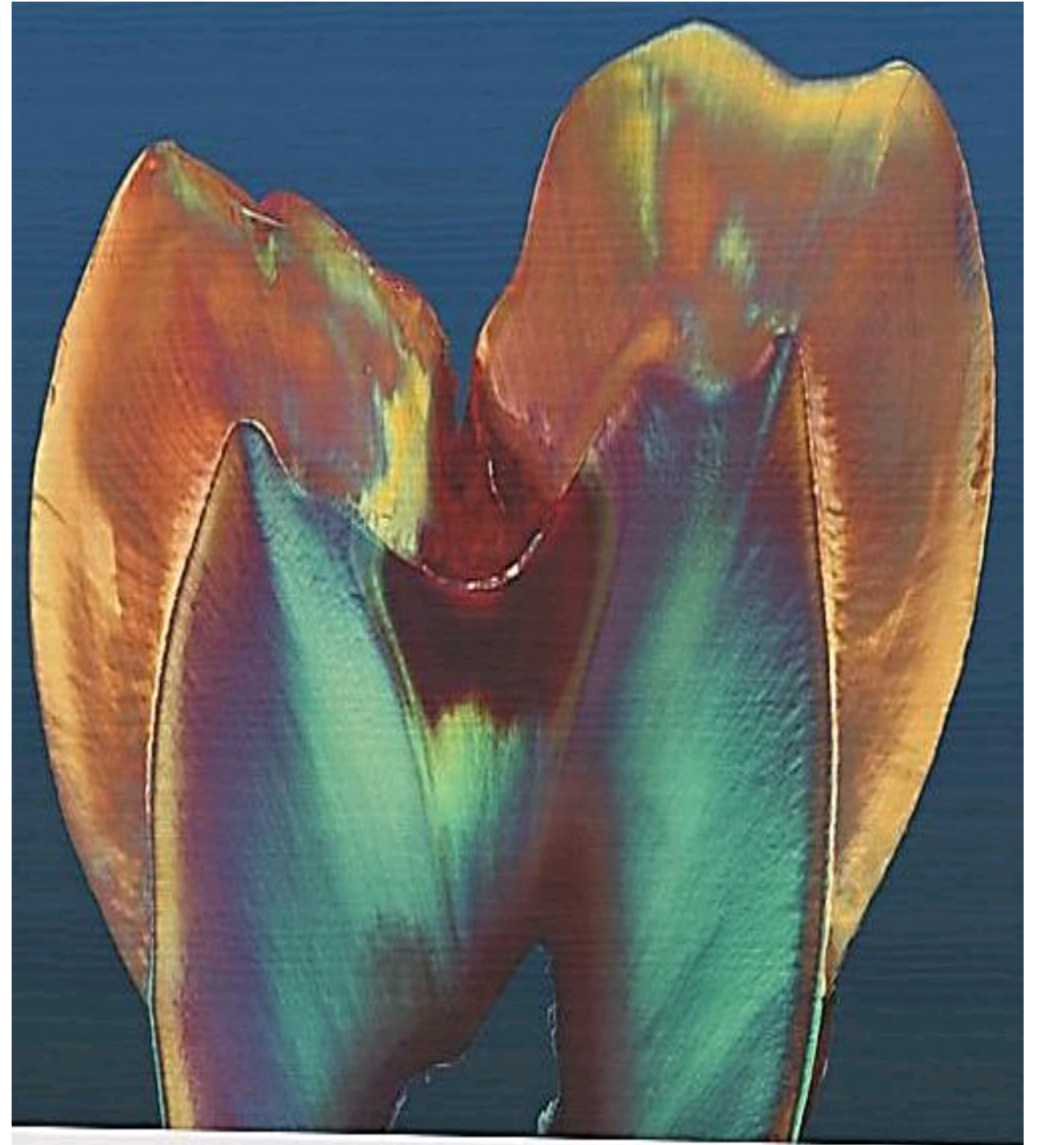


ENAMEL

OMYMA MEABED



INTRODUCTION

- Enamel is the hardest calcified structure in the body.
- The cells that are responsible for formation of enamel is the ameloblasts.
- They are lost as the tooth erupts into the oral cavity, and hence enamel cannot renew itself.

PHYSICAL CHARACTERISTICS OF ENAMEL

Color and translucency

- Enamel is translucent and varies in color from light yellow to gray-white.



Figure 13. Opalescence type 1.



Figure 14. Opalescence type 2.



Figure 15. Opalescence type 3.

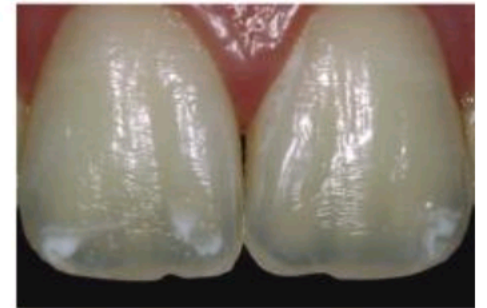
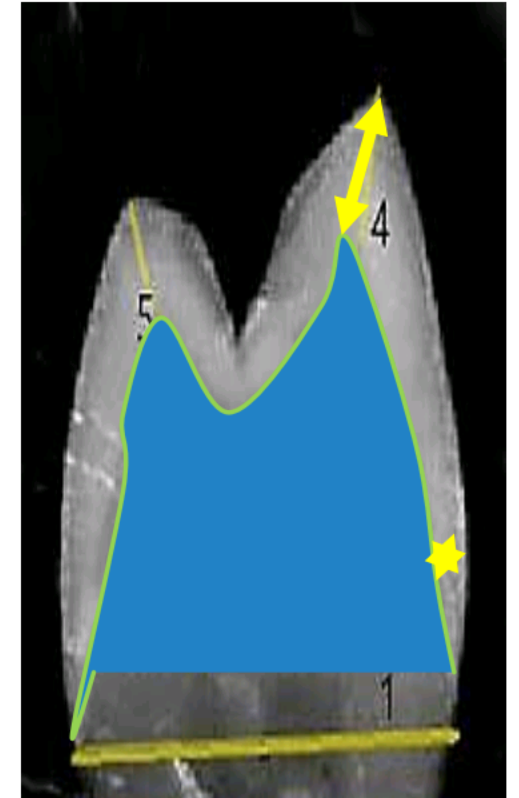
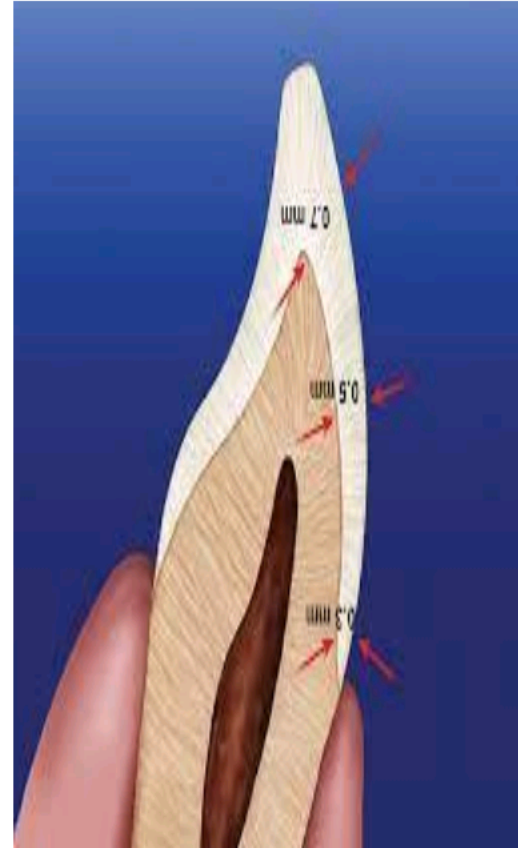


Figure 16. Opalescence type 4.

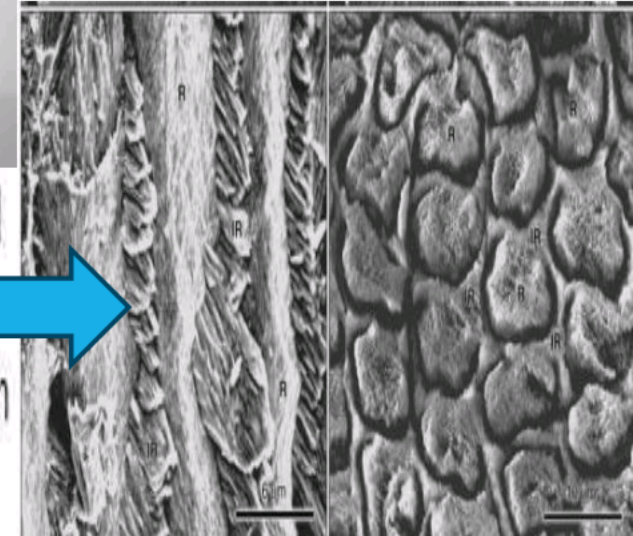
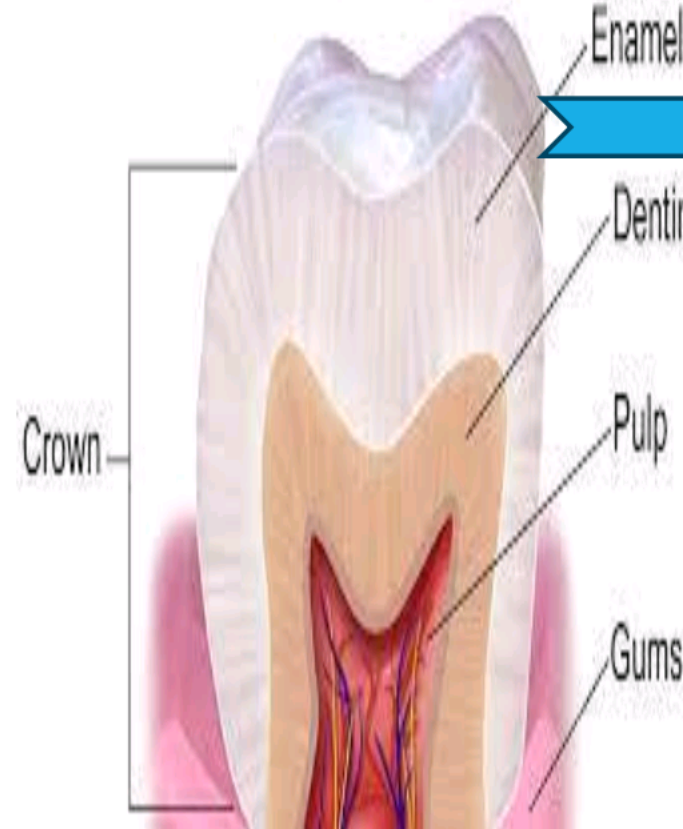
THICKNESS

- It also varies in thickness, from a maximum of approximately **2.5 mm** over working surfaces to a **feather edge** at the cervical line.
- This variation influences the color of enamel because the underlying yellow dentin is seen through the thinner regions.



