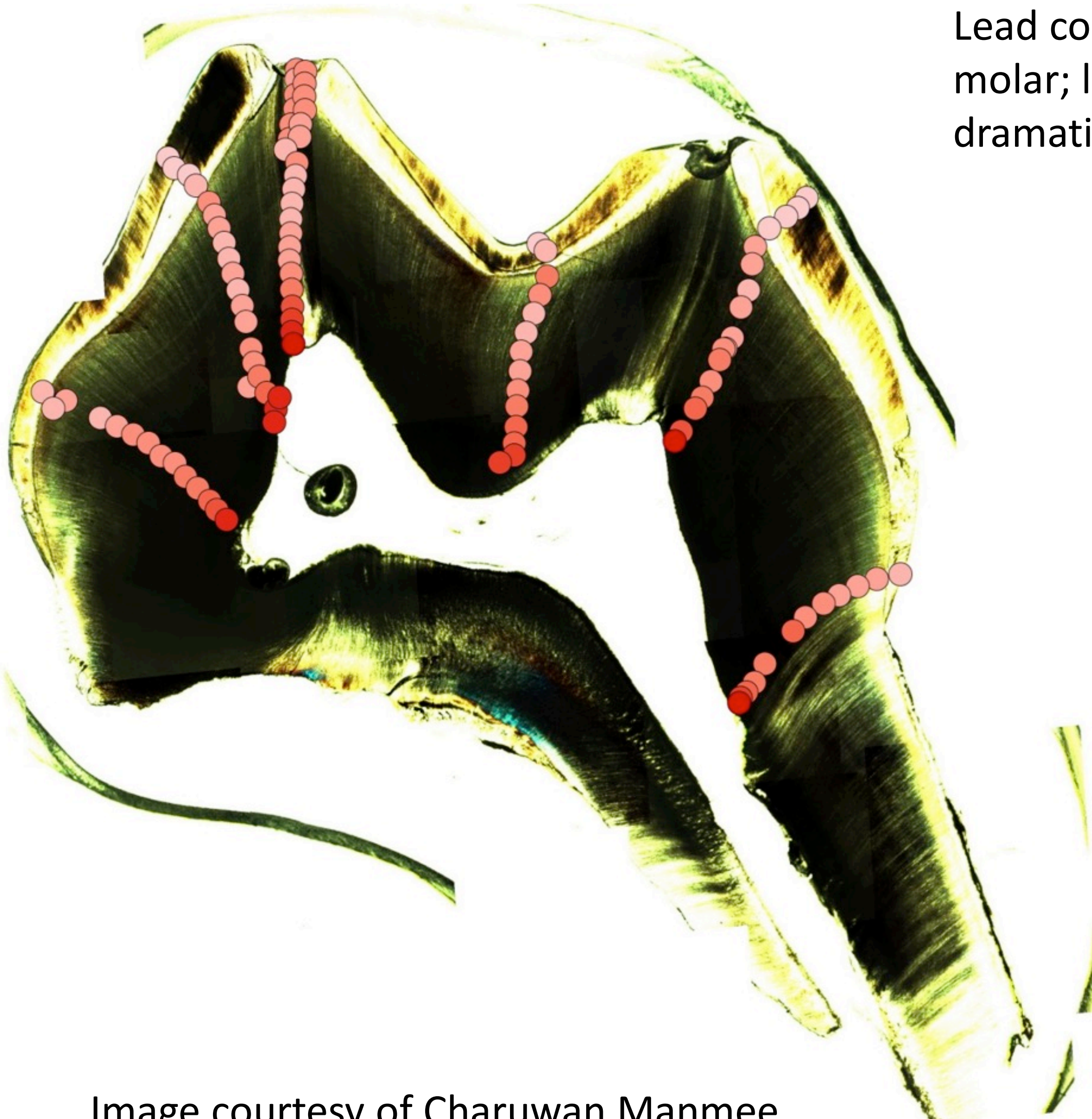


Numbers of tubules in dentine

- Cross-section of 1 square mm dentine contains about 40 000 dentinal tubules
  - About 20 000 near enamel
  - About 60 000 near pulp
  - Because tubules are more separated near enamel and more tightly packed near pulp
  - More tubules per unit area near pulp and tubules are wider (2-3μm) here than near enamel (1 μm)
  - So permeability of dentine increases as get nearer pulp

Dentine permeability increases from EDJ towards pulp (drawing courtesy of Doug Luke)

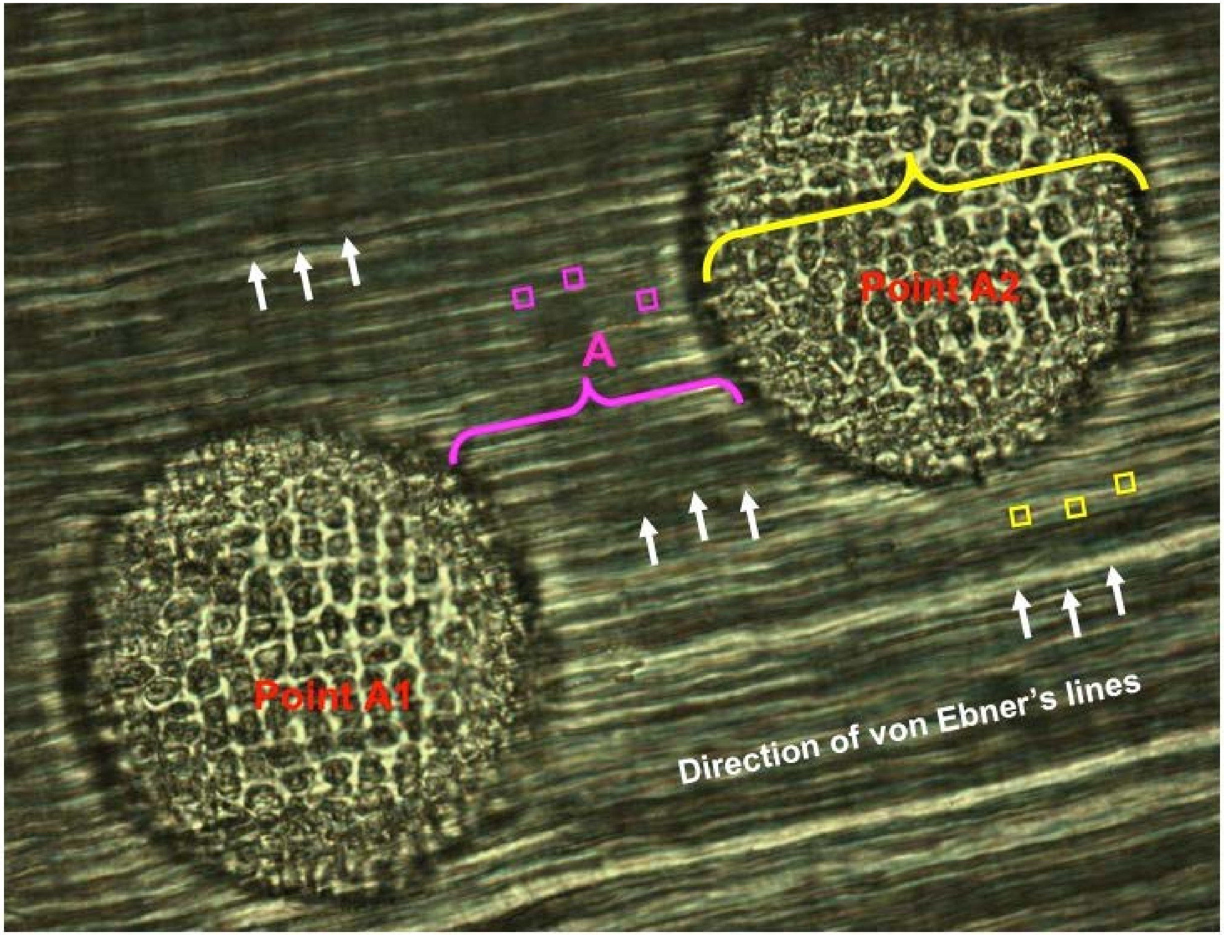


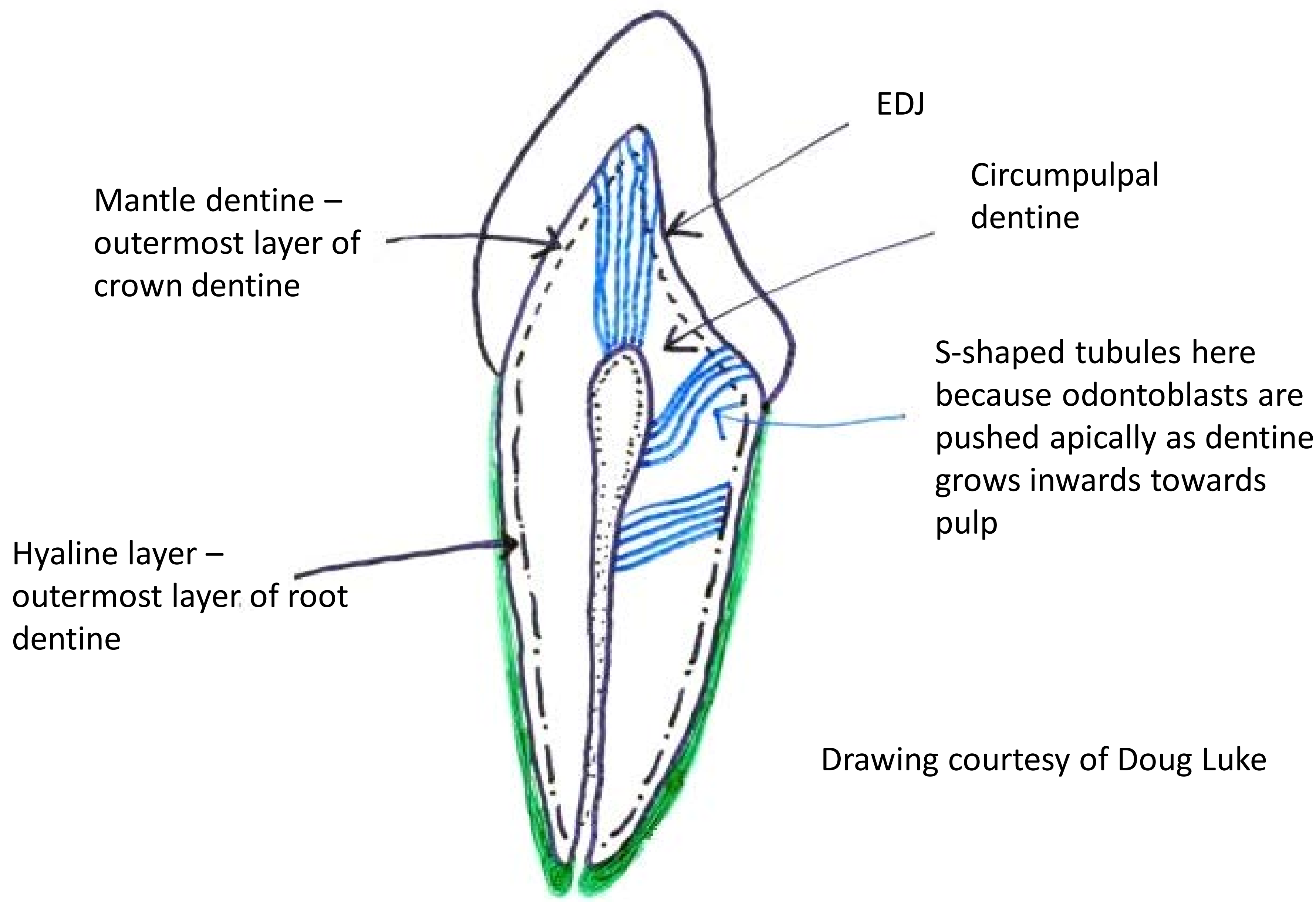


Lead concentration in child's primary molar; lead is low but increases dramatically at pulp.

