

*Applied Histology of the
Pulp and
Periradicular Tissues*

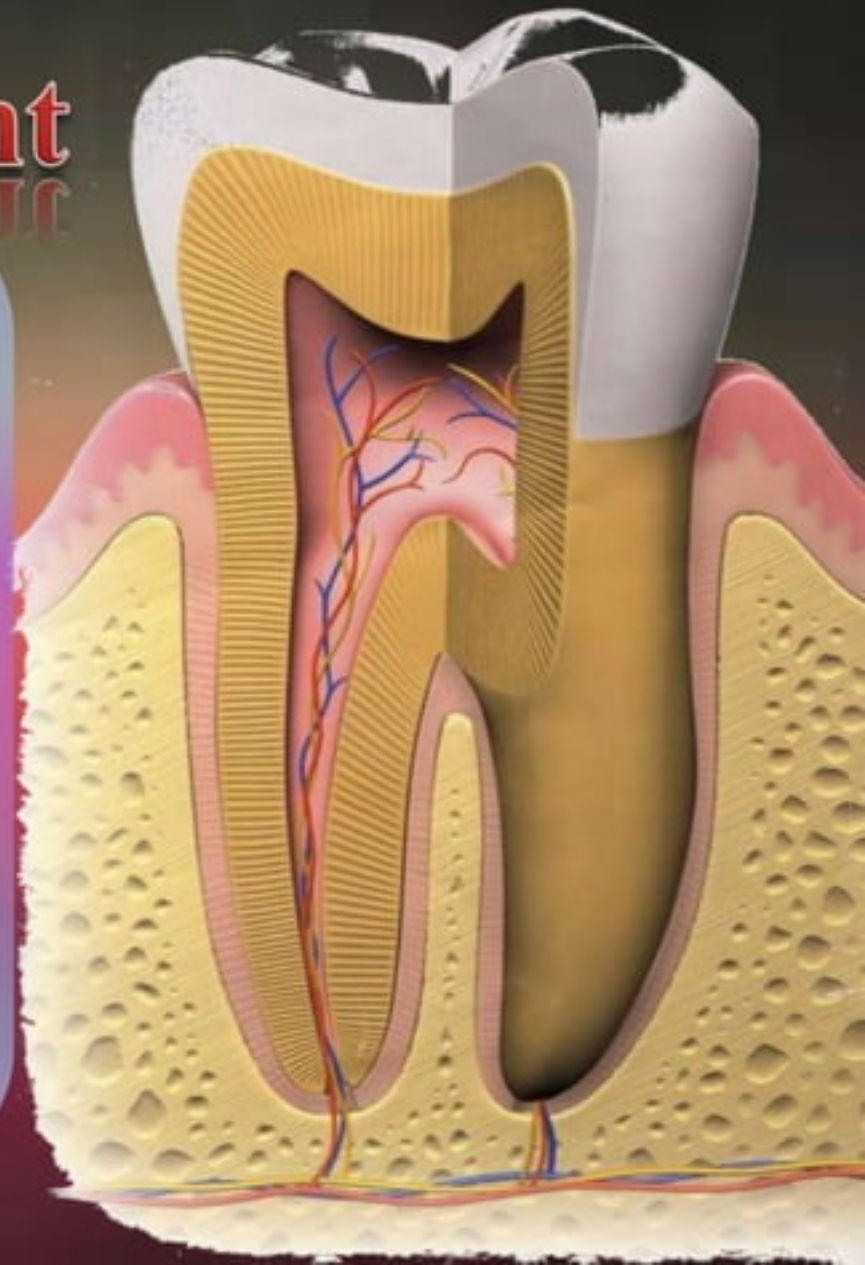


The Pulp

- ❑ The **pulp** is a soft tissue of mesenchymal origin with specialized cells, the odontoblasts, arranged peripherally in direct contact with dentin matrix.
- ❑ The close relationship between odontoblasts and dentin is one of the several reasons why dentin and pulp is considered a functional entity, sometimes referred to as **pulp-dentin complex**.
- ❑ The primary role of the pulp is to produce dentin, but it is rather a unique sensory organ.

Development

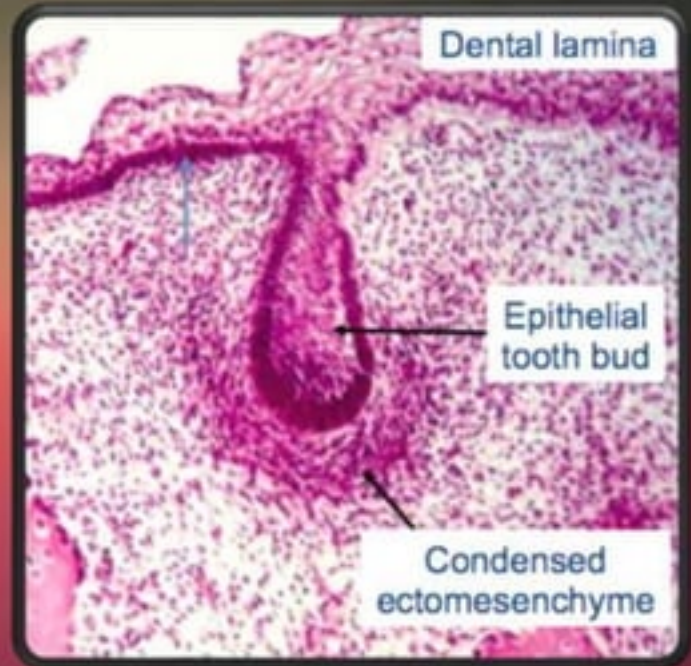
- ❑ Embryologic studies show that the pulp is derived from the cephalic neural crest cells.
- ❑ The dental papilla, from which the mature pulp arises, develops as ectomesenchymal cells proliferate and condense adjacent to the dental lamina at the sites where teeth will develop.



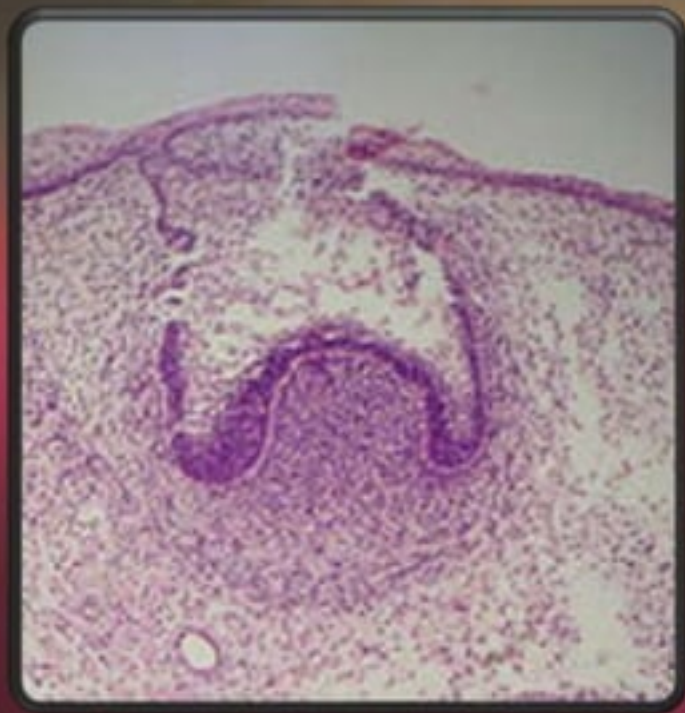
Development

Bud Stage

□ The bud stage is the initial stage of tooth development, wherein the epithelial cells of the dental lamina proliferate and produce a budlike projection into the adjacent mesenchyme



Development



Cap Stage

- ❑ The cap stage is reached when the cells of the dental lamina have proliferated to form a concavity that produces a caplike appearance.

Development

Bell Stage

- ❑ The ectomesenchyme of the dental papilla becomes partially enclosed by the invaginating epithelium. The blood vessels become established in the dental papilla.
- ❑ The condensed ectomesenchyme surrounding the enamel organ and dental papilla complex forms the dental sac.



Development

Odontoblast Differentiation

- ❑ occurs during bell stage
- ❑ more advanced in the apex of the “bell” than in the area of cervical loop.
- ❑ Dentin matrix is formed before enamel matrix.
- ❑ As the ameloblasts undergo differentiation, changes are taking place across the basement membrane in the adjacent dental papilla.
- ❑ With the onset of differentiation a single layer of cells, the presumptive odontoblasts, align themselves along the basement membrane separating the inner enamel epithelium from the dental papilla.



Development

Stellate
reticulum

Stratum
intermedium

Inner
enamel
epithelium

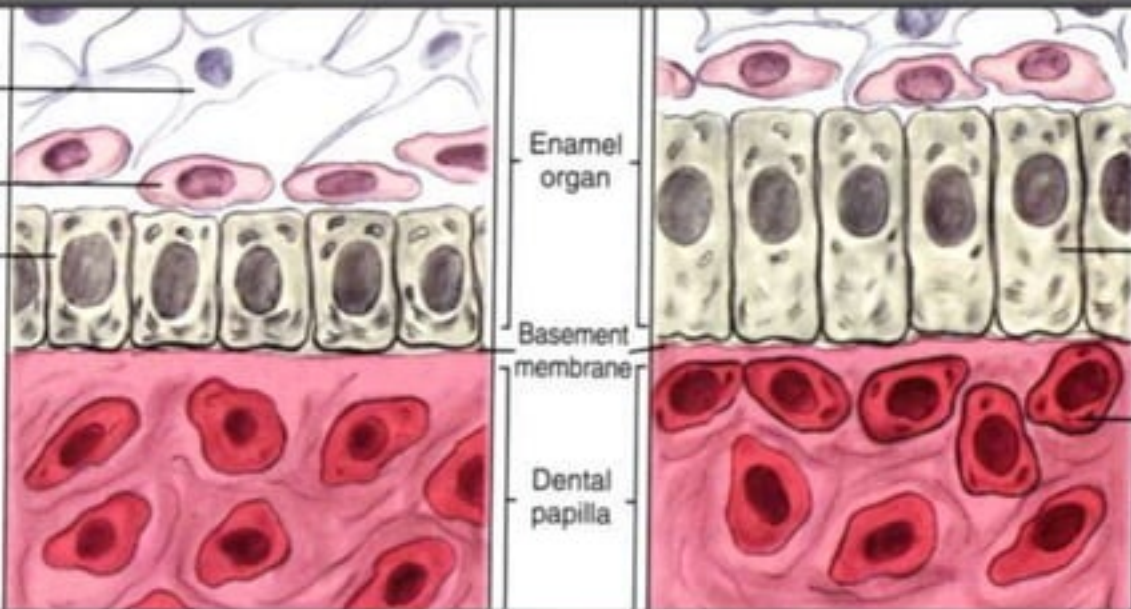
Enamel
organ

Basement
membrane

Dental
papilla

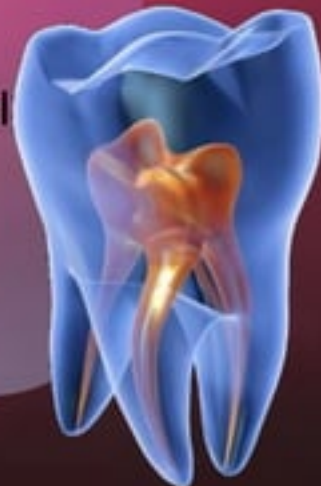
Preameloblast

Outer
cell

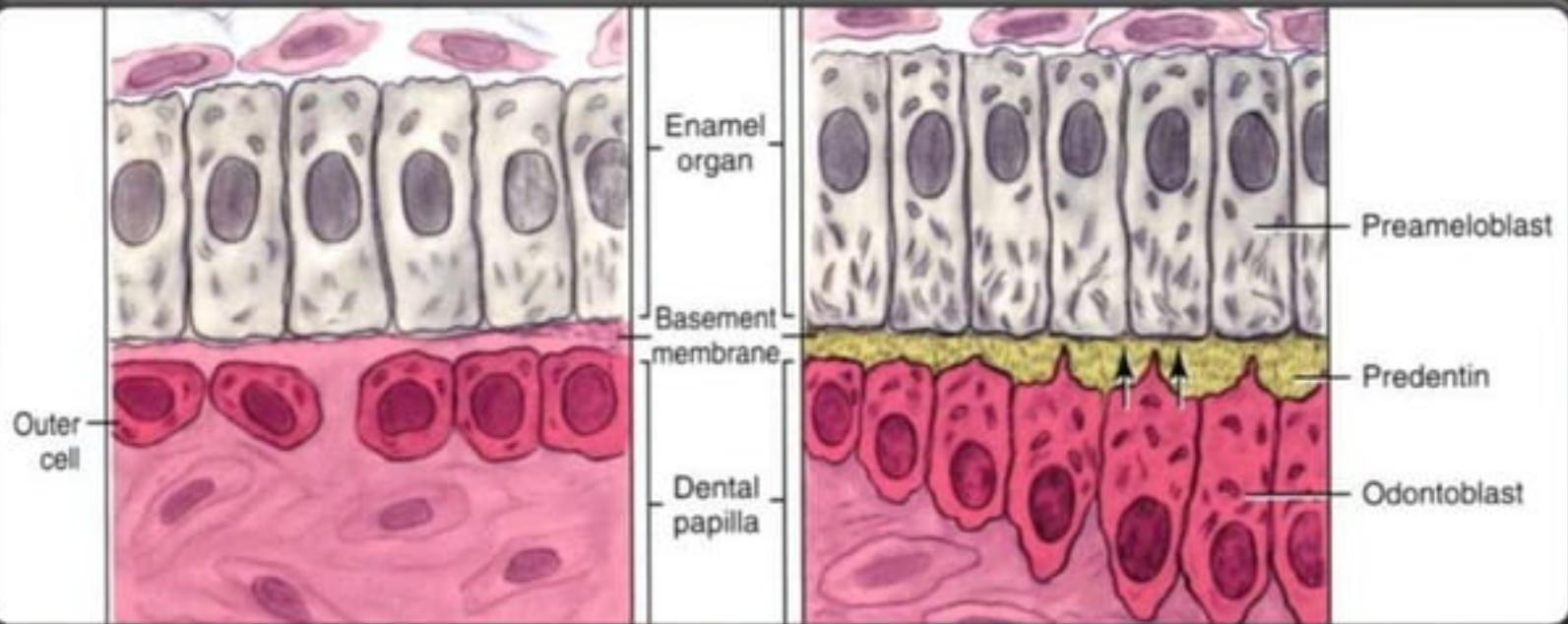


Development

- ❑ Cytoplasmic processes from these cells extend through the DBM toward the basal lamina, and more and more collagen fibrils appear within the ECM.
- ❑ The first formed collagen fibers pass between the preodontoblasts and extend toward basal lamina to form large, fan-shaped bundles, often referred to as **von Korff fibers**.
- ❑ Production of the first dentin matrix involves the formation, organization, and maturation of collagen fibrils and proteoglycans.
- ❑ As more collagen fibrils accumulate subjacent to the basal lamina, the lamina becomes discontinuous and eventually disappears.