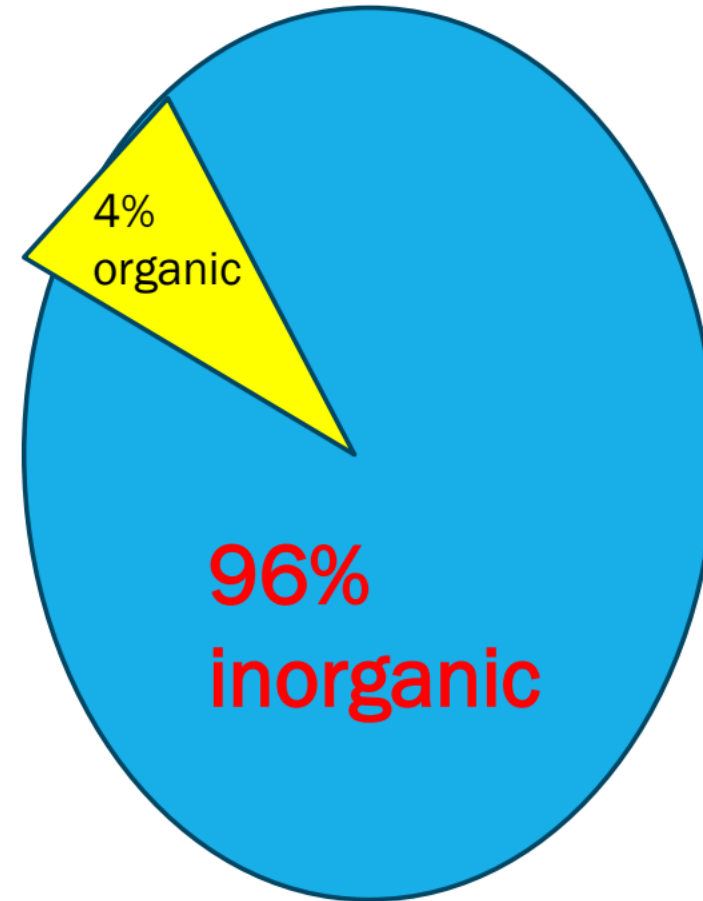
hardness

- The high mineral content renders enamel extremely hard
- this is a property that together with its complex structural organization enables enamel to withstand the mechanical forces applied during mastication.
- This hardness also makes enamel **brittle**; therefore an underlying layer of more **resilient dentin** is necessary to maintain its integrity



CHEMICAL CHARACTERISTICS

- **Fully formed enamel** consists of approximately 96% mineral and 4% organic material and water **by weight**,
- **by volume** organic and inorganic are equal



ORGANIC CONTENT

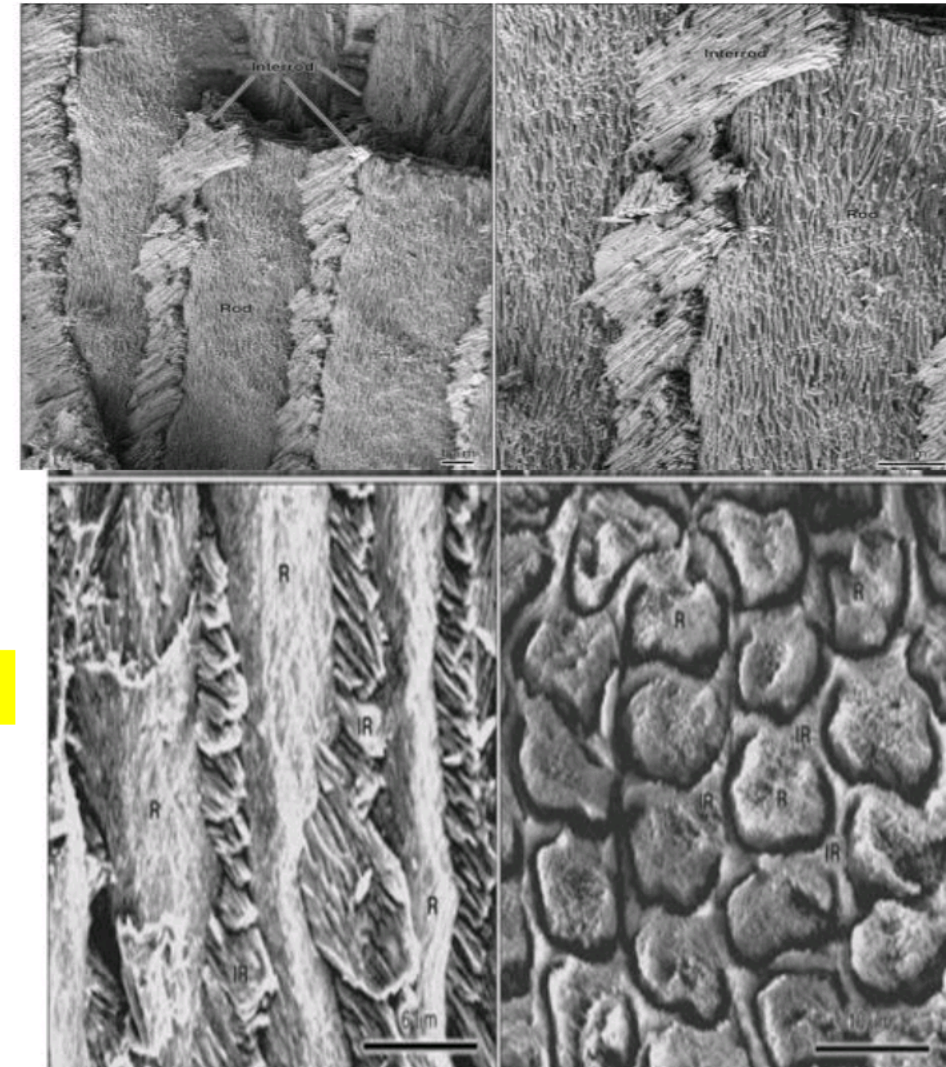
- **The organic content of enamel is proteinous non collagenous 1:2%**
- **In developing enamel amelogenins are dominant**
- **In mature enamel non amelogenins is dominant (enamelin, tuftlen)**
- **2:3% water**
- **Enzymes : degradation enzymes during enamel maturation**

In organic content

The inorganic content of enamel is a crystalline calcium phosphate (hydroxyapatite), which also is found in dentin, and cementum. Various ions—strontium, magnesium, lead, and fluoride—if present during enamel formation, may be incorporated into the crystals. The susceptibility of these crystals to dissolution by acid provides the chemical basis for dental caries.

STRUCTURE OF ENAMEL

- Enamel structure examined by **ground section**
- The fundamental organizational units of mammalian enamel are **the rods (prisms)** and interrod enamel (interprismatic substance).
- The enamel rod was first described as **hexagonal and prism-like in cross section**, and the term enamel prism still is used frequently. This term is a wrong scientific term because rods do not have a regular geometry and hence are not prismatic.

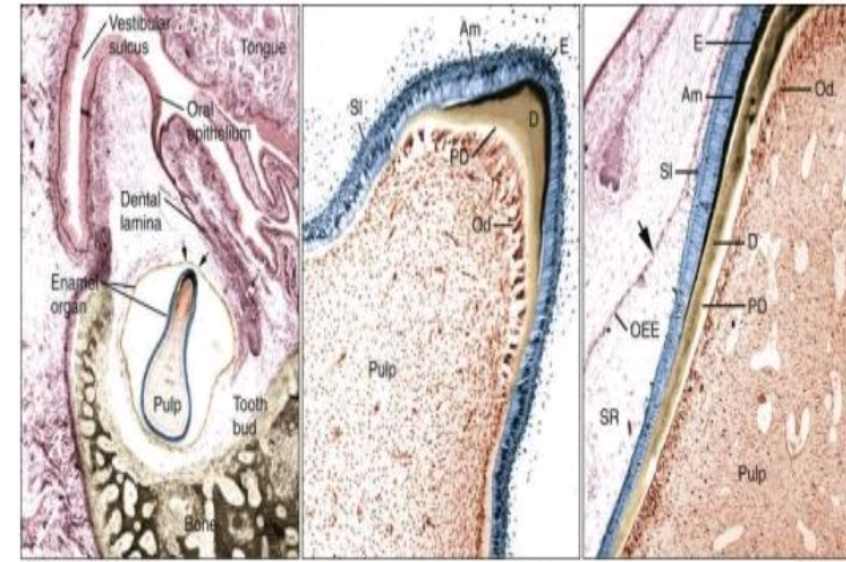


AMELOGENESIS

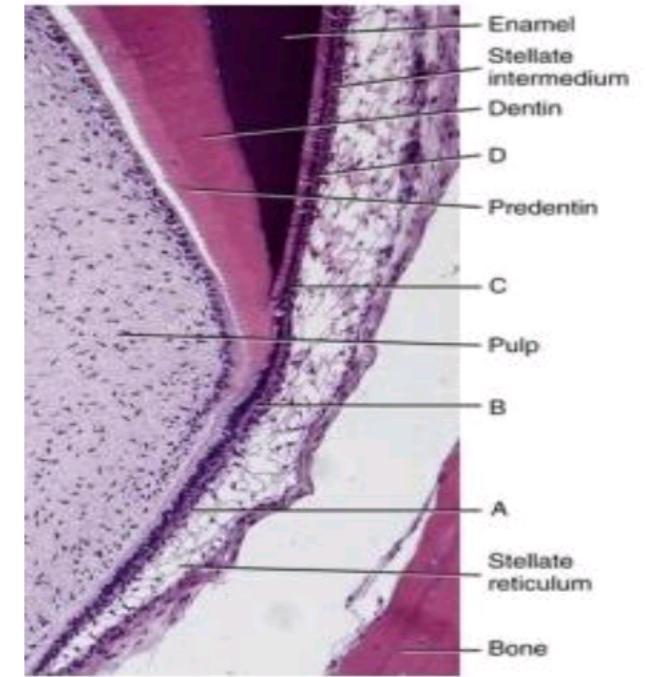
- Amelogenesis or enamel formation begins **when enamel first forms**, it mineralizes only partially to approximately **30%**. Subsequently, as the organic matrix breaks down and is removed, crystals grow wider and thicker. This process whereby organic matrix and water are lost and mineral is added accentuates after the full thickness of the enamel layer has been formed to attain greater than **96% mineral content**. Ameloblasts secrete matrix proteins and are responsible for creating and maintaining an extracellular environment favorable to mineral deposition.
- Amelogenesis stages referred to as **the presecretory, secretory, and maturation stages**
- **First**, during the **presecretory stage, differentiating** ameloblasts develop an extensive protein synthetic apparatus, and prepare to secrete the organic matrix of enamel.
- **Second, during secretory stage** (also called the formative stage), ameloblasts elaborate and organize the entire enamel thickness, resulting in the formation of a highly ordered tissue.
- **Last, during the maturation stage**, ameloblasts modulate and transport specific ions required for mineralization.