Image courtesy of Charuwan Manmee

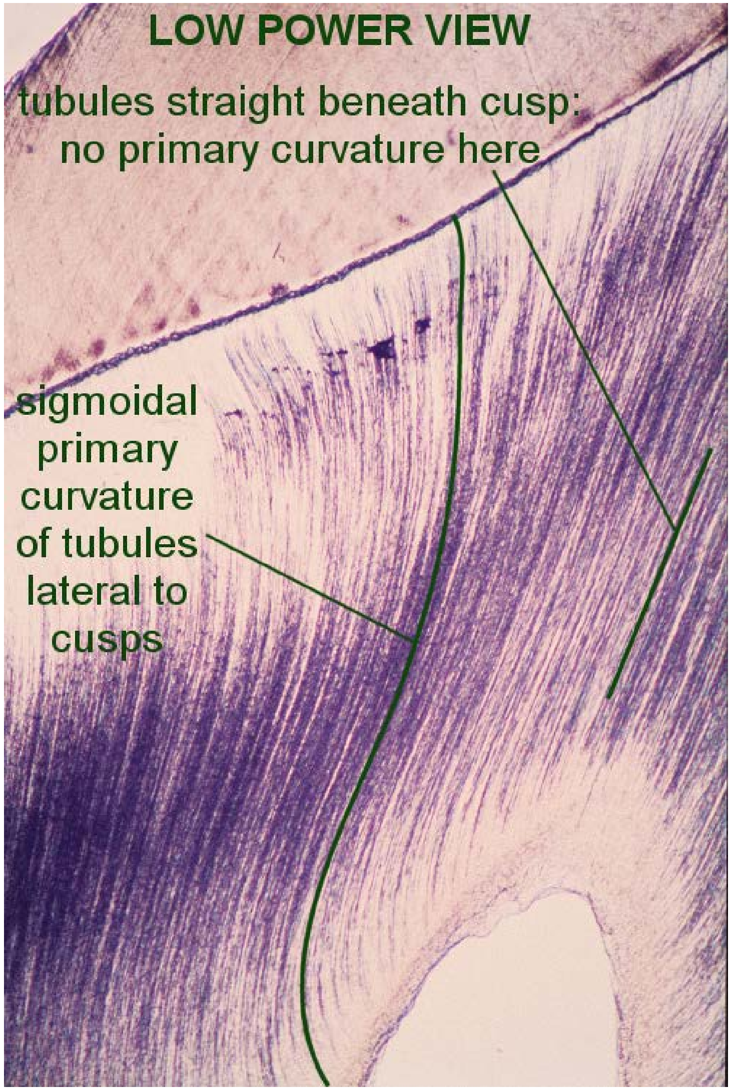
Ablation pits in dentine; white arrows show daily von Ebner lines



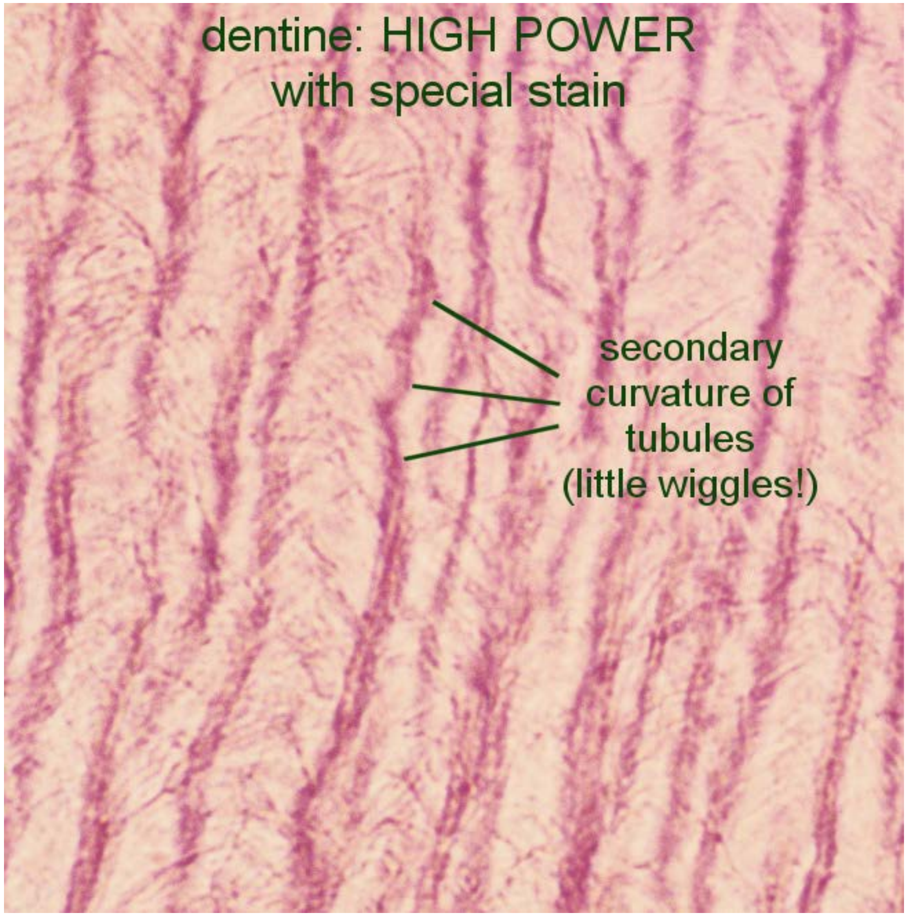


Drawing courtesy of Doug Luke

Primary (left) and secondary (right) curvature of dentinal tubules



- Primary cuvature involves whole tubules seen at low power; Secondary involves single tubules at very high power magnification



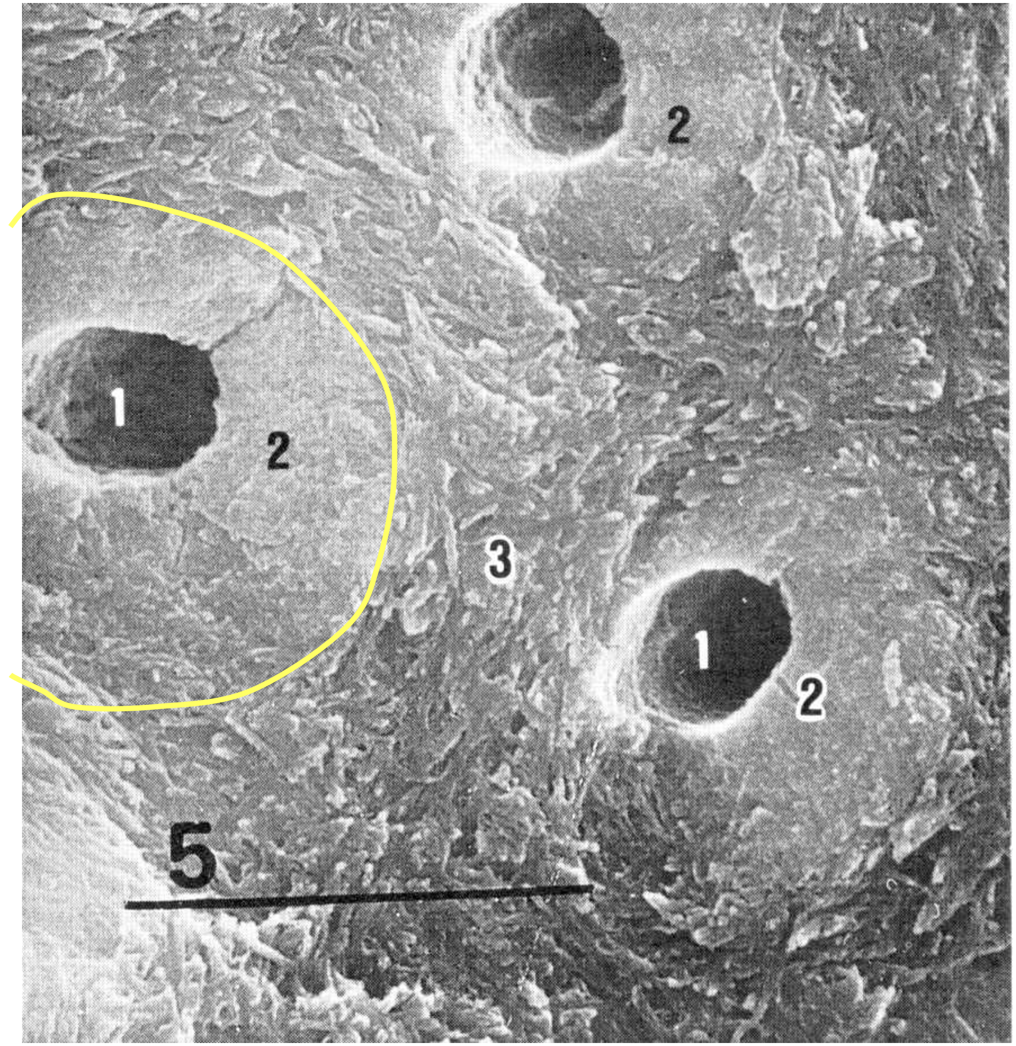
Dentine: peritubular dentine

- Forms on the walls of dentinal tubules
- About 90 % mineral
- Contains no collagen
- Forms by precipitation of mixed calcium phosphates from calcium-rich dentinal fluid
- Begins to form in older dentine (outer dentine)
- Can fill tubule
- Dentine tubules that are completely occluded with material are called sclerotic dentine.

