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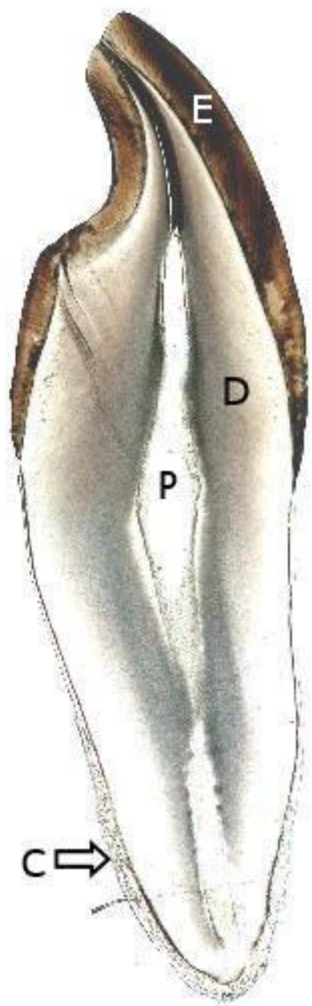
Second stage - Al Ameed University

College of Dentistry 2024-2025

ENAMEL

Enamel is forming a hard protective covering of variable thickness over the entire surface of the crown of the tooth. It is the hardest biological substance. Unlike dentin, cementum and bone, enamel is ectodermal in origin. Enamel provides shape to the crown of teeth and covers part of the tooth exposed to the oral environment.
It meets the dentin at the dentinoenamel junction (DEJ) and the cementum at cementoenamel junction (CEJ). Enamel is composed of interlocking rods that resist masticatory forces.

Enamel most highly mineralized extracellular matrix 96% mineral 4% organic material & water.



Physical properties:

Thickness: The maximum thickness of enamel is on the cusps of human molars and premolars where the impact of mastication is greatest. It is 2-2.5 mm thinning down, in cervical region, to almost a knife edge at the neck of tooth where masticatory impact is the least.

Hardness: Enamel is considered as the hardest calcified tissue in human body due its high content of mineral salts and their crystalline arrangement. Thus, the enamel is forming a resistance covering of the teeth, making it suitable for mastication. This hardness renders the enamel brittle (dentin is more elastic). In deciduous teeth, the enamel is less hard than that of permanents teeth. Enamel can endure crushing pressure of approximately 100,000 pounds per square inch. A layering of the dentin and periodontium, coupled with the hardness of the enamel, produces a cushioning effect of the tooth's different structures enabling it to endure the pressures of mastication.

Permeability: With the use of radioactive tracer (as C_ label urea, or iodine etc….), it has been found that the enamel is acting as a semi permeable membrane.

Color: The color is ranging from yellowish white to grayish white depending on the difference of **translucency** of enamel. The translucency of enamel is due to the variation in the degree of calcification, thickness, and homogeneity of enamel. The yellowish teeth are having thin translucent enamel reflecting through which the yellow color of the dentin. Grayish teeth are having more opaque enamel. Thus the color of the enamel is reflections to the color of the dentin. The enamel on deciduous teeth are appearing much whiter.
The translucency of the enamel increases with age and some of the color of the dentin is then transmitted in a more yellowish appearance.

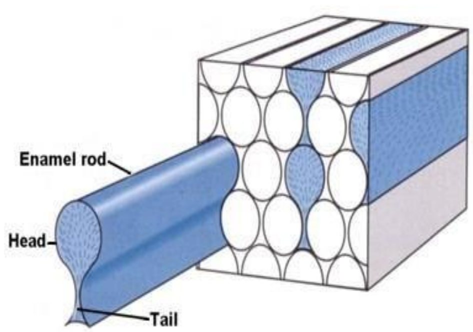
Chemical properties:

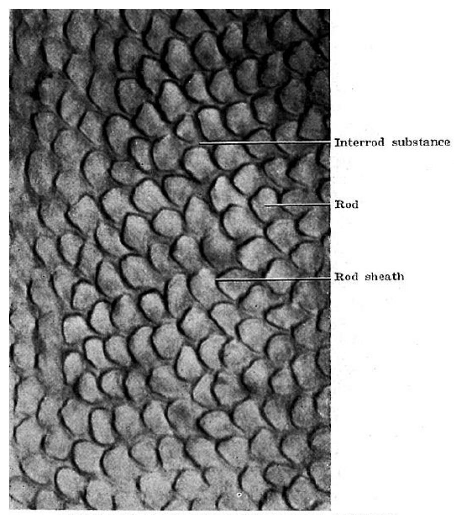
The enamel consists mainly of inorganic materials (96%), mainly in the form of calcium phosphate, and small amount of organic substance and water (3% water, and 1% organic substance). The inorganic material of enamel is arranged in a form of hydroxy apatite crystals. The protein of the enamel is **noncollagenous protein**, which includes enamelin and amelogenin.