■ Enamel formation begins at **bell stage** of tooth development and involves the differentiation of the cells of the inner enamel epithelium first at the tips of the cusp outlines formed in that epithelium **(Figure A)**.

■ The process then sweeps down the slopes of the tooth crown until all cells of the epithelium have differentiated into enamel-forming cells, or ameloblasts **(Figure B)**.



A



B

LIFE CYCLE OF AMELOBLAST

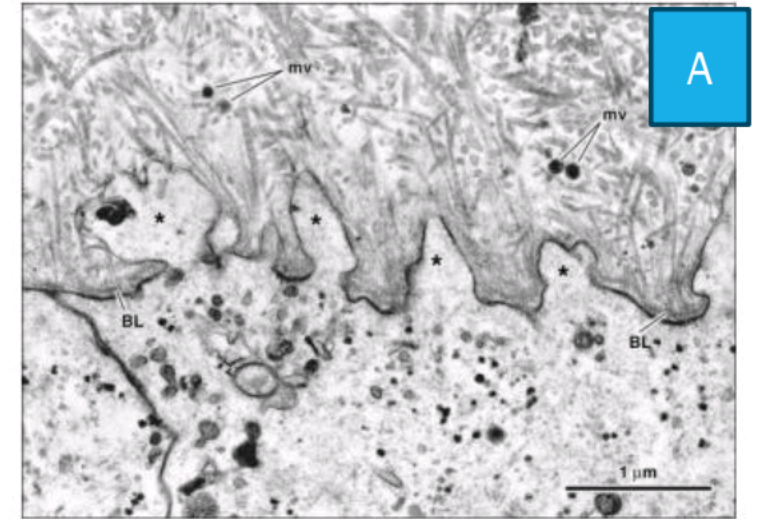
PRESECRETORY STAGE

MORPHOGENETIC PHASE

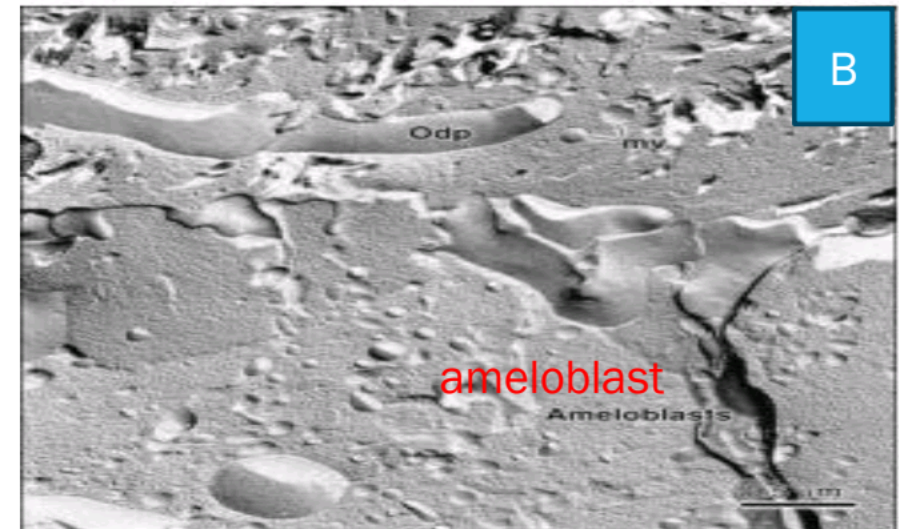
- During the bell stage of tooth development, the shape of the crown is established. A basal lamina is present between cells of the inner enamel epithelium and dental papilla
- At this stage the dentin is not yet mineralized
- The cells of the inner enamel epithelium still can undergo mitotic division, till the cervical portion of the tooth.
- These cells are cuboidal or low columnar, with large, centrally located nuclei and poorly developed Golgi elements in the proximal portion of the cells (facing the stratum intermedium), where a junctional complex exists. Mitochondria and other cytoplasmic components are scattered throughout the cell.

DIFFERENTIATION PHASE

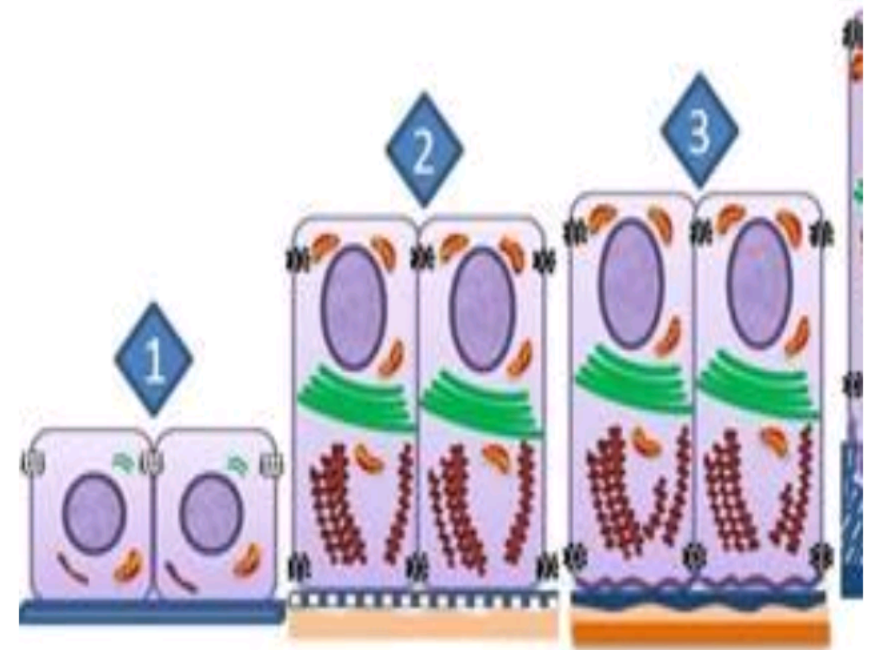
- As the cells of the inner enamel epithelium differentiate into **ameloblasts**, they **elongate** and their **nuclei shift proximally toward the stratum intermedium**.
- **The basal lamina supporting them is fragmented** by cytoplasmic projections and is then degraded during mantle predentin formation. **(A)**
- In each cell **the Golgi complex increases in volume and migrates distally** from its proximal position to occupy a major portion of the supranuclear cytoplasm.
- The amount of **rough endoplasmic reticulum increases significantly**
- mitochondria cluster in the infranuclear compartment, with only a few scattered through the rest of the cell.
- **A second junctional complex develops** at the distal extremity of the cell (facing differentiating odontoblasts), **(B)** Thus the ameloblast becomes a polarized cell, with the majority of its organelles situated in the cell body distal to the nucleus. **These cells can no longer divide.**



Differentiating ameloblasts extend cytoplasmic projections (*) through the basal lamina (BL), separating them from the forming mantle predentin. The basal lamina is fragmented and is removed before the active deposition of enamel matrix. *mv*, Matrix

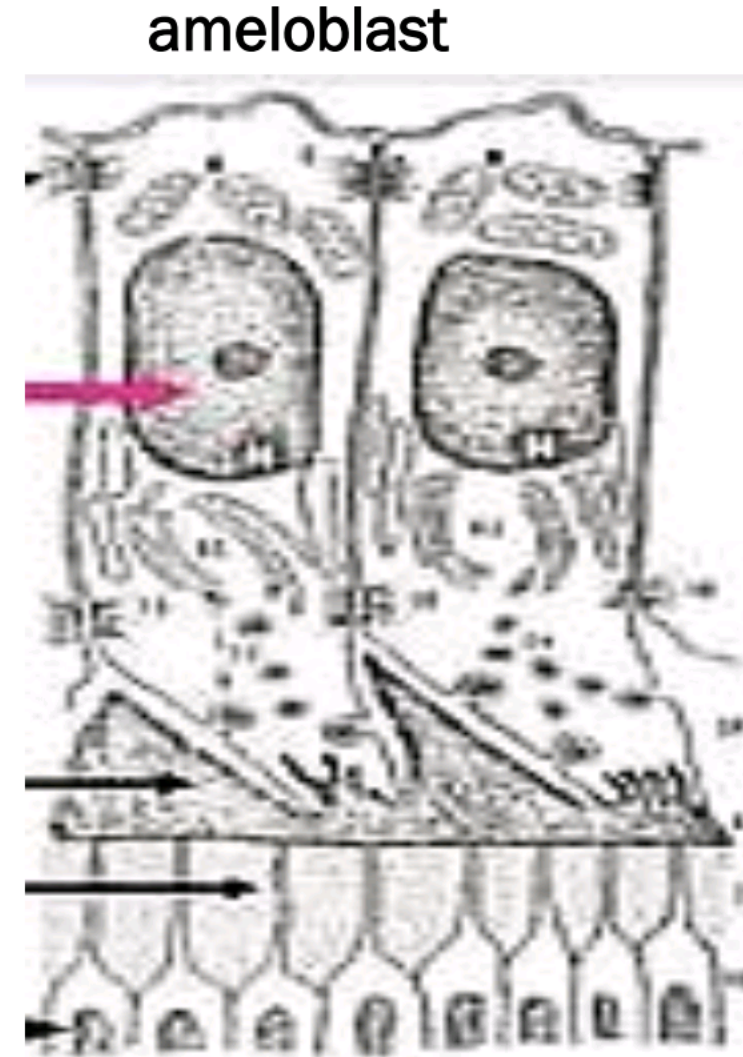


- ameloblasts are aligned closely with each other by junctional complexes, between them maintain the alignment.
- These complexes encircle the cells at their **distal** (adjacent to enamel) and **proximal** (adjacent to the stratum intermedium) extremities.
- These junctional complexes **play an important role in amelogenesis** by tightly holding together ameloblasts and determining at different times what may, and what may not, pass between them to enter or leave the enamel.



