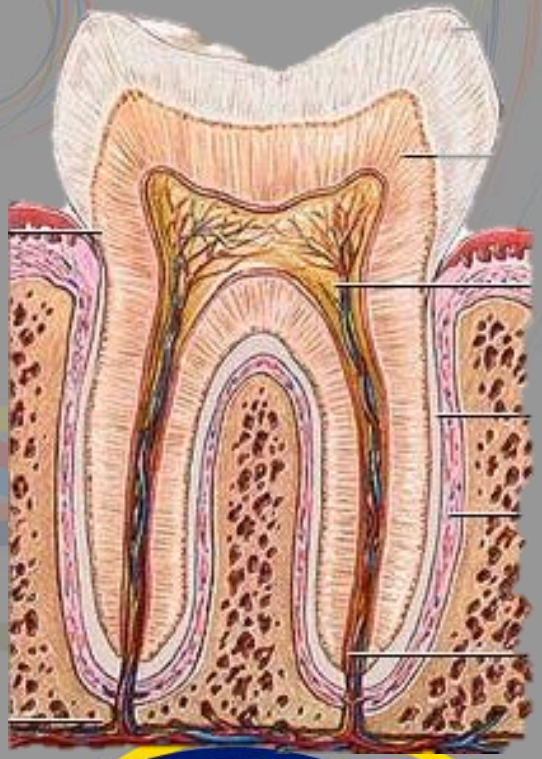


ENAMEL

Dr.Ashtuosh Agrawal

CONTENTS

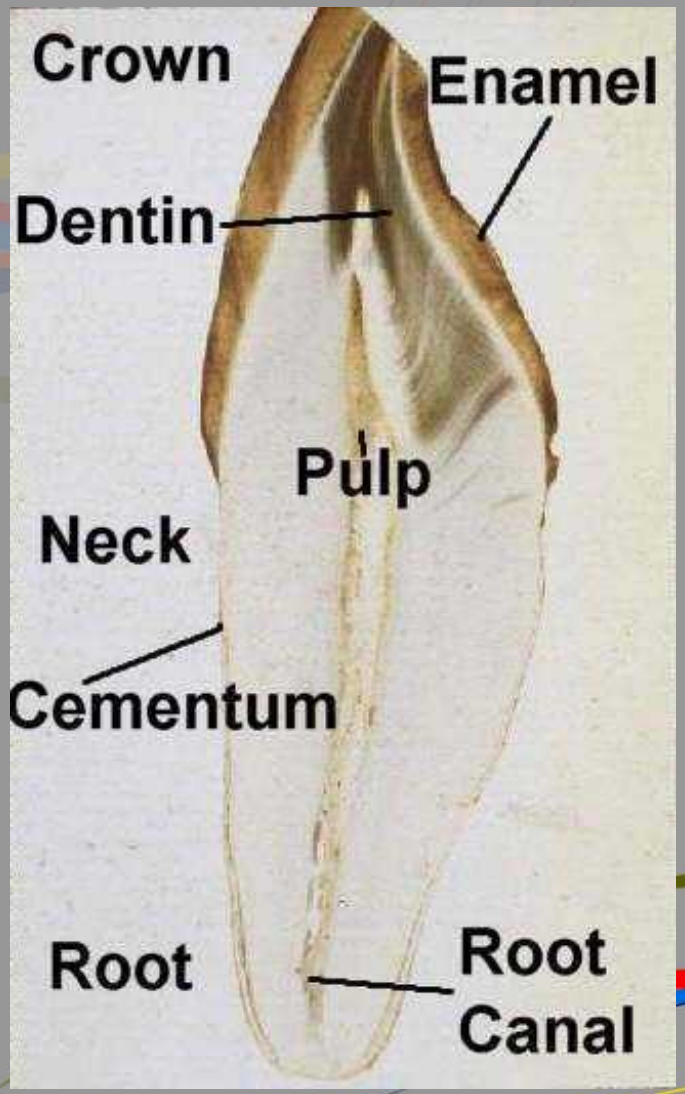
- Introduction
- How to Study Enamel
- Physical Characteristics
- Chemical Properties
- Structures
- Age Changes
- Clinical Considerations

INTRODUCTION

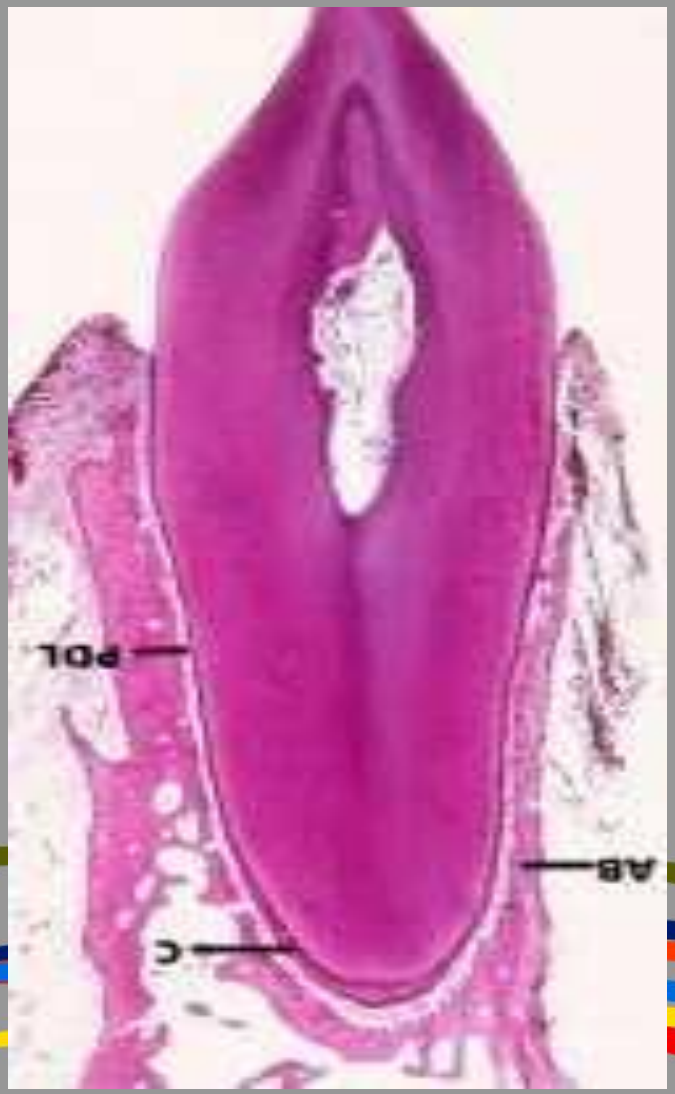
- Enamel forms a protective covering of variable thickness over the entire surface of the crown.
- Enamel is ectodermal in origins.
- It is derived from inner enamel epithelium of enamel organ.
- Mature enamel is completely non cellular.
- The cells that are responsible for formation of enamel, the ameloblasts, are lost as the tooth erupts into the oral cavity, and hence enamel cannot renew itself.

How to Study Enamel ???

Ground section



Decalcified section



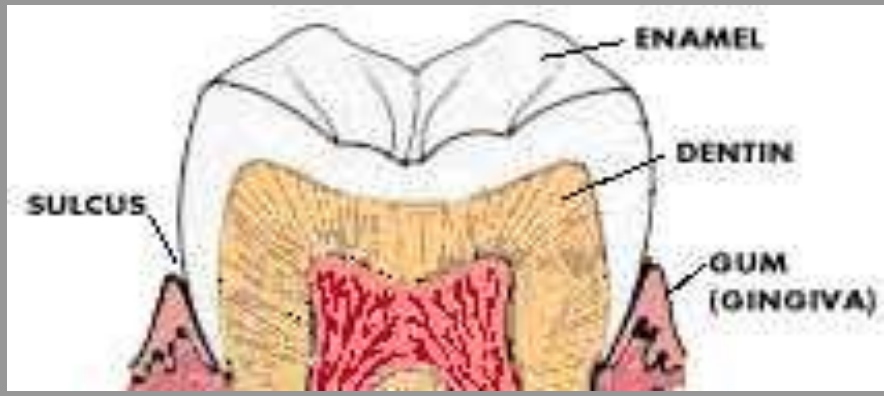
Physical characteristics

1. Thickness
2. Color
3. Hardness
4. Permeability
5. Tensile strength
6. Solubility

so ha col pe te thi

1. THICKNESS

- Thickest over cusps and incisal edges and thinnest at the cervical margin.
- Over the cusps of unworn permanent teeth it is about 2.5 mm thick (over the cusps of deciduous teeth 1.3 mm),
- Lateral surfaces up to 1.3 mm.



- The thickness declines gradually to become a very thin layer at the cervical margin.

2. COLOR

- Enamel is a birefringent crystalline material, the crystals refracting light differently in different directions.
- Young enamel is white and has low translucency.

- The translucency ∝ age → color of the underlying dentine is then transmitted → more yellow appearance.
- The tissue has an average refractive index of 1.62.

3. HARDNESS

- Enamel is the hardest calcified tissue in the body because of its high content of minerals and crystalline structure.
- Enamel can withstand load of mastication and resist wear process.
- Hardness → brittle
- Specific gravity- 2.8/2.9

4. PERMEABILITY

- Enamel is selectively permeable, permitting partial or complete passage of ions due to the presence of microscopic pores.
- Surface enamel is harder, denser and less porous than subsurface enamel.

5. TENSILE STRENGTH

- Although it is hard, enamel is extremely brittle and depends on the strength of the underlying dentin.

Characteristic	Enamel	Dentin
Specific Gravity	2.9	2.14
Hardnes (Knoop no.)	296	64
Stiffness	133 GN/m^2	12 GN/m^2
Compressive Strength	76 MN/m^2	262 MN/m^2
Tensile Strength	46 MN/m^2	33 MN/m^2

6. SOLUBILITY

- **Enamel dissolves in acid media. Its surface is less soluble than deep enamel.**

Chemical Properties

Mature enamel consists of:

- ***Mainly(96%)***

inorganic substance

- ***Small (3%)***

organic substance

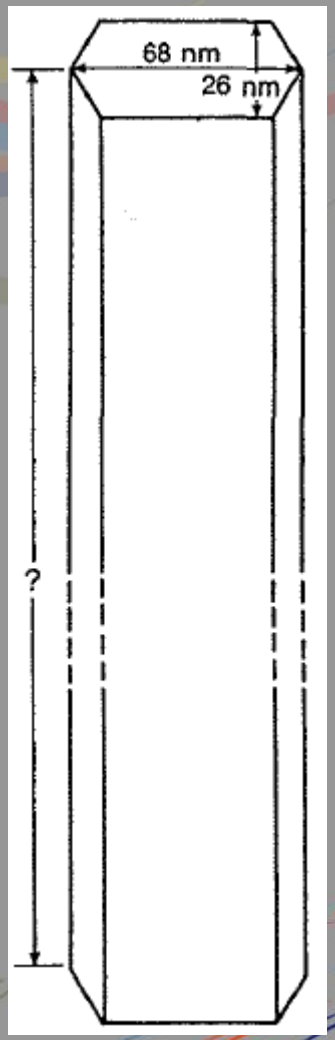
- **1%**

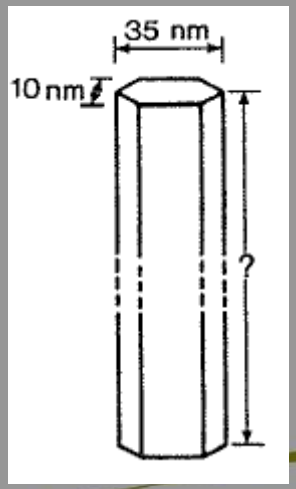
water

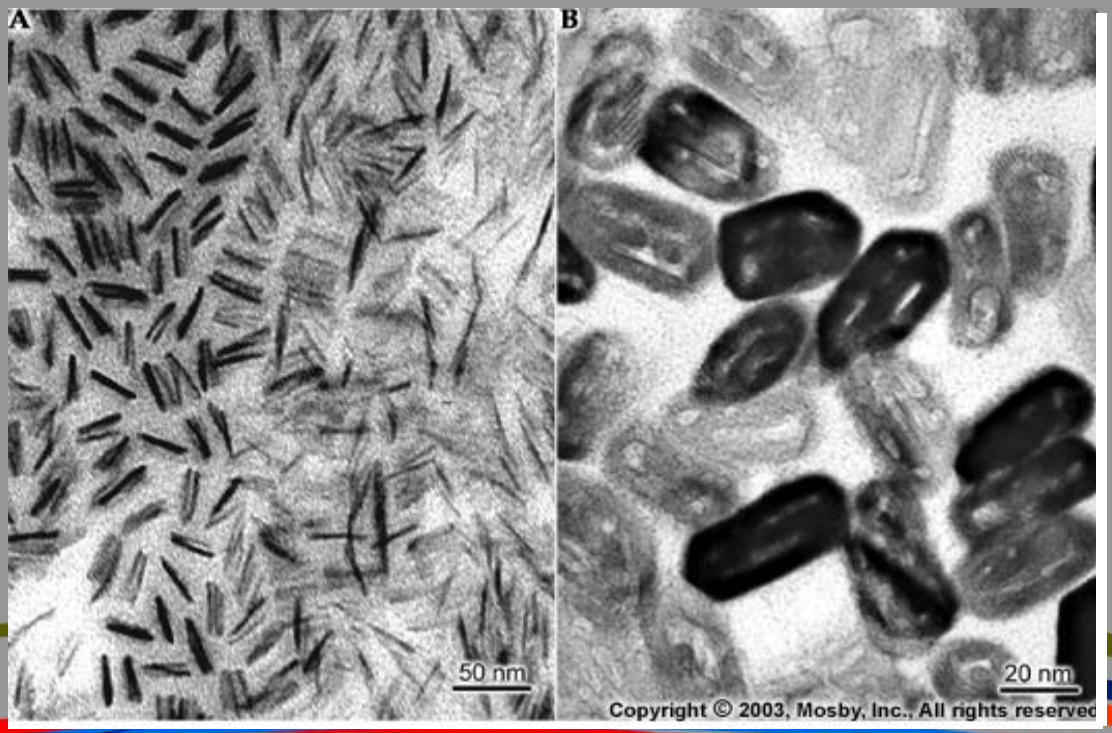
INORGANIC COMPONENT

- **HYDROXYAPATITE CRYSTALS-** calcium hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$
- 88-90% by volume
- 95-96% by weight
- Hydroxyapatite is present in the form of crystallites about 70 nm in width, 25 nm thick and of great length and generally extend across the full width of the tissue.