The hydroxy apatite crystals of the enamel are four times much larger than those of other calcified tissue in the body. They are about 70nm in width, 25 nm in thickness.

Structure:

Structurally, enamel is composed of millions of enamel rods or prisms, rod sheath and cementing interprismatic substance.
An enamel rod is the basic unit of tooth enamel. An enamel rod is a tightly packed, highly organized mass of hydroxyl apatite crystals
Each rod begins at the dentinoenamel junction (DEJ) and extends to the outer surface of the crown. Enamel is formed by epithelial cells (ameloblasts) that lose their functional ability when the crown of the tooth has been completed. Therefore, enamel, after formation, has no power of further growth or repair. The number of enamel rods is ranging from 5 million in the lower lateral incisors to 12 million in the upper first molars. They ran from DEJ to the surface of tooth in a somewhat tortuous course. The length of most rods is greater than the thickness of enamel because of the oblique direction and wavy course of the rods. The rods located in the cusps (the thickest part of enamel) are larger than those at cervical areas of the teeth. The diameter of the rods is about 4 um and increases from DEJ towards the surface of enamel at a ratio of 1:2. In cross section under light microscope the enamel rods are compared to a keyhole.





From Orban (1949) Oral Histology and Embriology. St. Louis: C.V. Mosby.

Clinical consideration

Enamel rods can resist masticatory impact of 12-25 kg per tooth.

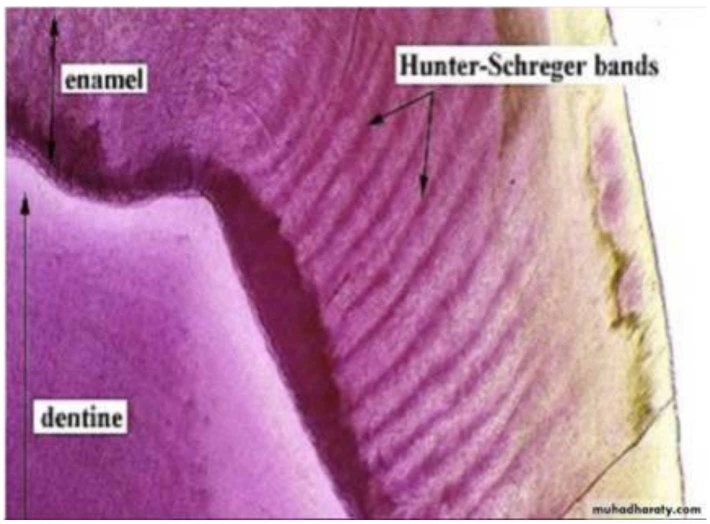
Hunter-Schreger bands:

The change in the direction of enamel rods is responsible for the appearance of these bands, which are alternating dark and light bands of varying width (nearly 50 um apart), best seen in longitudinal ground sections under oblique reflected light. They originate at the DEJ and pass outwards ending at some distance from the outer enamel surface. These **bands represent:**

a) variation in calcification of enamel.

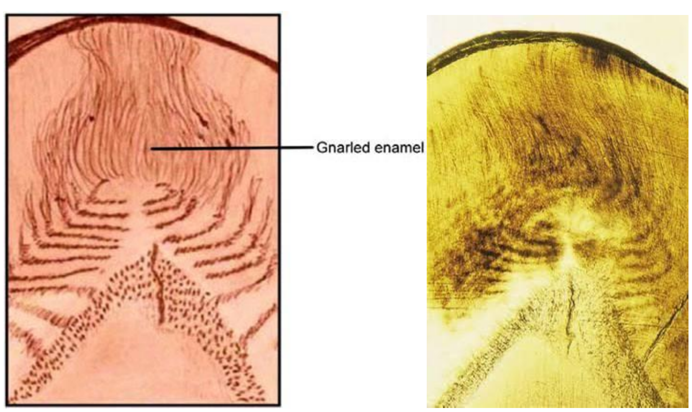
b) different content of organic material.

c) variations in the course of adjacent groups of prisms.



Gnarled enamel:

It is an optical appearance of enamel. Near the dentin in the region of cusps or incisal edges the rods arrangement appears to be further complicated as the bundles of rods seems to intertwine more irregularly. This arrangement in the cuspal or incisal regions is to withstand and bear the high force of masticatory load imposed on these regions.