Development

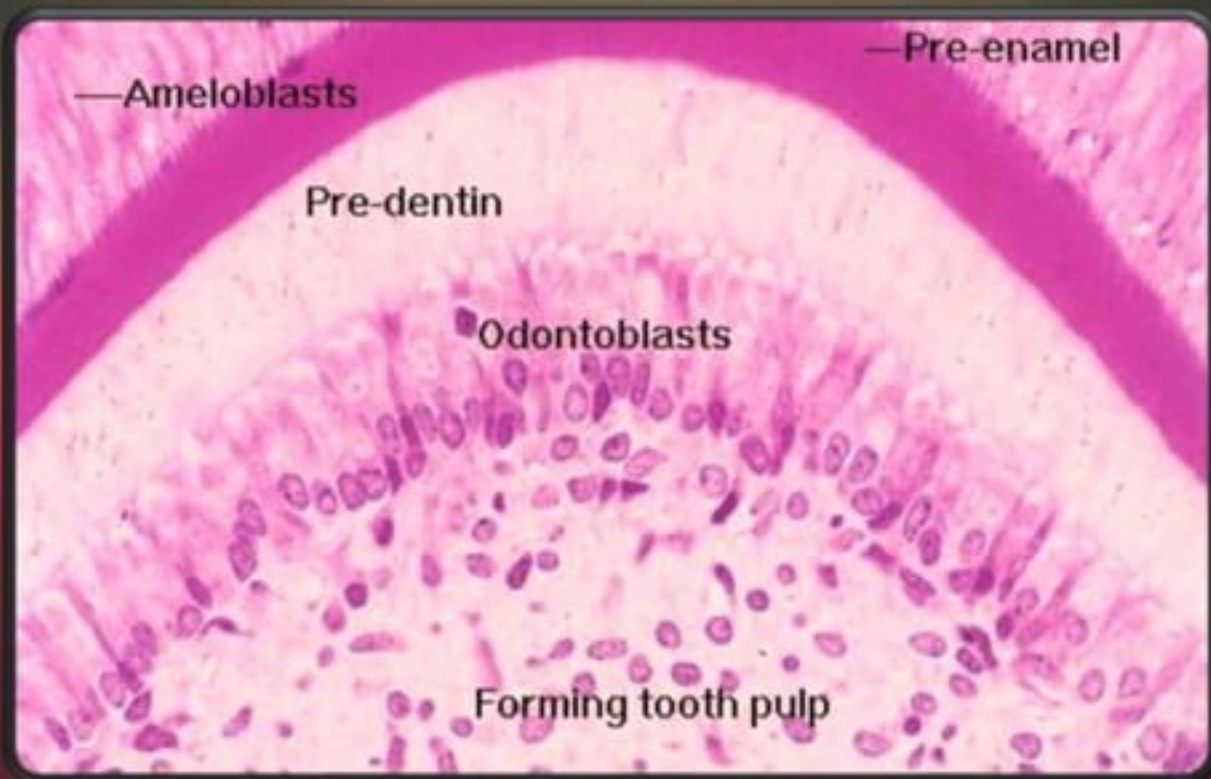


Development

- ❑ The odontoblasts extend several small processes of toward the ameloblasts. Some become interposed between the processes of ameloblasts, resulting in the formation of enamel spindles.
- ❑ With the onset of dentinogenesis the dental papilla becomes the dental pulp.
- ❑ As predentin matrix is formed, the odontoblasts commence to move away toward the central pulp, depositing matrix.
- ❑ A process from each odontoblast remains to form the primary odontoblast process. It is around these processes that the dentinal tubules are formed.

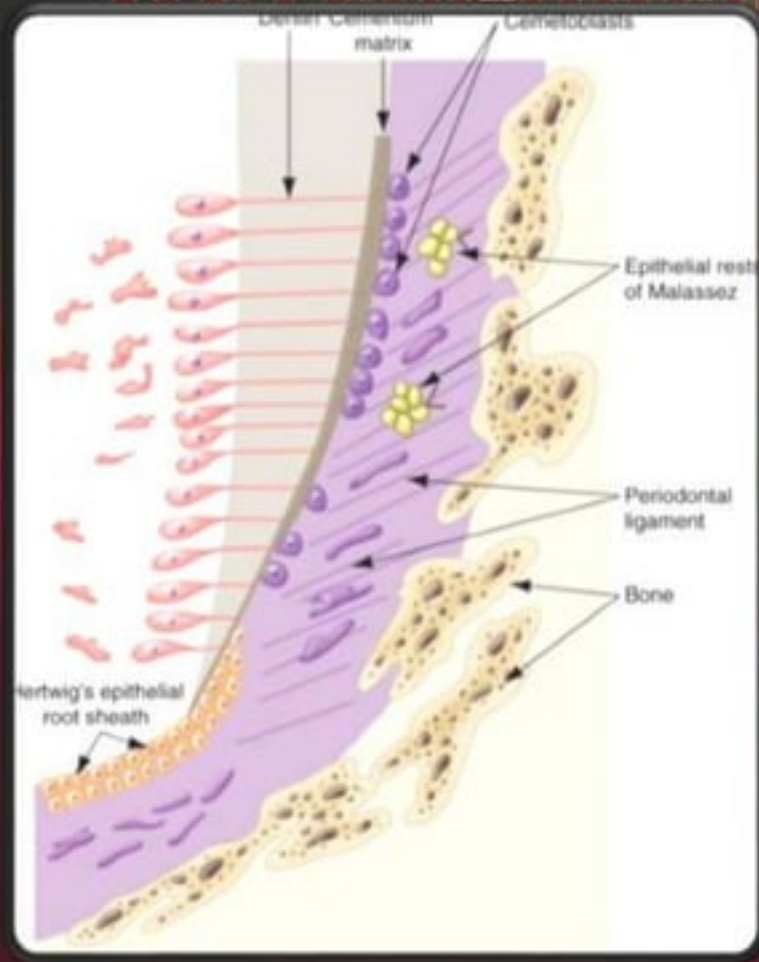


Development



Forming tooth pulp

Development



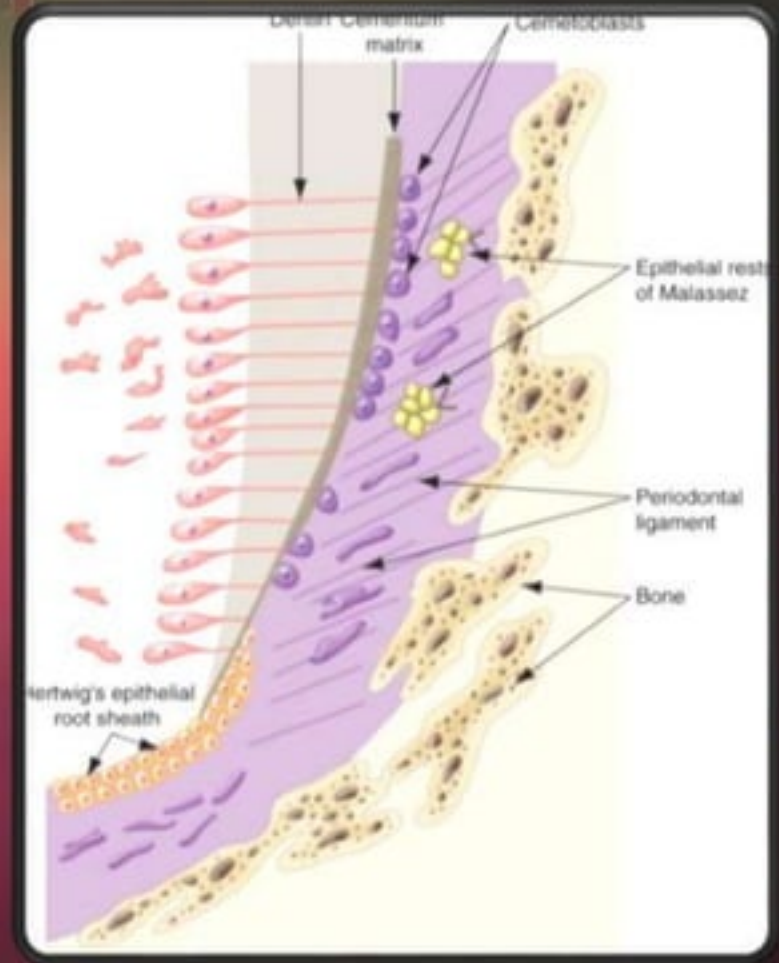
Root Development

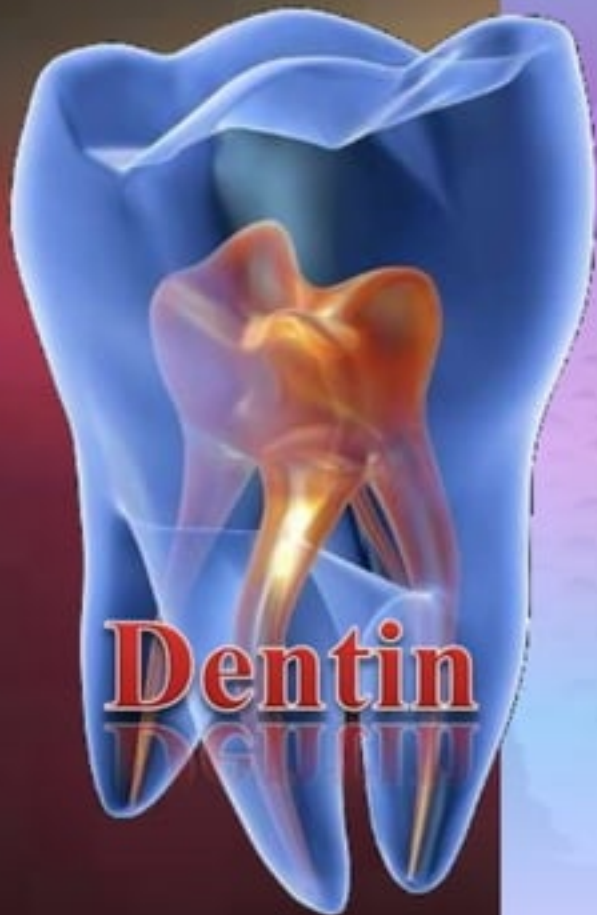
- ❑ The cells of IEE and OEE, which comprise the cervical loop, begin to proliferate and form a structure known as Hertwig epithelial root sheath.
- ❑ As soon as the first layer of dentin matrix mineralizes, gaps appear in the root sheath, allowing mesenchymal cells from the dental sac to move into contact with the newly formed dentin.
- ❑ Some cells persist within the PDL and are known as *epithelial rests of Malassez*

Development

Root Development

- ❑ Occasionally during formation of the root sheath a break develops in the continuity of the sheath, producing a small gap.
- ❑ When this occurs, dentinogenesis does not take place opposite the defect resulting in a small *accessory canal* between the dental sac and the dental pulp.





❑ Fully mature dentin is composed approx. 70% inorganic material, 10% water, and 20% organic material (91% collagen).

❑ Dentin and enamel are closely bound together at the dentinoenamel junction (DEJ), and dentin joins cementum at the cemento-dentinal junction (CDJ)