- Mineral content increases from the dentine-enamel junction to the surface.







- Although the basic molecular arrangement of the crystal is highly organized, it is subjected to variation.
- 'Normal' ions may be replaced by different ionic species.
- Phosphate or hydroxyl → Carbonate
- Calcium ion → Magnesium
- Hydroxyl ions → Fluoride (conferring greater stability and resistance to acidic dissolution)

- calcium—37%,
- sodium—0.5 %,
- magnesium—0.5 %,
- phosphate—55.5%,
- carbonate—3.5 % and
- traces of other components.

- Water is present in enamel in the following two physical states:
- 1. Loosely bound form or free water
- 2. Strongly bound form, as a part of the apatite crystals
- Water determines certain physicochemical properties of the enamel such as permeability, ion ex-change and elasticity.

ORGANIC COMPONENT

- **Mainly non collagenous proteins:**
  - **A- amelogenins** (90%)
  - **B- non-amelogenins** (10%).

- The non-amelogenins (enamel proteins)
- Enamelin
- Ameloblastin
- Sulphated protein
- Tuftelin

- Non-amelogenins promote and guide the function of inorganic enamel crystals.
- Amelogenins regulate the growth of the crystals.

WATER

- **enamelysin and kallikrein- 4**
- The organic matrix of the enamel, made up of enamel proteins, has to be degraded to make way for the inorganic minerals.

MICROSCOPIC STRUCTURE

1. Rods (prism).
2. Rod sheath.
3. Inter rodal cement substance

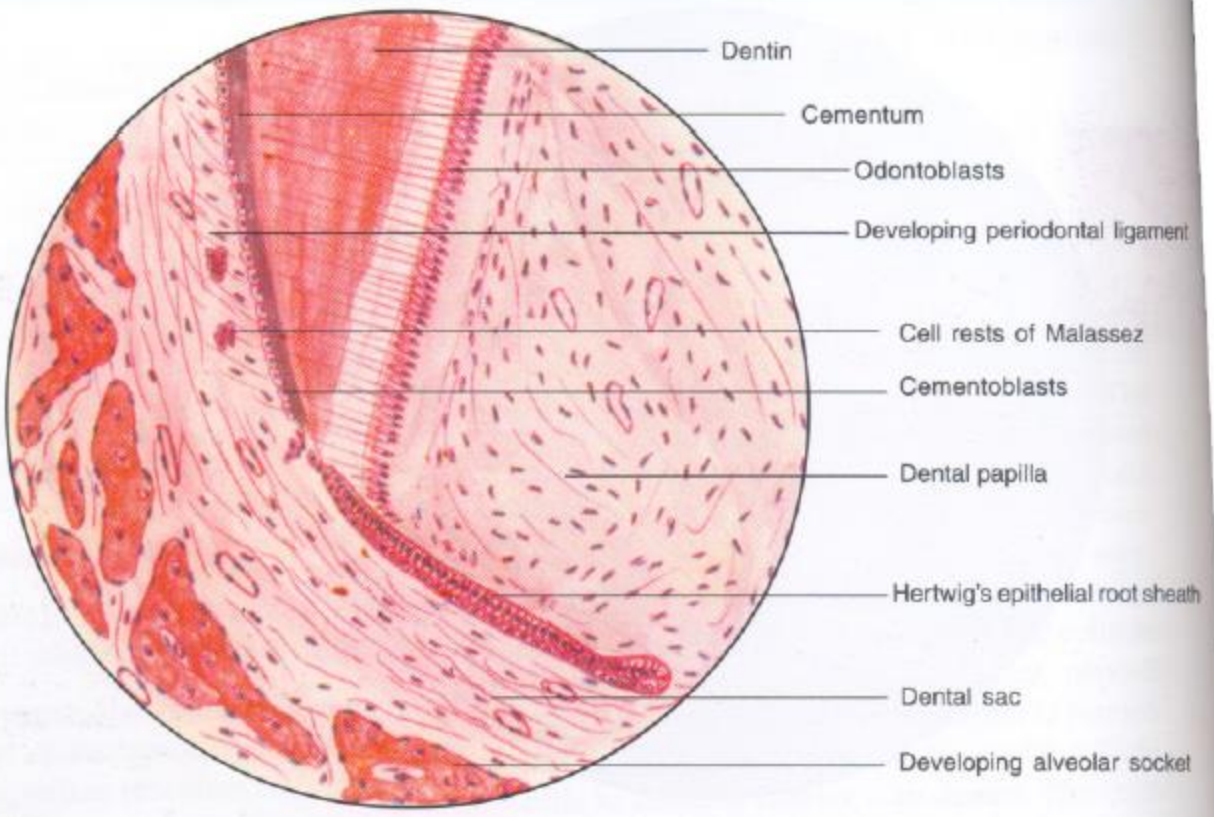
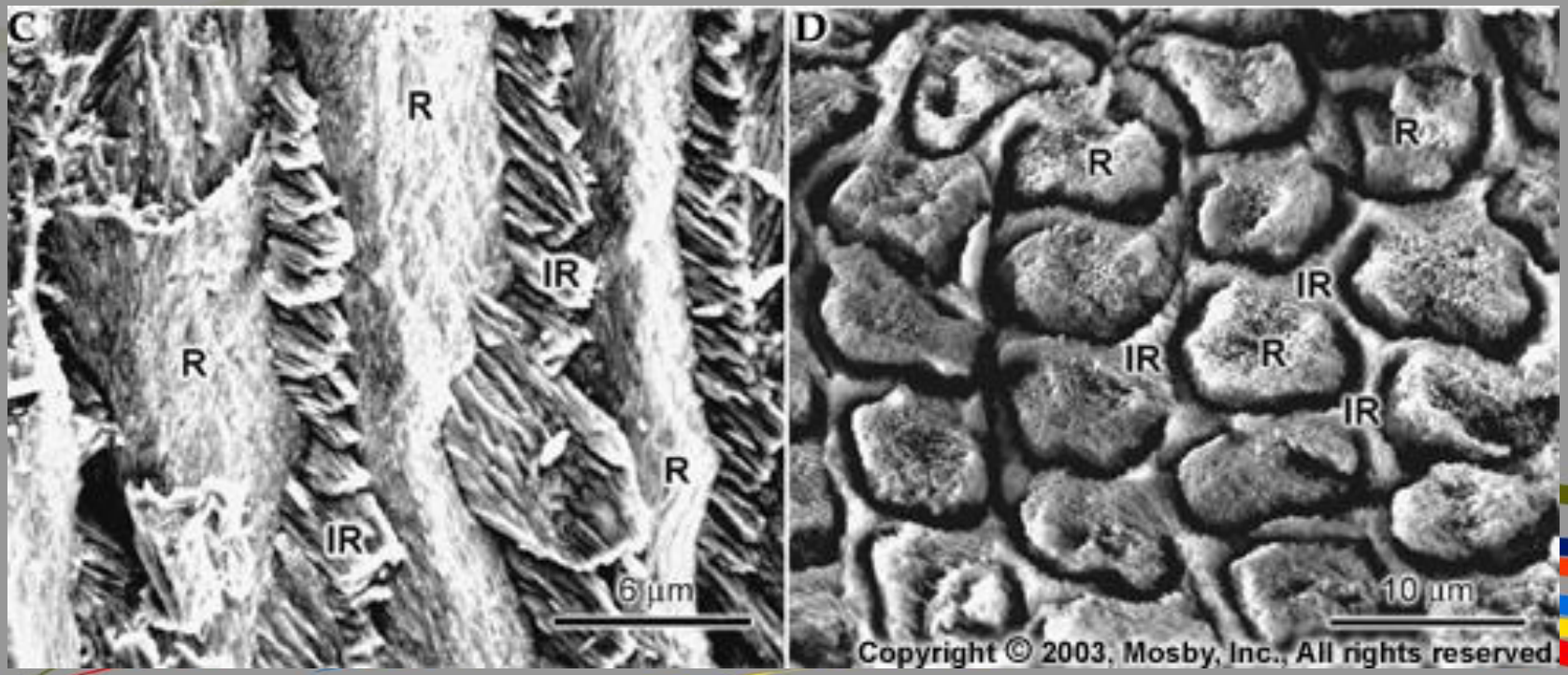
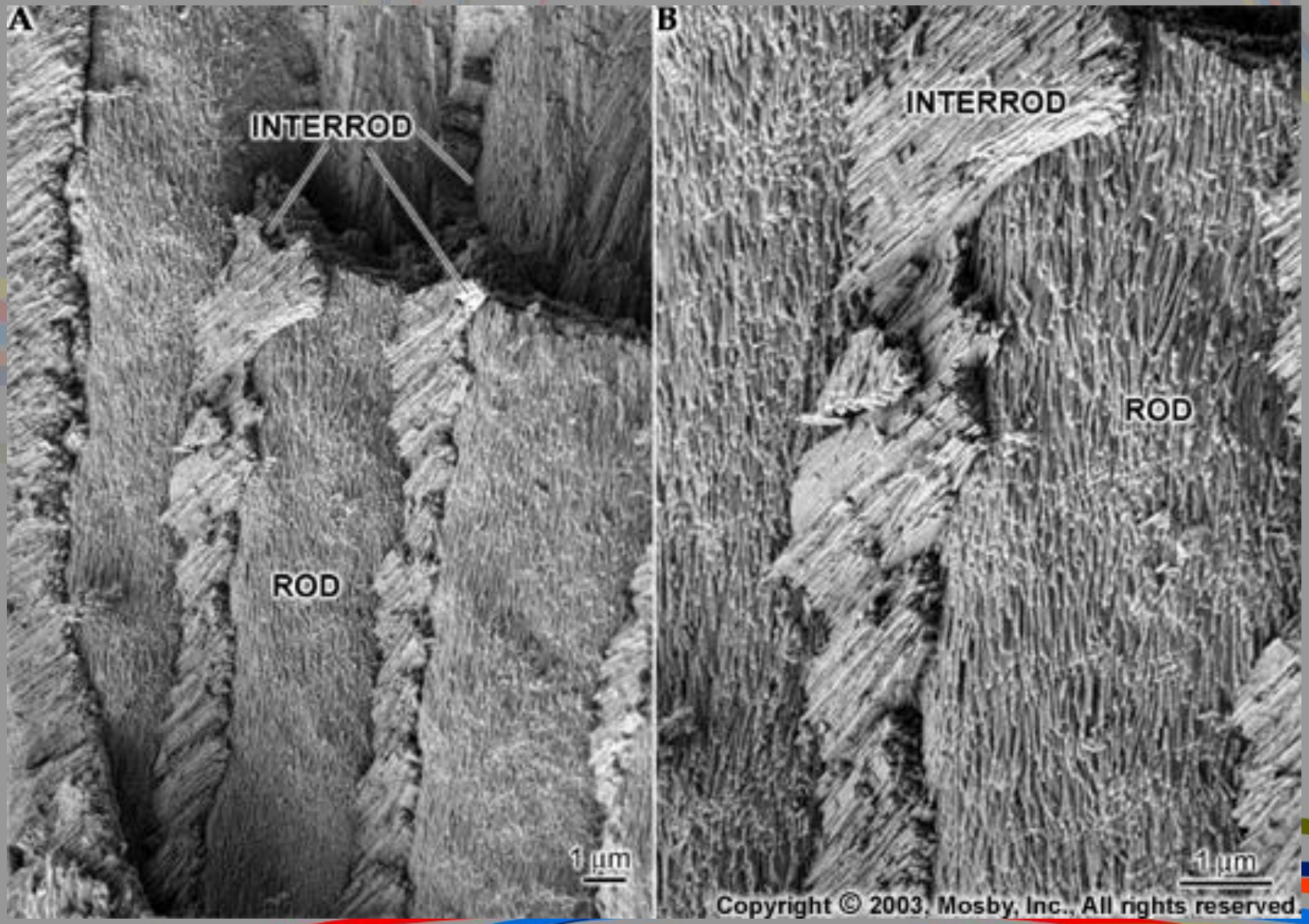


Fig. 3.5 Development of root

- The basic structural unit of the enamel is the enamel rod. The rods are surrounded by an interrod substance. The boundaries of the rod and interrod substance are surrounded by the rod sheath.



- The fundamental organizational units of mammalian enamel are the *rods* (prisms) and interrod *enamel* (interprismatic substance).
- Enamel is built from closely packed long, ribbon-like crystals.
- The crystals are extremely long; some investigators believe that the length of the crystals actually spans the entire thickness of the enamel layer.