Incremental lines of enamel:

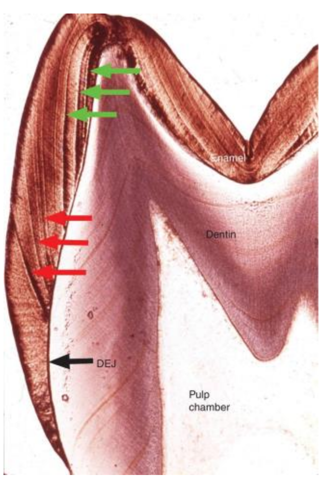
The incremental lines in enamel are the result of rhythmic recurrent deposition of the enamel.
Mature enamel like in any hard tissue in the body, is characterized by the presence two different incremental lines. Both reflect the fact that enamel, during amelogenesis, grows by an appositional process characterized by alternating periods of growth and rest. Both incremental lines are best demonstrated by ground sections.

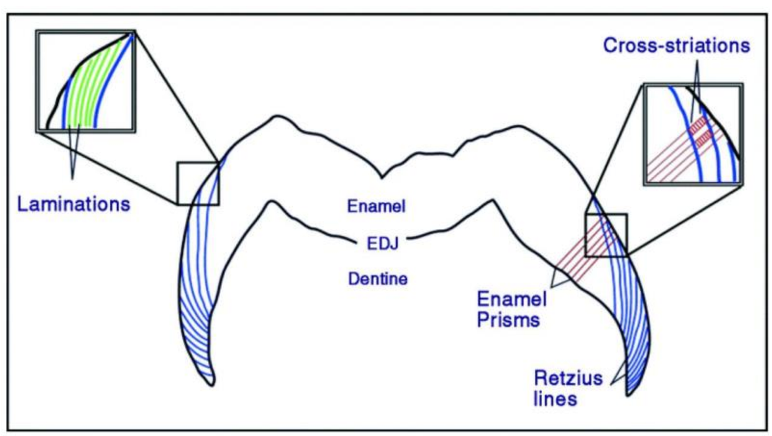
1. Cross striations:

Represent incremental lines indicative of daily appositional growth of enamel i.e. daily increment of amelognesis.They occur at repeating intervals of 4-6 um subdivide the enamel prisms into brick-like units of well calcified enamel. Striations are more pronounced in enamel that insufficiently calcified.

2. Incremental lines of Retzius (Brown striae):

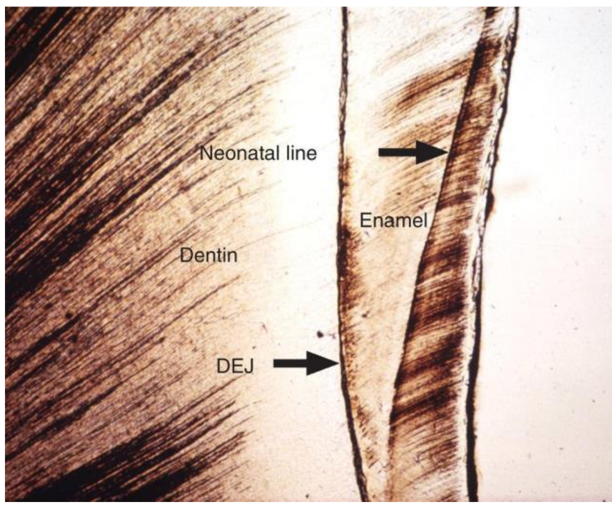
They are a series of bands appear in ground sections of enamel. They illustrate the successive apposition of layers of enamel during formation of crown at approximately weekly intervals. The striae (or lines) are 20-80 um apart and 4-15 um in width. In longitudinal section they surround the tip of the dentin. In the cervical part of the crown, they run obliquely from DEJ to the surface they are deviating occlusally. In transverse section these incremental lines appear as concentric circles. The lines reflect **variation in structure and mineralization either hypomineralizion or hypermineralizion that occur during amelogenesis.**





3. The neonatal line in enamel:

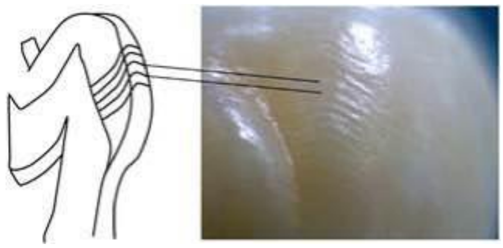
It is considered as one kind of incremental line of Retzius and represents the boundary between the prenatal enamel and postnatal enamel. This line is seen in all deciduous teeth and also in the region of the mesial cusps of all first permanent molars. It arises at the time of birth, marking the boundaries between prenatal and postnatal enamel and dentin. It appears to result of the abrupt change in the environment and metabolic disturbances of the new born infant. The prenatal enamel is usually better developed than postnatal enamel. In children with low birth weight, deciduous teeth are formed with wide neonatal lines and hypoplastic postnatal enamel because of disturbances of calcification.