1 = T.S. tubule

2 = peritubular dentine

3 = intertubular dentine



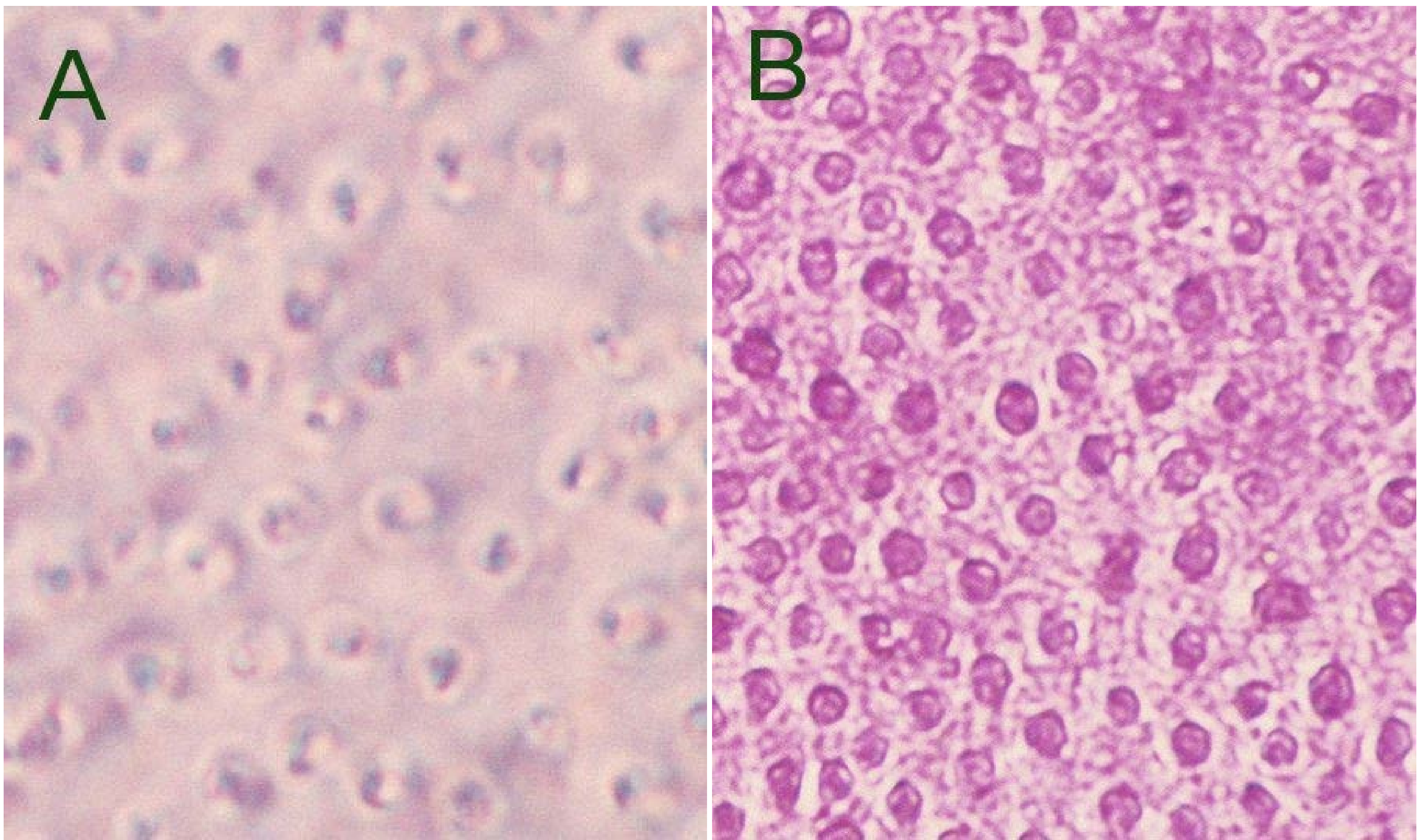
Intertubular and peritubular dentine (sections same scale)

A Appearance in transverse ground section.

Tubule space appears black, ringed with white highly-mineralised peritubular dentine, with grey intertubular dentine between.

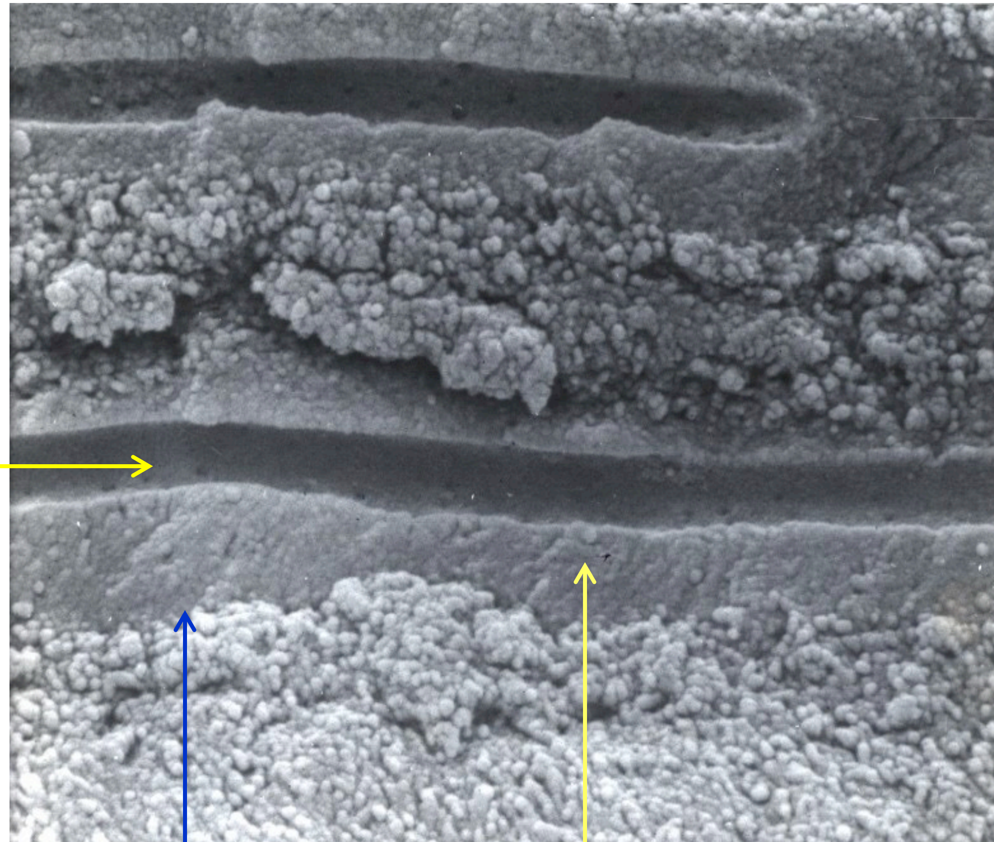
B Appearance in transverse demineralised section.

Demineralisation has completely removed the peritubular dentine leaving a peritubular space: ‘tubule’ therefore appears wider, separated only by the intertubular dentine



Peritubular dentine

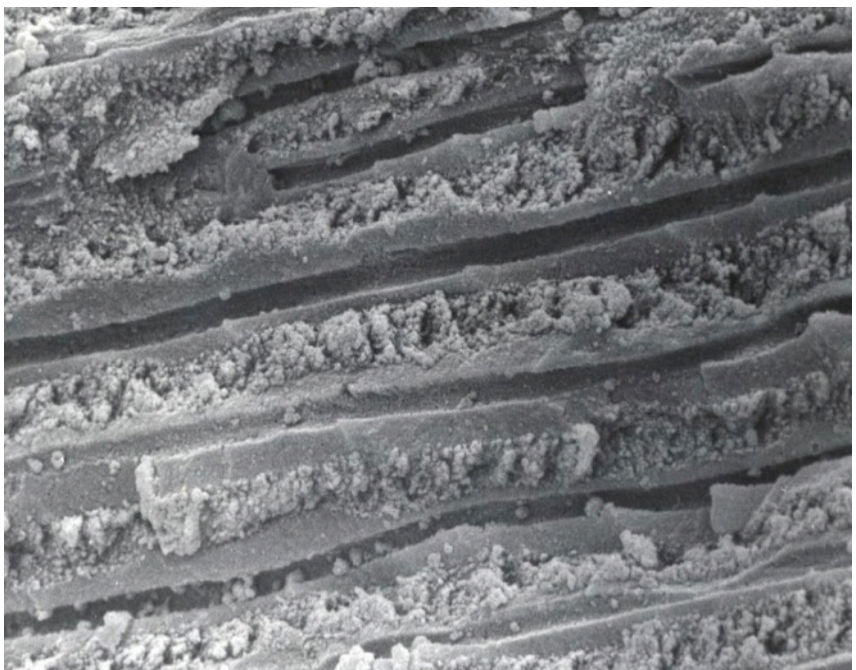
SEMs of dentine: odontoblast process and organic material have been removed



tubule

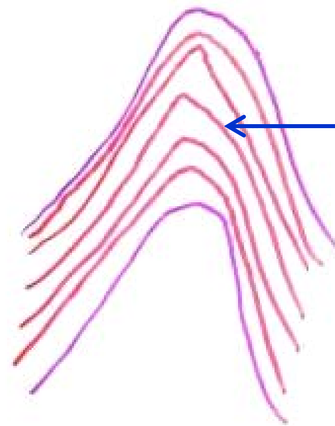
wall of original tubules

peritubular dentine (90% mineral)



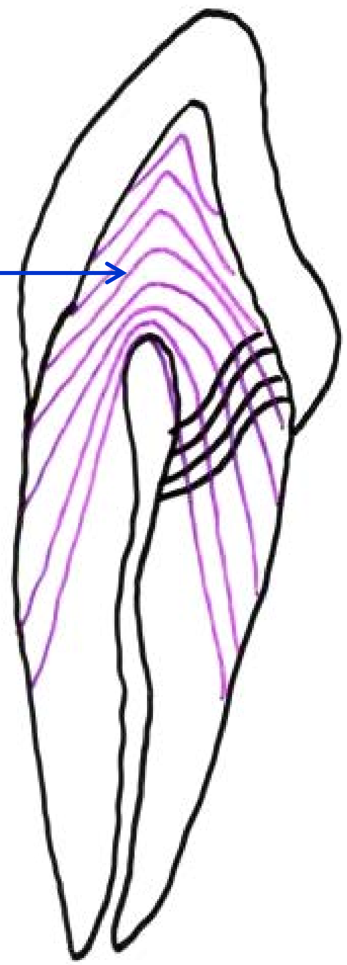
Dentine: incremental growth lines (drawing courtesy of Doug Luke)

The naming of the lines in dentine varies from book to book



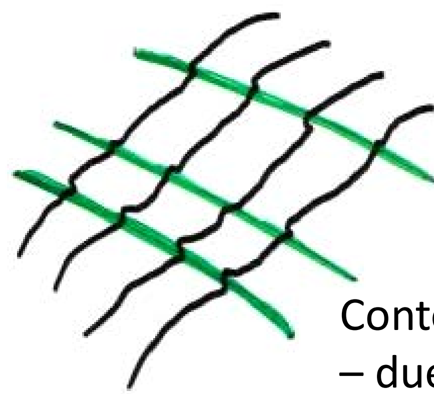
Short period or daily lines (von Ebner lines) – equivalent to cross striations in enamel

Long-period lines (Andresen lines) – equivalent to striae of Retzius in enamel



Angle at which they intersect the surface is a reflection of the rate of root extension.