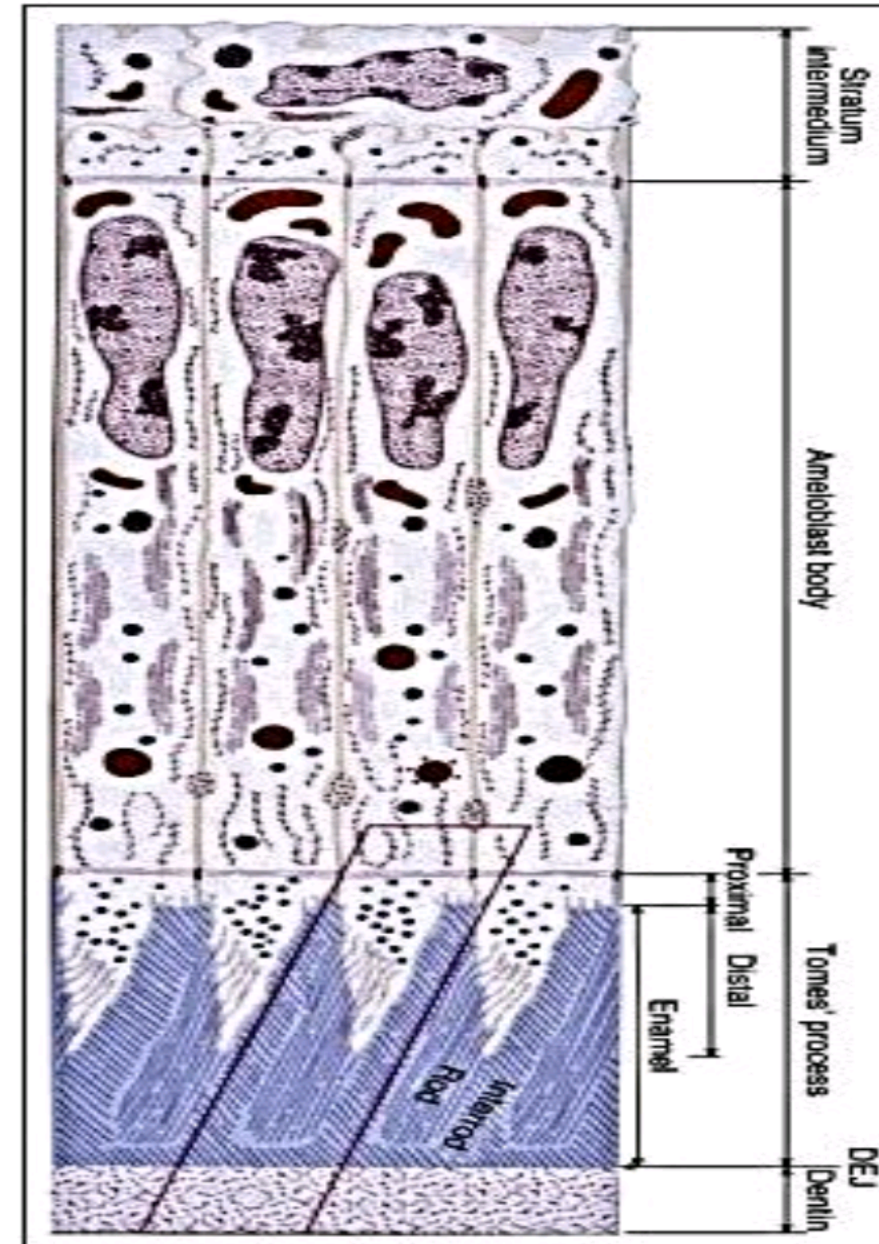
SECRETORY STAGE

- The fine structure of secretory stage ameloblasts reflects their intense synthetic and secretory activity.
- The **Golgi complex** is extensive and forms a cylindrical organelle surrounded by numerous cisternae of **rough endoplasmic reticulum** that occupying a large part of the supranuclear compartment.
- The messenger RNA for enamel proteins is translated by ribosomes on the membrane of the rough endoplasmic reticulum.
- The proteins then progress through the Golgi complex for continued posttranslational modification and are packaged into membrane-bound secretory granules.
- These granules migrate to the distal extremity of the cell, that is, into **Tomes' process**.

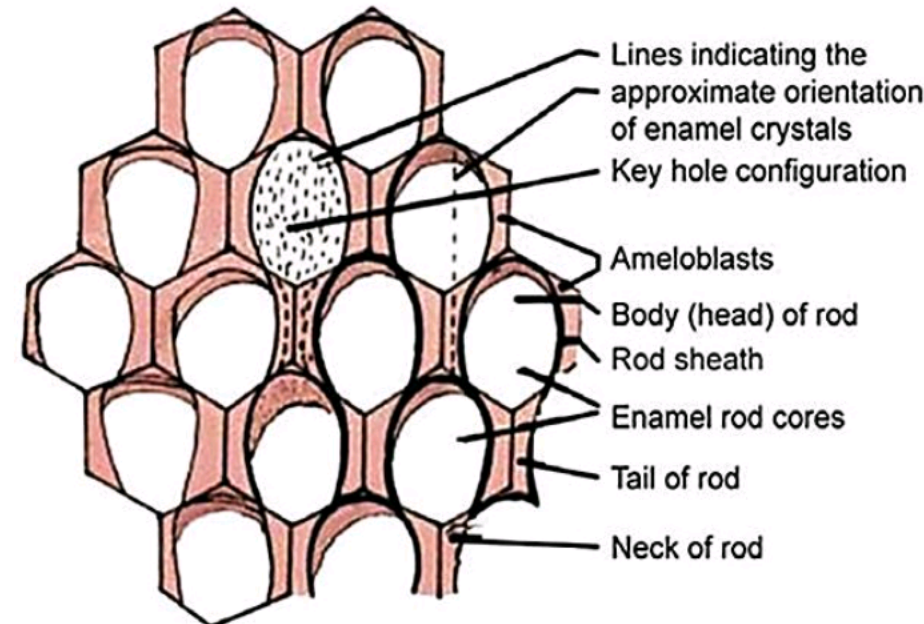
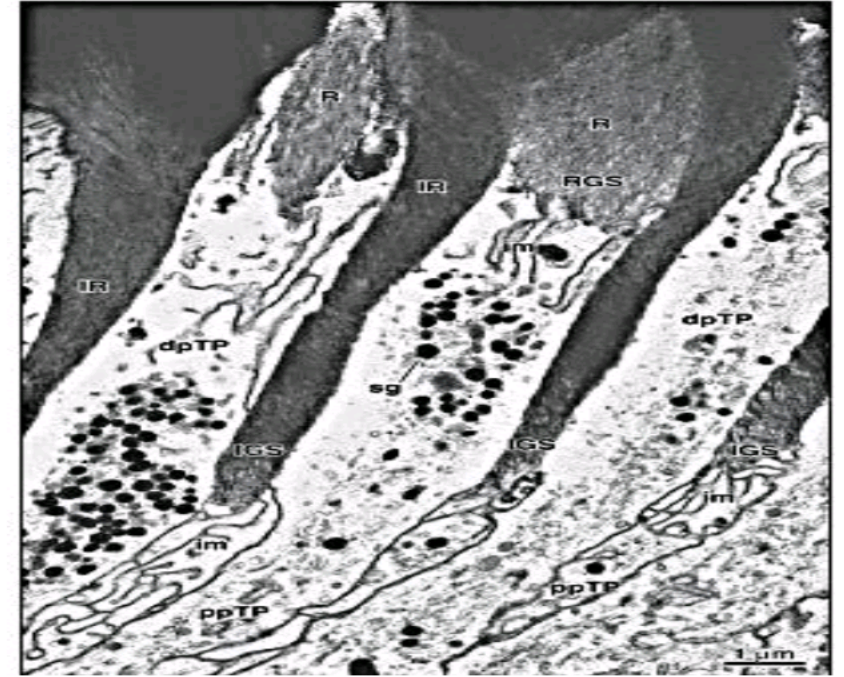