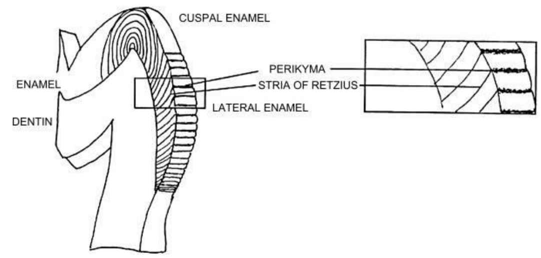


Surface structures of enamel:

1. **Prismless enamel**: This is a structureless layer of enamel with a 30um thickness below the surface of enamel. It is found in 70% of permanent teeth and all deciduous teeth. It is least often over the cusp tips and most commonly towards the cervical areas of the enamel surface. No prisms are visible in this layer and all apatite crystals are parallel to one another and perpendicular to the striae of Retzius. It is more heavily mineralized than the bulk of enamel beneath it.This type of enamel also found near the dentino-enamel junction (DEJ). Prismless enamel is formed due to absence of Tome's process from the ameloblasts. Prismless enamel contains more fluoride than the deeper enamel.

2. **Perikymata**: are transverse waves like grooves believed to be the external manifestation of the incremental lines of Retzius





3. **Enamel rod ends**: They are concave and vary in depth and shape. They are shallowest in the cervical regions of surfaces and deepest near the incisal or occlusal edges.

4. **Cracks**: Surface narrow fissure like structures representing the outer edge of enamel lamellae. They extend for varying distance along the surface, at right angle to DEJ, from which they originate. Most of them are less than 1 um in length but some are longer and a few reaches the occlusal or incisal edge of the surface.

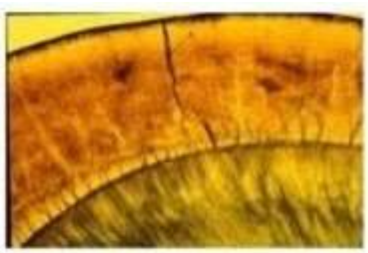
5. **Enamel cuticle** (other names are; **Nasmyth's membrane** or primary enamel cuticle): A delicate membrane 0.5-1.5 um thick covers the entire crown of the newly erupted teeth, but is soon removed by mastication. Electron microscopic studies showed that it is a typical basal lamina apparently secreted by ameloblasts when enamel formation is completed.

6. **Enamel pellicles**: Erupted enamel is normally covered by a pellicle which is a precipitate of salivary proteins. This pellicle is reformed within hours after an enamel surface is mechanically cleaned. Within a day or two after the pellicle has formed, it becomes colonized by microorganisms to form bacterial plaque. When the plaque is calcified it will be converted to form calculus.

Hypocalcified structures in enamel:

1. Enamel lamellae:

Are thin leaves like structures that extend from the enamel surface toward the DEJ. They may extend to and sometimes penetrate into dentin. They consist of organic materials with little mineral content. In ground sections these structures may be confused with cracks caused by grinding of the specimen. Careful decalcification of ground section can distinct between crack and enamel lamellae. The former disappear whereas the latter persist. Lamellae may develop in plans of tension, where rods cross such plane, a short segment of the rod may not fully calcify. If the disturbance is more sever, a crack may develop that is filled by the surrounding cells. The cracks may occur in the un-erupted tooth. Also, the crack may be filled by organic substances from the oral cavity if the crack has developed after eruption.