Differs between molars.

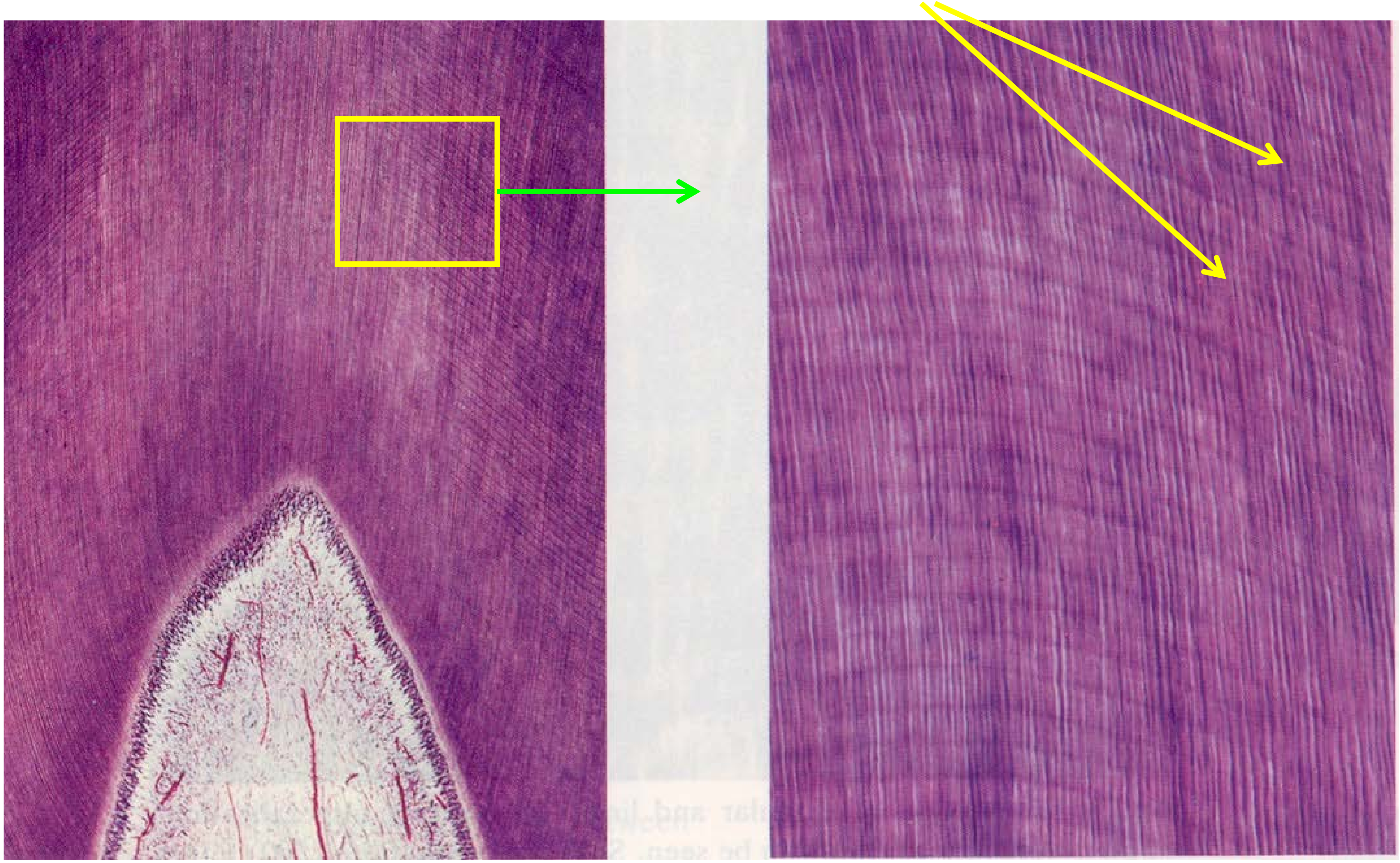


Contour lines of Owen – due to ill health, poor diet – stress lines

Incremental lines in dentine

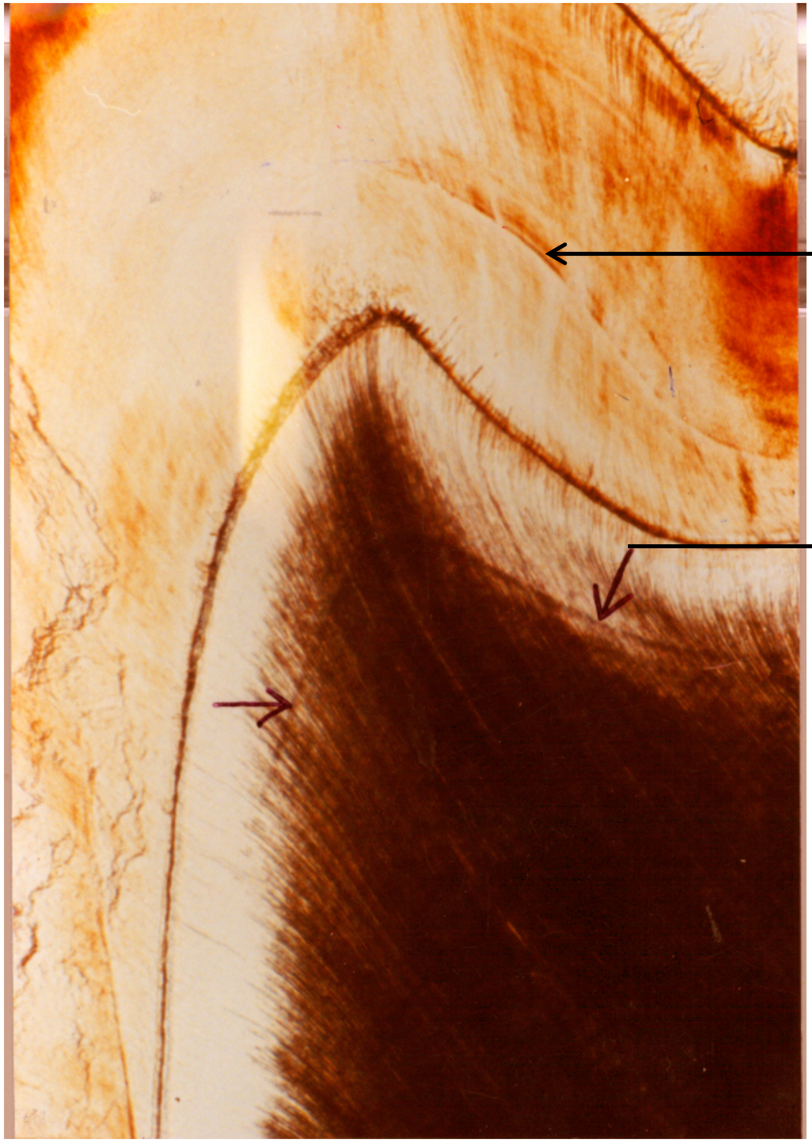
Coronal (crown) dentine is deposited at 1-2 μm per day near edj, rises to 4-5 μm per day, and then falls again approaching pulp cavity.

A growth line is left in the dentine each 24 h; this is called a von Ebner line and corresponds to the striae of Retzius in enamel. Longer period lines correspond to the striae of Retzius in enamel. These are called Andresen lines.



Dentine: neonatal line

In deciduous teeth and the first permanent molar, a neonatal line is found in dentine corresponding to the neonatal line in enamel.