A
INTERROD
ROD
1 µm
B
INTERROD
ROD
1 µm
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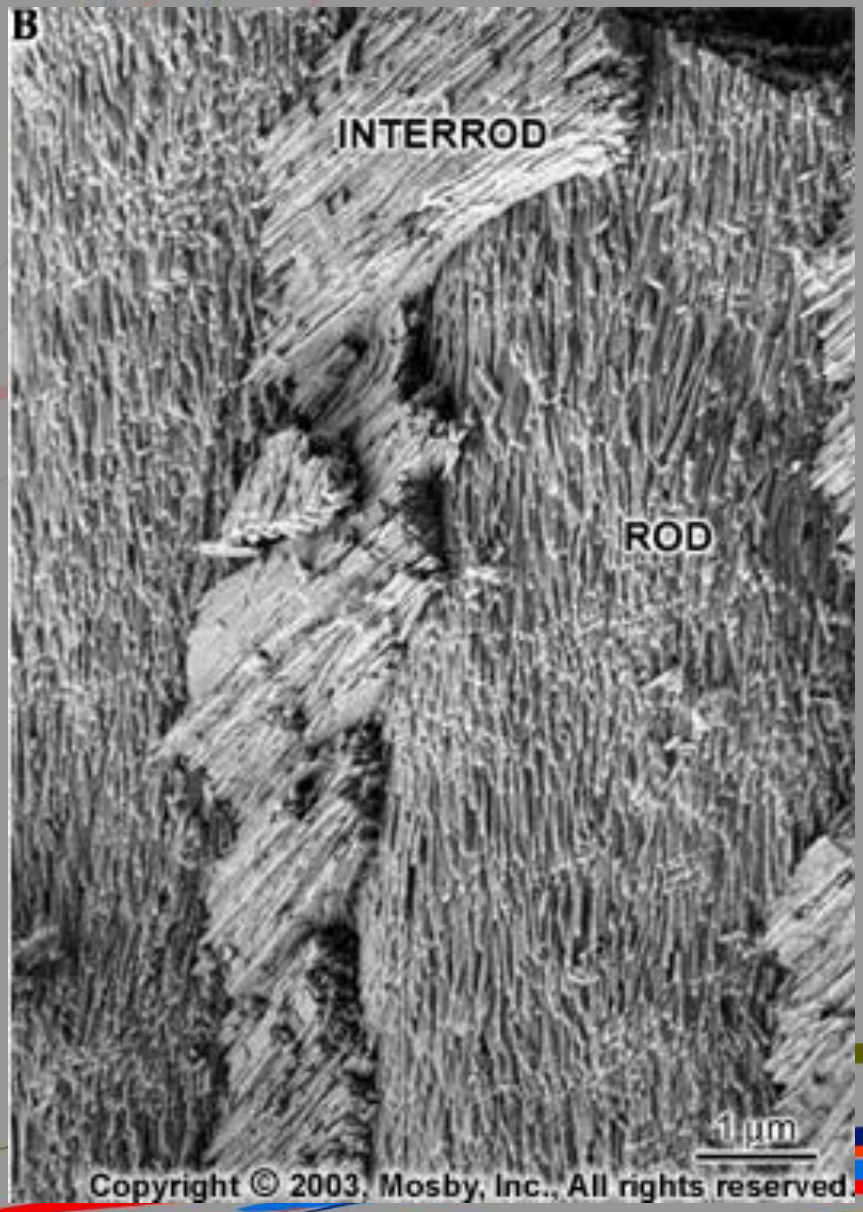
- Calcium phosphate unit cell has a hexagonal symmetry and stacks up to impart a hexagonal outline to the crystal.
- These crystals are grouped together as rod or inter-rod enamel.

- The rod is shaped somewhat like a cylinder and is made up of crystals with long axes that run, for the most part in the general direction of the longitudinal axis of the rod.
- The inter-rod region surrounds each rod, and its crystals are oriented in a direction different from those making up rods.


B
INTERROD
ROD
1 μm
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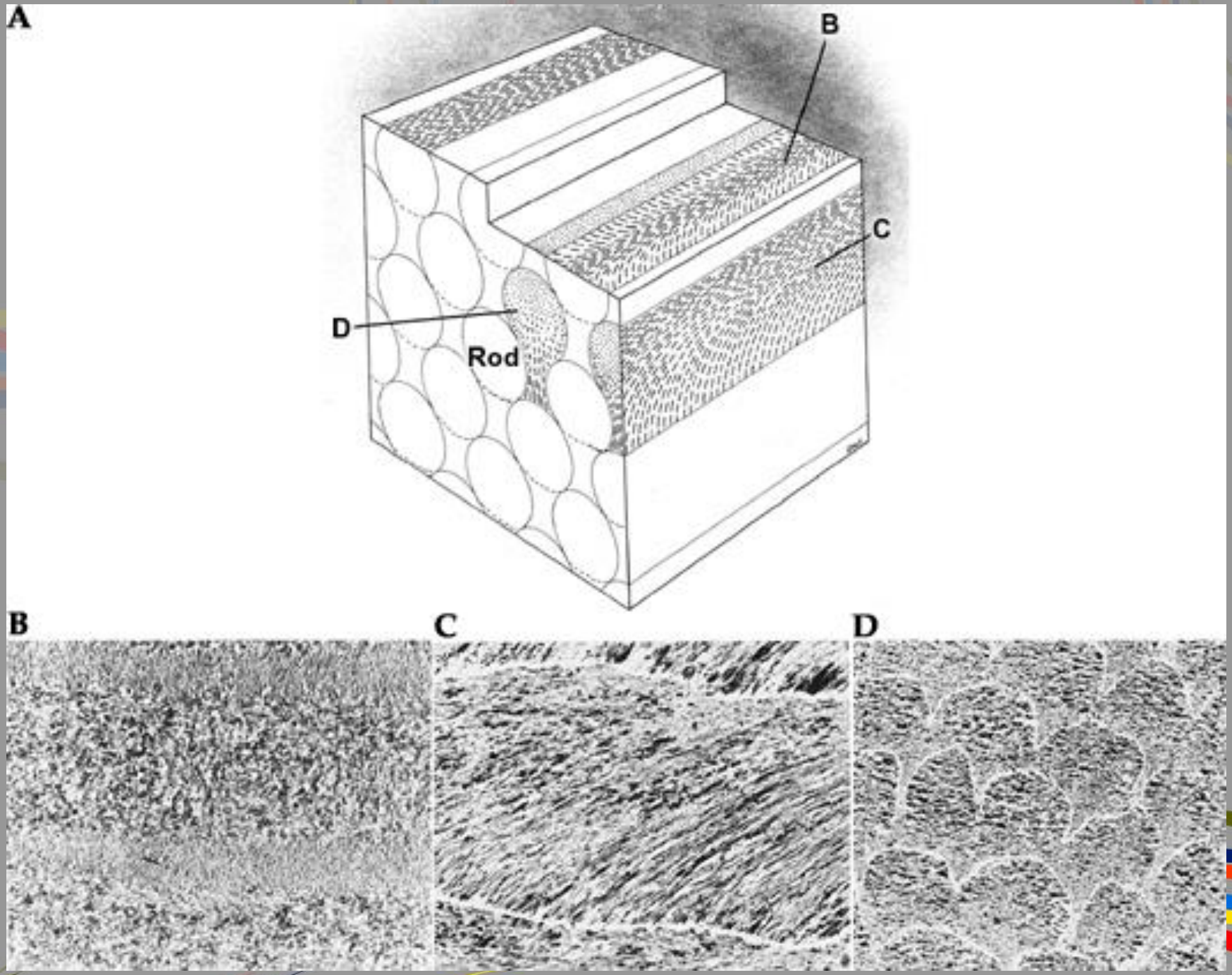
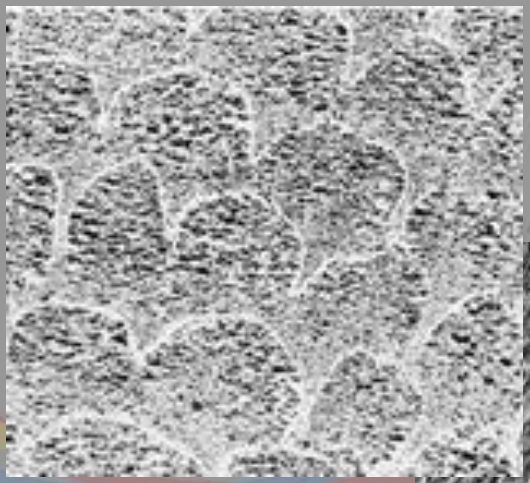
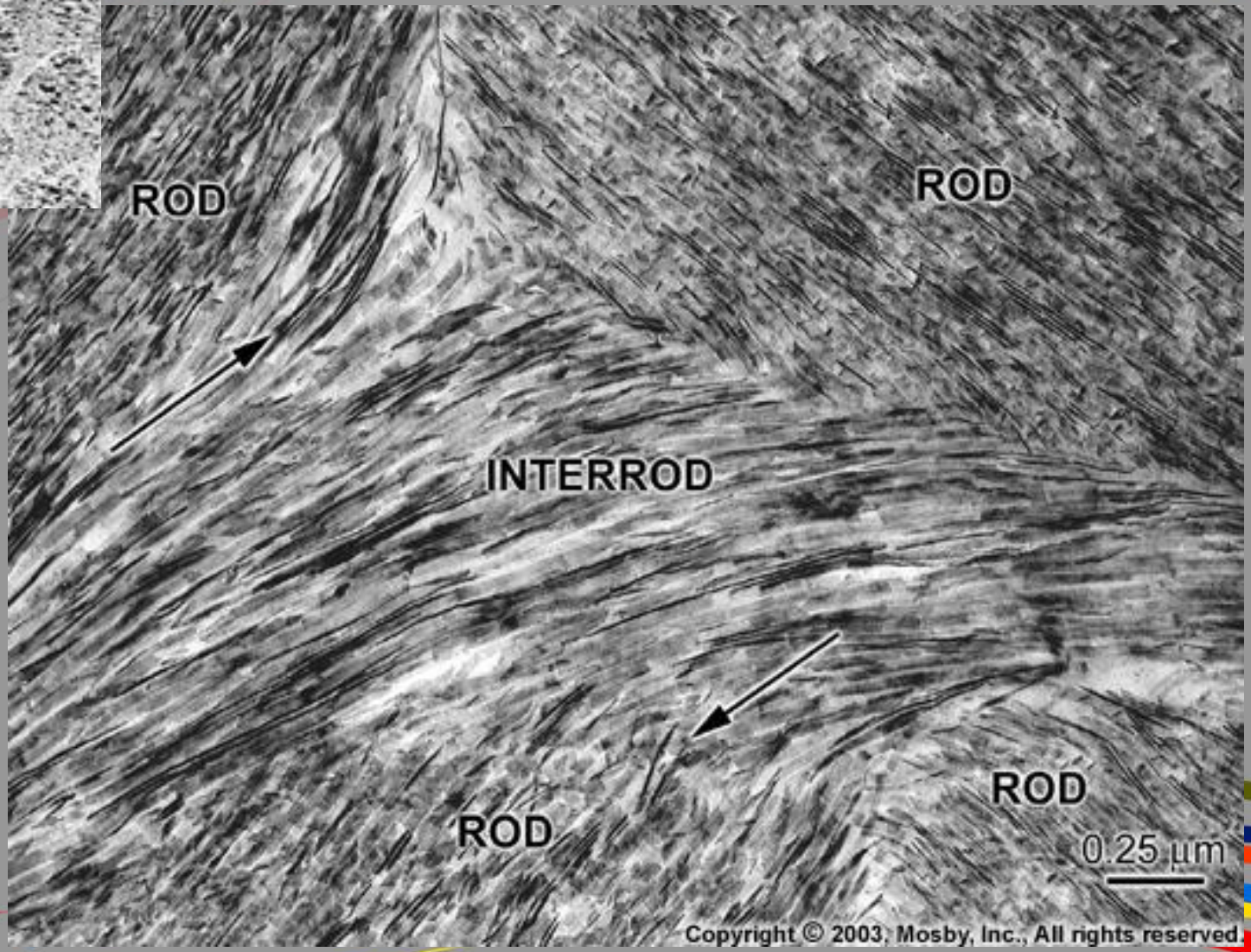
- The difference in the orientation is significant around approximately 3/4th of the circumference of a rod.
- The boundary between rod and inter-rod enamel is delimited by a narrow space containing organic matrix known as the ROD SHEATH.