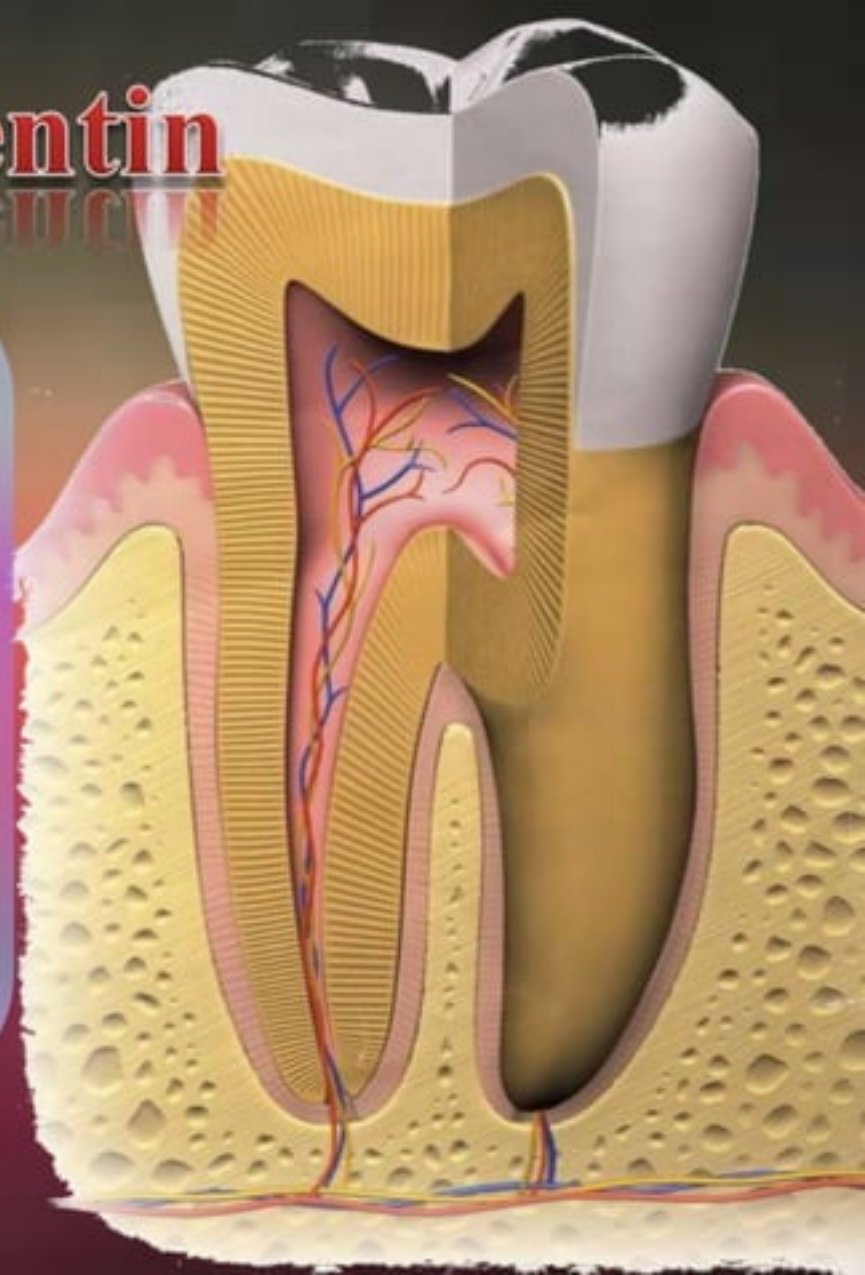
Types of Dentin

A. Primary Dentin

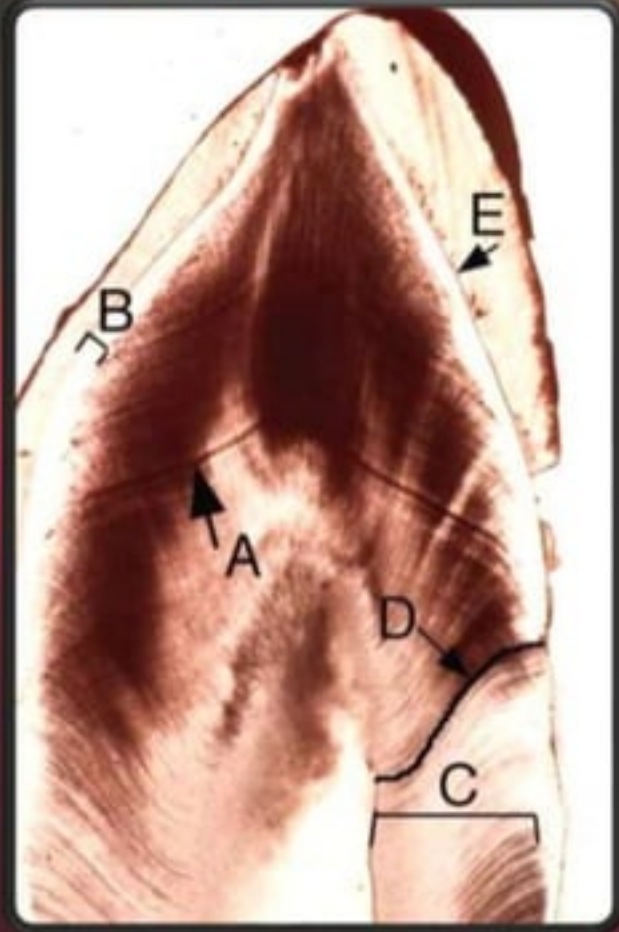
1. Mantle Dentin
2. Circumpalpal dentin

B. Secondary dentin

C. Reparative dentin



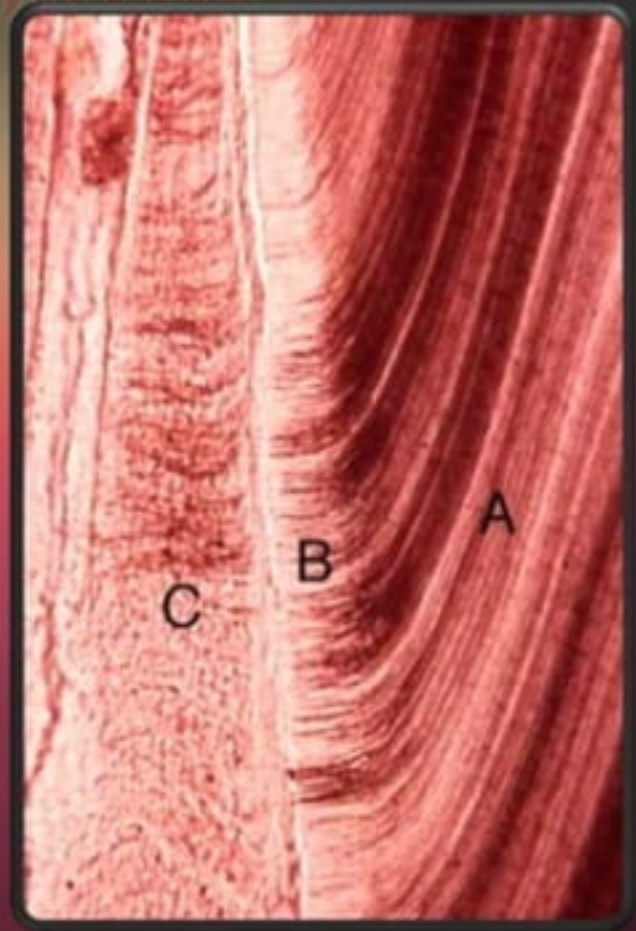
Primary Dentin



- ❑ **Primary or developmental dentin** is that which formed during tooth development, before the teeth erupt.
- ❑ It is divided into: mantle and circumpulpal dentin.
- ❑ **Mantle dentin** is the first formed dentin and is situated immediately subjacent to the enamel and cementum.
- ❑ **Circumpulpal dentin** is formed after the layer of mantle dentin, and constitutes the major part of developmental dentin.

Secondary Dentin

- ❑ **Secondary dentin** is formed physiologically after the root is fully developed.
- ❑ It is deposited unevenly on primary dentin at a low rate and has incremental patterns and tubular structures less regular than primary dentin
- ❑ This deposition of secondary dentin protects the pulp.



Predentin

□ **Predentin** is the unmineralized organic matrix of dentin situated between the odontoblastic layer and the mineralized dentin.

□ Calcium and phosphorus are deposited into this matrix to produce the mineralized structure known as dentin.



Dentinal Tubules

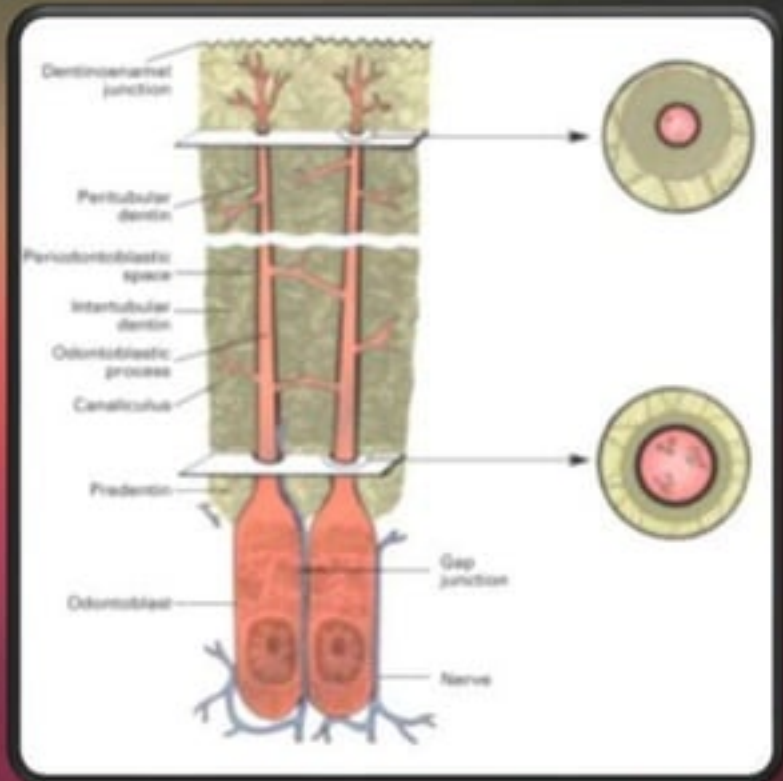


- ❑ The dentinal tubules extend from the predentin border to the DEJ and CDJ.
- ❑ It occupies 20% to 30% of the volume of intact dentin.
- ❑ These tubules house the major cell processes of odontoblasts.
- ❑ They are slightly tapered with the wider portion situated toward the pulp.

Intertubular dentin

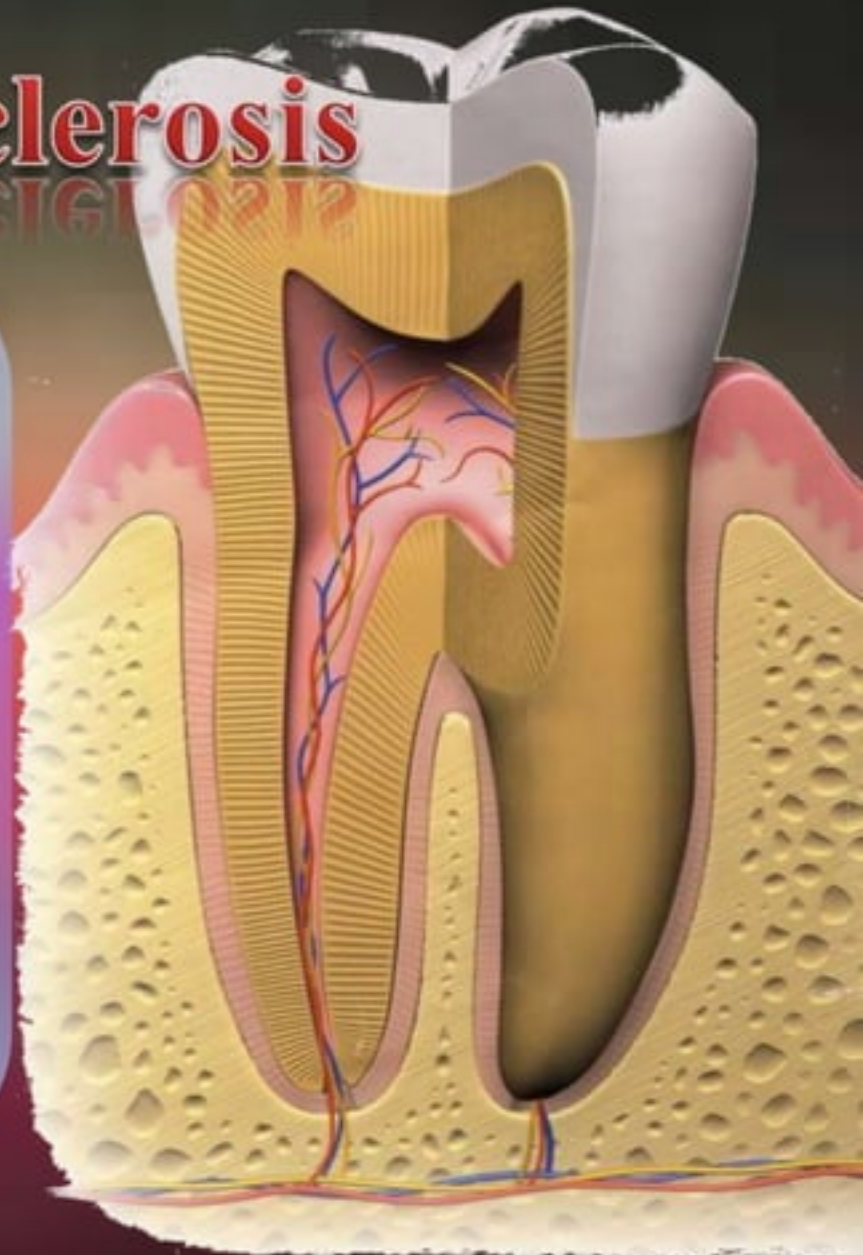
❑ Intertubular dentin is located between the rings of peritubular dentin and constitutes the bulk of circumpulpal dentin.

❑ Its organic matrix consists mainly of collagen fibrils oriented approximately at right angles to the dentinal tubules.



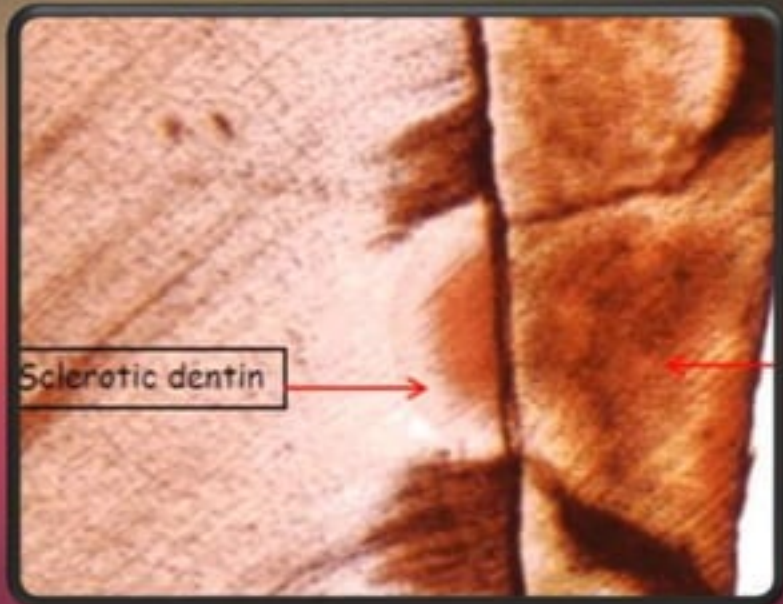
Dentinal Sclerosis

- ❑ Partial or complete obturation of dentinal tubules may occur as a result of aging or develop in response to stimuli such as attrition of the tooth surface or dental caries.
- ❑ One form of dentinal sclerosis is thought to represent an acceleration of peritubular dentin formation. This form appears to be a physiologic process, and in the apical third of the root it develops as a function of age.



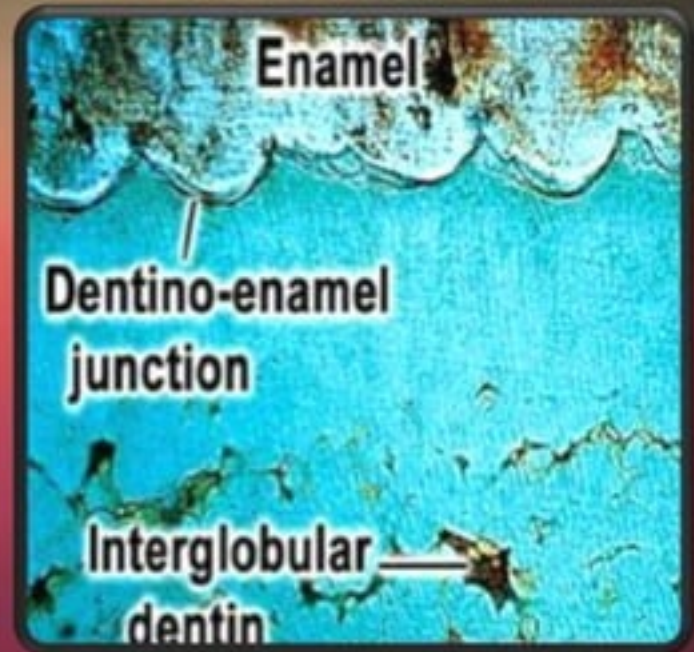
Dentinal Sclerosis

□ Dentinal tubules can also become blocked by the precipitation of hydroxyapatite and whitlockite crystals within the tubules. This type occurs in the translucent zone of carious dentin and in attrited dentin and has been termed pathologic sclerosis.