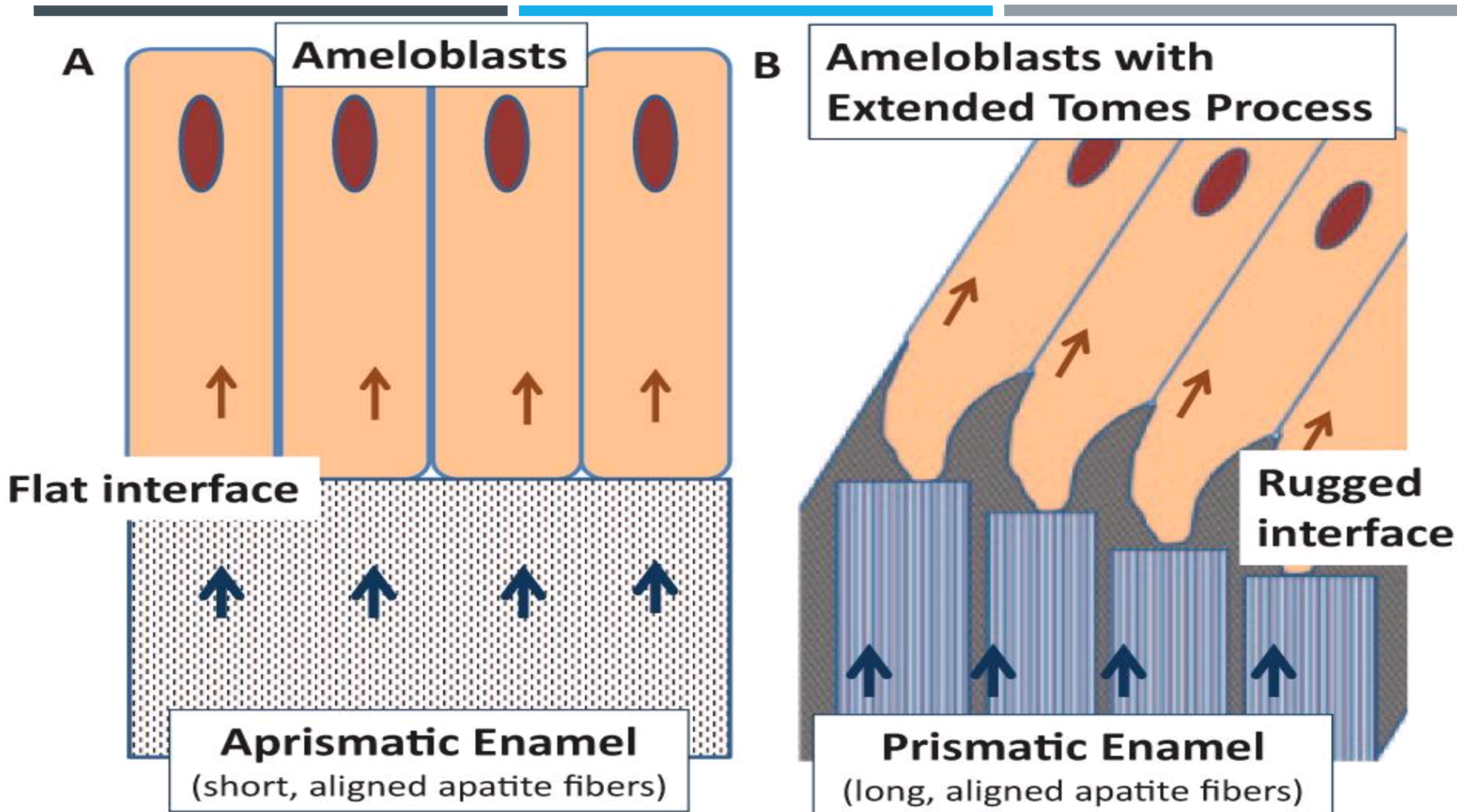
odontoblast

- When enamel formation begins, **Tomes' process composes only a proximal portion.** The content of secretory granules is released against the newly formed mantle dentin along the surface of the process to form an initial layer of enamel that does not contain enamel rods.
- Little if any time elapses between the secretion of enamel matrix and its mineralization. **The first hydroxyapatite crystals formed interdigitate with those of dentin.**
- As the initial enamel layer is formed, ameloblasts migrate away from the dentin surface and develop the distal portion of Tomes' process as an outgrowth of the proximal portion.
- The cytoplasm from both portions of Tomes' process is continuous with that of the body of the ameloblast. The rod and interrod configuration of enamel crystals is a property of the ameloblasts and their Tomes' processes.



- When the distal portion of Tomes' process is established, secretion of enamel proteins becomes staggered and is confined to two sites.
- Secretion from the first site on the **proximal end** of the process, close to the junctional complex results in the formation of **interrod enamel**.
- Secretion from the second site on the **distal end** of Tomes' process provides the matrix that participates in formation of the enamel rod. Formation of interrod enamel is always a first step because the cavity into which an enamel rod is formed must first be defined.
- Rod and interrod enamel differ only in the orientation of their crystallites





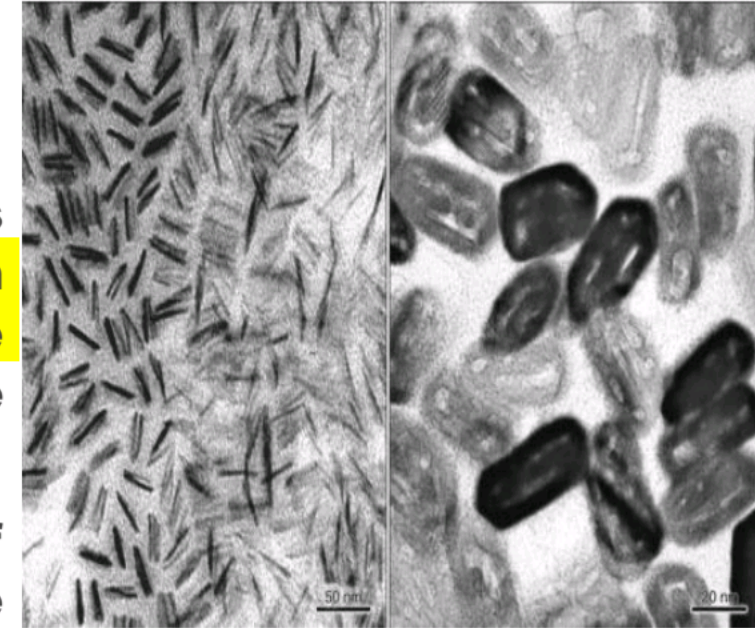
- The distal portion of Tomes' process generally is believed to lengthen as the enamel layer thickens and becomes gradually thinner.
- The distal Tomes' process eventually is squeezed out creating a narrow space along most of the circumference between rod and interrod enamel that fills with organic material and forms **the rod sheath**
- When the outer portion of the enamel layer is being formed, the ameloblast becomes shorter and loses its distal portion of Tomes' process, the final few enamel increments (**final enamel**), just as the first few, do not contain any rods.
- The enamel layer is thus composed of a rod/interrod-containing (prismatic) layer, sandwiched between thin, rodless (aprismatic) initial and final enamel layers.



 A prismatic enamel

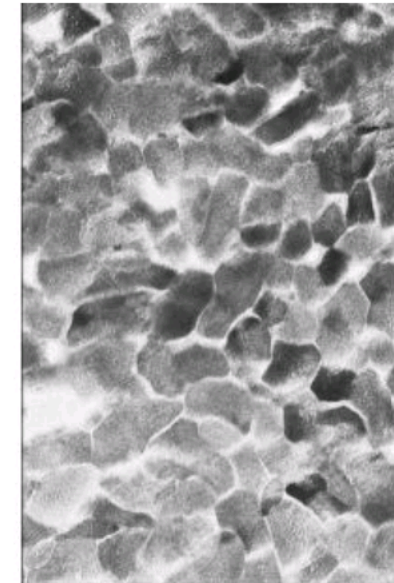
MATURATION STAGE

- Before the tooth erupts in the oral cavity, enamel hardens. This change in physicochemical properties results from **growth in width and thickness of preexisting crystals seeded during the formative phase** of amelogenesis and not because additional crystals are created de novo (see Figures A and B).
- Crystal growth during the maturation stage occurs at the expense of matrix proteins and enamel fluid that are largely absent from mature enamel. (see Figure C).
- Amelogenesis is a rather slow developmental process that can take as long as 5 years to complete on the crowns of some teeth in the permanent dentition in the human being; up to about two thirds of the formation time can be occupied by the maturation stage.
- Maturation stage referred to as postsecretory cells, they still synthesize and secrete proteins. These ameloblasts still exhibit a prominent Golgi complex, a structural feature consistent with such activity



A

B



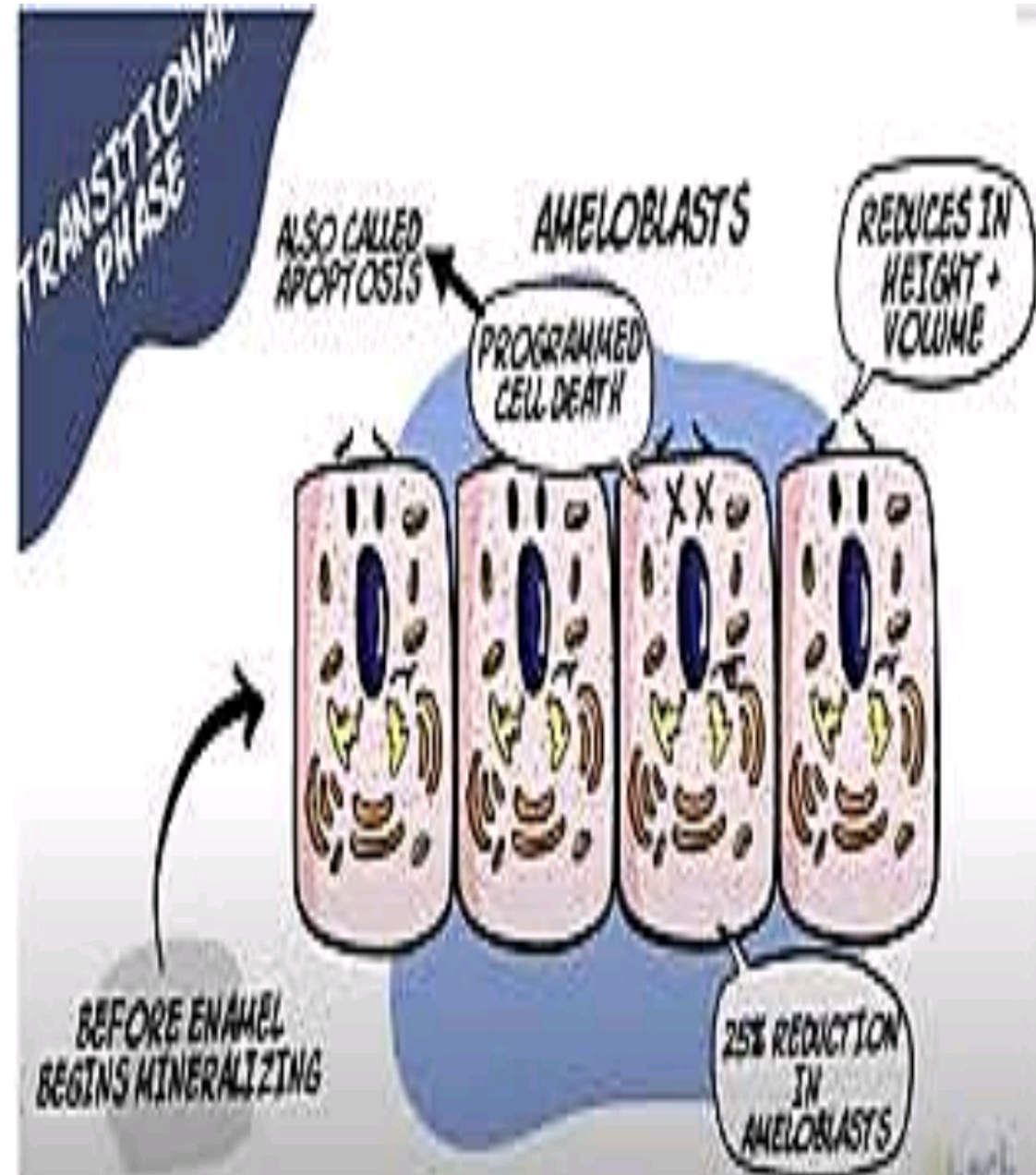
C

TRANSITIONAL PHASE

- After the full thickness of immature enamel has formed, ameloblasts undergo significant morphologic changes in preparation for their next functional role, that of maturing the enamel. **A brief transitional phase involving a reduction in height of the ameloblasts and a decrease in their volume and organelle content occurs.**