There are three types of lamellae:
a) Type A which is composed of poorly calcified rod segments,

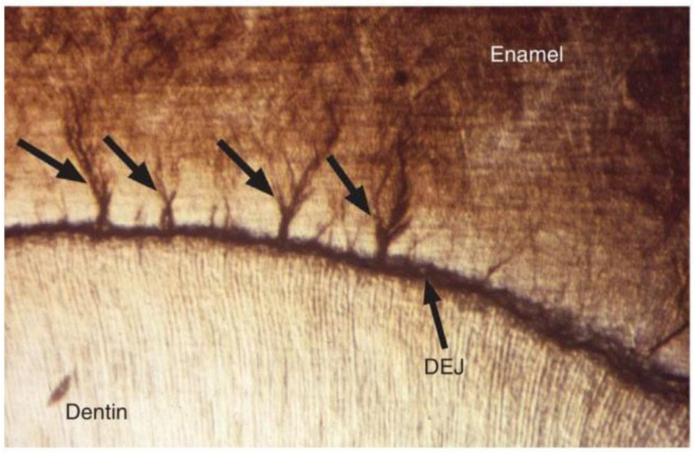
b) Type B which is consisting of degenerated cells of enamel organ,

c) Type C which is arising in erupted teeth where the cracks are filled with organic matter originating from the saliva.

Type A and B are arising before eruption, while type C arises after eruption. In addition to that types B and C cross the DEJ, type A not.
Enamel lamellae may be a site of weakness in the teeth and may form a road of entry for bacteria that initiates caries.The lamellae extend in the longitudinal and radial direction in the tooth, from the tip of the crown toward the cervical region. This arrangement explains why they can be observed better in horizontal sections.

2. Enamel tufts:

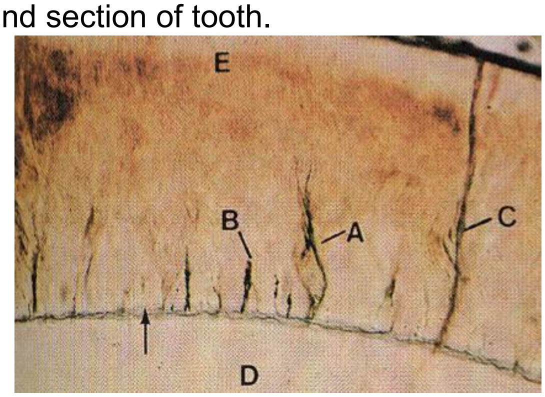
These are hypocalcified areas in enamel occurring in enamel due to defects in process of calcifications of enamel rods leading to an increase in the percentages of organic matters. They arise at the DEJ and reach to about one fifth to one third of the thickness of the enamel. They were so named because they resemble a tuft of grass when viewed in ground sections. They consist of hypocalcified enamel rods and interprismatic substance. Like the enamel lamellae they are extending in the direction of long axis of the crown. Therefore, they are seen mostly in cross transverse sections of the crown.



3. Enamel spindles:

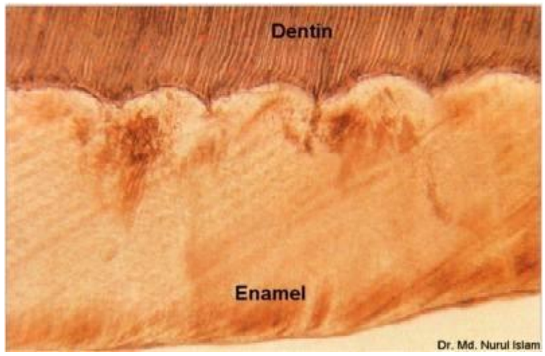
One type of structural defects in the enamel

Occasionally odontoblastic processes cross the DEJ 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 (insinuate) in between the preameloblast before hard substance were formed. They appear at angles to the surface of dentin. In ground sections the spindles are replaced by air and the spaces appear dark in transmitted light. Enamel spindles extend from the dentin surface, 10-40 um into the enamel. They are common beneath cusps and incisal edges. Enamel spindles are best seen in longitudinal ground section of tooth.



Dentinoenamel junction (DEJ):

The surface of the dentin at the DEJ is pitted. In to the shallow depressions of the dentin, fit rounded projections of the enamel. This relation assures firm hold of the enamel on the dentin to prevent tissue shearing apart during mastication. In ground sections the DEJ appears not as a straight line but as a **scalloped line**.