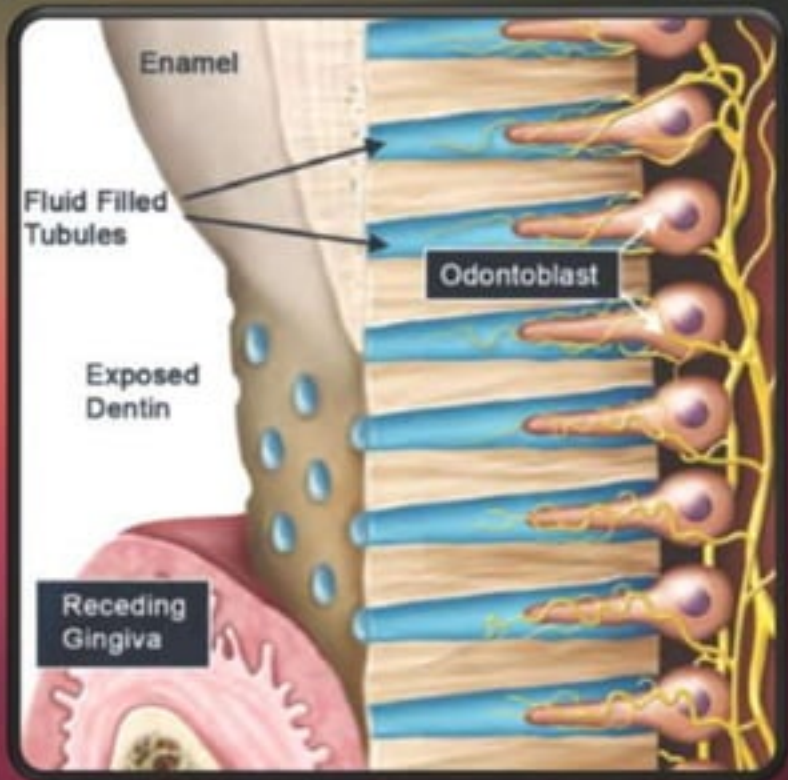
Interglobular dentin

- ❑ Interglobular dentin is an organic matrix that remains unmineralized because the mineralizing globules fails to coalesce.
- ❑ This occurs most often in circumpulpal dentin just below the mantle dentin where the pattern of mineralization is more likely to be globular than appositional.

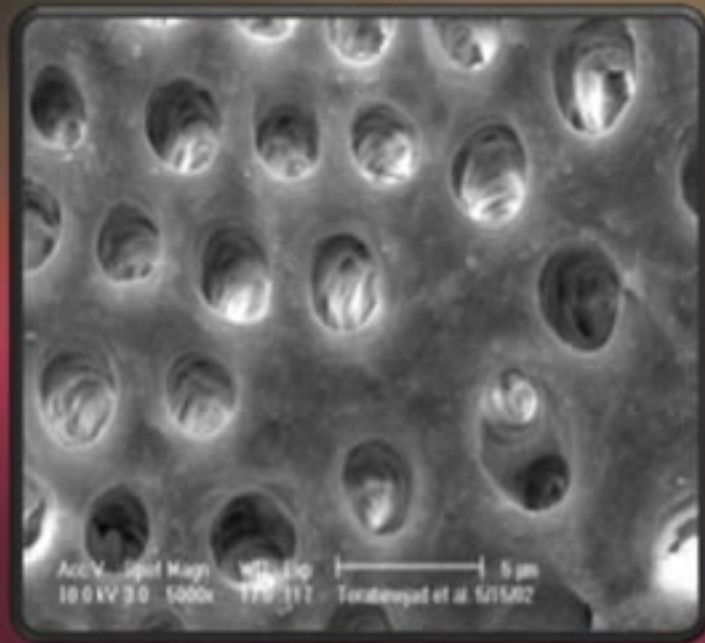


Dentinal Fluid

- ❑ Free fluid occupies about 22% of the total volume of dentin.
- ❑ The fluid flows outward between the odontoblasts into the dentinal tubules and eventually escapes through small pores in the enamel.
- ❑ There is a pressure gradient between the pulp and the oral cavity that accounts for the outward flow of the fluid.



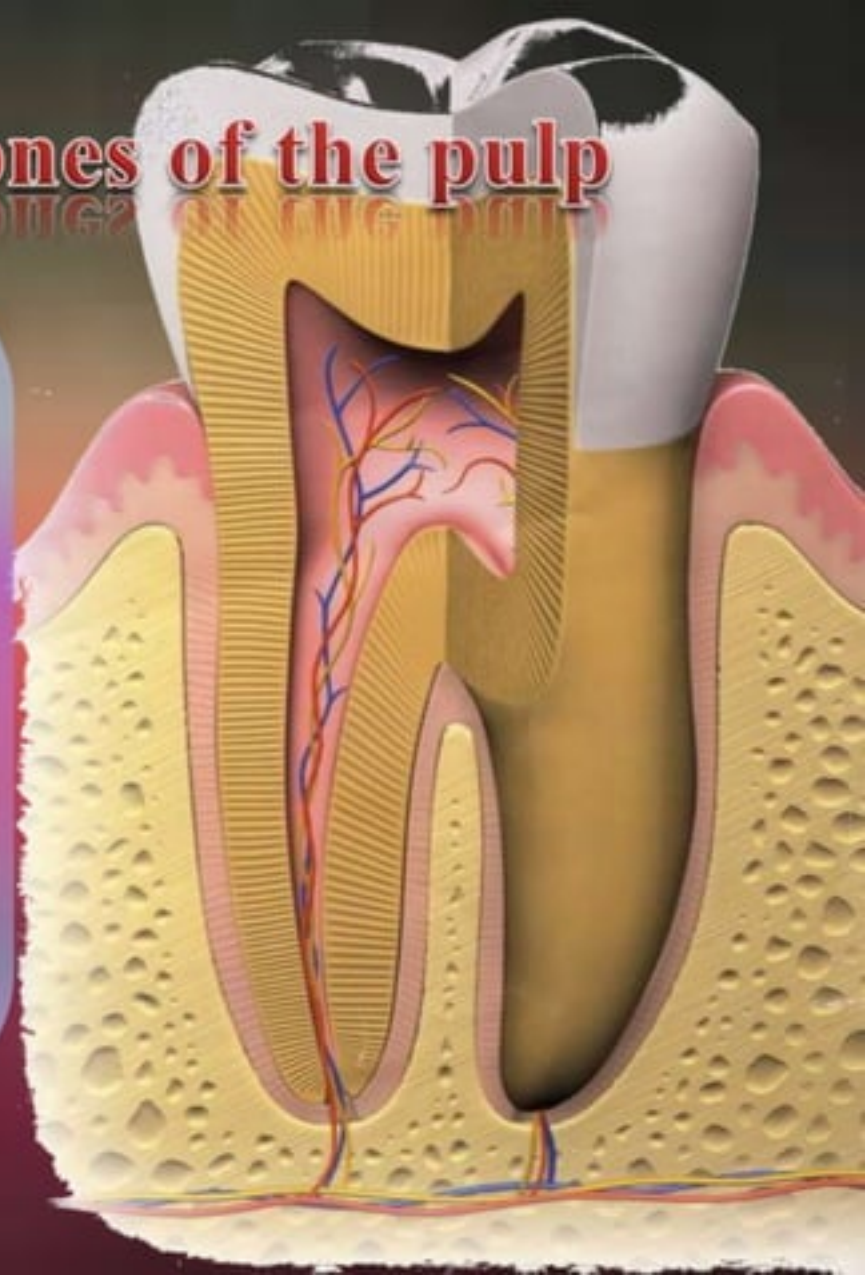
Dentin Permeability



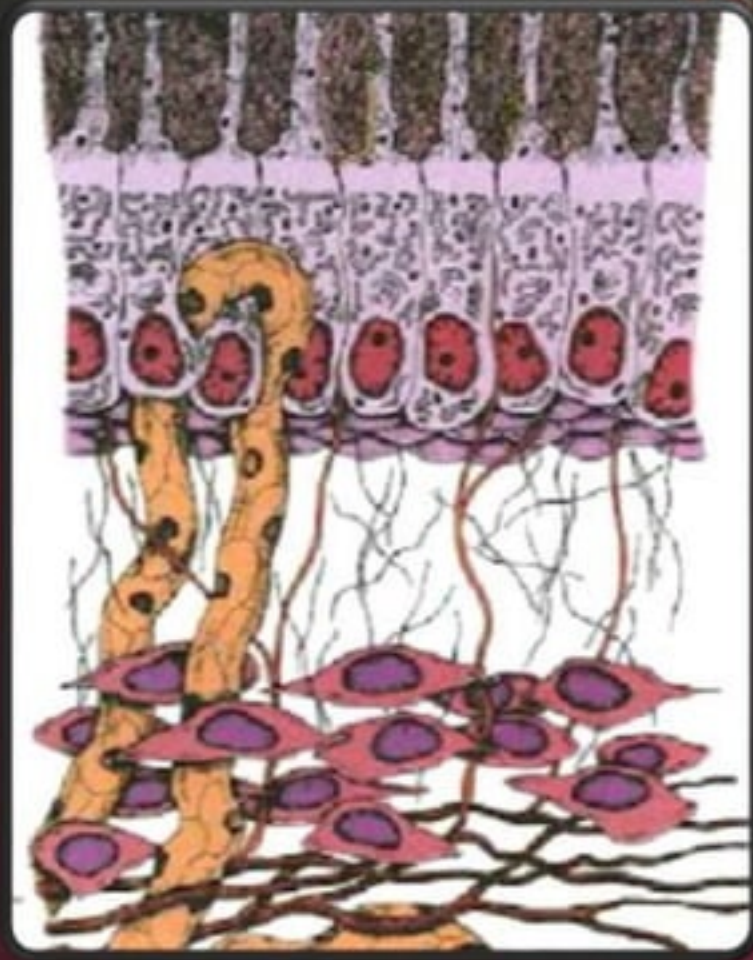
- ❑ Dentinal tubules are major channels for fluid diffusion across dentin.
- ❑ The cutting of dentin during cavity preparation produces microcrystalline grinding debris that coats the dentin and clogs the orifices of the dentinal tubules. This layer of debris is termed **smear layer** which is capable of preventing bacteria from penetrating dentin.

Morphologic zones of the pulp

1. Odontoblast layer
2. Cell-Poor Zone
3. Cell-Rich Zone
4. Pulp Proper



Odontoblast Layer



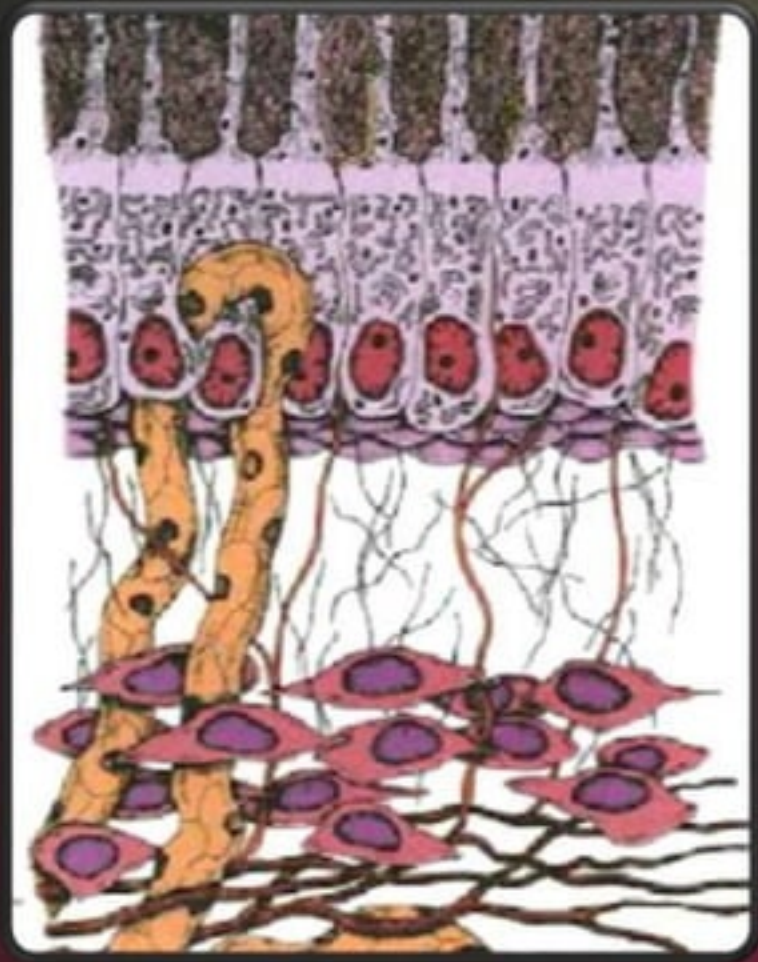
- ❑ the outermost stratum of cells of the healthy pulp
- ❑ located immediately subjacent to the pre-dentin; the odontoblastic processes, however, pass on pre-dentin through dentin.
- ❑ composed of cell bodies of odontoblasts.
- ❑ The odontoblast layer in the coronal pulp contains more cells than in radicular pulp.
- ❑ In the coronal portion, the odontoblasts are usually columnar.

Odontoblast Layer

- Between adjacent odontoblasts are a series of specialized cell-to-cell junctions:
 1. **Gap junctions** (nexuses) – provide low resistance pathways through which electrical excitation can pass between cells
 2. **Desmosomes** (zonula adherens) – located in the apical part of odontoblasts mechanically join them together
 3. **Tight junctions** (zonula occludens) – found mainly in the apical part of odontoblasts in young teeth; determine the permeability of the odontoblast layer by restricting the passage of molecules, ions, and fluid between the extracellular components of the pulp.