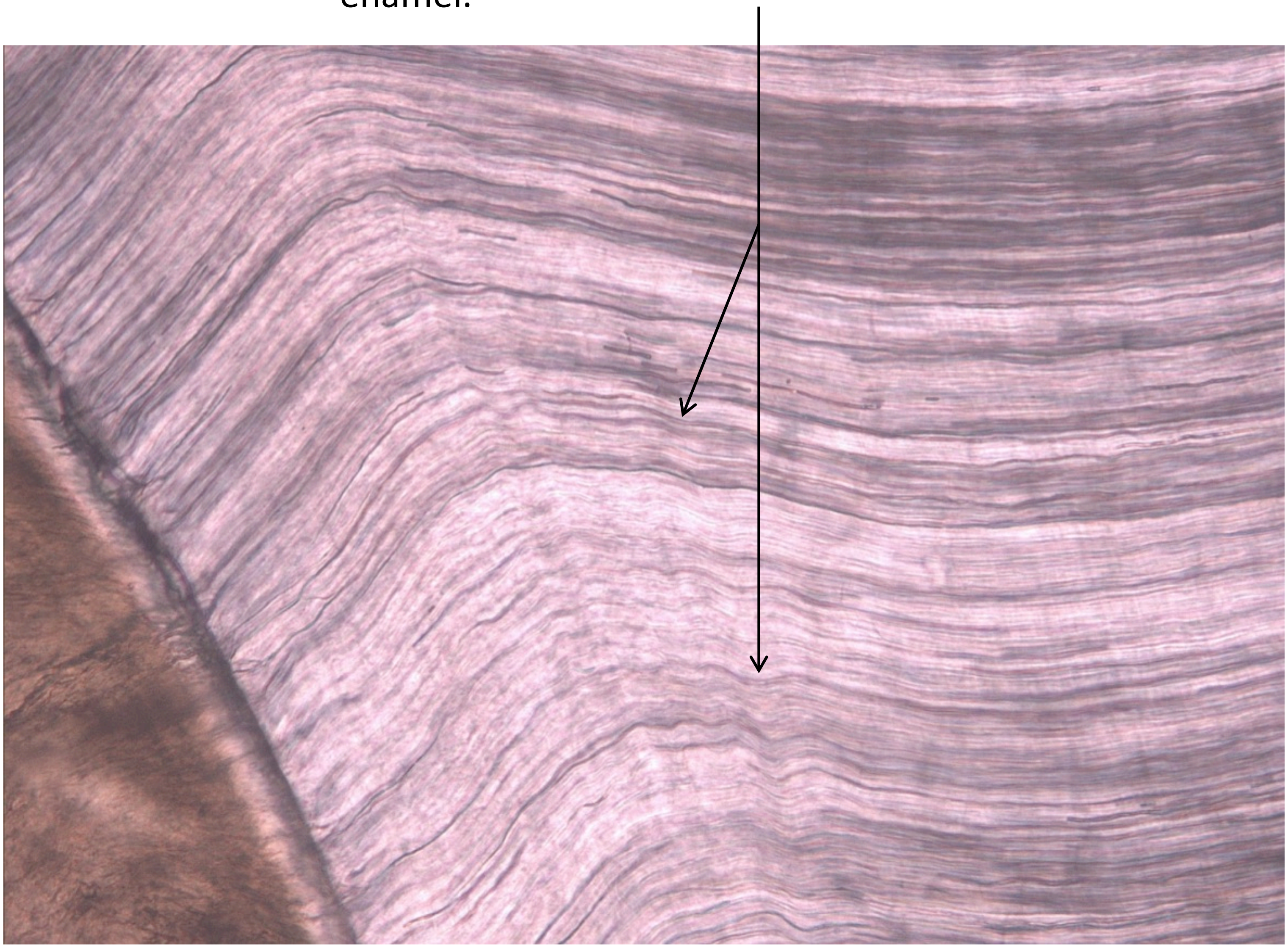


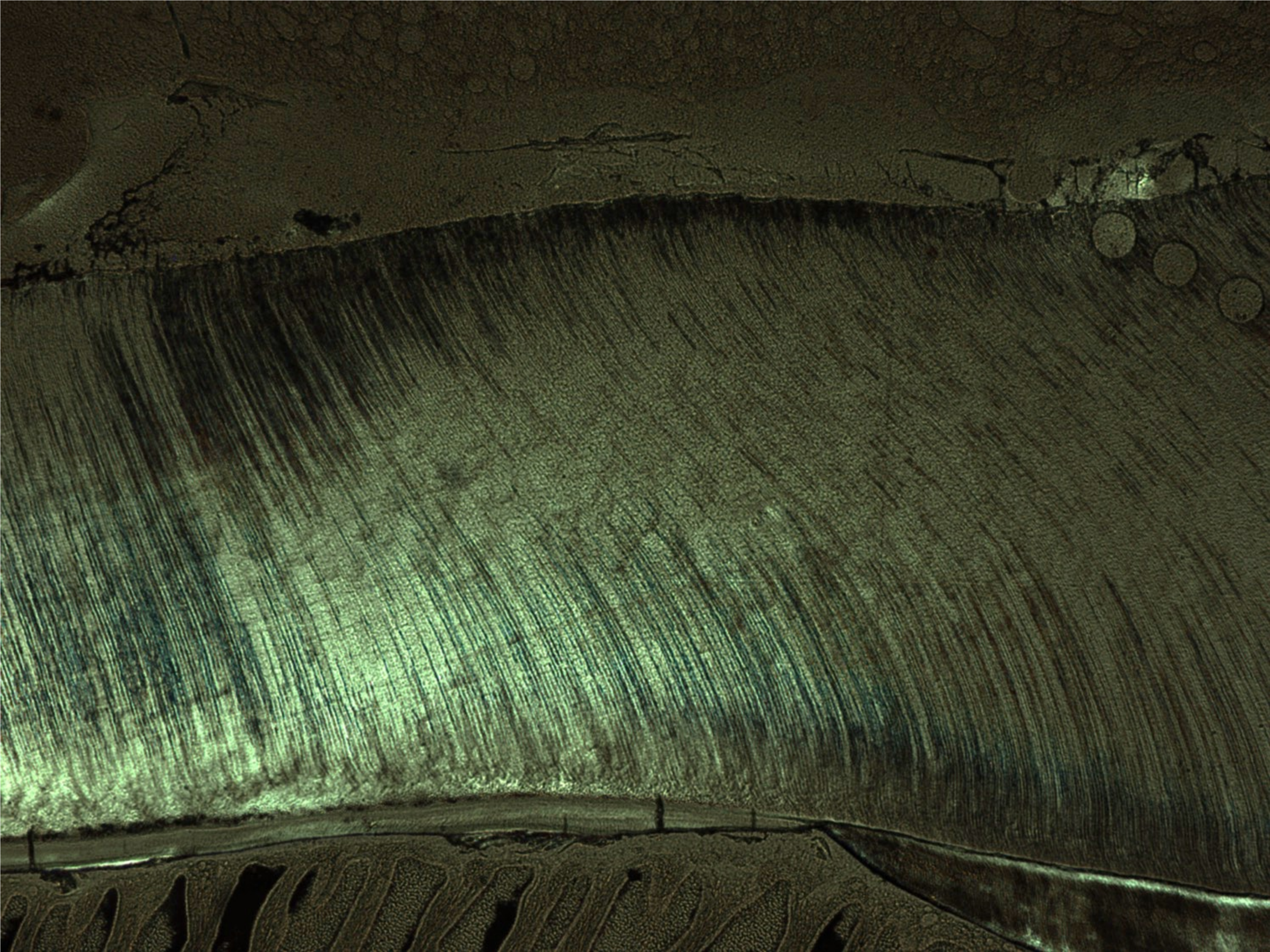
Neonatal line in enamel of deciduous molar tooth

Neonatal line in dentine

Contour lines of Owen

Bends in tubules coincide to produce Owen line; accentuated markings that reflect a disturbance in dentine formation; correspond to accentuated lines in enamel.





Secondary dentine

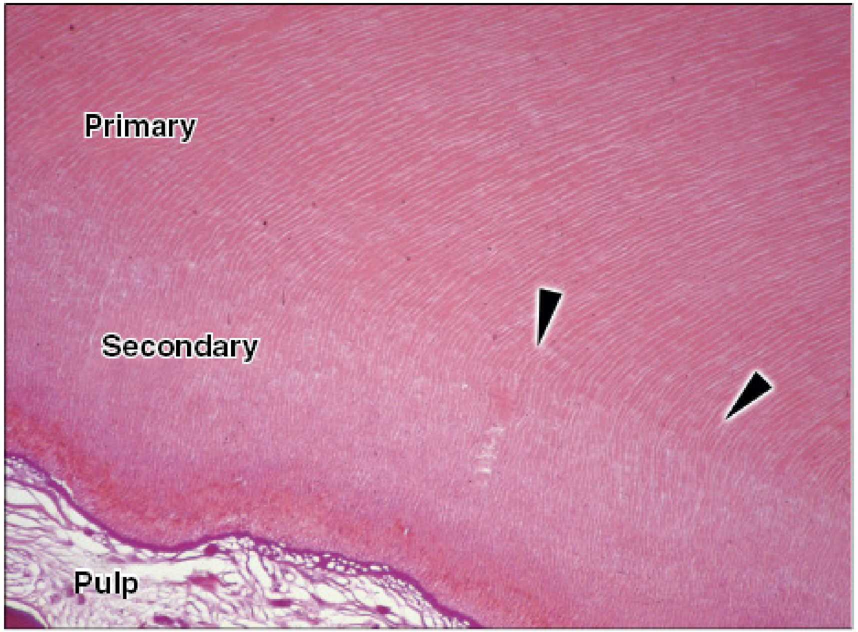
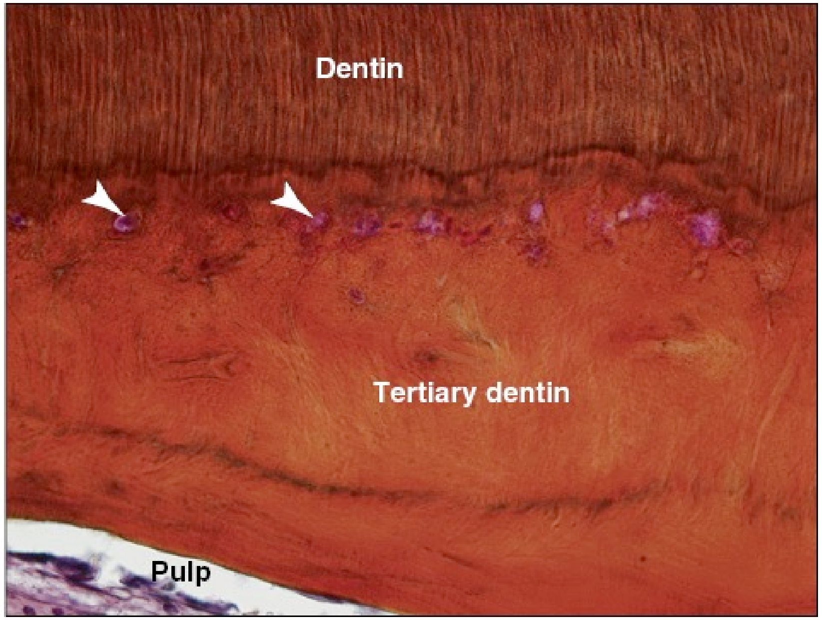


FIGURE 8-5 Section of dentin. The region where dentinal tubules change direction *(arrowheads)* delimits the junction between primary and secondary dentin.