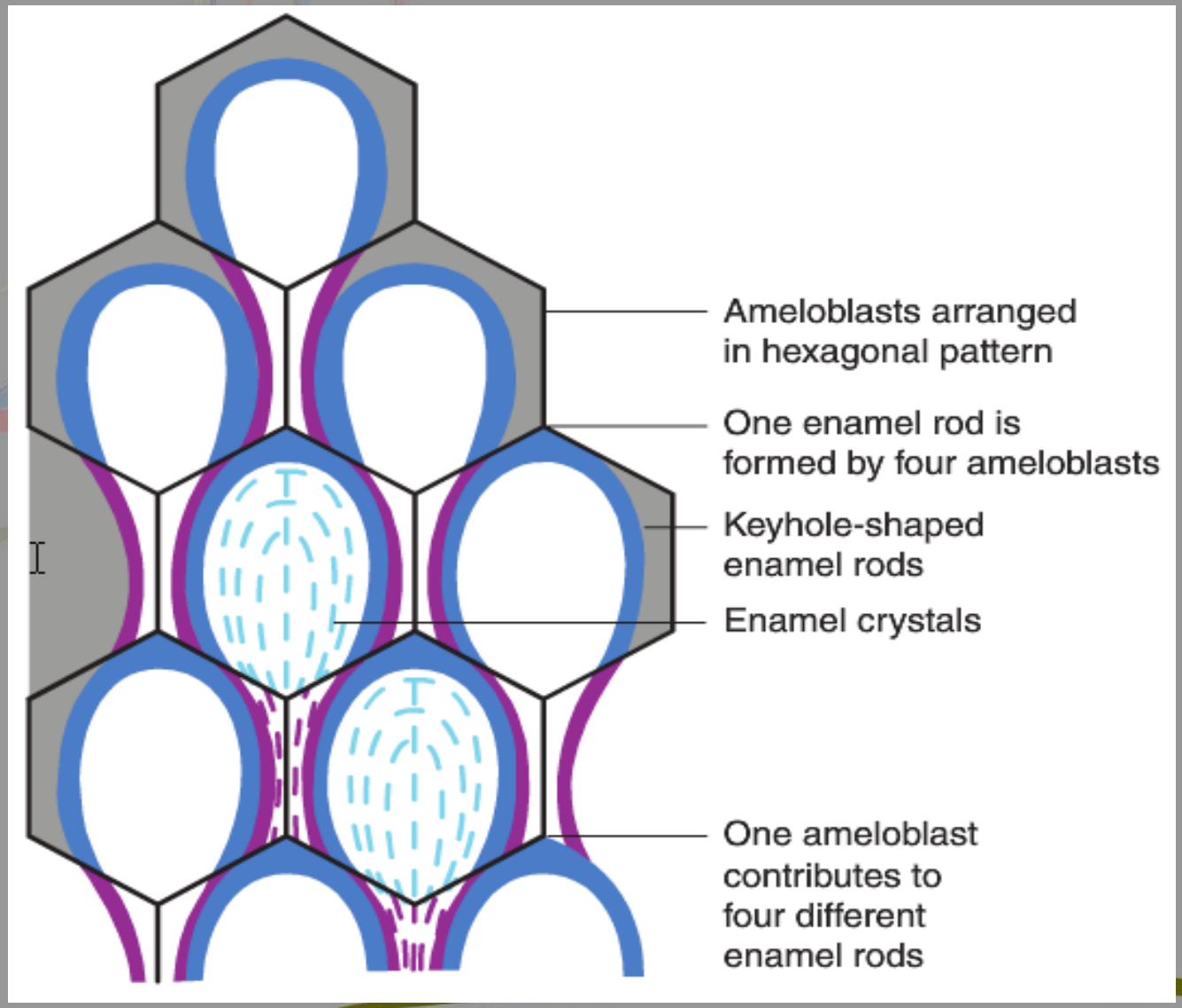
- Along a small portion of the circumference of the rod the crystals are confluent with those of inter-rod enamel.
- In this region, rod and inter-rod enamel are not separated- no rod sheath.





- In the sections cut along the longitudinal axis of enamel rods and passing through the narrow region where rods and inter-rod are confluent, rod crystals can be seen to flare out into inter-rod enamel- key-hole pattern. (paddle-shaped pattern)

- Rounded head and a narrow tail region.
- The rounded head of each rod fits closely into the concavities between the heads and tails of the rods on either side.
- The region between the two enamel rods in one row, thought to be the interrod substance.


Ameloblasts arranged in hexagonal pattern
One enamel rod is formed by four ameloblasts
Keyhole-shaped enamel rods
Enamel crystals
One ameloblast contributes to four different enamel rods

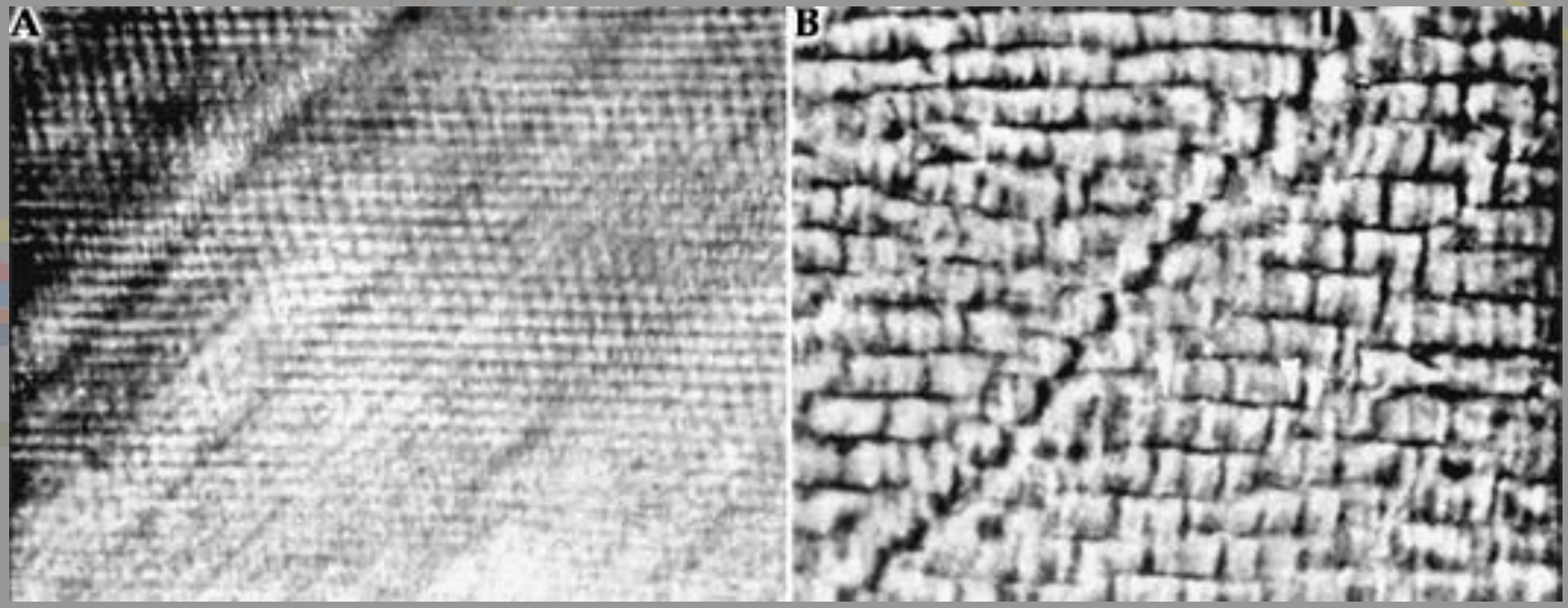
- Head portion pointing occlusal or the incisal surface
- Tail portion pointing cervically.

- In the tail region, the crystal orientation deviates to 65°–70° from the axis. The greatest change in the orientation of the crystallites is found while passing from the tail of the rod to the head of the adjacent rod.

- When sections are examined under light microscope, the transmitted light is deflected at these planes and shows up the boundaries of the rods.

STRIATIONS

- Longitudinal ground sections of enamel seen under a light microscope show that each enamel rod is composed of a series of segments separated by lines, giving it a striated appearance. These striations cross the enamel rods at intervals of about 4 µm.



- Each striation is thought to represent a rest phase during the formation of the enamel.

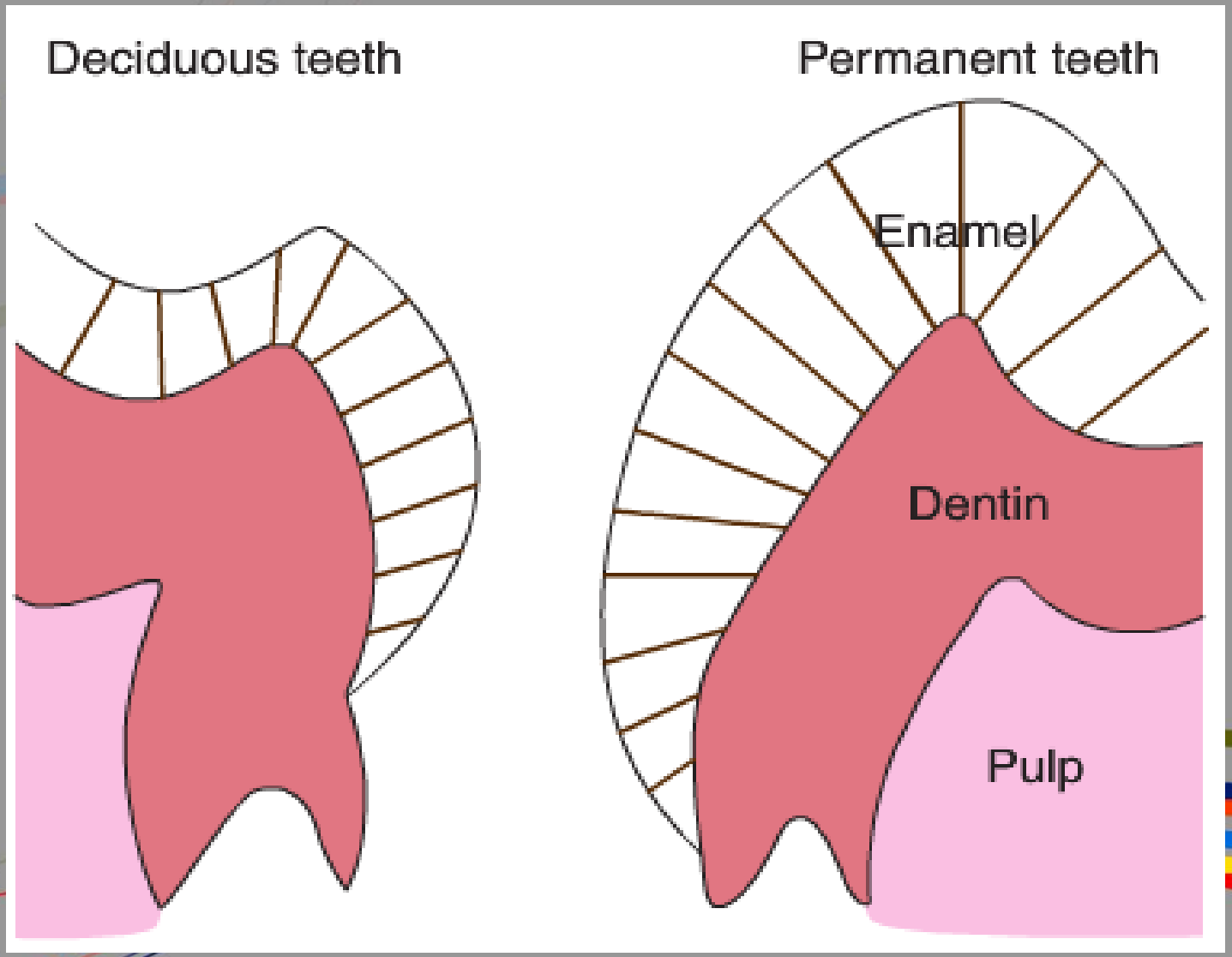
- The diameter of the enamel rods increases in the ratio of 1:2 while passing from the DEJ to the outer surface.

NON-PRISMATIC (APRISMATIC/PRISMLESS) ENAMEL

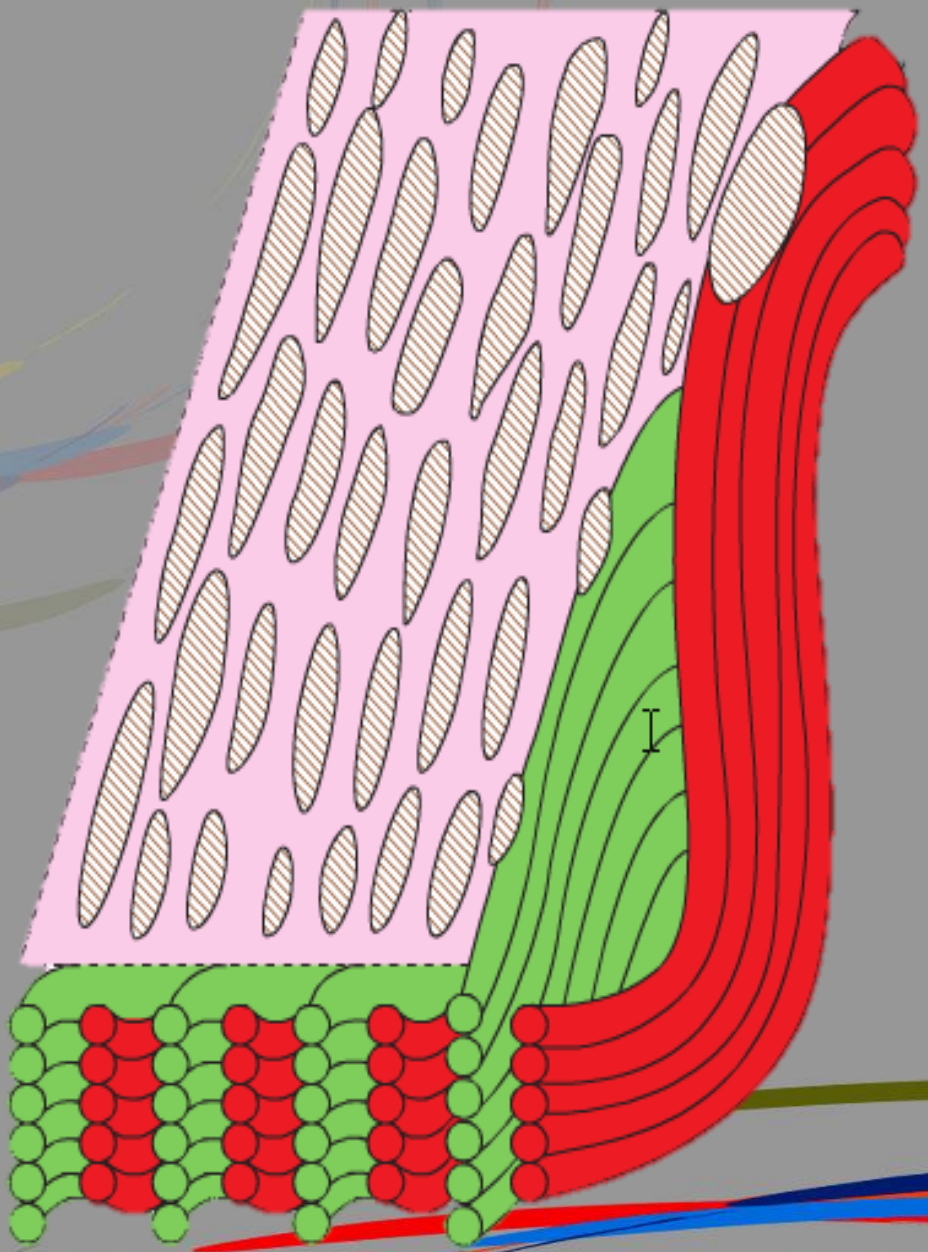
- The outer 20-100 µm of enamel of newly erupted deciduous teeth and the outer 20-70 µm of newly erupted permanent teeth is non-prismatic.