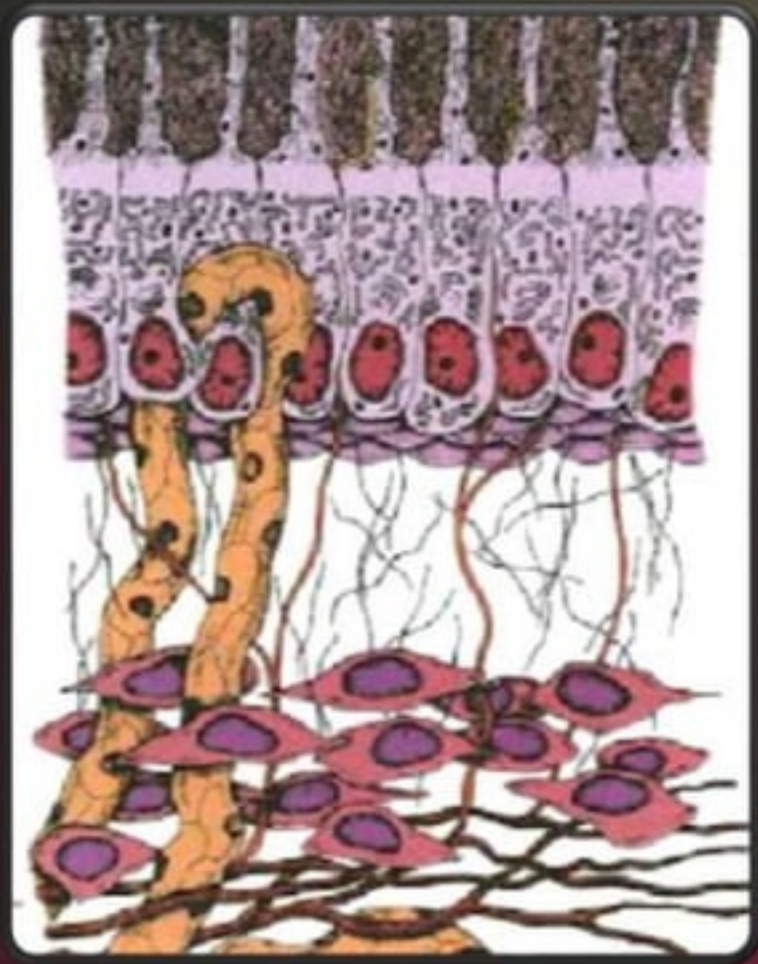


Cell-Poor Zone



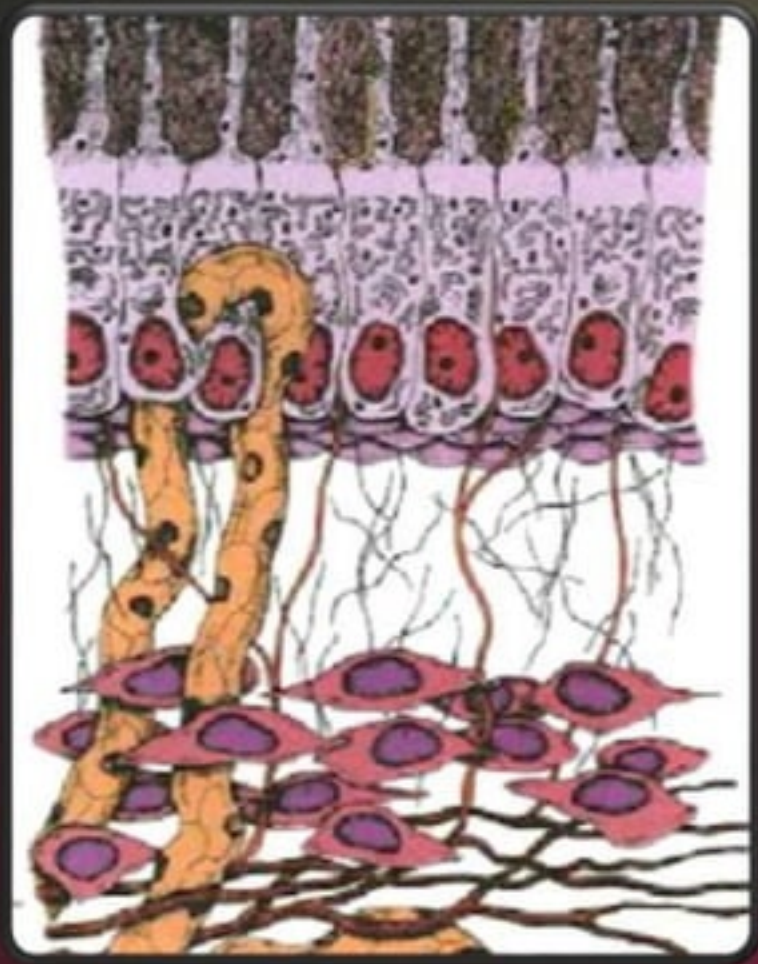
- ❑ zone of Weil or cell-free zone
- ❑ a relatively acellular zone of the pulp
- ❑ The main constituents of this zone are a plexus of capillaries, the nerve plexus of Raschkow, and the ground substance.
- ❑ It is more prominent in the coronal pulp, but it may be completely absent during periods of dentinogenesis.

Cell-Rich Zone



- ❑ located central to the cell-free zone.
- ❑ Its main components are ground substance, fibroblasts with their product the collagen fibers, undifferentiated mesenchymal cells, and macrophages.

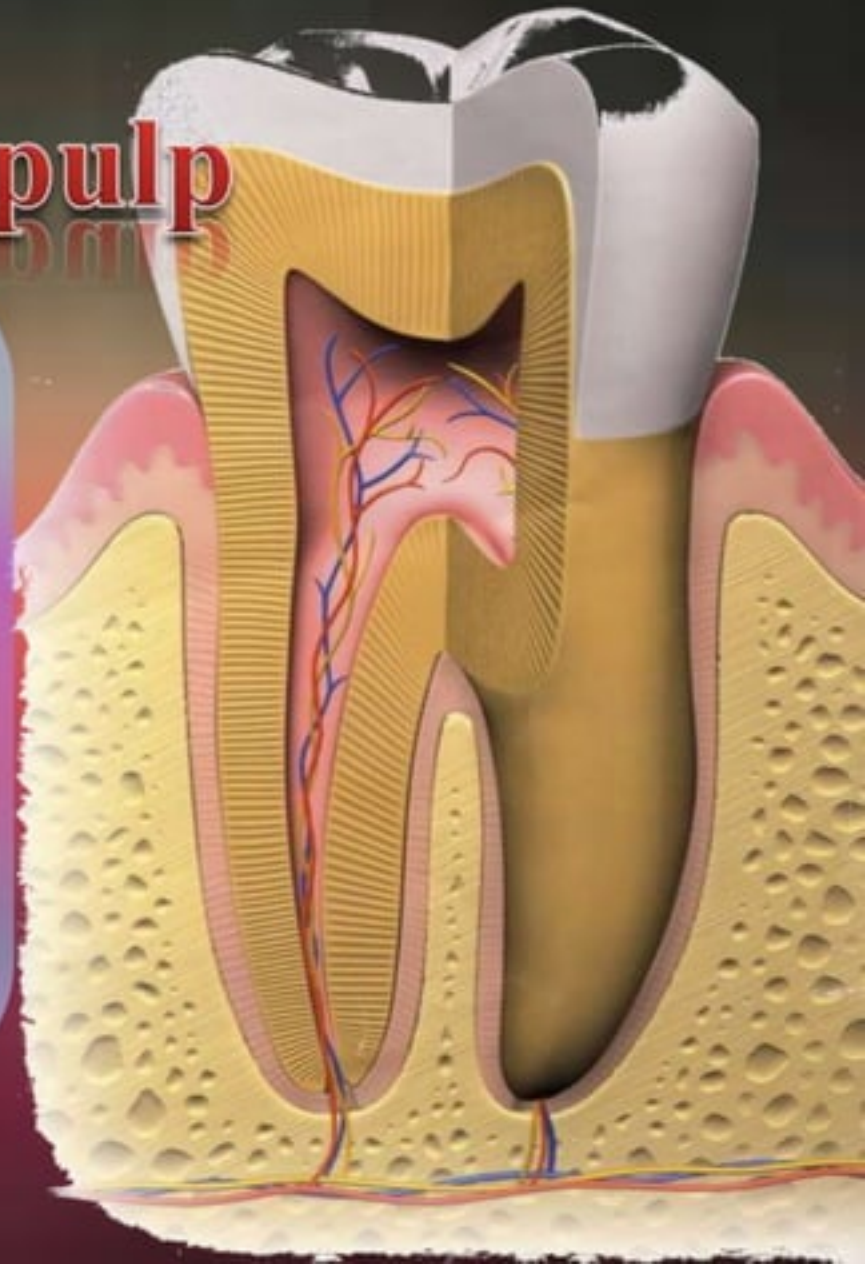
Pulp Proper



- ❑ The pulp proper is the central mass of the pulp
- ❑ It contains the larger blood vessels and nerves.
- ❑ The connective tissue cells in this zone are fibroblasts, or pulpal cells.

Cells of the pulp

1. Odontoblasts
2. Pulp fibroblasts
3. Macrophage
4. Dendritic cell
5. Lymphocyte
6. Mesenchymal cells
7. Mast Cell

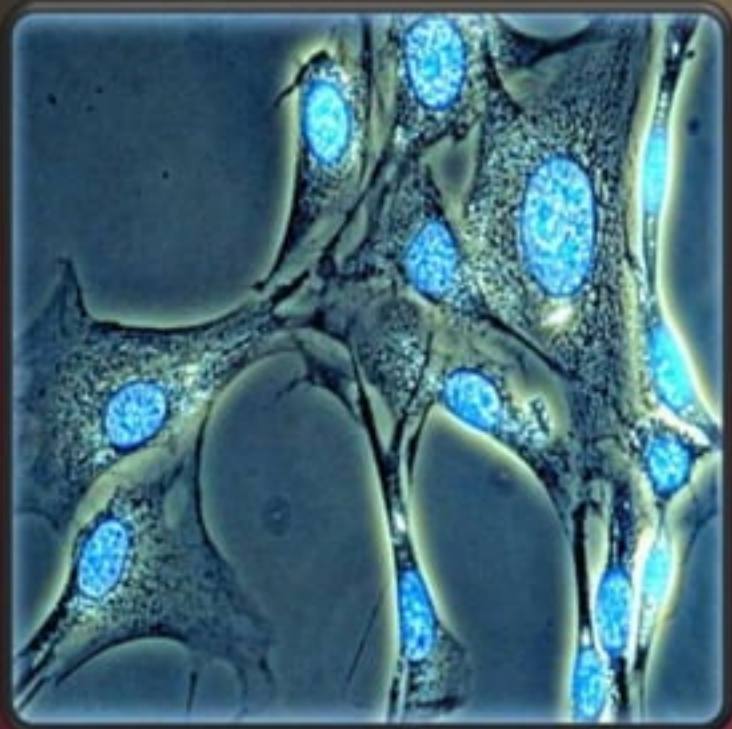


Odontoblasts



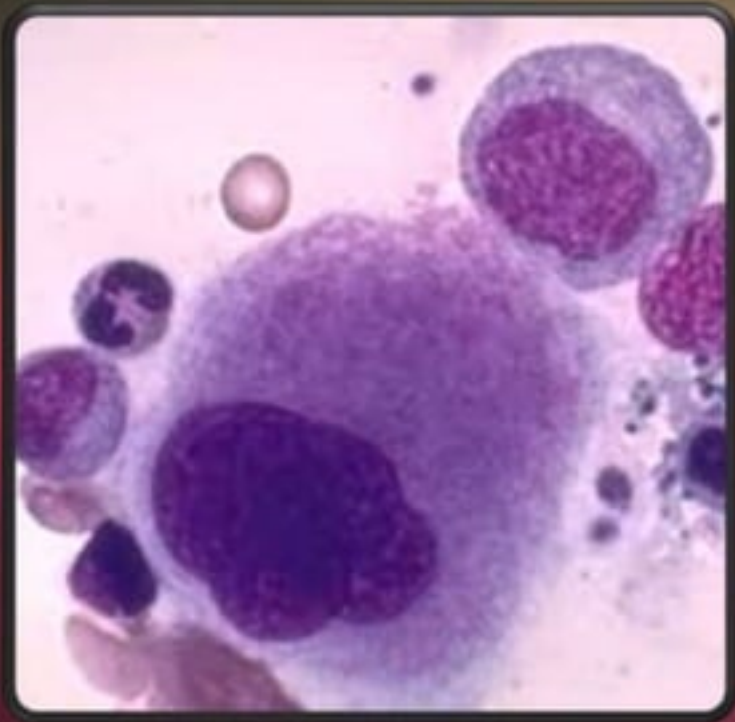
- ❑ Because it is responsible for dentinogenesis both during tooth development and in mature tooth, the odontoblast is the most characteristic cell of the pulp-dentin complex.
- ❑ During dentinogenesis the odontoblasts form the tubules, and their presence within the tubules makes dentin a living tissue.

Fibroblasts



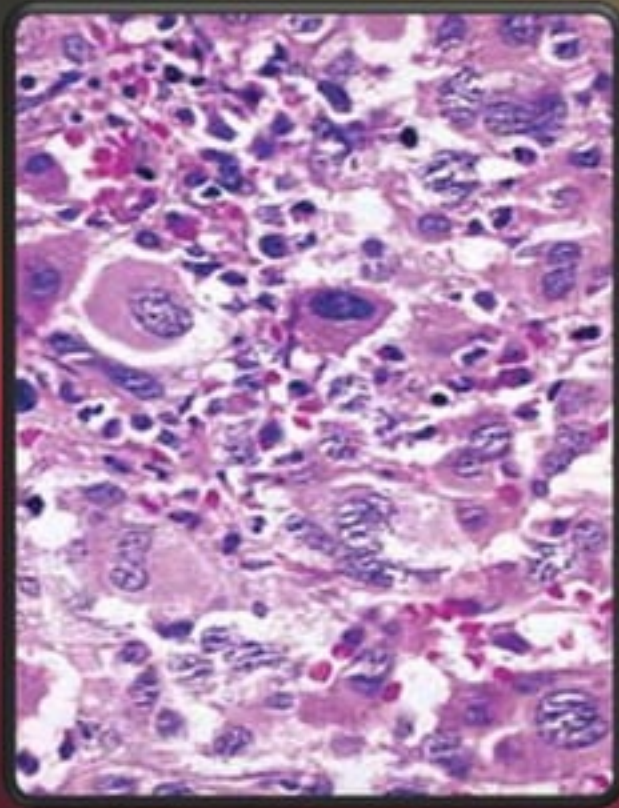
- ❑ The fibroblasts are the predominant cells of the pulp
- ❑ The function of the fibroblasts is elaboration of ground substance and collagen fibers, which constitutes the matrix of the pulp.
- ❑ They are also involved in the degradation of collagen and the deposition of calcified tissue.

Macrophage



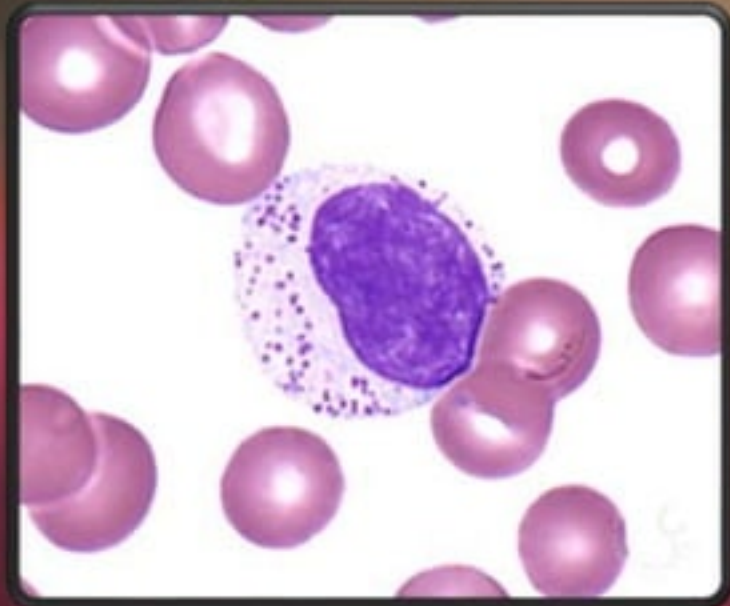
- ❑ Tissue macrophages, or histiocytes, are monocytes that have left the bloodstream, entered the tissues and differentiated into macrophages.
- ❑ These cells are active in endocytosis and phagocytosis.
- ❑ They are able to act as scavengers, removing extravasated RBC, dead cells, and foreign bodies from the tissue.