- Normal continuation of dentine formation that occurs throughout life by the odontoblasts lining the pulp and root canals.
- Irregular: found mostly on roof and floor of pulp chamber

Tertiary Dentine

- Reactionary or Reparative
- Produced in response to stimuli
  - Reparative: new odontoblast-like cells induced from pulp stem cells; caries or restoration, rapid response, little structure
  - Reactionary: slower response from odontoblasts lining pulp, few tubules, response to attrition

A 

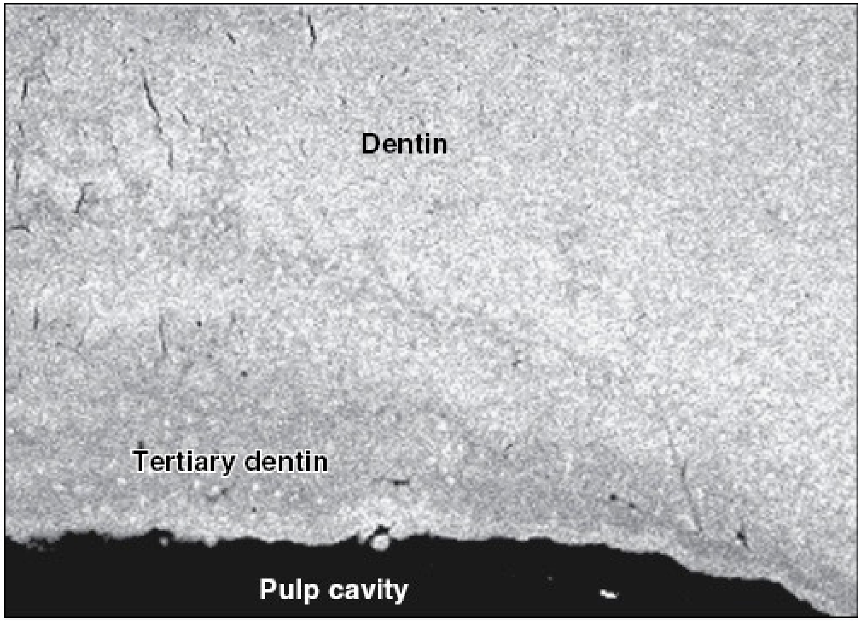
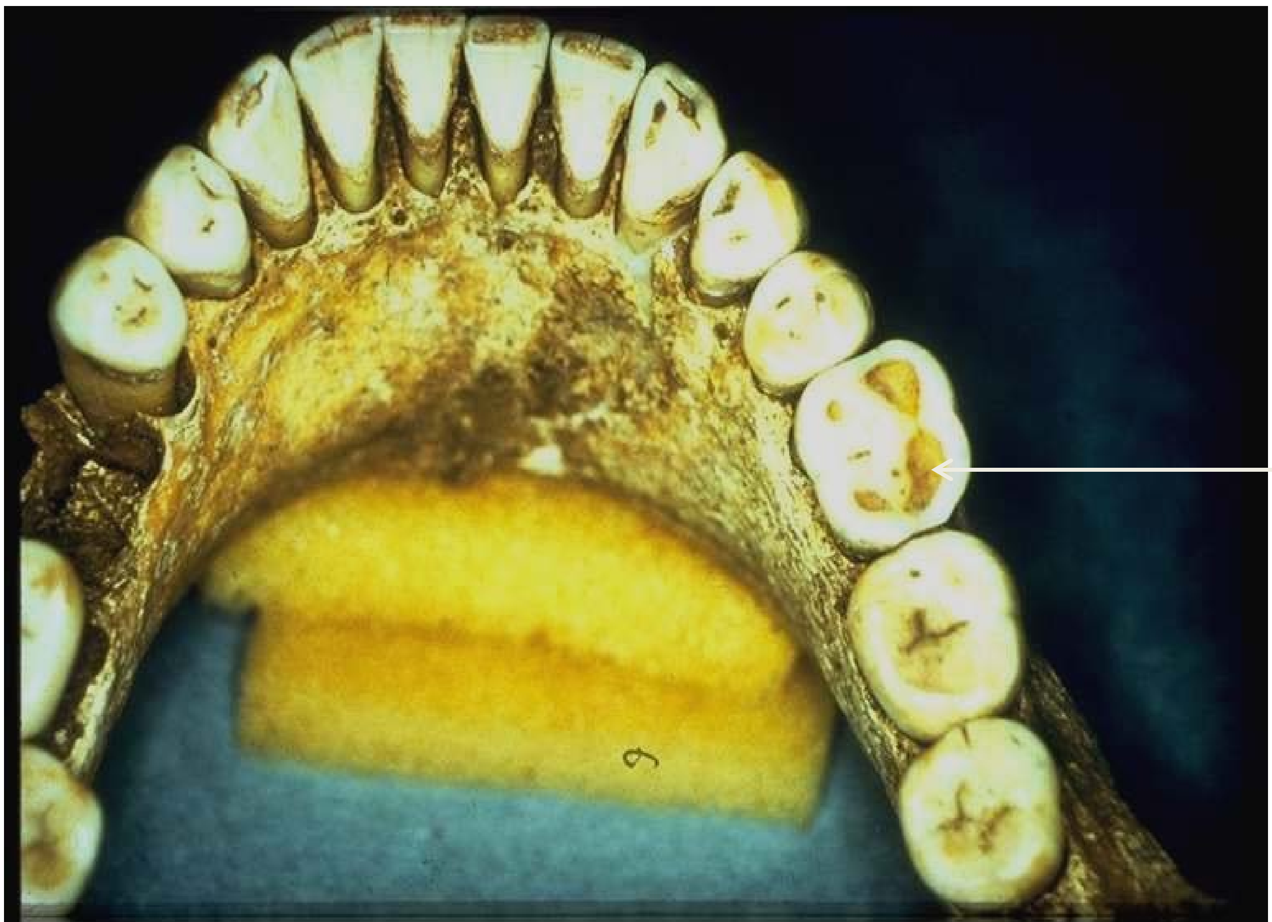
B 

FIGURE 8-8A Light **(A)** and scanning electron **(B)**

Dentine: response to wear

Slow, natural wear of the crown stimulates peritubular dentine to form so the dentine is hard, impermeable and insensitive when it is exposed. This is an important adaptation because it allows teeth to be useful even if enamel is worn away.

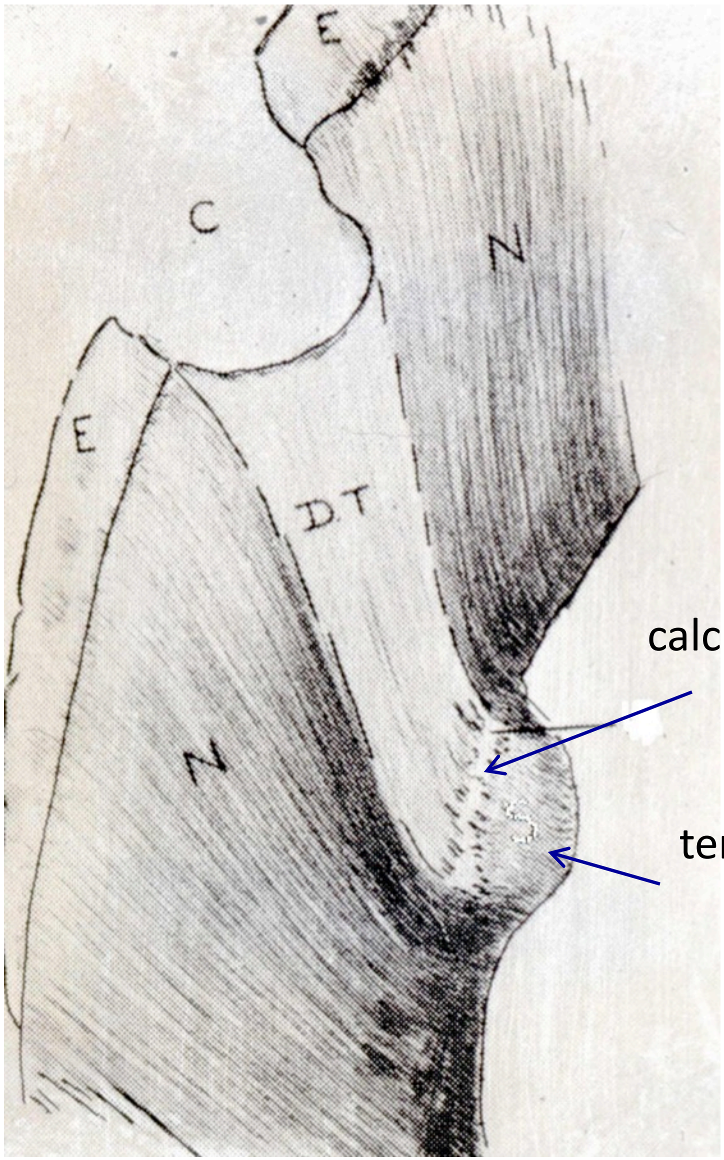
Dentine that forms in response to attrition is reactionary tertiary dentine.

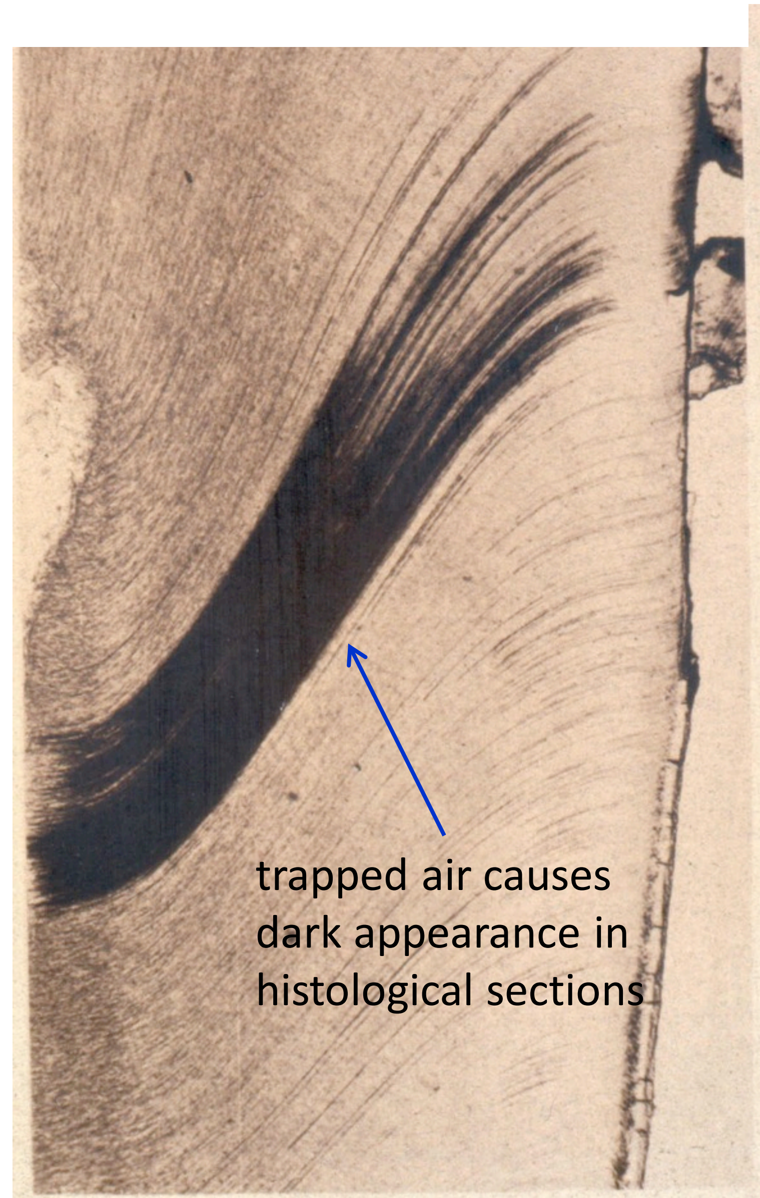


Attrition has worn through the enamel of cusps (photo courtesy of Doug Luke)

Dead tracts occur when dentine is sealed off from pulp by a calcified barrier. Dentine that is formed in response to caries is called reparative tertiary dentine.