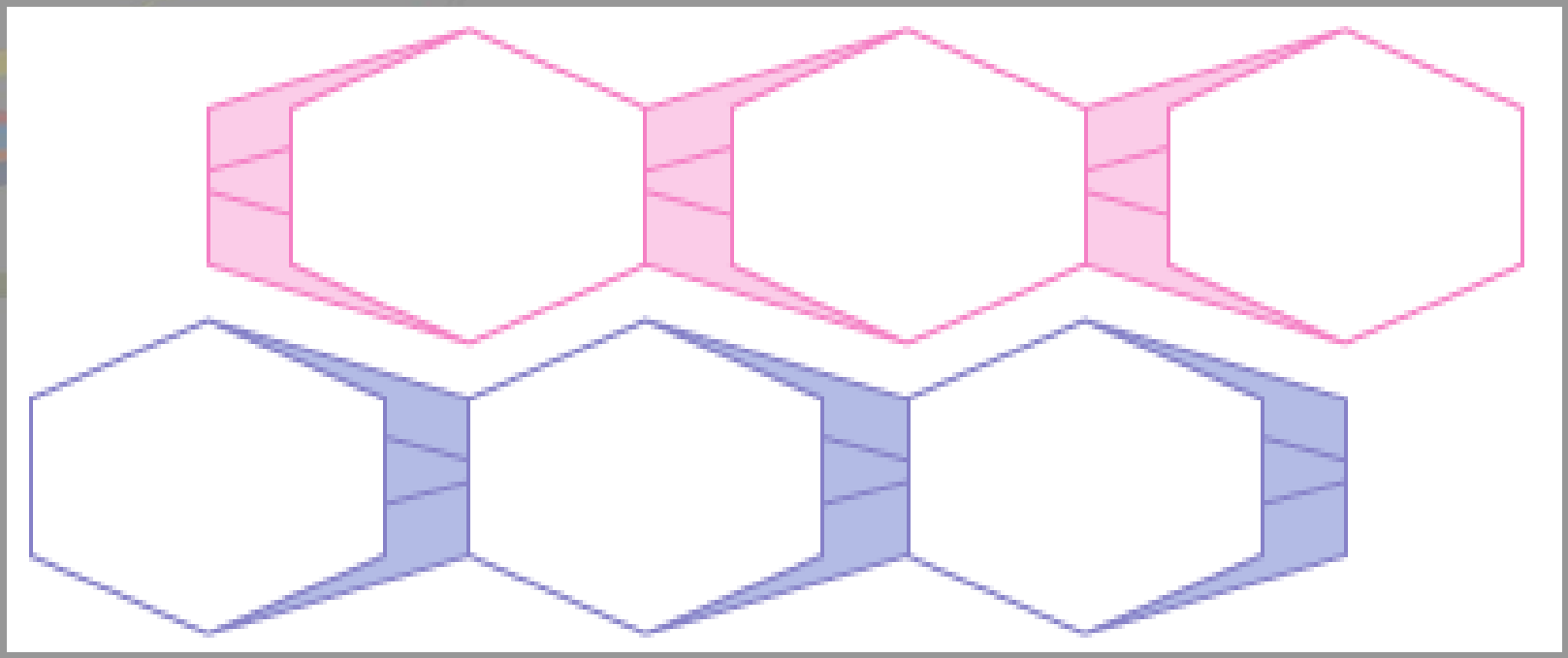
- This surface layer is more highly mineralized than the rest of the enamel because of the absence of prism boundaries, where more organic material is located.
- Non-prismatic enamel occurs as a result of the absence of Tomes processes from the ameloblasts in the first and final stages of enamel deposition

ORIENTATION OF ENAMEL RODS



- wavy arrangement

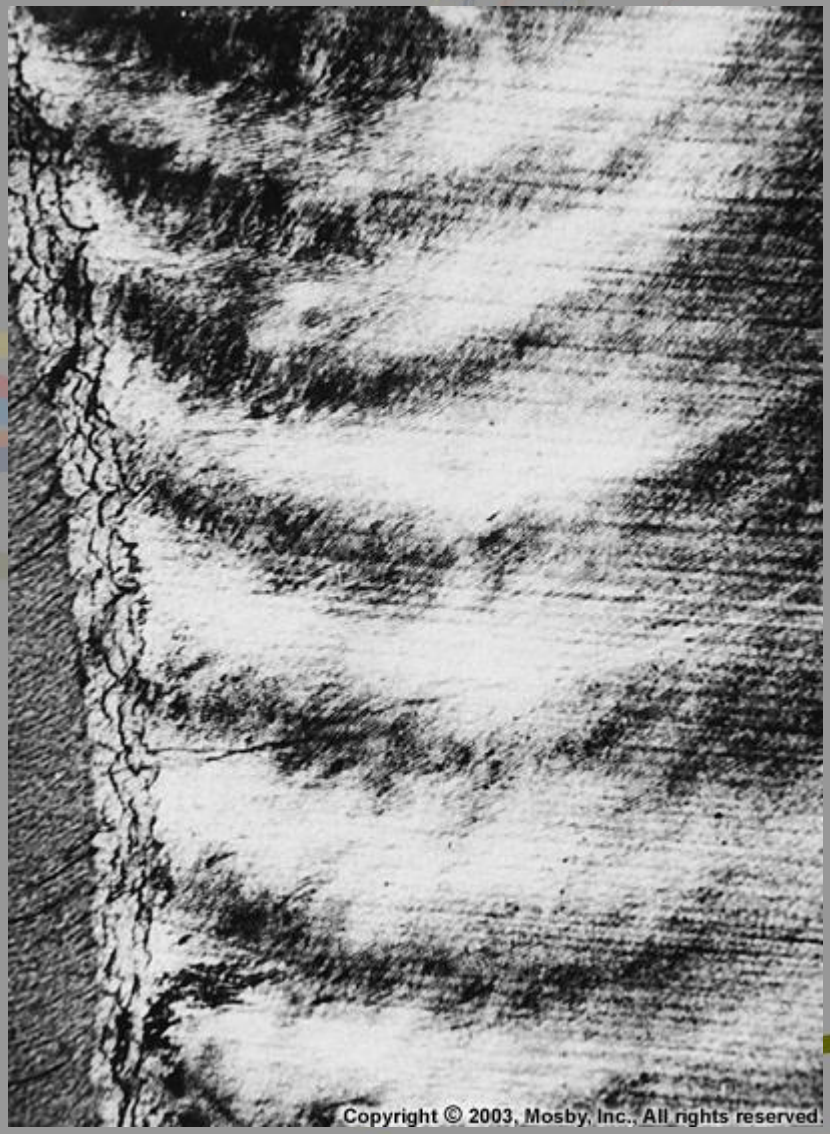




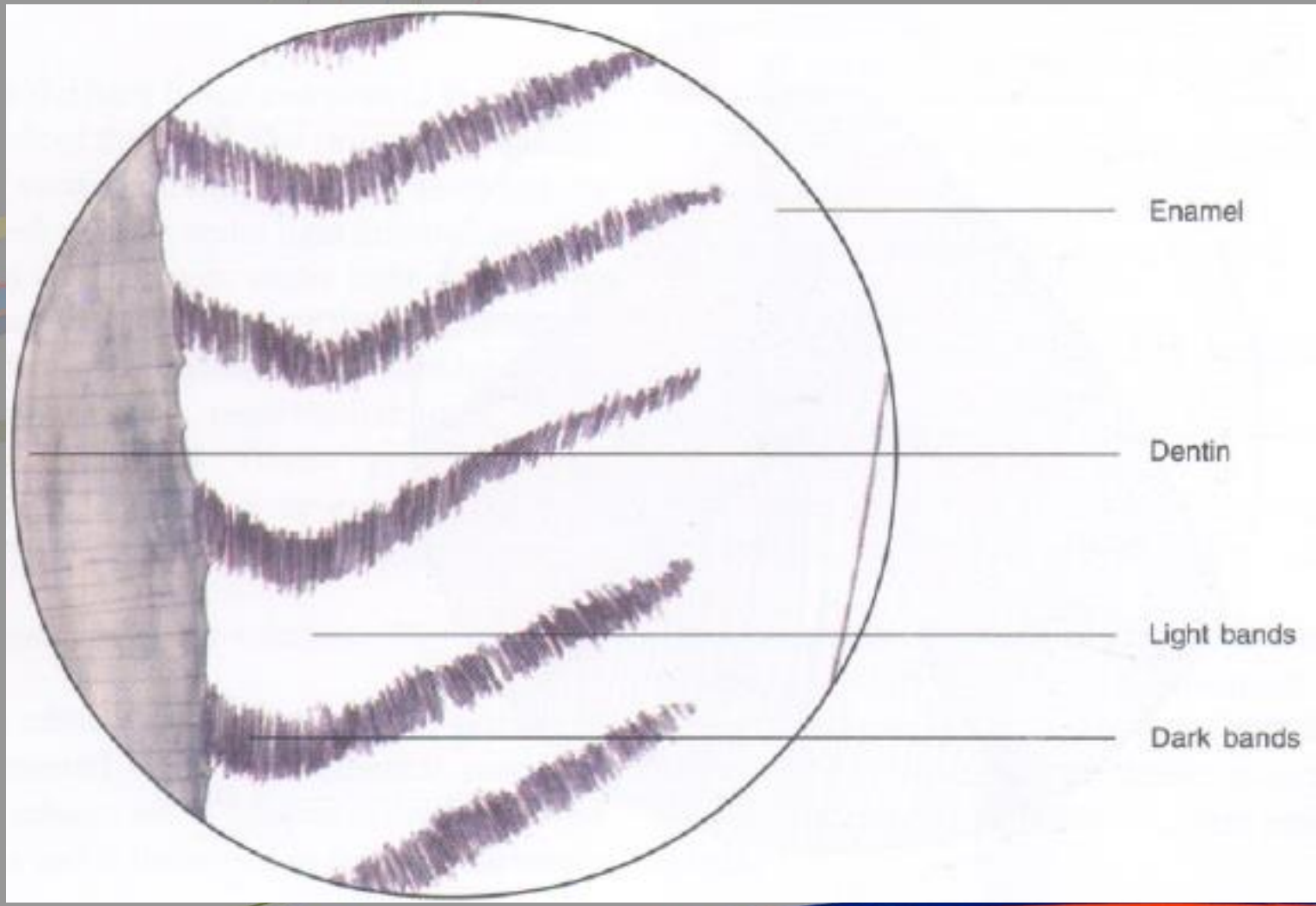
HUNTER–SCHREGER BANDS

- H–S bands are optical phenomena as a result of change in the direction of enamel rods.
- H–S bands are seen as alternating light and dark bands of varying width when longitudinal ground sections of the enamel are viewed under oblique reflected light.