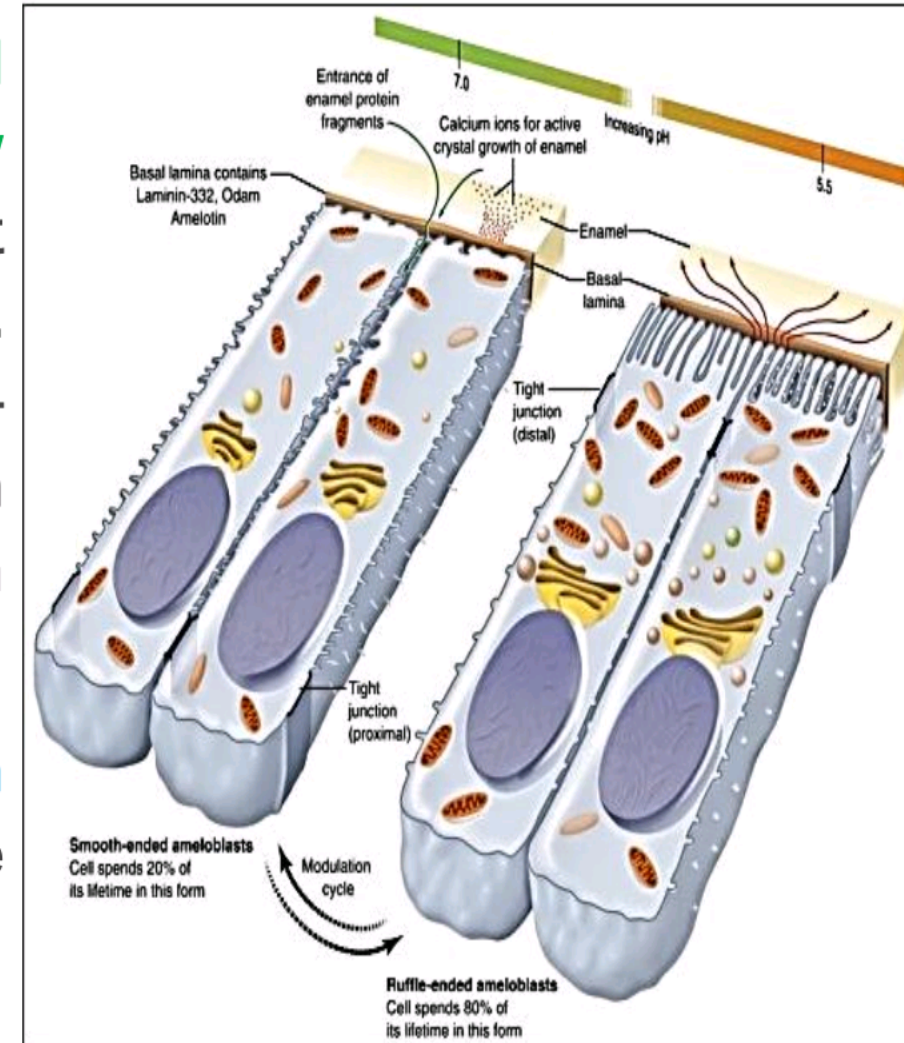
- During the maturation stage, ameloblasts undergo programmed cell death (apoptosis)

- approximately 25% of the cells die during the transitional phase, and another 25% die as enamel maturation proceeds.



MATURATION PROPER PHASE

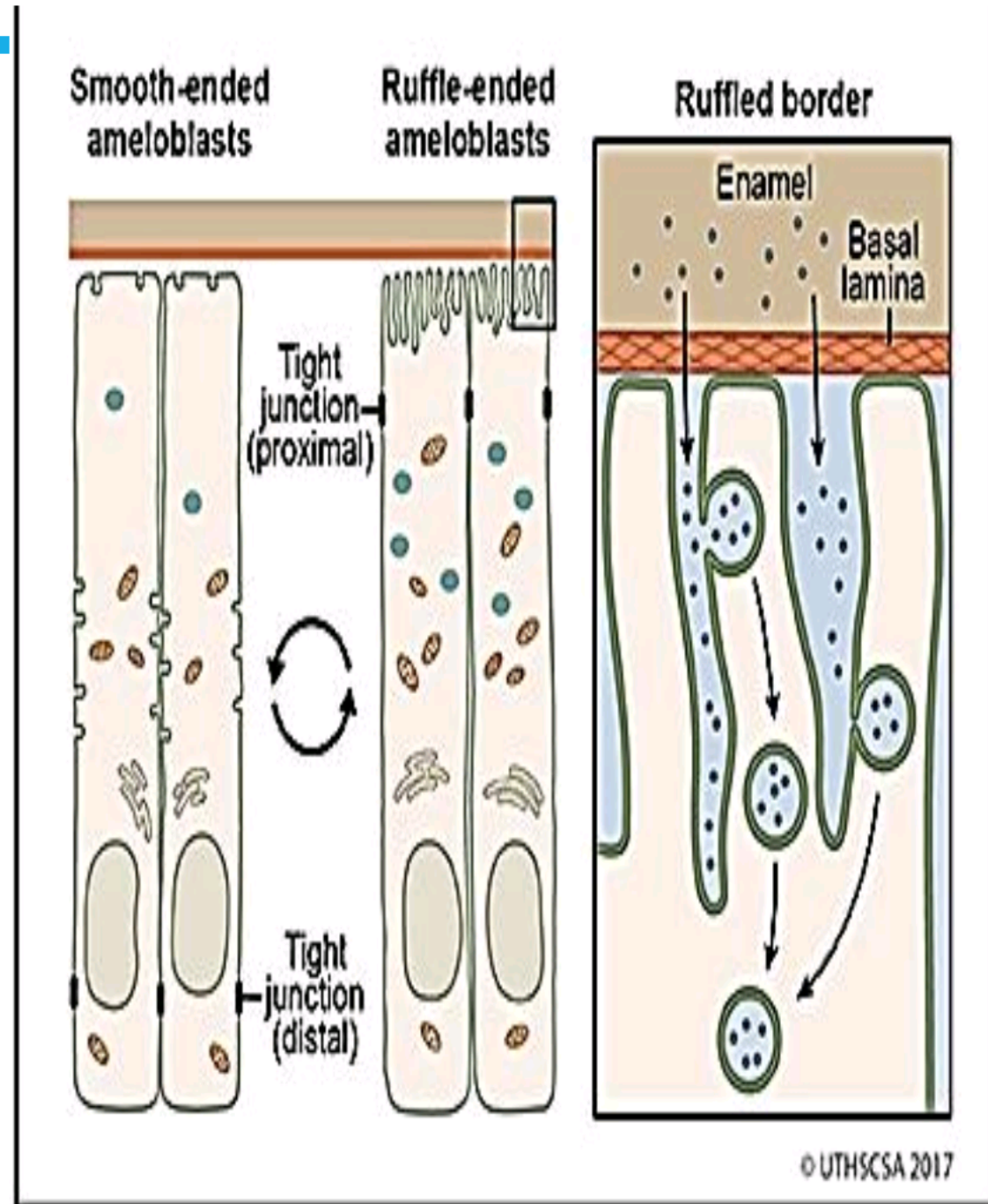
- the principal activity of ameloblasts is **the bulk removal of water and organic material from the enamel to allow introduction of additional inorganic material**. The most visually dramatic activity of these cells is modulation, the cyclic creation and loss of a highly invaginated ruffle-ended apical surface (the cells alternate between possessing a ruffled border [ruffle-ended] or a smooth border [smoothended]).
- ameloblasts in some species **modulate rapidly—as often as once every 8 hours**—thereby yielding three complete modulation cycles per day.



■ The significance of the modulations is not yet fully understood, but they appear to be related to 1-maintaining an environment that allows accretion of mineral content and loss of organic matrix, in part through alterations in permeability of the enamel organ.

2- acidification associated with ongoing mineral accretion during maturation causes ruffle-ended ameloblasts to produce bicarbonate ions.

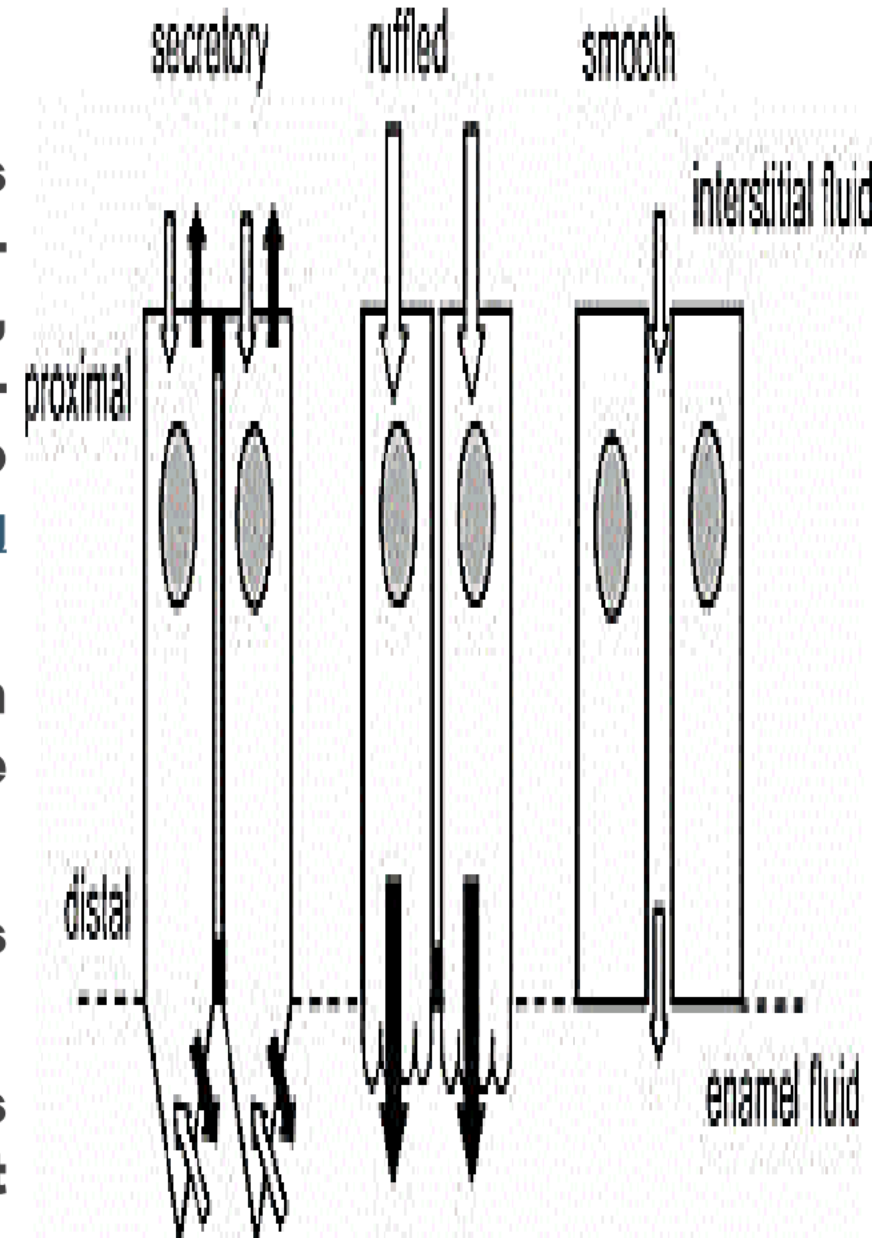
• This process continuously alkalizes the enamel fluid to prevent reverse demineralization of the growing crystallites



3- Ruffle-ended ameloblasts possess proximal junctions that are leaky and distal junctions that are tight, Ruffle-ended ameloblasts contains calcium-binding proteins, and membrane-associated calcium-adenosinetriphosphatases (ATPases) that appear to promote the pumping of calcium ions into the maturing enamel.