Dendritic cell



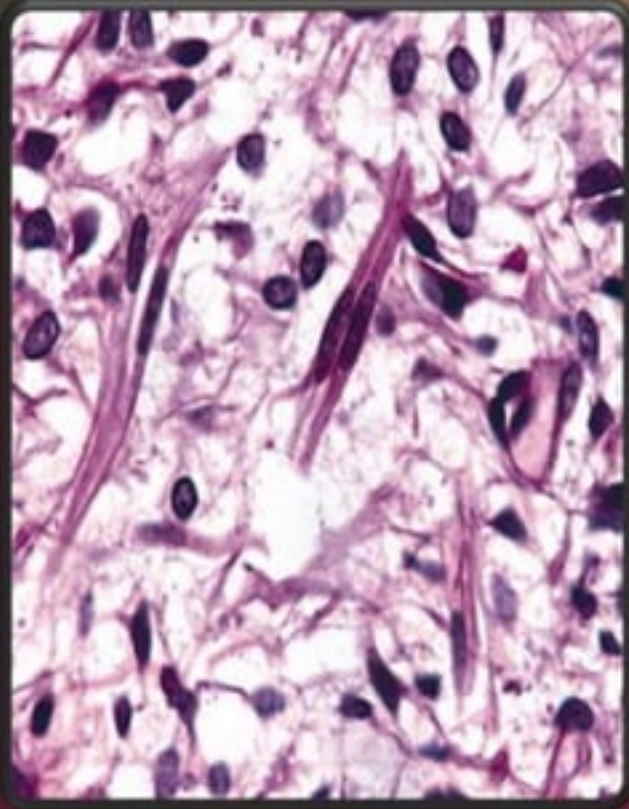
- ❑ Dendritic cells are primarily found in lymphoid tissues, but they are also widely distributed in connective tissues including the pulp.
- ❑ These cells are termed *antigen-presenting cells*.
- ❑ Together with macrophages and lymphocytes, dendritic cells are believed to participate in immunosurveillance of the pulp.

Lymphocyte



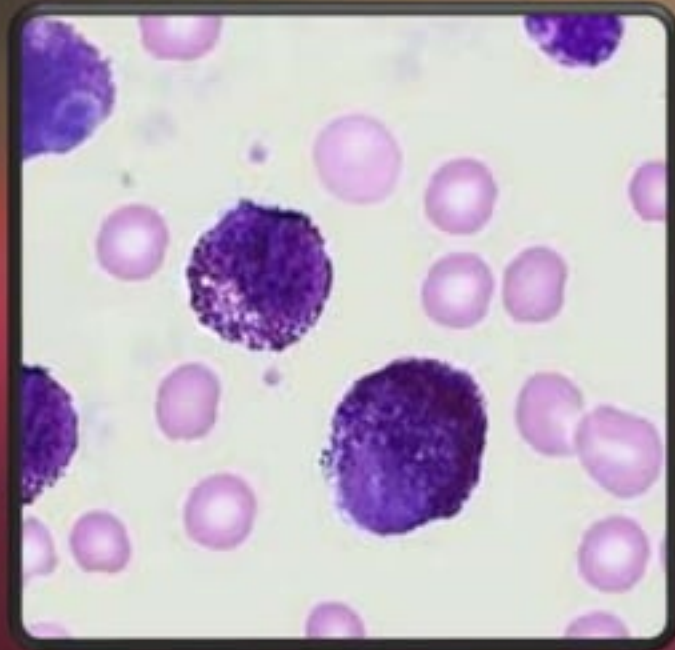
- ❑ T8 (suppressor) lymphocytes were the pre-dominant T-lymphocyte subset present in these pulps.
- ❑ They may be found in the coronal subodontoblastic region.

Mesenchymal cell



- ❑ The undifferentiated mesenchymal cells are derived from the mesenchymal cells of the dental papilla.
- ❑ Because of their function in repair and regeneration, they retain pluripotential characteristics and can differentiate into fibroblasts, odontoblasts, macrophages, or osteoclasts

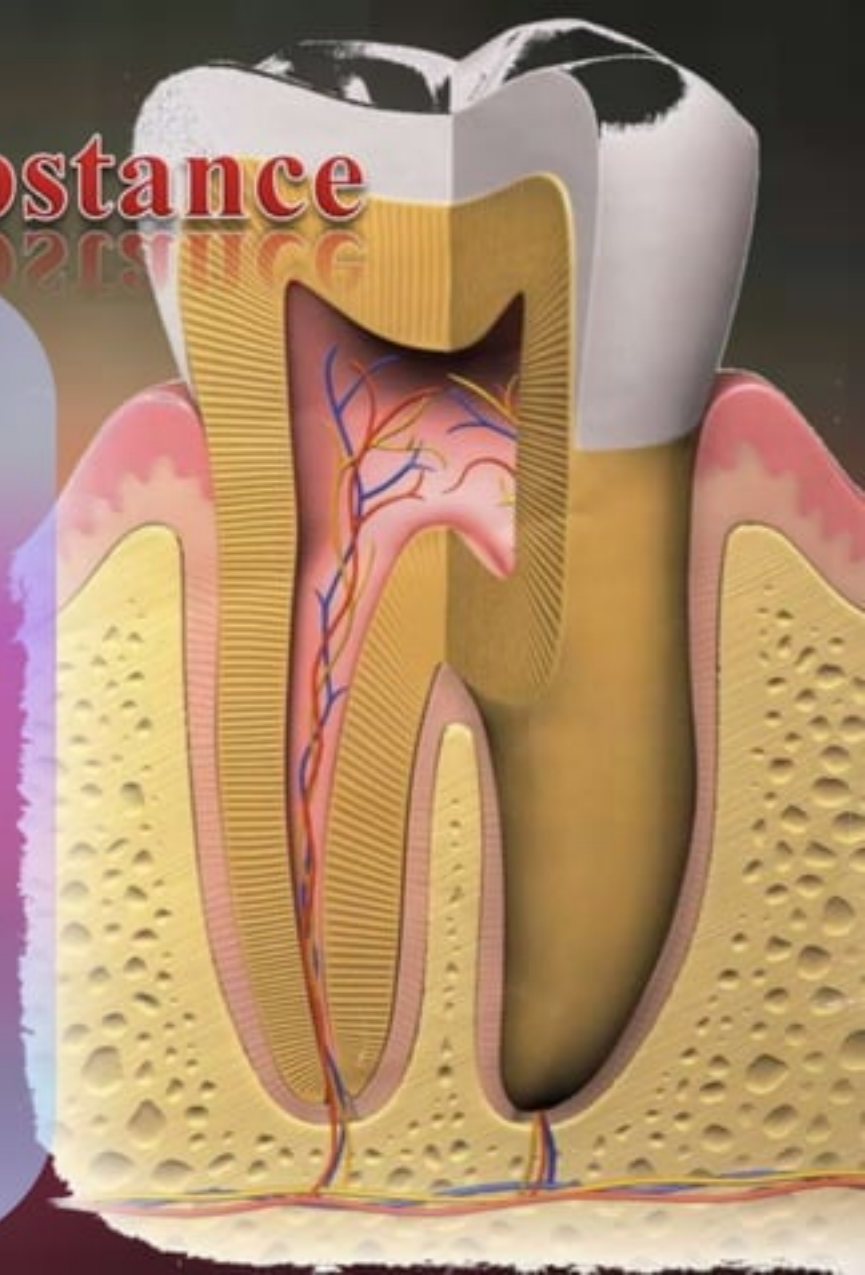
Mast cell



- ❑ Mast cells are widely distributed in connective tissues, where they occur in small groups in relation to blood vessels.
- ❑ They are found in chronically inflamed pulps.

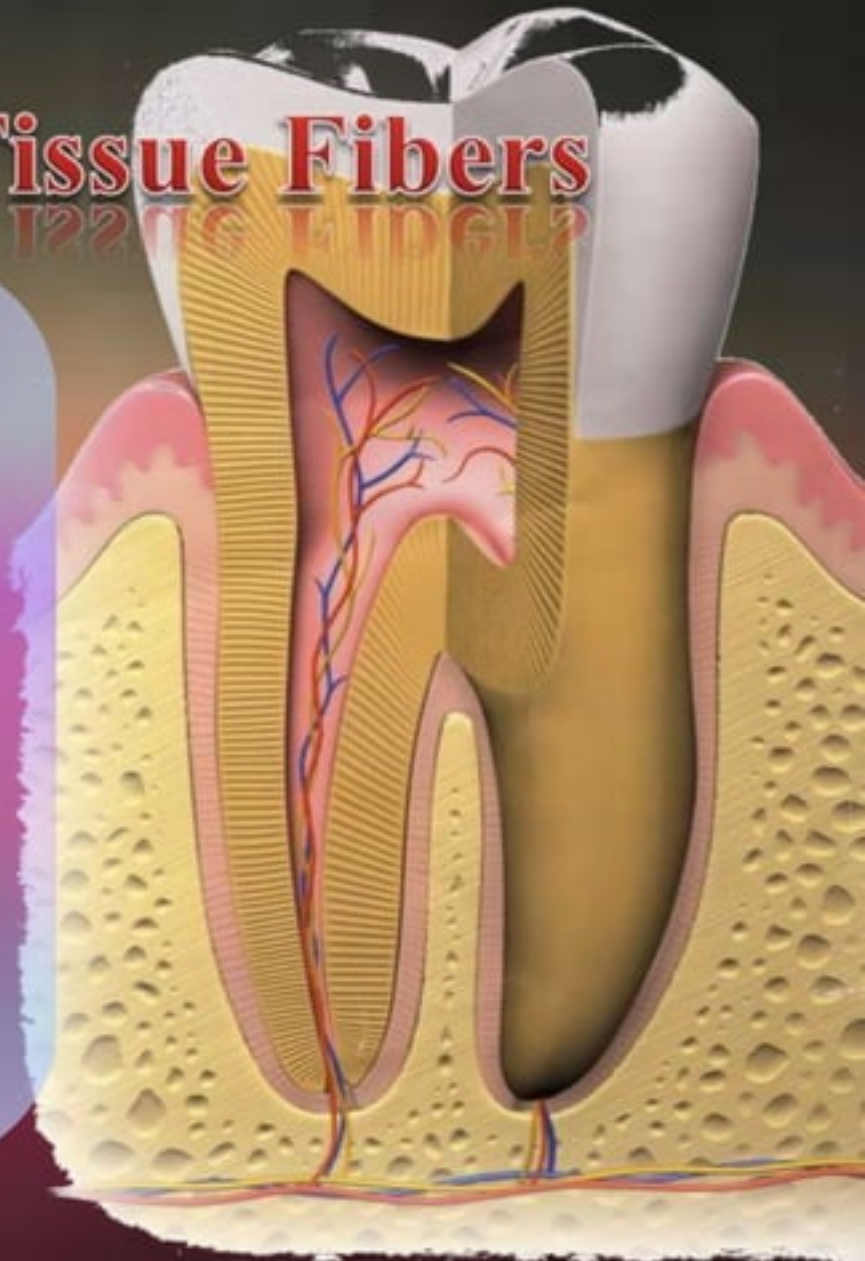
Ground Substance

- ❑ Connective tissue is a system consisting of cells and fibers, both embedded in the pervading ground substance.
- ❑ Proteoglycans present in ground substance support cells, provide tissue turgor, and mediate a variety of cell interactions
- ❑ Fibronectin is a major surface glycoprotein that, together with collagen, influences adhesion, motility, growth and differentiation of cells.



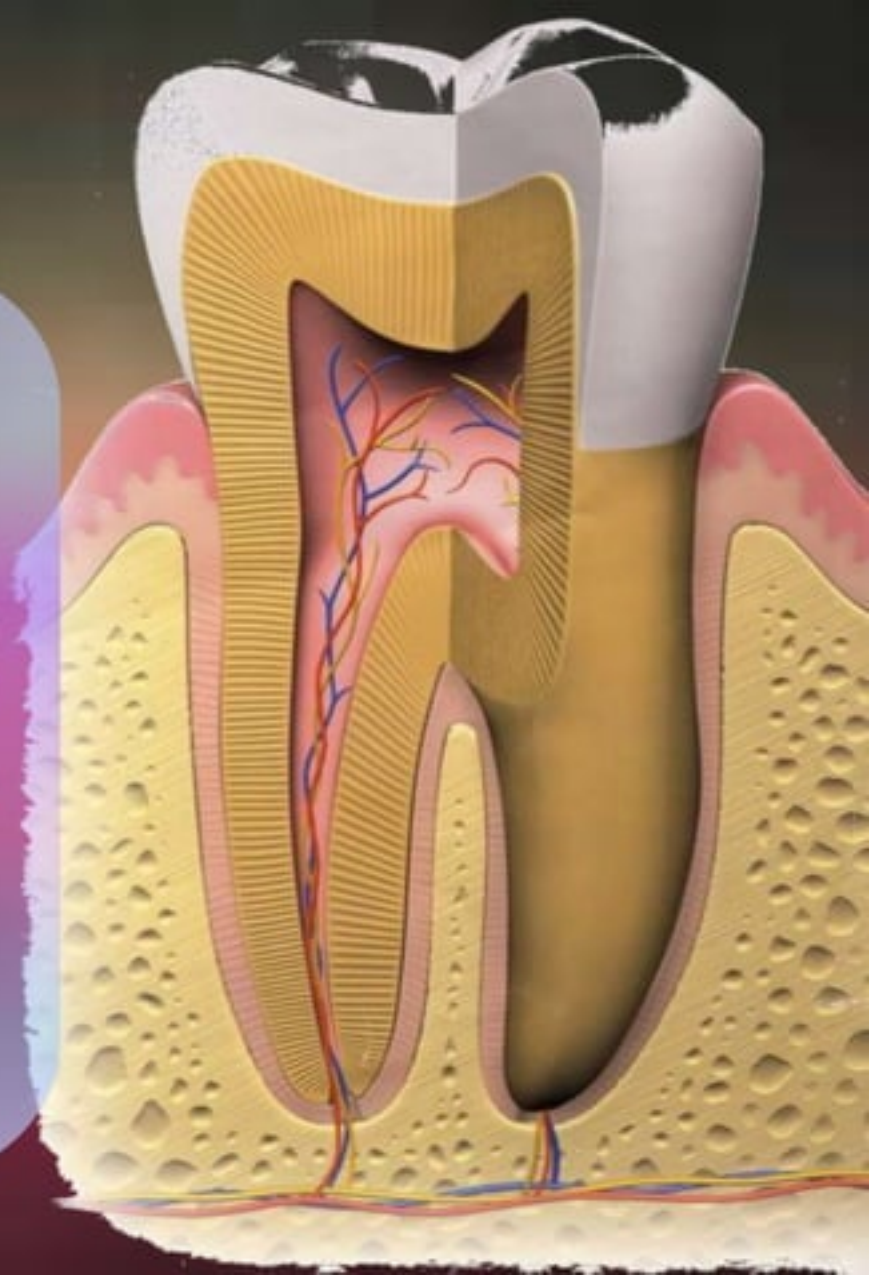
Connective Tissue Fibers

- ❑ Elastin fibers are confined to the walls of arterioles and are not a part of ECM.
- ❑ TYPE I collagen fibers are found in pulp and are synthesized by odontoblasts and osteoblasts.
- ❑ TYPE III is found in most unmineralized connective tissues. It is a fetal form found in the dental papilla and mature pulp.
- ❑ Fibroblasts synthesize types I, III, V, and VII