- These are curved bands, with the concavity facing rootwards, commencing near the DEJ.
- They are seen in the inner two-thirds of the enamel thickness and disappear as the outer part of the enamel is approached.
- These bands are approximately 50 µm wide

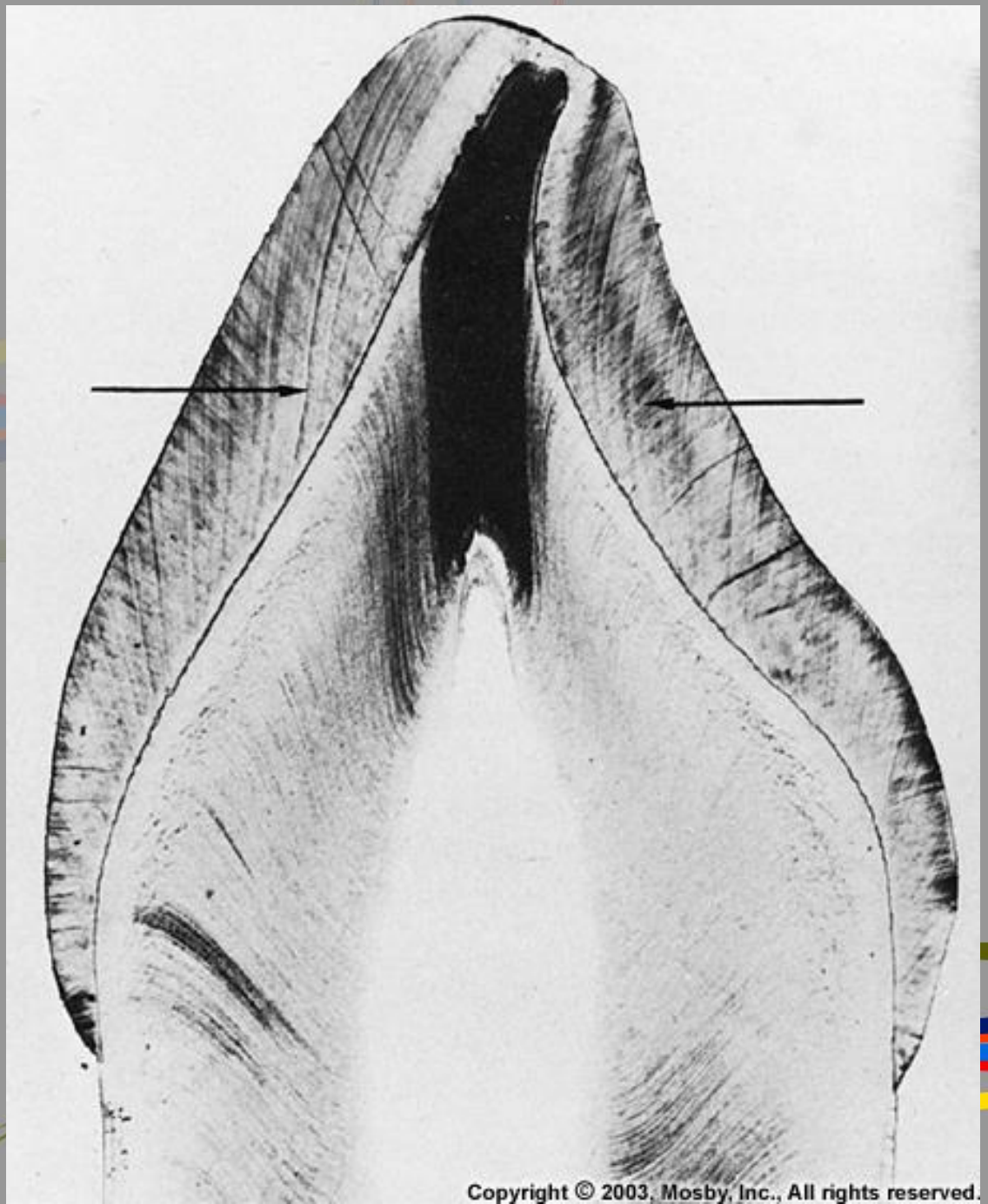


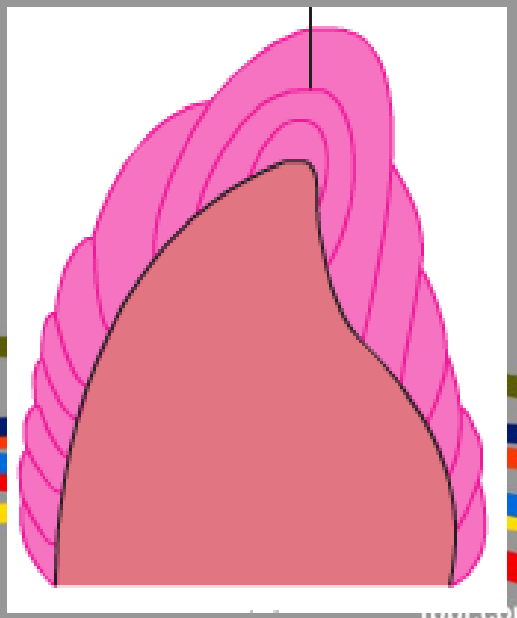
dark bands- para zones
lighter bands- dia zones.

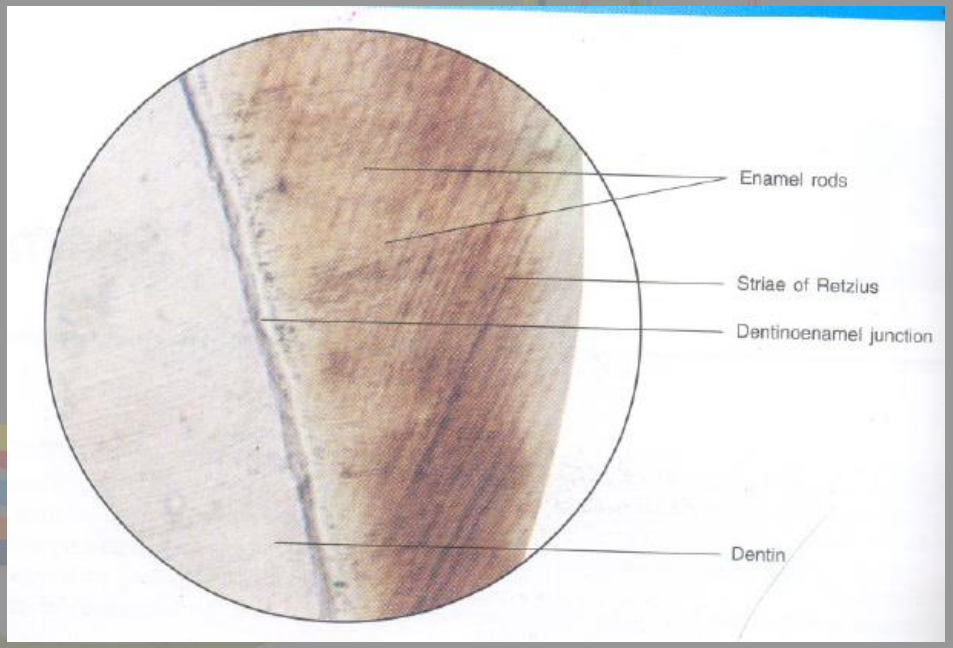


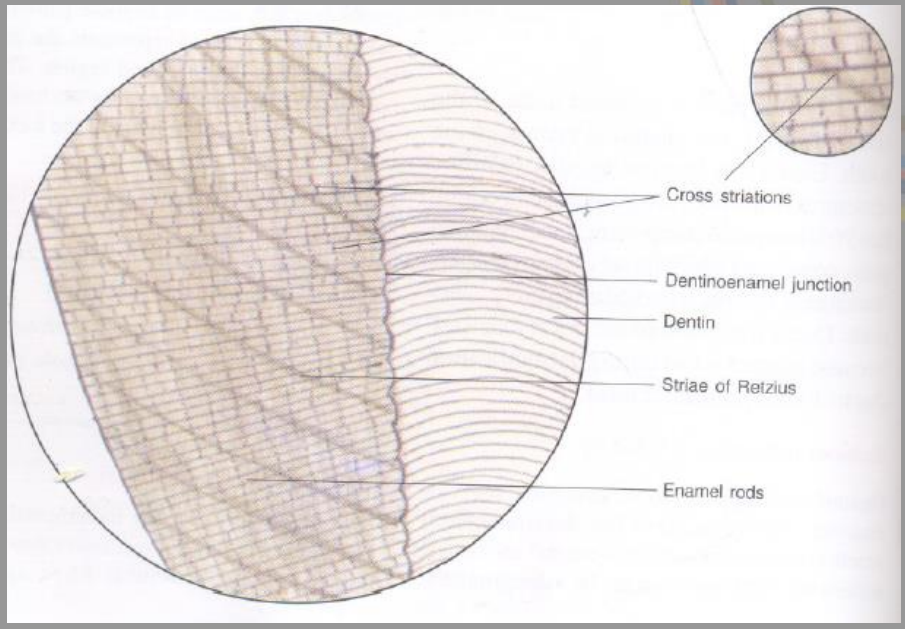
INCREMENTAL LINES OF RETZIUS

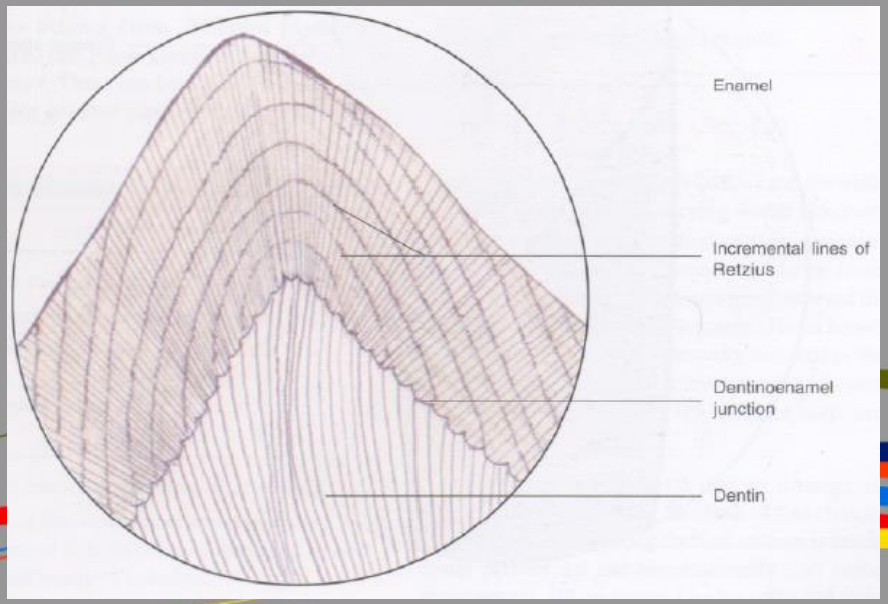
- These are a series of dark lines seen in enamel.
- Extending from the DEJ to the outer surface of the tooth in an upward and outward direction (deviating occlusally).
- The lines run obliquely in the cervical region to reach the surface.






Enamel rods
Striae of Retzius
Dentinoenamel junction
Dentin


Cross striations
Dentinoenamel junction
Dentin
Striae of Retzius
Enamel rods

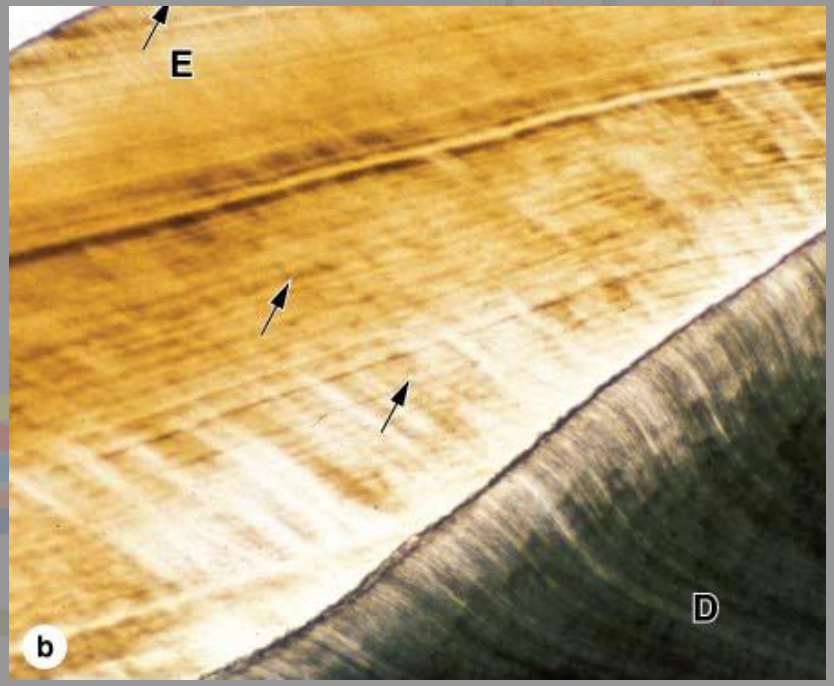

Enamel
Incremental lines of Retzius
Dentinoenamel junction
Dentin

- In cross-sections, they appear as concentric circles similar to the growth rings seen on the cut surface of a tree trunk.

- The enamel is formed by incremental or appositional growth pattern where the lines actually represent the periods of quiescence/rest and the space between the lines represents periods of active enamel formation.

Neonatal Line

- The rhythmic pattern of enamel formation can be altered, causing a prolonged resting period. This leads to the broadening of the incremental lines making them more prominent or accentuated.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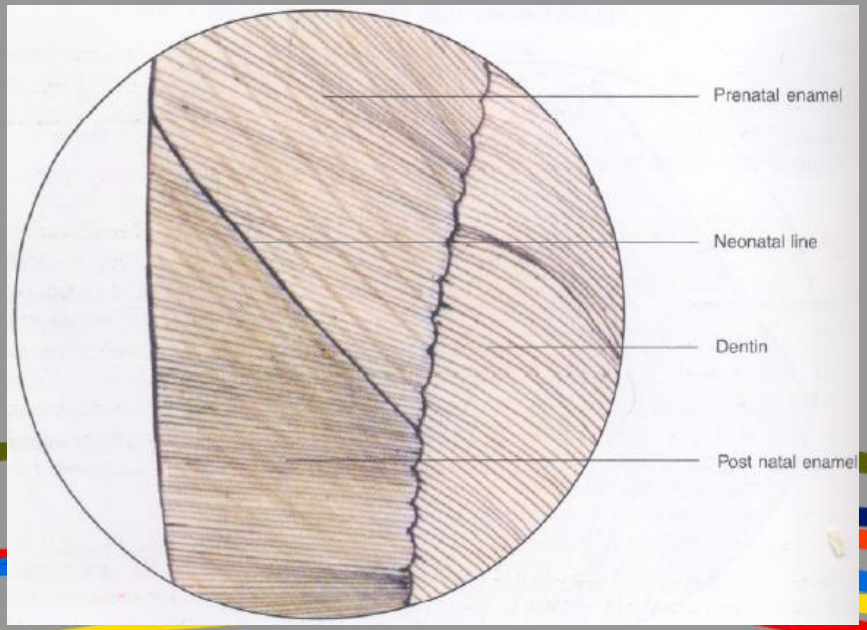

Prenatal enamel
Neonatal line
Dentin
Post natal enamel

- The neonatal lines are seen in deciduous teeth and in the first permanent molars, separating the enamel formed before and after birth.
- This is due to the physiologic changes in nutrition and environment occurring at birth.