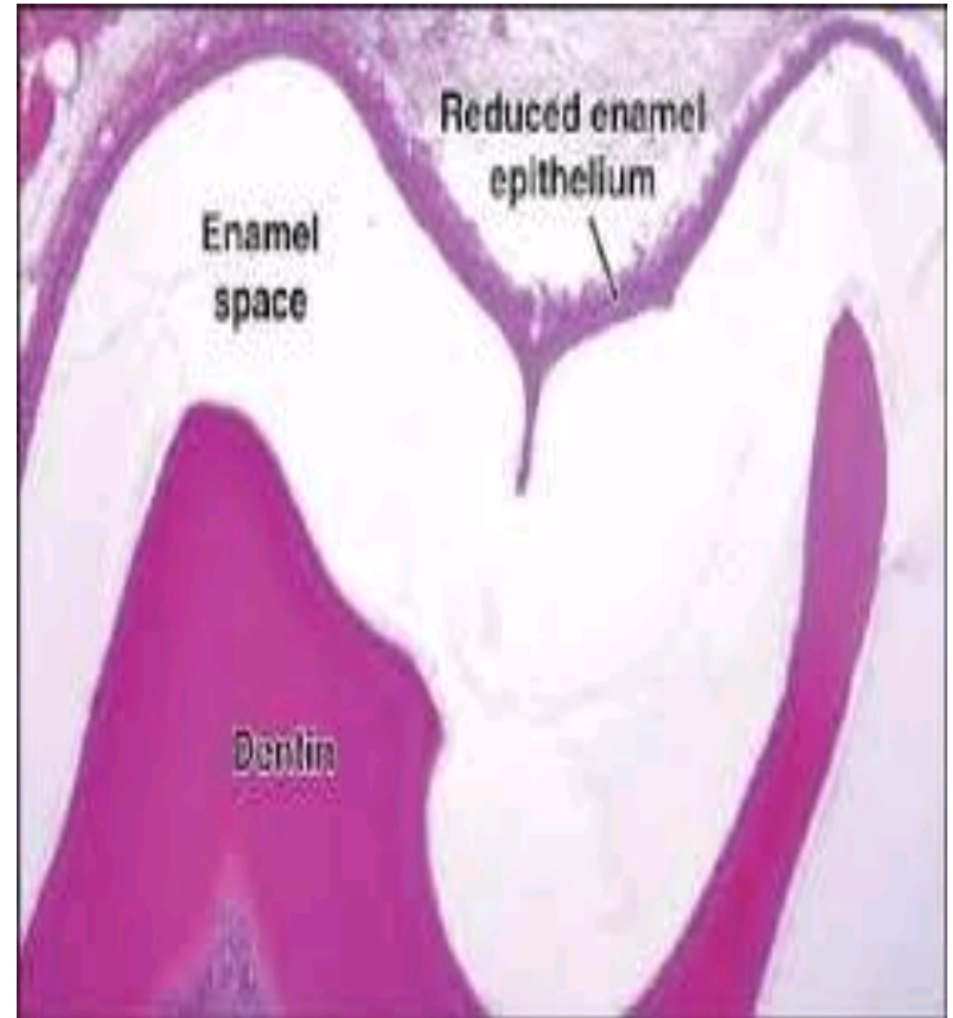
- **the calcium ions required for active crystal growth pass through the ruffle-ended ameloblasts (because their distal junctions are tight).**
- **Active incorporation of mineral ions into crystals occurs mainly in relation to the ruffle-ended cells.**

4- most smooth-ended ameloblasts have distal junctions that are leaky and proximal ones that are tight. That promotes proteins reabsorption.

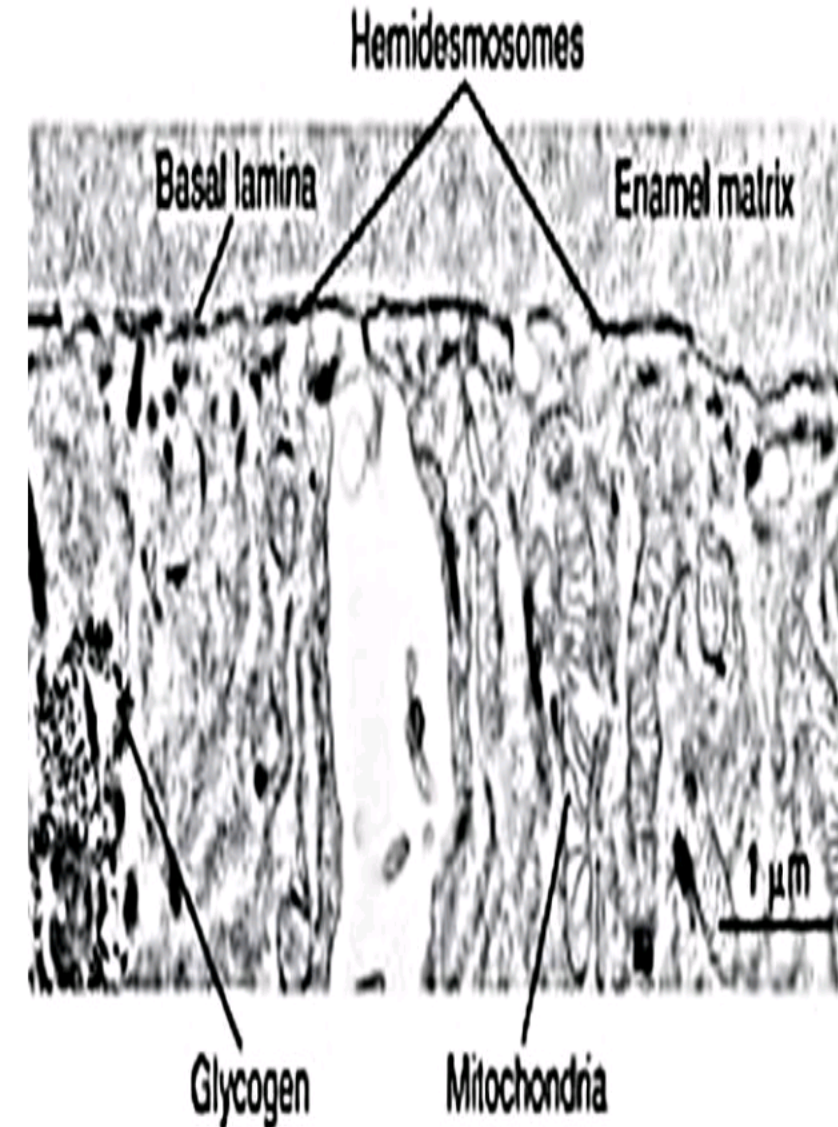


PROTECTIVE STAGE

- Near completion of enamel maturation, the ameloblasts lose their ruffled border and secrete a thin continuous layer that covers the enamel this is the primary enamel cuticle.
- The ameloblasts lose their regular arrangement and join the other layers of the dental organ to form the reduced enamel epithelium. (3-4 stratified flattened epithelial layer).
- **Reduced enamel epithelium** protects enamel from the connective tissue of the dental follicle until tooth erupt.
- If cells of dental sac come in contact with enamel, tooth resorption or cementum deposition (afibrillar cementum) occurs.