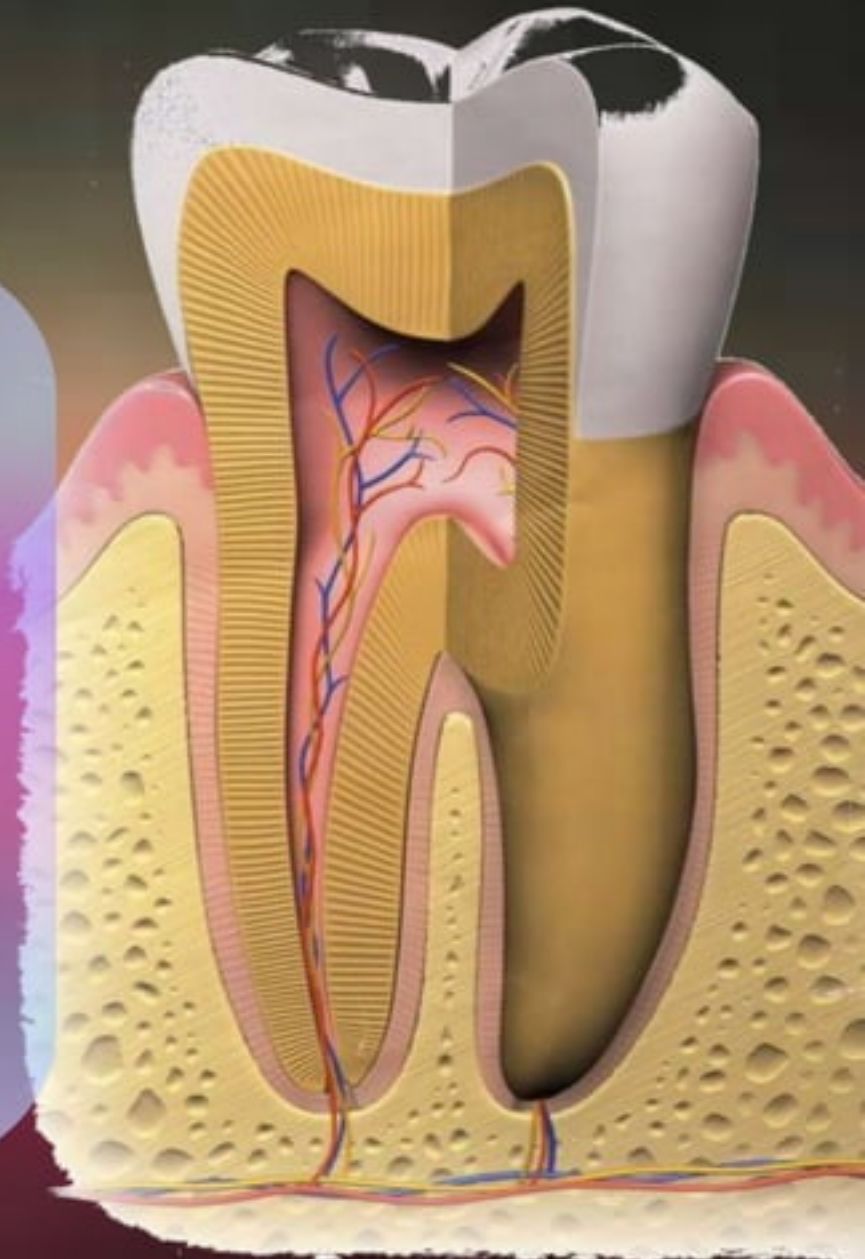
Innervation

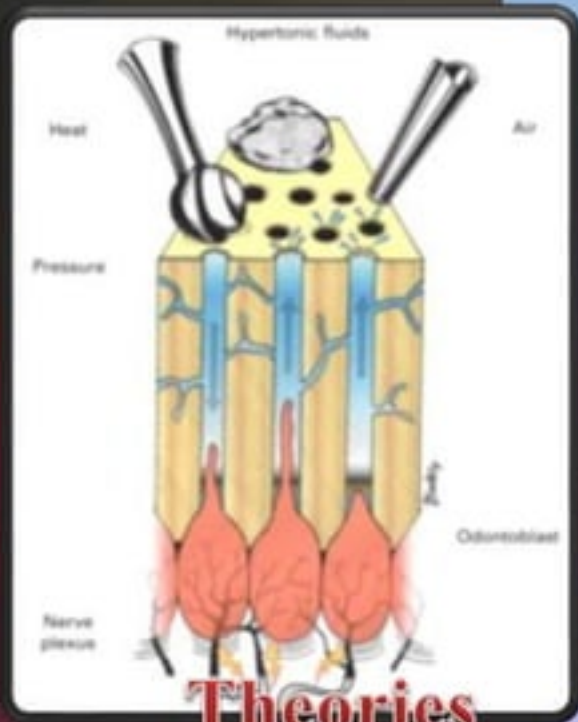
- ❑ Regardless of the nature of the sensory stimulus, all afferent impulses from the pulp result in the sensation of pain.
- ❑ Innervation of pulp includes *afferent neurons*, which conduct sensory impulses, and *autonomic fibers*, which provide neurogenic modulation of the microcirculation and perhaps regulate dentinogenesis



Innervation

- ❑ Approximately 80% of the nerves of the pulp are C-type fibers, and the rest are A-delta fibers.
- ❑ **A-delta fibers** are distributed in the odontoblastic and subodontoblastic zones, conduct sharp prickling pain and are associated with dentinal pain.
- ❑ **C-fibers** are distributed throughout the pulp, they conduct throbbing pain associated with pulp tissue damage.

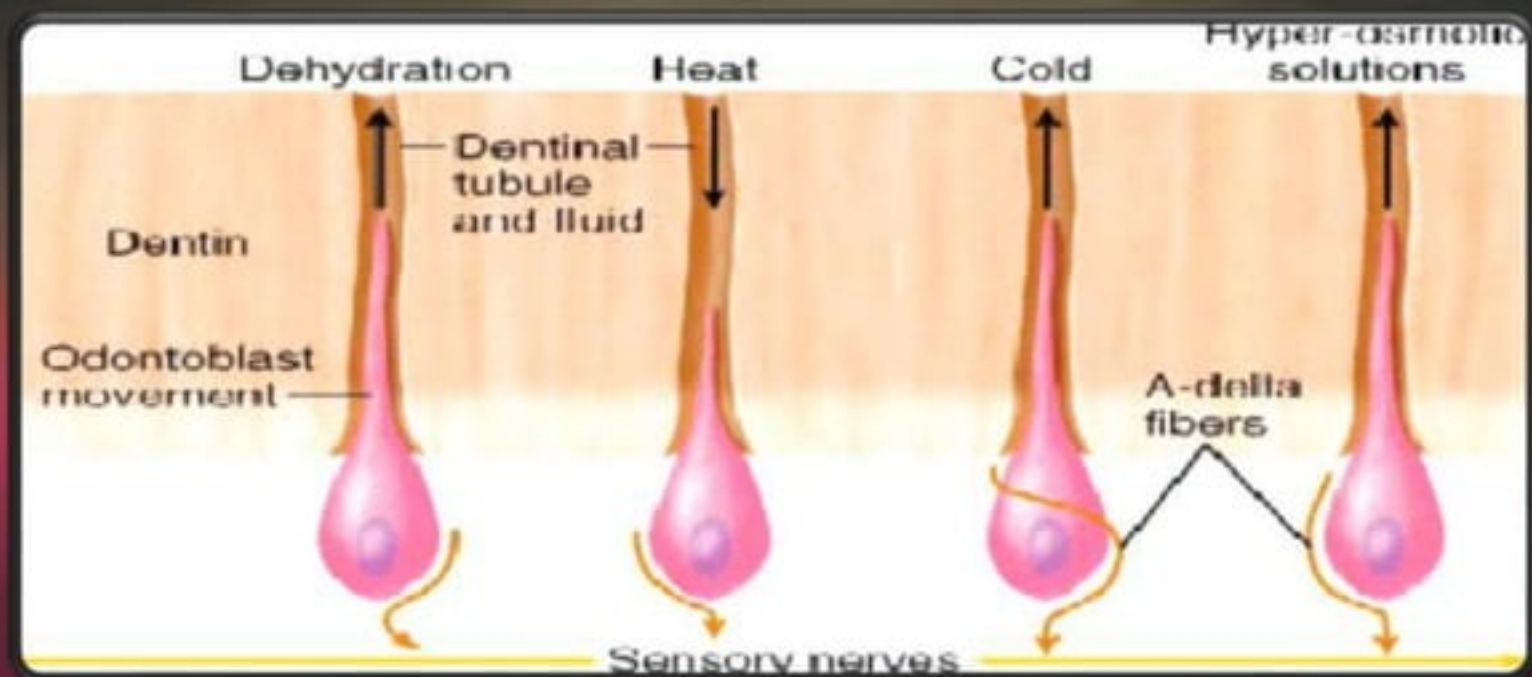




Theories Of Dentin

Hypersensitivity

1. Direct stimulation of the nerve endings in the pulp.
2. Odontoblasts function as nerve endings.
3. Hydrodynamic theory
 - states that any fluid movement in the dentinal tubules and around the odontoblasts as the result of a stimulus excites the nerve endings and produces an impulse.
 - Heat expands the dentinal fluid, cold contracts the fluid, cutting the dentinal tubules allows the fluid to escape, and probing the cut or exposed dentin may deform the tubules and produce fluid movement.



Hydrodynamic Theory

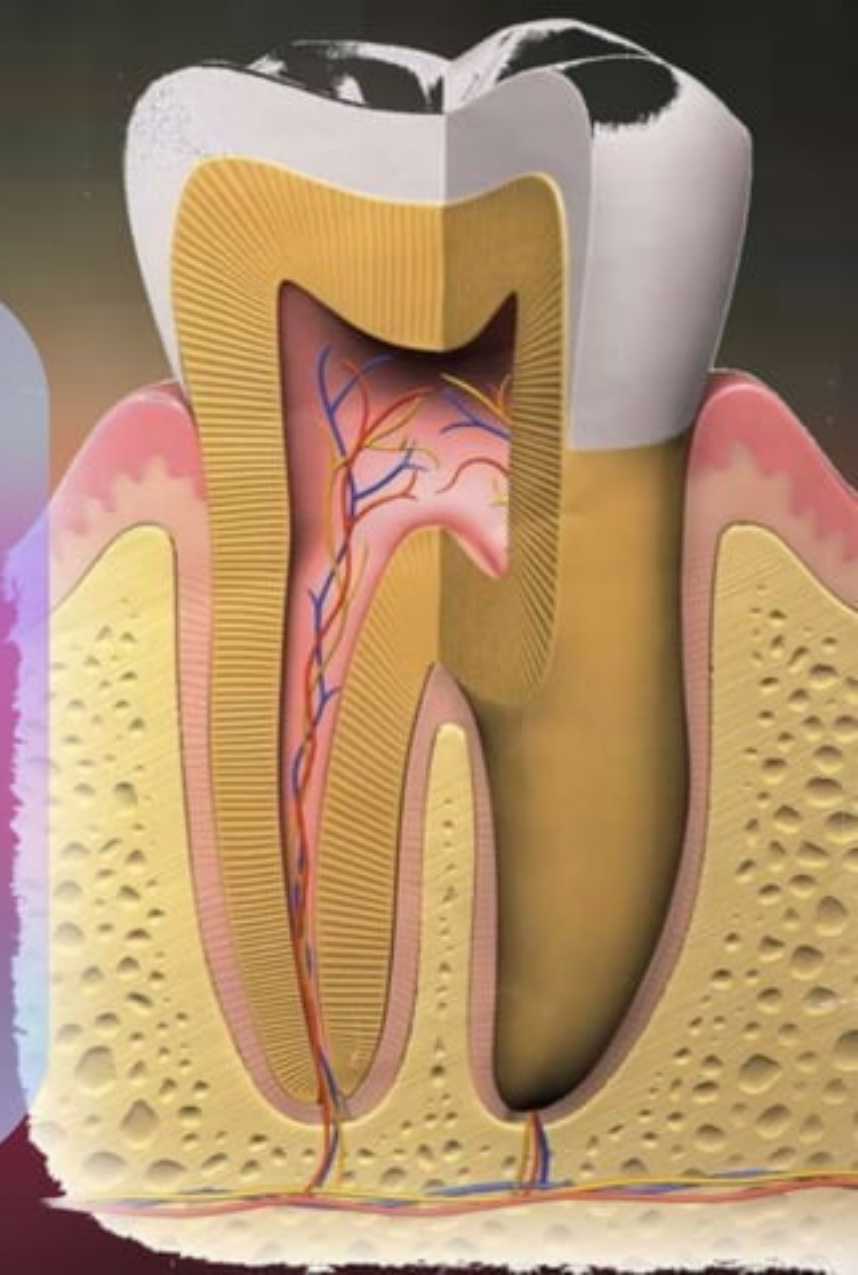
Hyperalgesia

□ a greater-than-normal sensitivity to pain that may result from a painful stimulus or a lowered pain threshold.