DEVELOPMENT OF ENAMEL: -

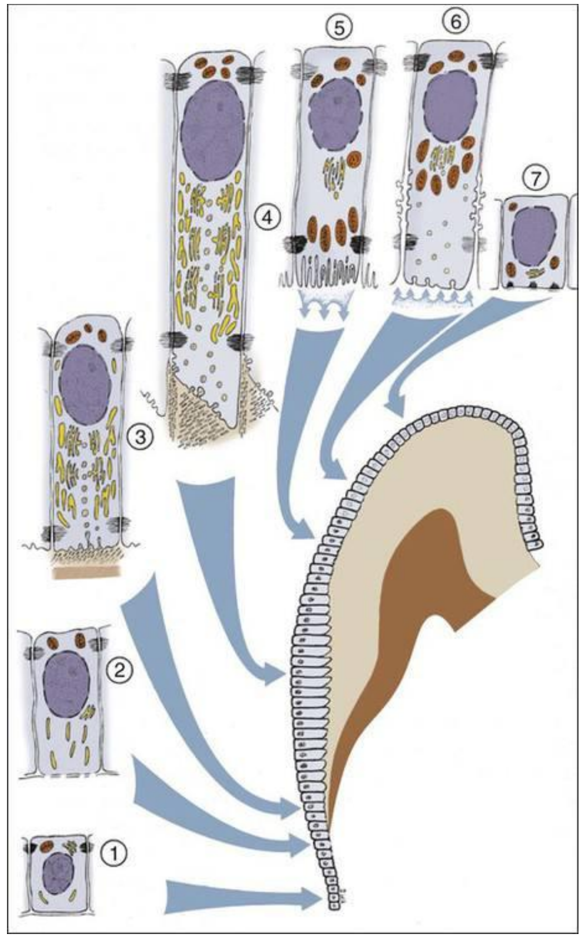
LIFE CYCLE OF AMELOBLAST: -

According to their function, the life span of the cells of the inner enamel epithelium can be divided into six stages: morphogenic, organizing, formative, maturative, protective, and desmolytic. Since the differentiation of ameloblasts is most advanced in the region of the incisal and cusp, all or some stages of the developing ameloblasts can be observed in one tooth germ, because ameloblasts are not yet fully differentiated in the region of cervical loop.

1. **Morphogenic stage:**

Before the ameloblasts are fully differentiated and produce enamel, they interact with the adjacent ectomesenchymal cells of dental papilla, to determine the shape of the DEJ and the crown. During this stage(bell stage) the cells are still called inner enamel epithelium, they are still short columnar with large oval nuclei that almost fill the cell body.

1. Morphodifferentiation
2. organizing
3. Secretory (initial)
4. Secretory (Tomes' process)
5. Maturation (ruffle-ended)
6. Maturation (smooth-ended)
7. Protective(as part of reduced enamel epithelium)

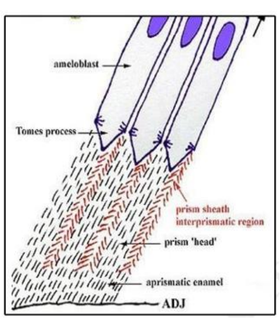


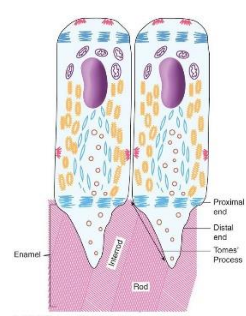
2. Organizing stage:

In this stage the IEE interacts becomes tall. There is reversal of functional polarity, by migration of centeriols and Golgi apparatus from proximal end to the distal ends of the cells. The mitochondria concentrate in the proximal part of the cells.

3) **Formative stage:**

This stage starts after the first layer of dentin has been formed During this stage the ameloblast retain the same length and arrangement. The earliest apparent change is the development of blunt cell processes on the distal end of the ameloblast, which penetrate the basal lamina and enter the dentin. This process is called **Tome's process.**