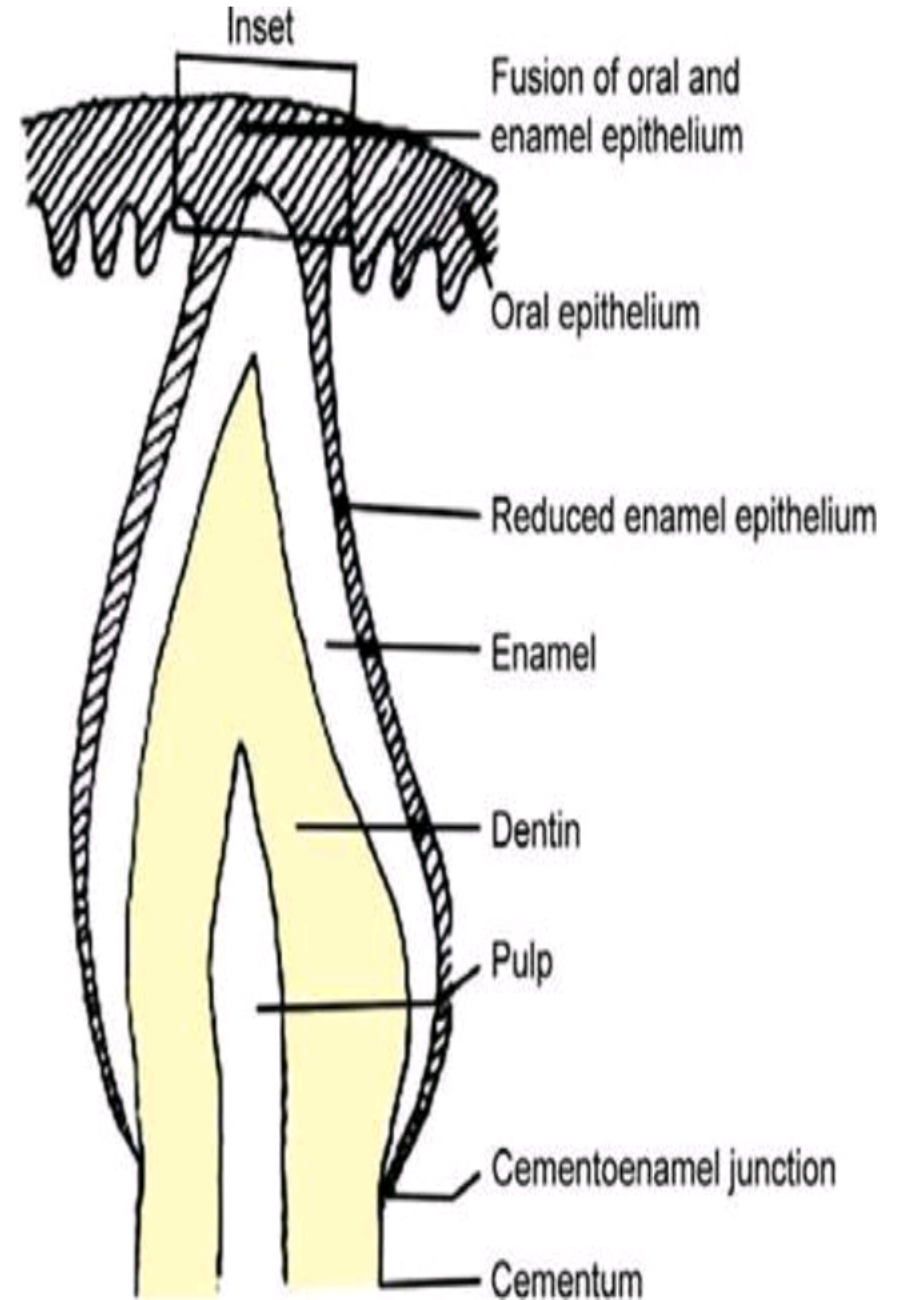


- This interfacial layer adheres to the enamel surface, and the ameloblasts attach to it by means of hemidesmosomes.



DESMOLYTIC STAGE

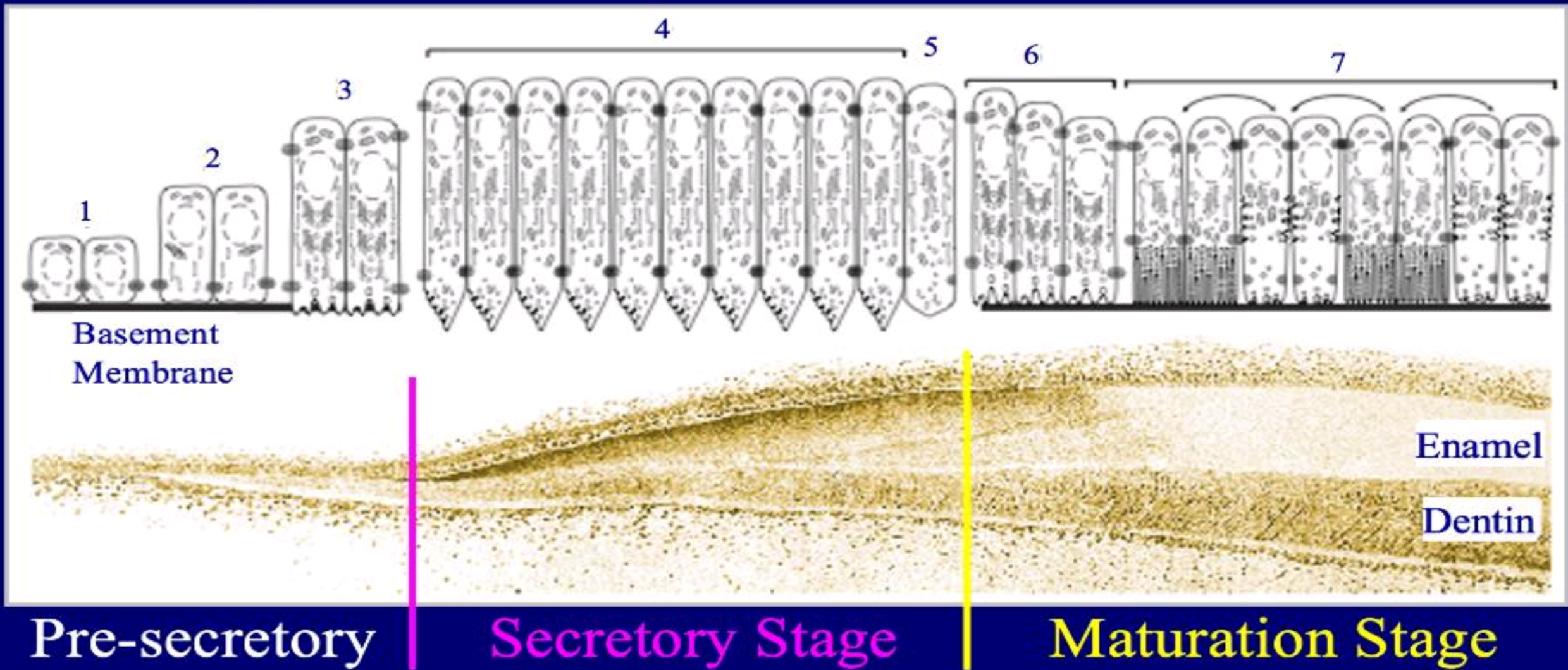
- Reduced enamel epithelium produces **enzymes** that causes destruction of the connective tissue separating the erupting tooth from the oral epithelium.



THE INNER ENAMEL EPITHELIUM

- the cells are involved in establishing the crown pattern of the tooth (morphogenesis); at this time they are small and low-columnar with centrally placed nuclei, and they undergo frequent mitoses.
- Then, the cells undergo morphologic changes, and they become ameloblasts (histodifferentiation). These changes are preparatory to their entering the next phase, active secretion of the enamel matrix, wherein they develop the Tomes' process.
- The secretory stage is followed by a short transitional phase of cell restructuring leading to enamel maturation proper, wherein the ameloblasts exhibit cyclical variations with ruffle- and smooth-ended borders against the enamel surface, the ruffle-ended cells allowing incorporation of inorganic material and the smooth-ended cells permitting exit of protein fragments and water. The final phase is protection of the newly formed enamel surface until the time of tooth eruption.

SUMMARY



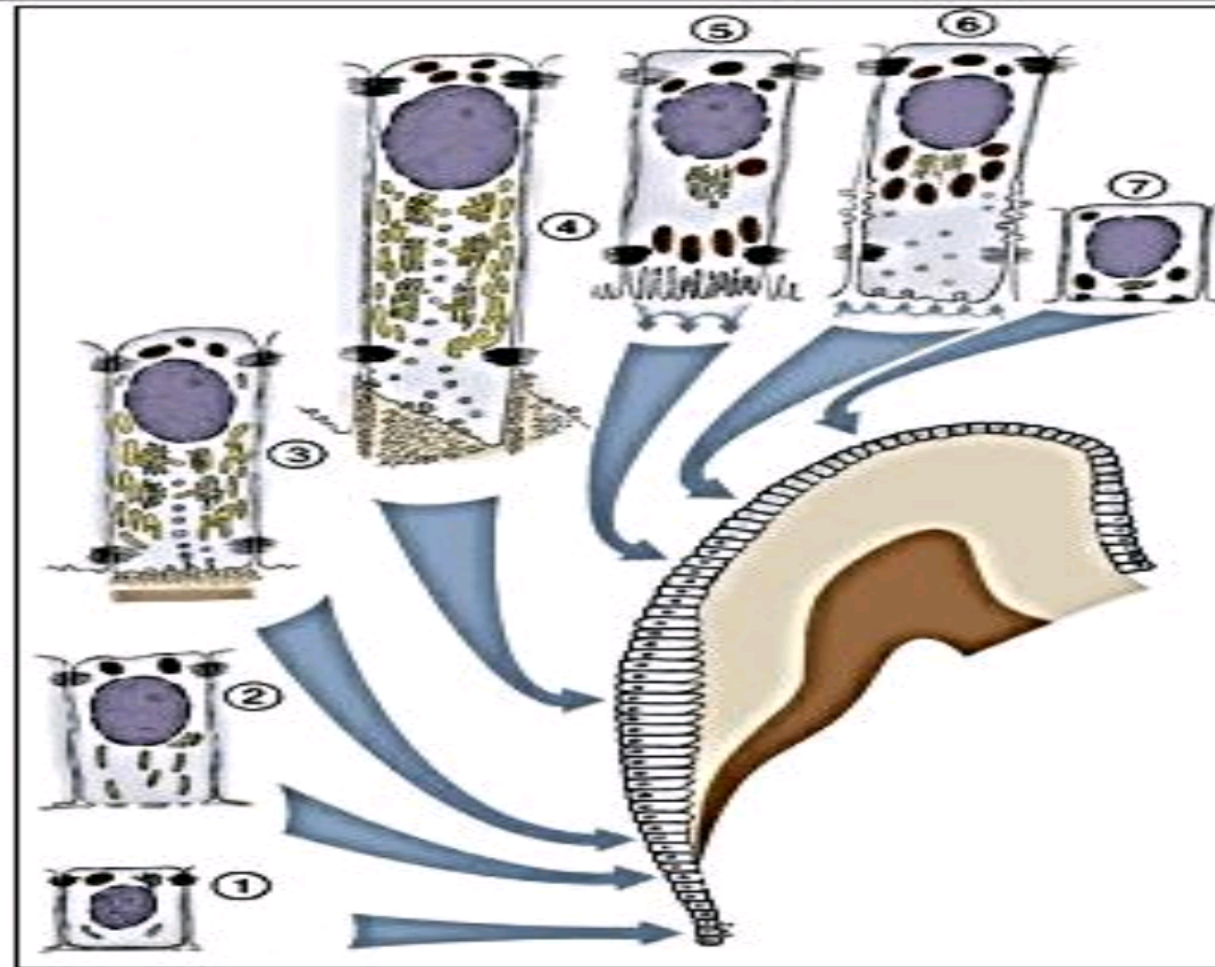


FIGURE 7-14 Schematic representation of the various functional stages in the life cycle of ameloblasts as would occur in a human tooth. 1, Morphogenetic stage; 2, histodifferentiation stage; 3, initial secretory stage (no Tomes' process); 4, secretory stage (Tomes' process); 5, ruffle-ended ameloblast of the maturative stage; 6, smooth-ended ameloblast of the maturative stage; 7, protective stage.