(Pictures courtesy of Doug Luke)



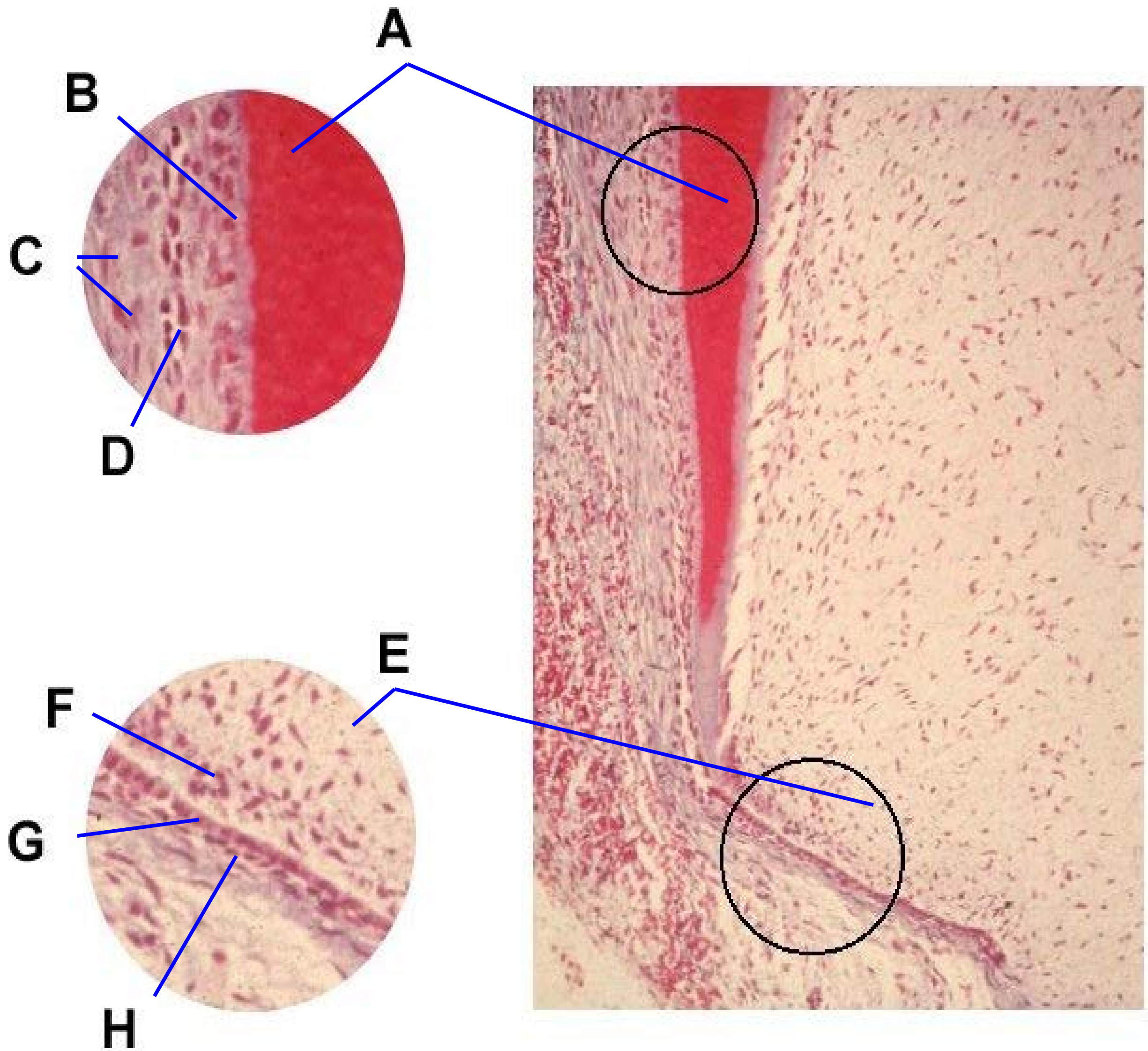


Reactionary Tertiary Dentine

Two primary incisors; left, little wear, ‘sharp’ pulp horn, little resorption – right, worn, significant root resorption, and pulp horn filled in by reactionary dentine in response to attrition

Histology of the tooth root

Decalcified unerupted first permanent molar from a 5-year-old child



Hertwig's epithelial root sheath (HERS)

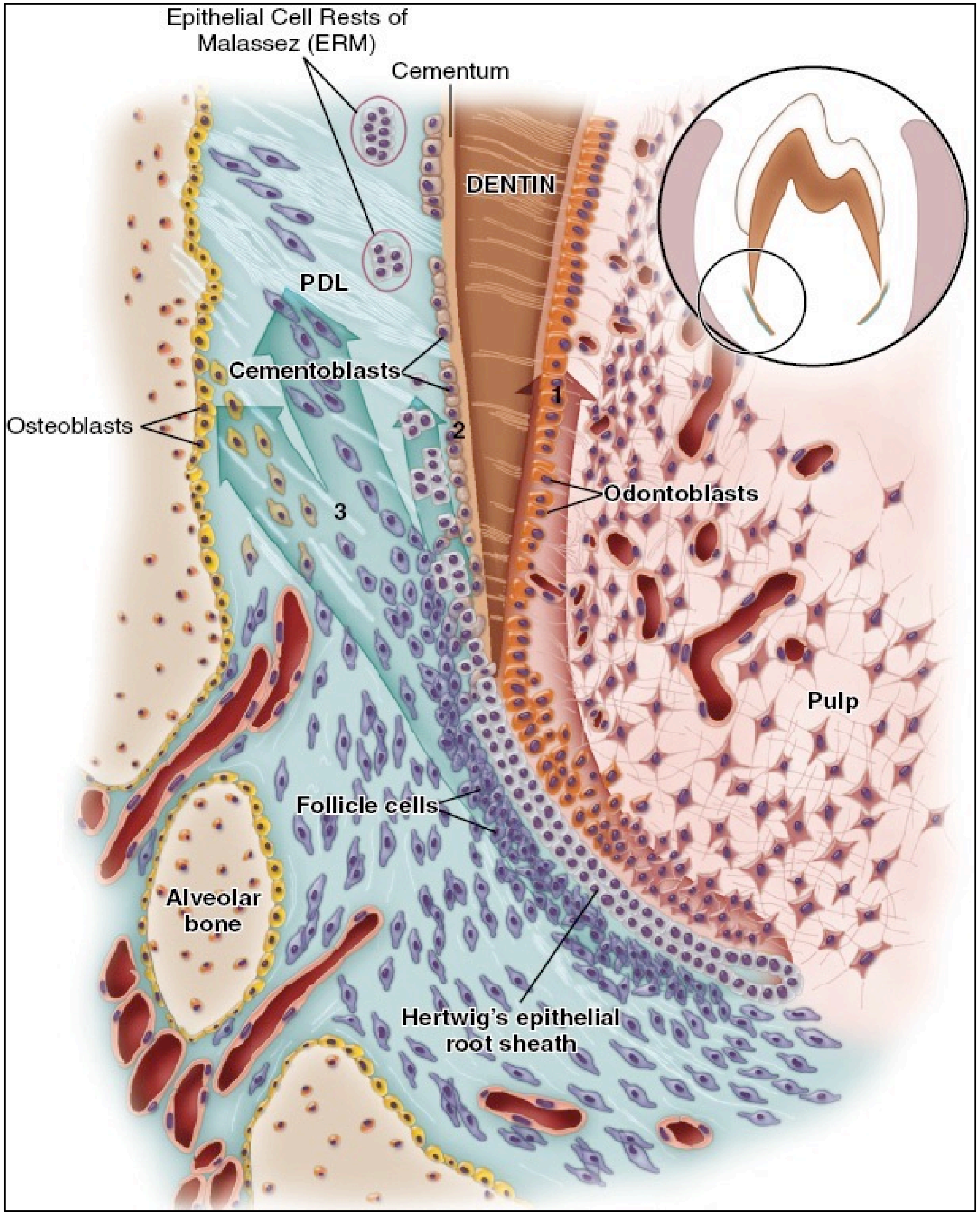


Fig. 9-1: Ten Cate's Oral Histology

Cementoblasts are formed by descendants of undifferentiated mesenchymal cells
in the dental follicle. However, HERS cells can undergo epithelial-mesenchymal transition and partially contribute to cementoblast formation.