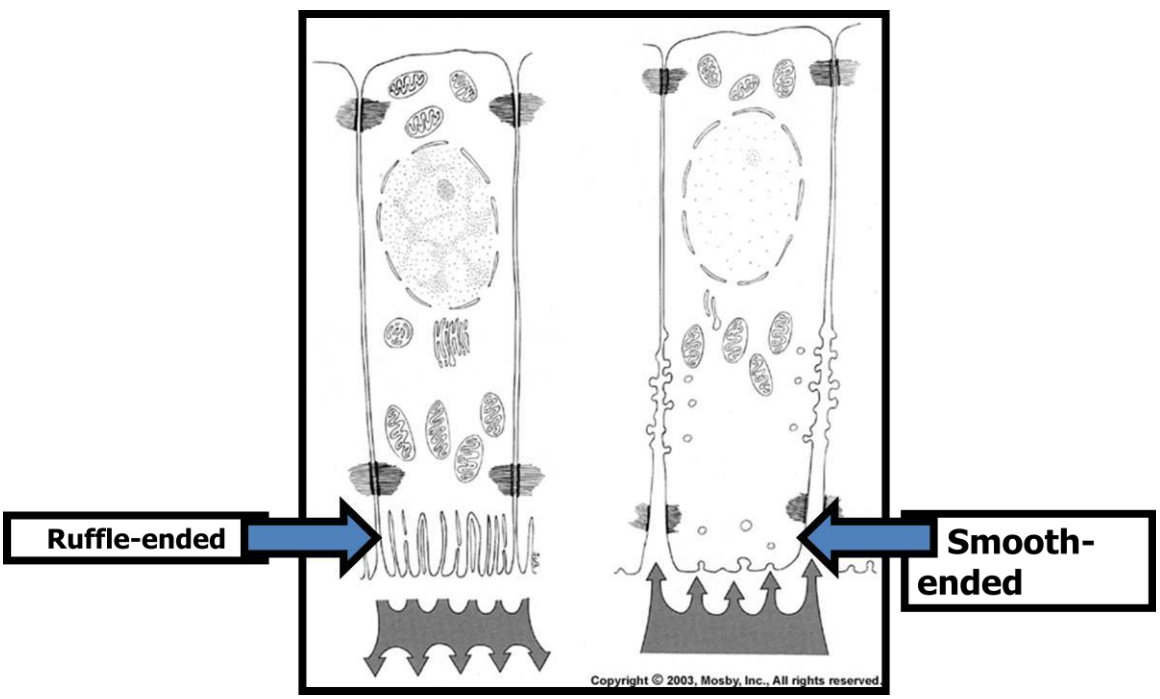


N.B: **The Tome's process**:

Is a conical blind distal extension at the distal end of each ameloblast, and it is marked off from the rest of the cell by the terminal bar. The terminal bar of the ameloblasts represents a form of junctional complex. At the proximal end of the ameloblasts a similar terminal bar is found. The Tome's processes are necessary to give keyhole arrangement of the enamel rods. Absence of Tome's processes lead to the formation of prismless enamel. Each head of the rod is formed by one ameloblast, where as three others contribute to the tail of each rod. Thus four ameloblast are related to formation of each rod.

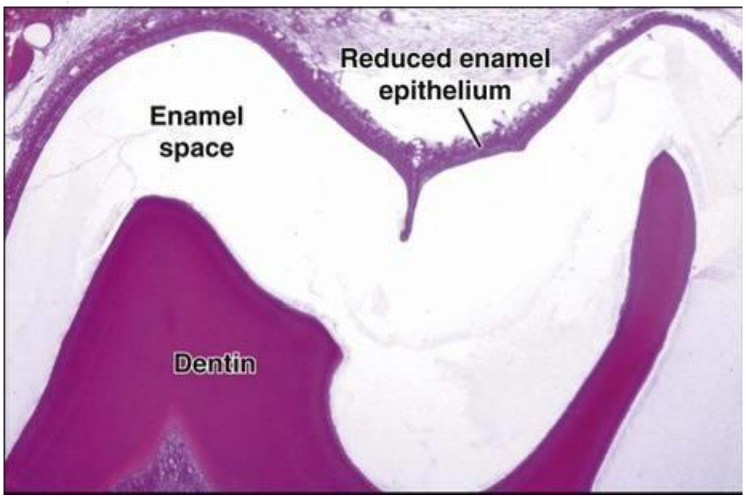
4) **Maturative stage:**

Enamel maturation (full mineralization) occurs after most of the thickness of enamel matrix has been formed in the occlusal or incisal areas. In the cervical parts of the crown, enamel matrix formation is still progressing. The ameloblasts are slightly reduced in length and are closely attached to enamel matrix. The cells of stratum- intermedium lose their cuboidal shape and regular arrangement and assume spindleshape. During maturation the ameloblasts display microvillus at their distal ends and cytoplasmic vacuoles containing material resembling enamel matrix. This arrangement indicates an absorptive function of these cells.



5. Protective stage:

After enamel maturation, the ameloblasts cease to be arranged in a well-defined layer and can no longer be differentiated from the cells of the stratum intermedium and OEE. These cells layer then form a stratified covering on the surface of enamel called **reduced enamel** epithelium. The function of the reduced enamel epithelium is to protect the mature enamel by separating it from the connective tissue until the tooth erupts. If the connective tissue comes in contact with the enamel, anomalies may develop. Under these conditions the enamel may be either resorbed or covered by a layer of cementum.



6. Desmolytic stage: -

The reduced enamel epithelium proliferates and seems to induce atrophy of the C.T separating it from the oral epithelium. Thus, the fusion between the two epitheliums can occurs. The cell of reduced enamel epithelium secretes enzymes that are able to destroy C.T fibers by desmolysis. Premature degeneration of reduced enamel epithelium may prevent the eruption of the tooth.