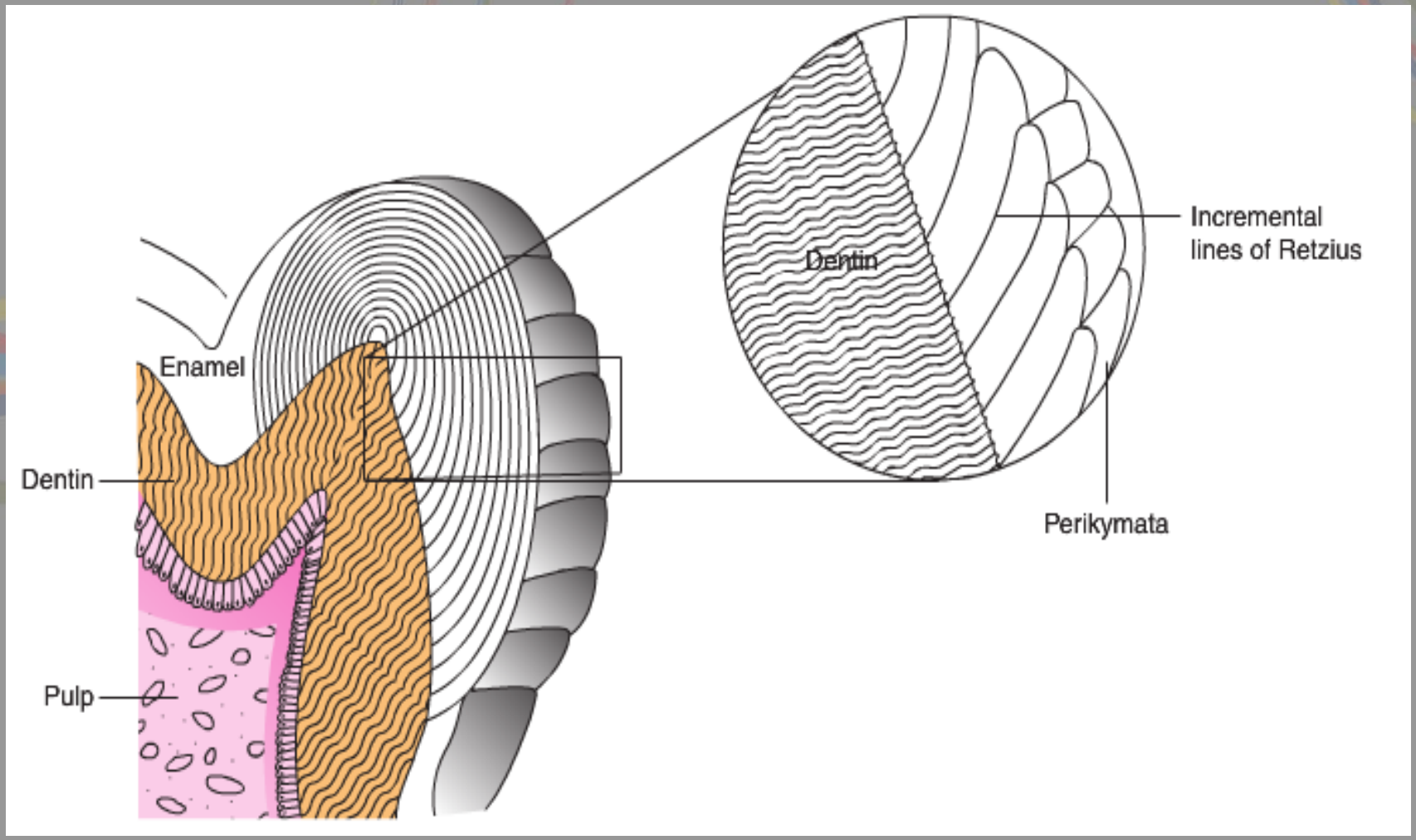
- The prenatal enamel is more homogenous than the post-natal enamel, probably because of more constant surroundings and nutrition of the foetus.
- Accentuated incremental lines can also be pathological, caused by metabolic and systemic disturbances such as **exanthematous fever** that affects enamel formation.

PERIKYMATA

- Perikymata are transverse wave-like grooves lying parallel to each other and to the cementoenamel junction and run circumferentially across the surface of the crown.

- These are seen in regions where the incremental lines of Retzius reach the outer surface of the enamel.
- They are thought to be the external manifestations of the lines of Retzius

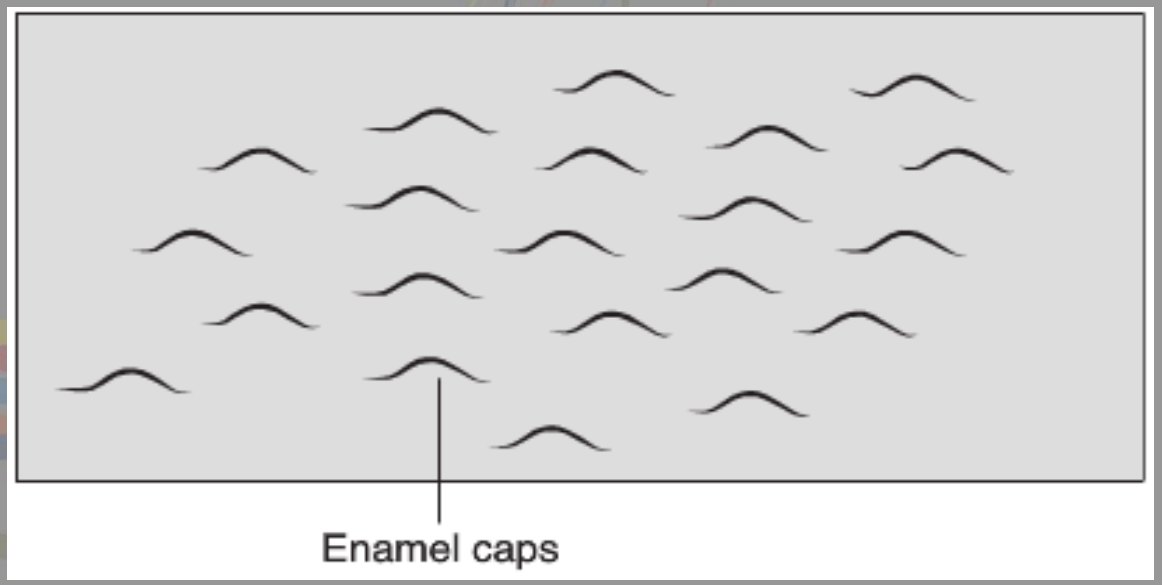
- They are more in number in the cervical region (30/µm) than in the occlusal or the incisal edge (10/µm).
- They are sometimes referred to as **imbrication lines of Pickerill** and can be demonstrated by rubbing graphite on the surface of the teeth.

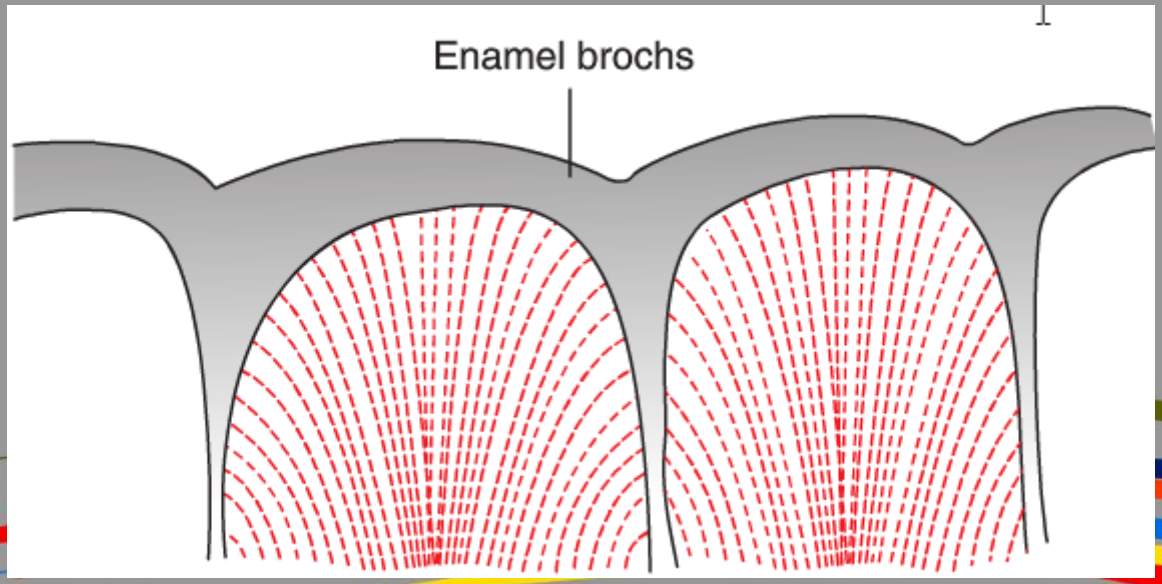

Enamel
Dentin
Pulp
Dentin
Incremental
lines of Retzius
Perikymata

ENAMEL CAPS AND BROCHS

- The surface of enamel is not even and shows pits and elevations. The pits are about 1–1.5 µm in depth and represent the ends of the ameloblasts lost after the formation of enamel.

- Elevations occur as a result of the deposition of enamel and debris of the enamel organ. Smaller elevations are called enamel caps which measure about 10–15 μm in width, and larger elevations are called enamel brochs, which measure about 30–50 μm in width.





ENAMEL LAMELLAE AND CRACKS

- Enamel lamellae are thin sheet-like structures arranged in longitudinal and radial directions of tooth, best demonstrated in horizontal sections. They extend from the surface of the enamel to the DEJ and some may even reach the dentin.

- Enamel lamellae are formed due to severe disturbance causing a crack in the newly formed enamel and are filled with organic matter. It is suggested that an enamel lamella can be a weak site, providing a pathway for bacteria to enter and cause caries.

- Enamel lamellae can be differentiated into three types:
- 1. Type A- enamel lamellae are poorly calcified rod segments that occur when a section of enamel rod fails to calcify when occlusal forces are applied on it while crossing a plane of tension.

- 2. Types B and C- enamel lamellae are defects in enamel filled with organic material.

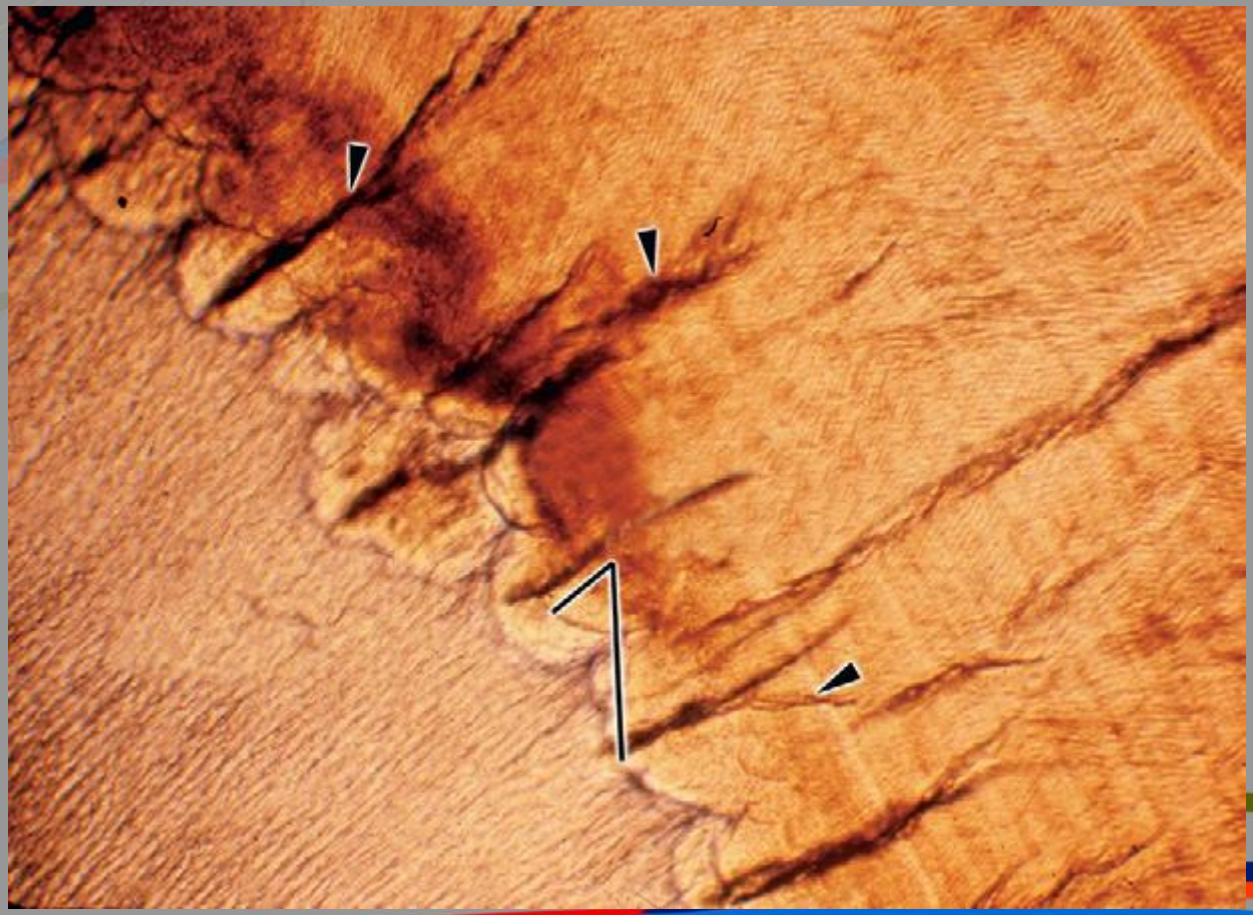
- 3. Type C- enamel lamellae occur in erupted teeth where the cracks are filled with organic matter from the connective tissue surrounding the teeth or from saliva. Cementum may be formed in these lamellae.