Two transverse ground sections of a human tooth root (cervical and periapical region)

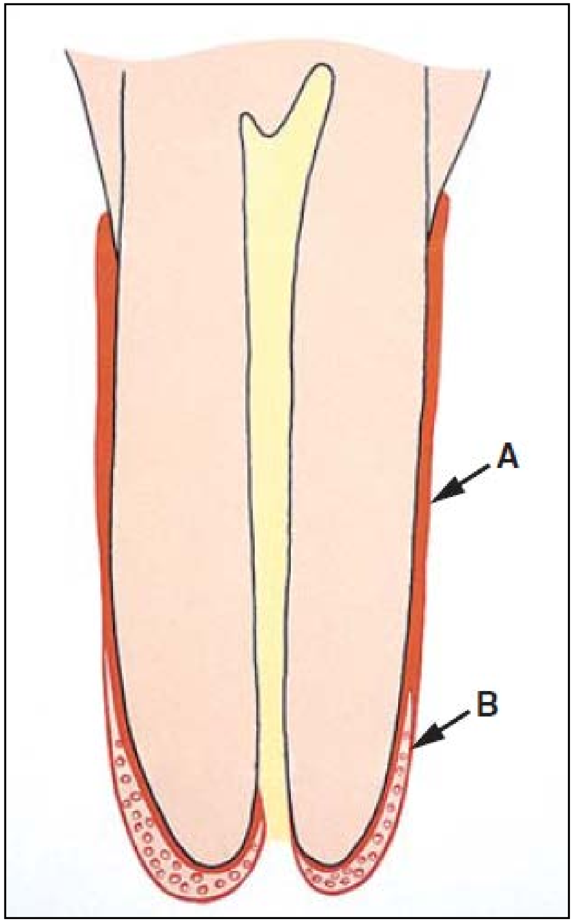


Fig. 11.6: Berkovitz

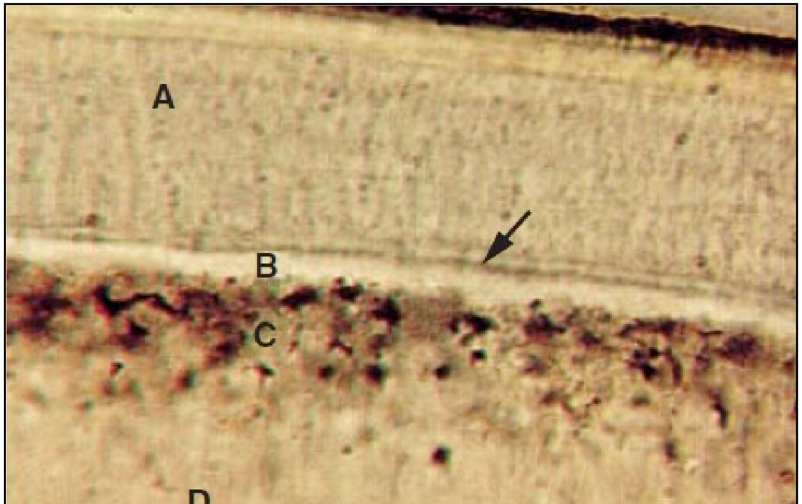


Fig. 11.7: Berkovitz

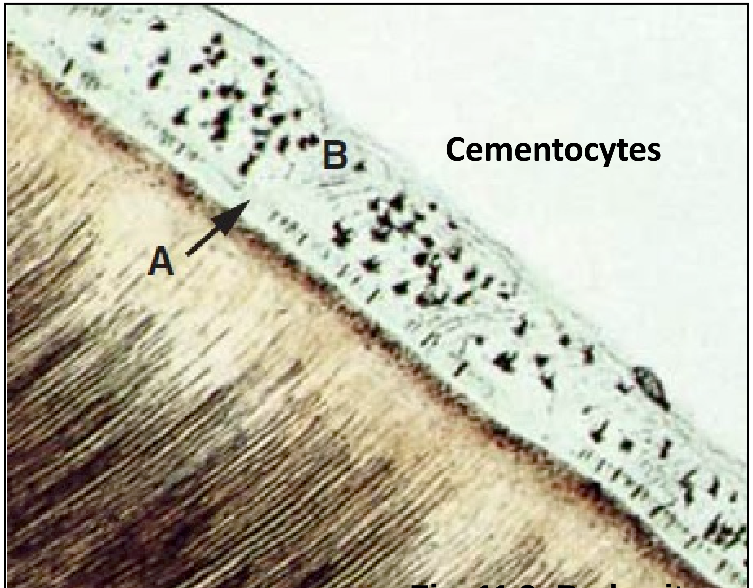


Fig. 11.8: Berkovitz

Incremental growth lines in cementum

Fig. 11.13: Berkovitz

Different types of cementum overlap

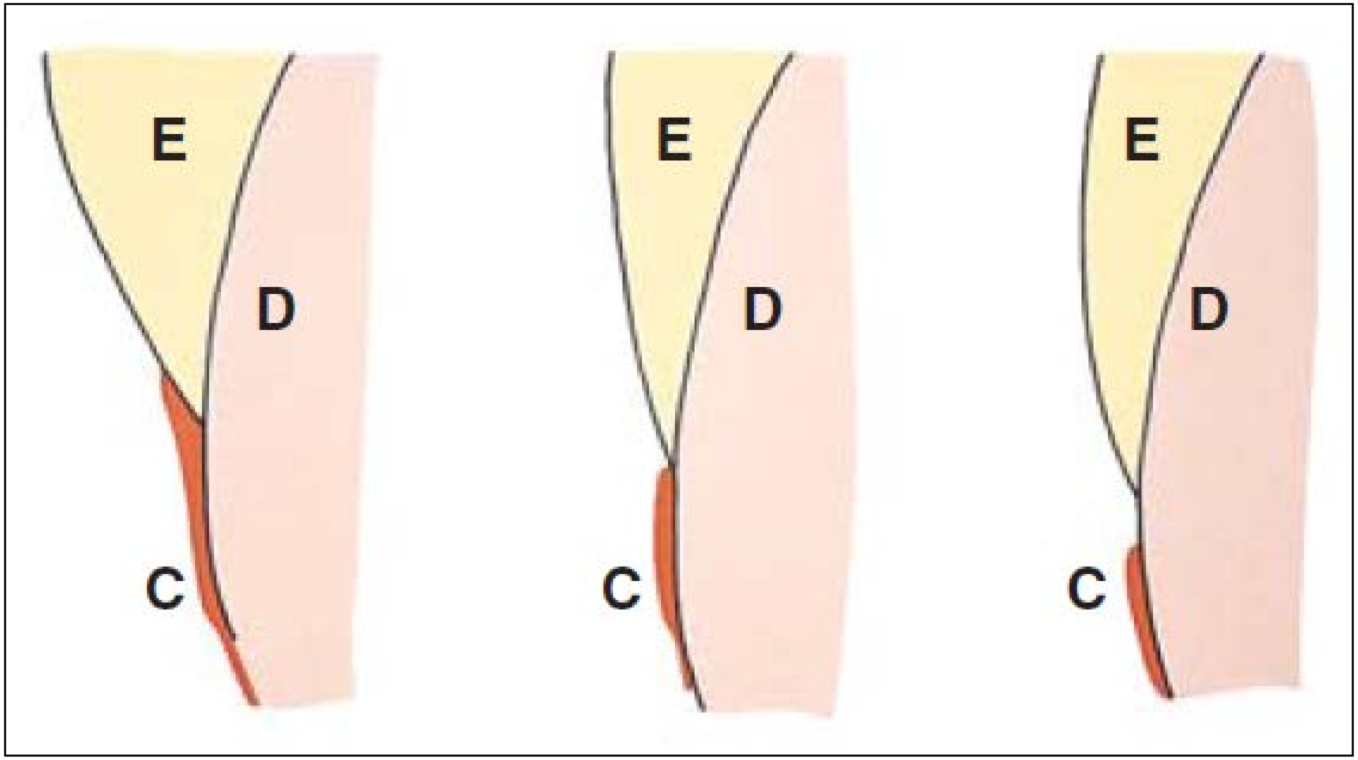
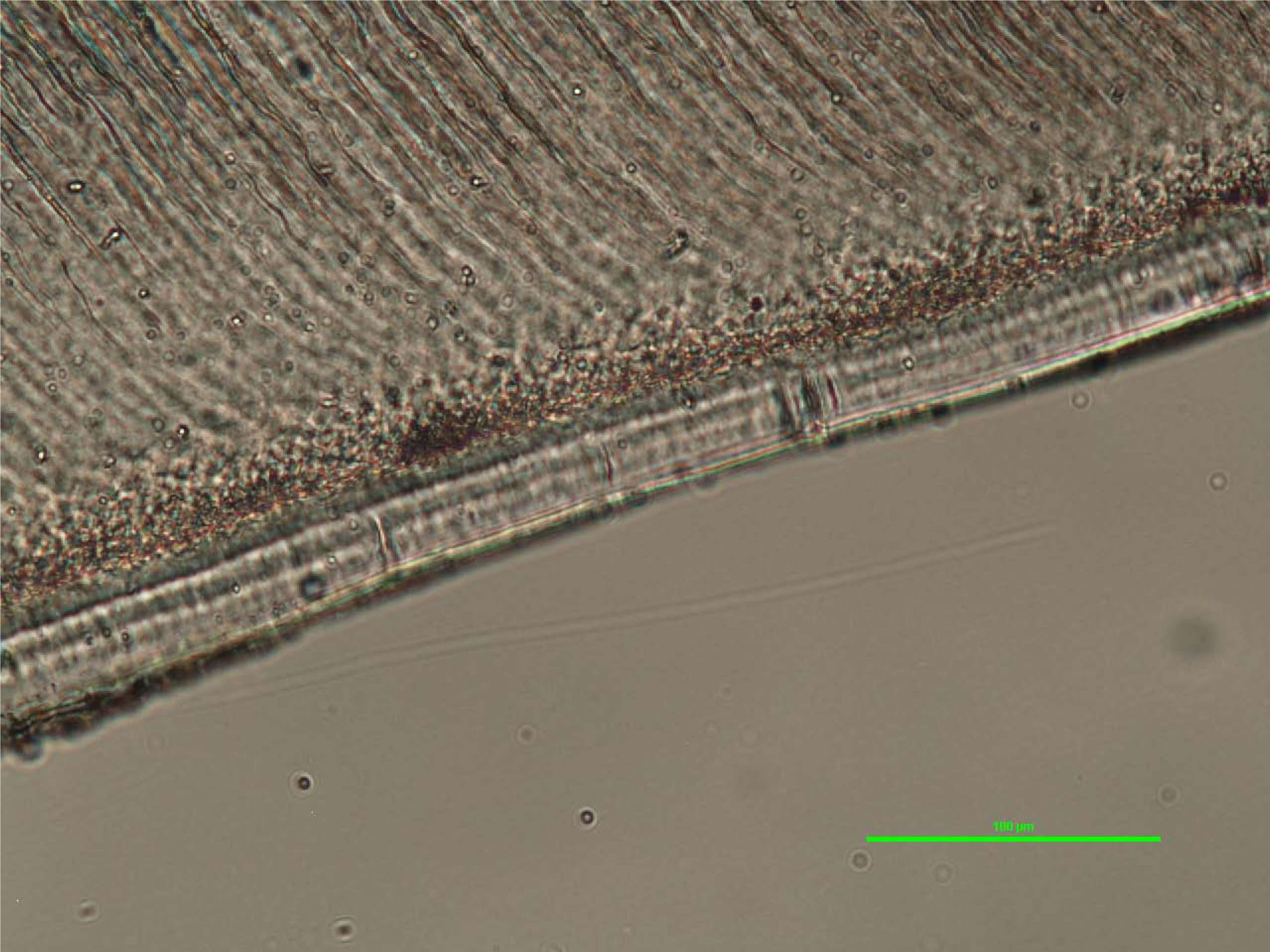


Fig. 11.3: Berkovitz


100 µm