AMELOGENESIS:

The development of enamel involves two processes:

a. **Organic matrix formation.**

b. **Calcification (mineralization)**

A- organic matrix formation:

The ameloblasts begin their secretory activity when small amount of dentin has been laid down. They lose their projections that had penetrated the dentin and islands of enamel matrix are deposited along the dentin. As enamel deposition continues, a thin, continuous layer of enamel matrix is formed along the dentin. This has been termed the dentinoenamel membrane. Its presence account for the fact, that the distal ends of enamel rods are not in direct contact with the dentin.

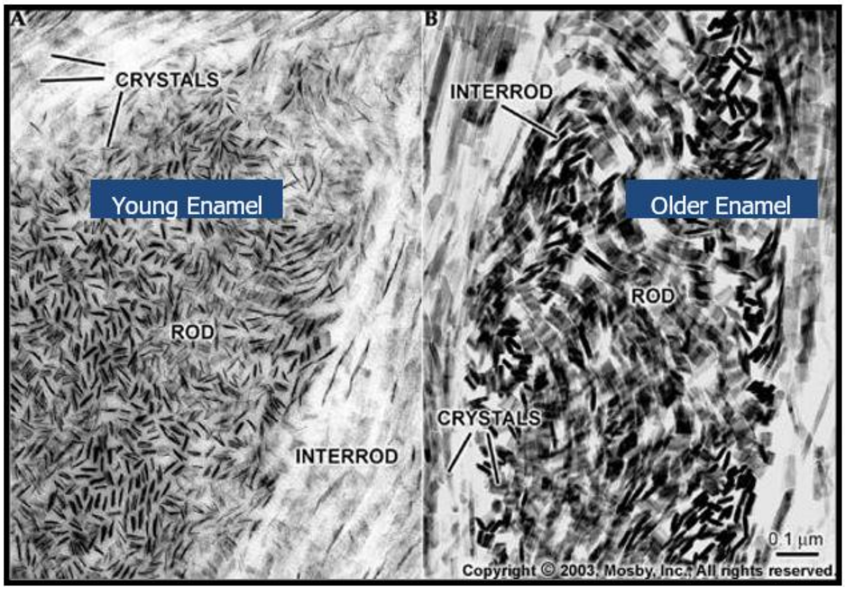
The newly formed (deposited) enamel is containing 65% water, 20% organic material and 15% inorganic).

B- Mineralization and maturation of enamel matrix maturation:

Is defined as the process by which the immature (partially calcified) enamel is converted to mature (highly calcified) enamel. Mineralization of enamel matrix takes place in two stages:

1. An immediate partial (initial) mineralization occurs in matrix of enamel as it is laid down. This initial influx may account **up to 30%** of final mineral content. This first mineral is in the form of crystalline apatite. Mineralization is a gradual process. This process starts from the height of the crown and progressing cervically.

2.Maturation is characterized by growth of crystals seen in the primary phase. The first formed crystals have a thickness of only 1.5nm, which increase to about 25nmin mature enamel. During growth of crystal the organic matrix gradually becomes thinned to make room for growing crystals. The loss of organic matrix is caused by withdrawal of large amount of protein and water.



CLINICAL CONSIDERATIONS ON DEVELOPMENT OF ENAMEL: -

Three types of aberrations can occur during amelogenesis:
a. Hypoplasia
b. Hypocalcification
c. Discoloration of the teeth

Because enamel development occurs in two phases
a. Matrix formation
b. Maturation

Thus, the disturbances may occur during developmental stages of enamel, the effect of which are seen clinically on examination of eruptive teeth. These **disturbances** can affect the formation of the enamel matrix or its calcification. **Disturbances of matrix formation result in hypoplasia, while disturbances of calcification or (maturation) results in hypocalcification of the enamel.**

Discoloration of teeth from administration of tetracycline during childhood is a very common problem due to deposition of tetracycline in the dentin**.**

Hypoplasia and hypocalcification may be caused by systemic, local or hereditary factors

I. Local causes: infection, trauma, and irradiation.

II. Systemic causes:

1) Environmental which include:

a). Prenatal: rubella, syphilis, and fluoride ions.
b). Neonatal: hemolytic disease of new born, hypocalcemia.

c). Postnatal: measles, chicken pox, scarlet fever, congenital heart disease, hypoparathyrodism, fluoride ion, vitamins A, C, D, deficiency. III. Genetics (hereditary): like amelogenesis imperfecta.

Hypoplasia is manifested by pitting, furrowing or even total absence of enamel. Hypocalcification: appear in the form of opaque or chalky areas on surface of enamel.

Systemic hypoplasia is termed chronologic hypoplasia.