- Type A enamel lamellae are restricted to enamel, while types B and C may extend up to the dentin.

- Enamel lamellae should not be confused with cracks, which can occur during the preparation of ground sections of the enamel. These cracks look very much like lamellae and can be distinguished by careful decalcification of the section. While cracks, which do not contain organic material, disappear after decalcification, lamellae persist.

Enamel tufts

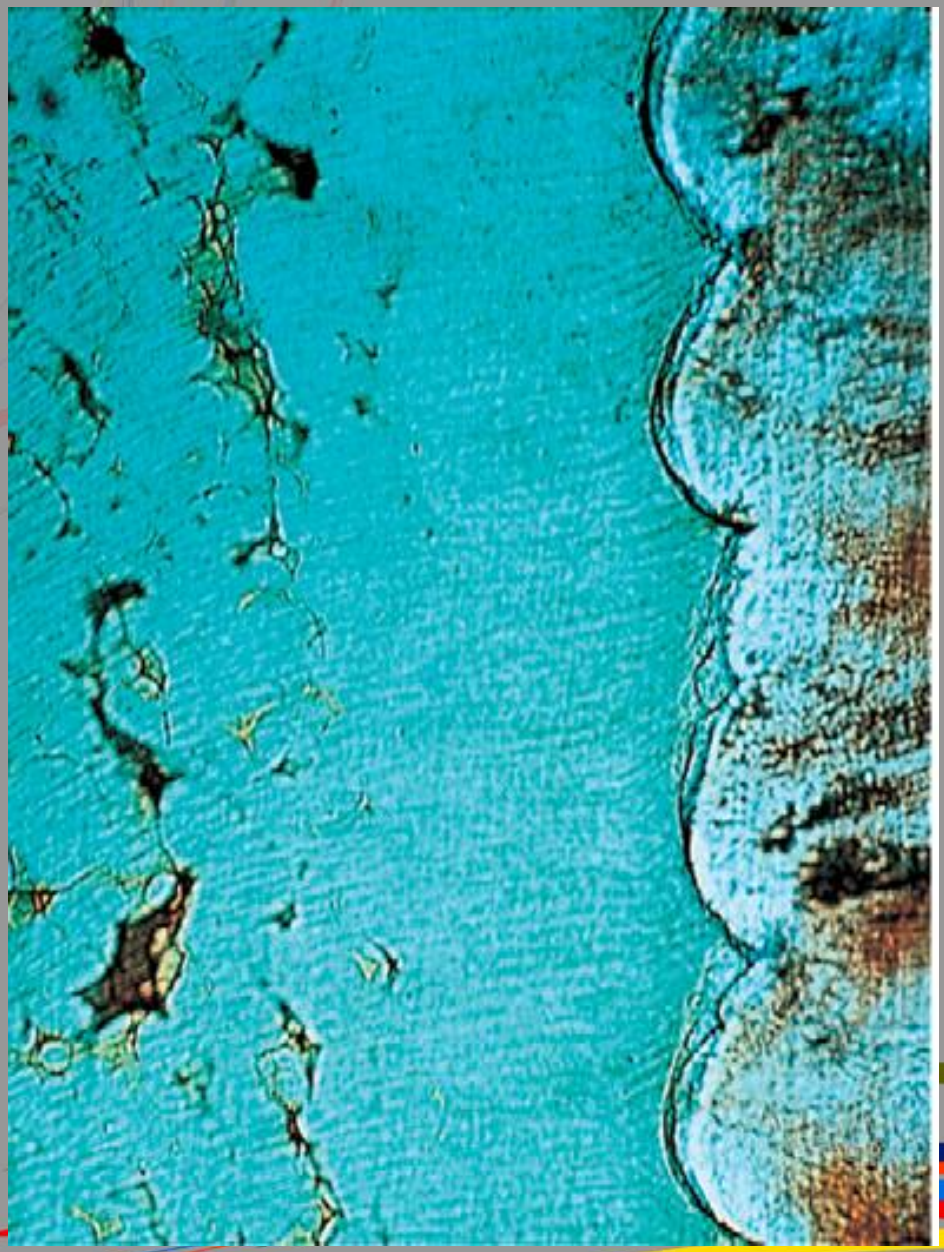
- Enamel tufts arise at the dentinoenamel junction and reach into the enamel to about one fifth to one third of its thickness.
- They were so termed because they resemble tufts of grass when viewed in ground sections.



- Tufts consist of hypocalcified enamel rods and interprismatic substance.
- Like the lamellae, they extend in the direction of the long axis of the crown.
- Therefore they are seen abundantly in horizontal, and rarely in longitudinal, sections.
- Their presence and their development are a consequence of, or an adaptation to, the spatial conditions in the enamel.

Dentinoenamel junction

- The surface of the dentin at the dentinoenamel junctions is pitted.
- Into the shallow depressions of the dentin fit rounded projections of the enamel.
- This relation assures the firm hold of the enamel cap on the dentin.
- In sections, therefore, the dentinoenamel junction appears not as a straight but as a scalloped line.



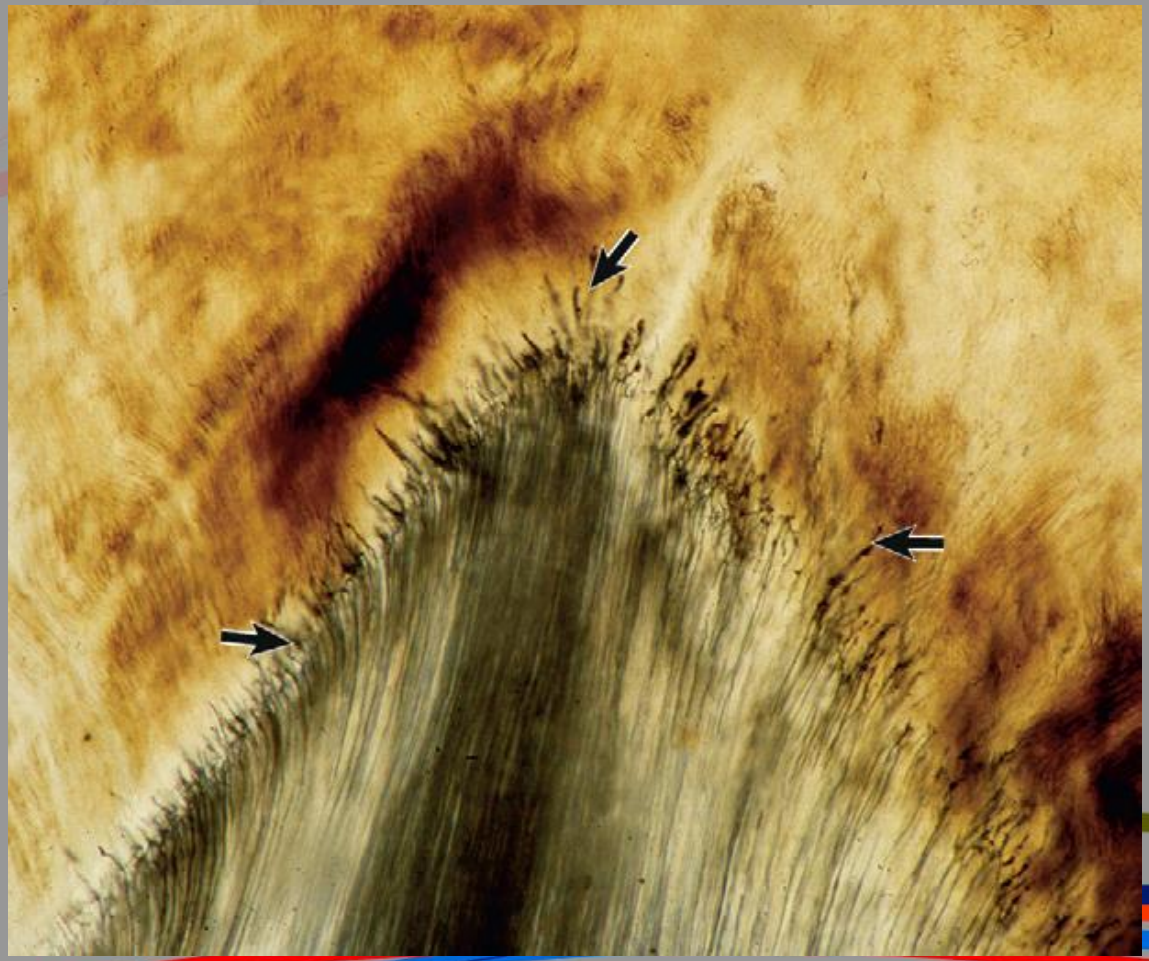
- The convexities of the scallops are directed toward the dentin.
- The pitted dentinoenamel junction is preformed even before the development of hard tissues and is evident in the arrangement of the ameloblasts and the basement membrane of the dental papilla.

- In the dentinoenamel junction (DEJ) the crystals of dentin and enamel mix with each other.
- The DEJ, which is a series of ridges is more pronounced in the occlusal area, where masticatory stresses are greater.

Odontoblast processes and enamel spindles

- Occasionally odontoblast processes pass across the dentinoenamel junction into the enamel.
- Since many are thickened at their end, they have been termed *enamel spindles*.

- They seem to originate from processes of odontoblasts that extended into the enamel epithelium before hard substances were formed.
- The direction of the odontoblast processes and spindles in the enamel corresponds to the original direction of the ameloblasts—at right angles to the surface of the dentin.



- In ground sections of dried teeth the organic content of the spindles disintegrates and is replaced by air, and the spaces appear dark in transmitted light.

Enamel cuticle

- A delicate membrane called *Nasmyth's membrane*, after its first investigator, or the *primary enamel cuticle* covers the entire crown of the newly erupted tooth but is probably soon removed by mastication.
- Electron microscopic studies have indicated that this membrane is a typical basal lamina found beneath most epithelia.

- This basal lamina is apparently secreted by the ameloblasts when enamel formation is completed.
- The function of enamel cuticle is to protect the surface of enamel from the resorptive activity of the adjacent vascular tissue prior to the eruption of the teeth.

Age Changes

- Wear off
- Vertical dimensions
- Color
- Perikymata
- Microscopic None
- Chemical- Nit & Flourine increase

Clinical considerations

- Direction of rods
- Deep pits and fissures
- Enamel lamellae
- Fluoride Application

Table: 9.2 Structural features of Enamel

Structural feature	Developmental origin	Clinical relation
Enamel rod	Secretory product of one ameloblast from the distal or interdigitating portion of Tomes' process	Confers strength to the enamel Paths are important in cavity preparations
Enamel spindle	Extension of an odontoblast process and tubule across the basal lamina during the initial stage of matrix formation	No major clinical significance but may confer additional permeability to the deeper layers of enamel
Enamel tufts	Hypomineralized areas of enamel (rich in enamelin) near the DEJ formed during the initial stages of matrix secretion; resemble "tufts of grass"	No major clinical significance, but represent areas of enamel weakness
Enamel lamellae	Hypomineralized areas of enamel extending from the DEJ for considerable distances into the enamel	Represent a significant weakness in the structure of enamel and is susceptible to cracking
Cracks	May occur naturally, especially in hypomineralized areas between enamel rods; may be the result of lamellae; may be distinguished from lamellae in that they arise from the enamel surface and contain salivary proteins	Significant weakness in enamel; prone to breaking and caries
Hunter-Schreger bands	Viewed in ground sections with incident light and represent differences in the pattern of sectioning of enamel rods	Of no clinical significance
Gnarled enamel	Twisting of enamel rods in the cusps of teeth due to the small radius of rotation of ameloblasts during secretion	May confer some strength to the enamel
Enamel pits	Found between cusps; represent thin areas of enamel matrix due to the crowding of ameloblasts during development	Significant area of caries development; difficult to clean areas are often treated with sealants
Incremental lines: **1. Neonatal line** **2. Rezius' striae** **3. Cross striations**	All are formed due to the cyclical activity of ameloblasts ; represent hypomineralized areas or are due to small variations in rod orientation; during significant physiologic changes (birth and illnesses) these lines are accentuated or hypomineralized; cross striations have been explained as being due to sectioning of enamel rods across rows	Banding patterns formed during illnesses will show up o contralateral teeth which are developing at the same tir Patterns of enamel hypoplasia on a single tooth or on or side indicate trauma or a localized rather than systemic infection
Perikymata	Represent the external boundary of Retzius' striae	No real clinical significance
External layer of prismless enamel	Formed during the latter stages of enamel secretion by the proximal part of Tomes' process after the distal portion is lost; this layer is thicker on primary teeth	This layer must be removed by acid etching to create "tags" prior to the application of orthodontic appliances or bonding agents
Enamel cuticle	Formed by the remnants of the reduced enamel epithelium and its secretory products; it is quickly lost	Of no major clinical significance
Enamel pellicle	Formed after the tooth is in the oral cavity; acquired from saliva and the oral flora	May contain factors which hinder the attachment of bacteria to tooth surfaces

Thank you....