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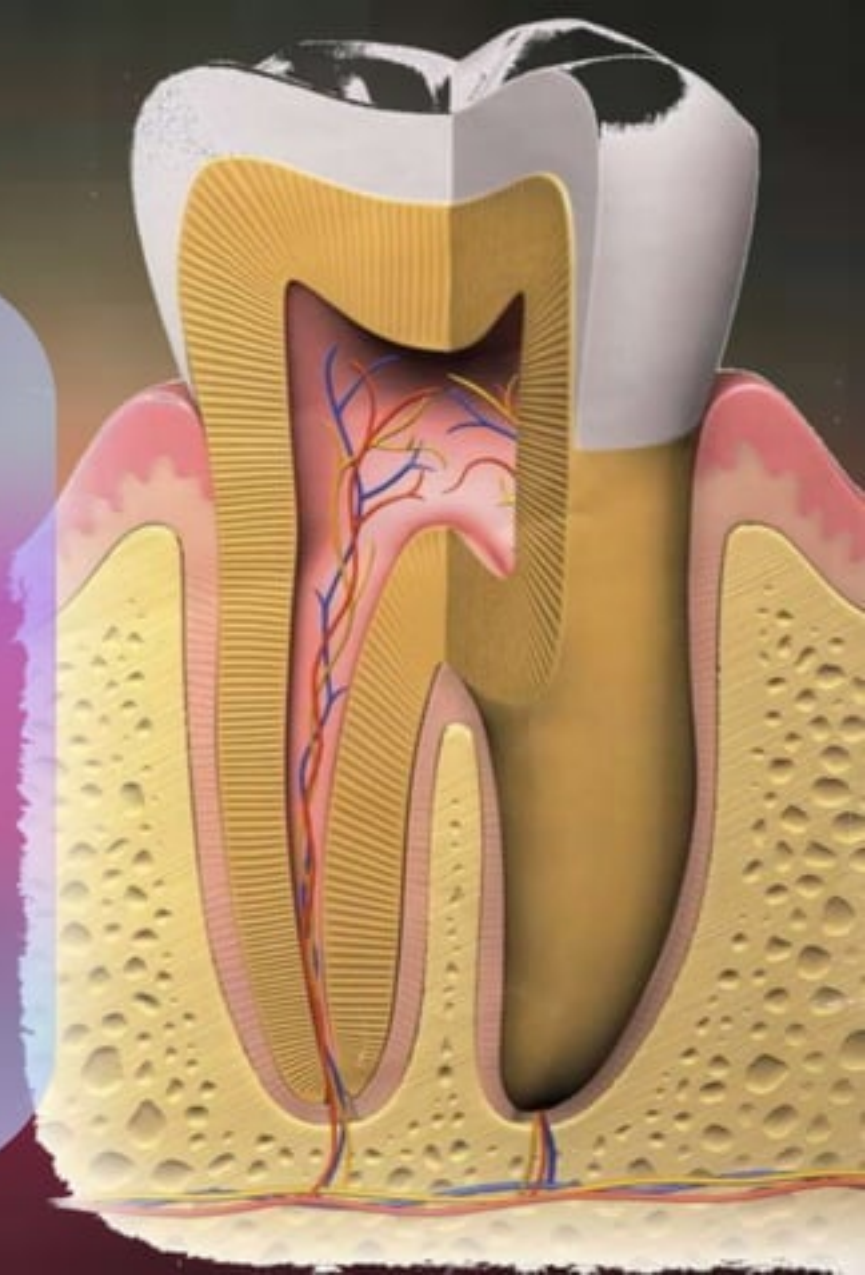
□ Three characteristics of hyperalgesia are spontaneous pain, a decreased pain threshold, or an increased response to painful stimulus.

□ Sensitivity of dentin is often increased when the underlying pulp is acutely inflamed.



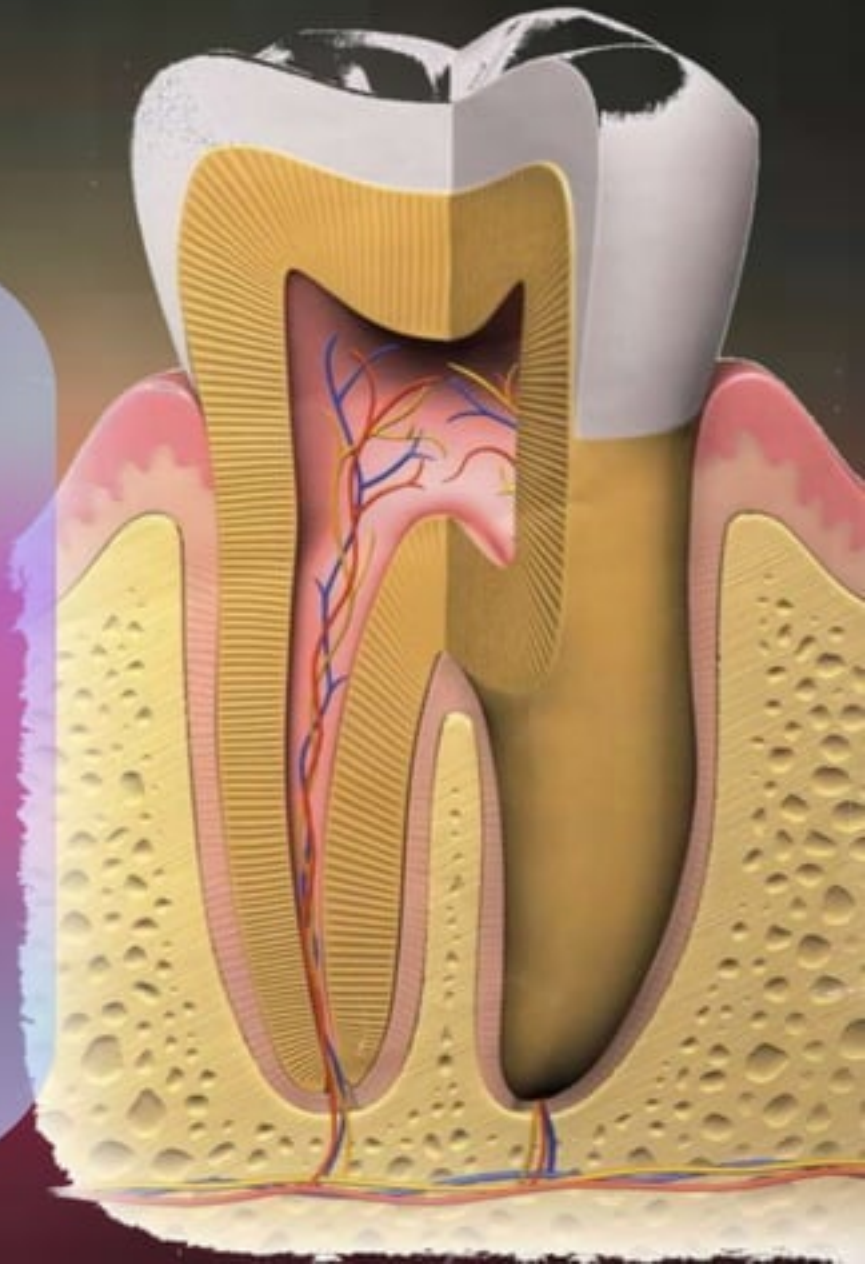
Pulp Atrophy

□ The continuous deposition of secondary dentin throughout life of the pulp and the deposition of reparative dentin in response to stimuli reduce the size of the pulp chambers and root canals and thereby decrease the pulp volume.



Fibrosis

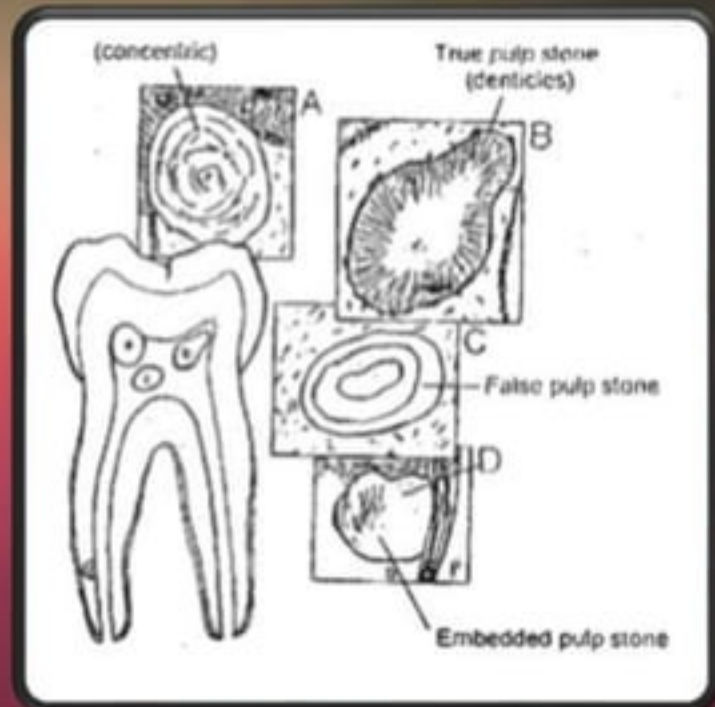
- ❑ The fibroblasts are reduced in size and numbers, but the collagen fibers are increased in number and in size, probably because of the decrease in the collagen solubility and turnover with advancing age.
- ❑ more evident in radicular portion of the pulp



Pulpal Calcifications

❑ In the coronal pulp calcifications usually takes the form of discreet, concentric pulp stones, whereas in the radicular pulp calcification tends to be diffuse.

❑ Pulp stones that form around epithelial cells (remnants of HERS) are termed denticles. These pulp stones are found near the root apex and contain dentinal tubules.



Calcific Metamorphosis

- ❑ Luxation of teeth as a result of trauma may result in calcific metamorphosis, a condition that can in a matter of months or years lead to partial or complete radiographic obliteration of the pulp chamber.
- ❑ There is excessive deposition of mineralized tissue resembling cementum or bone on the dentin walls
- ❑ May show a yellowish hue as compared with adjacent normal teeth.



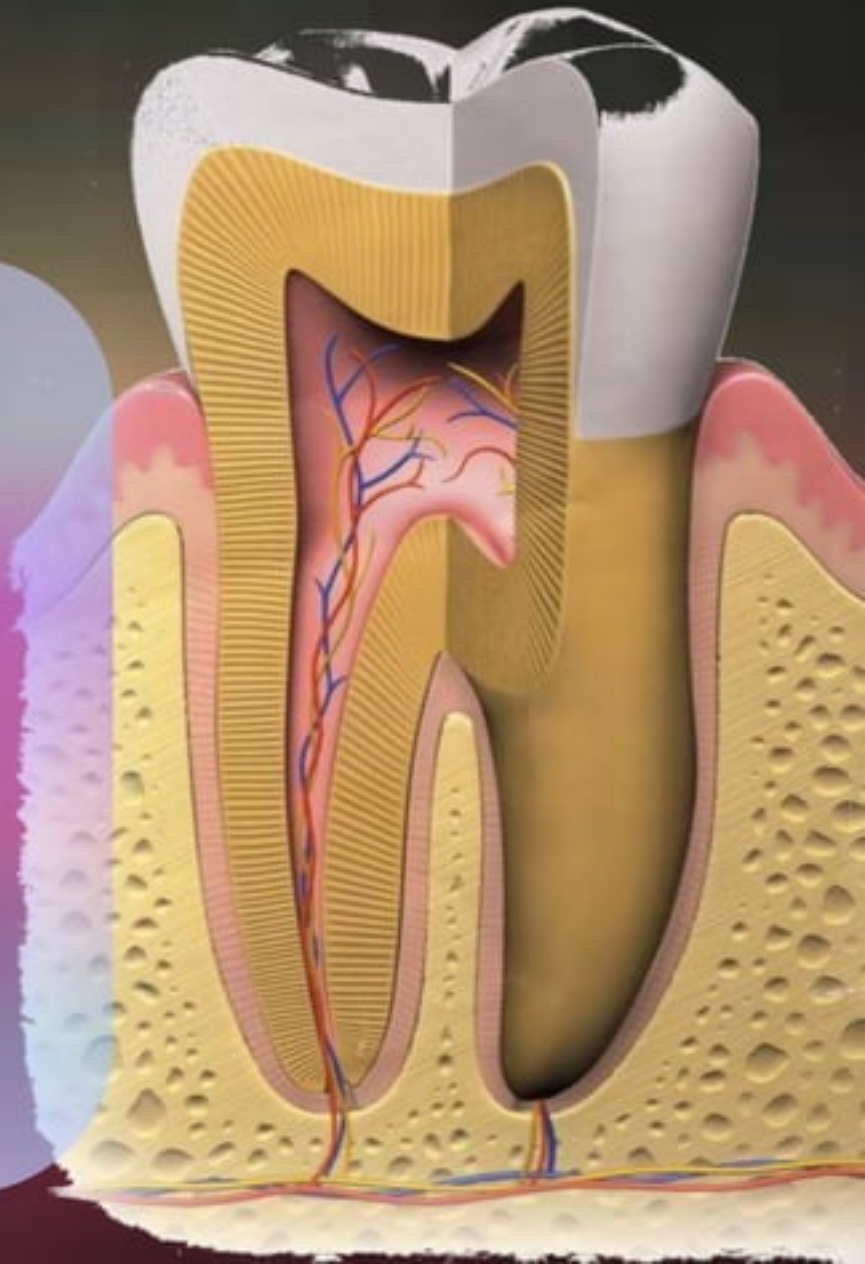
□ The periradicular tissues consist of the **cementum**, which covers the roots of the teeth, the **alveolar process** which forms the bony troughs containing the roots of the teeth, and the **periodontal ligament** whose collagen fibers, embedded in the cementum of the roots and in the alveolar process, attach the roots to the surrounding tissues.



The Periradicular Tissues

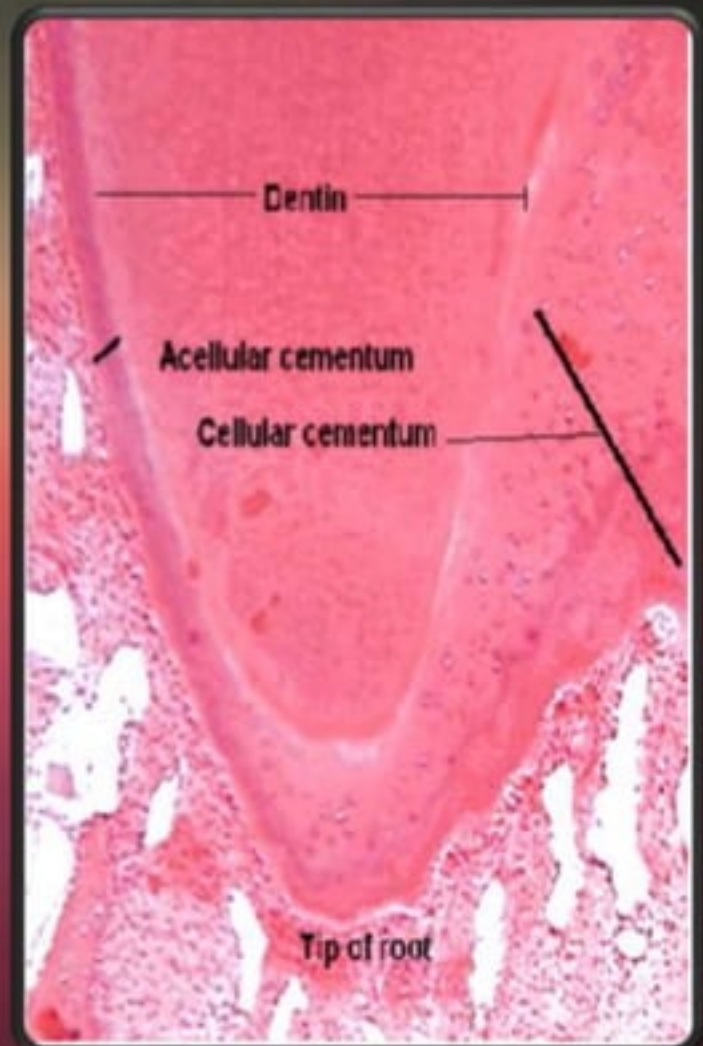
Cementum

- ❑ Cementum is bone-like calcified tissue that covers the roots of the teeth.
- ❑ It is derived from mesenchymal cells of the dental follicle that differentiate into cementoblasts.
- ❑ The cementoblasts deposit a matrix, called cementoid, that is incrementally calcified and produces two types of cementum: acellular and cellular.



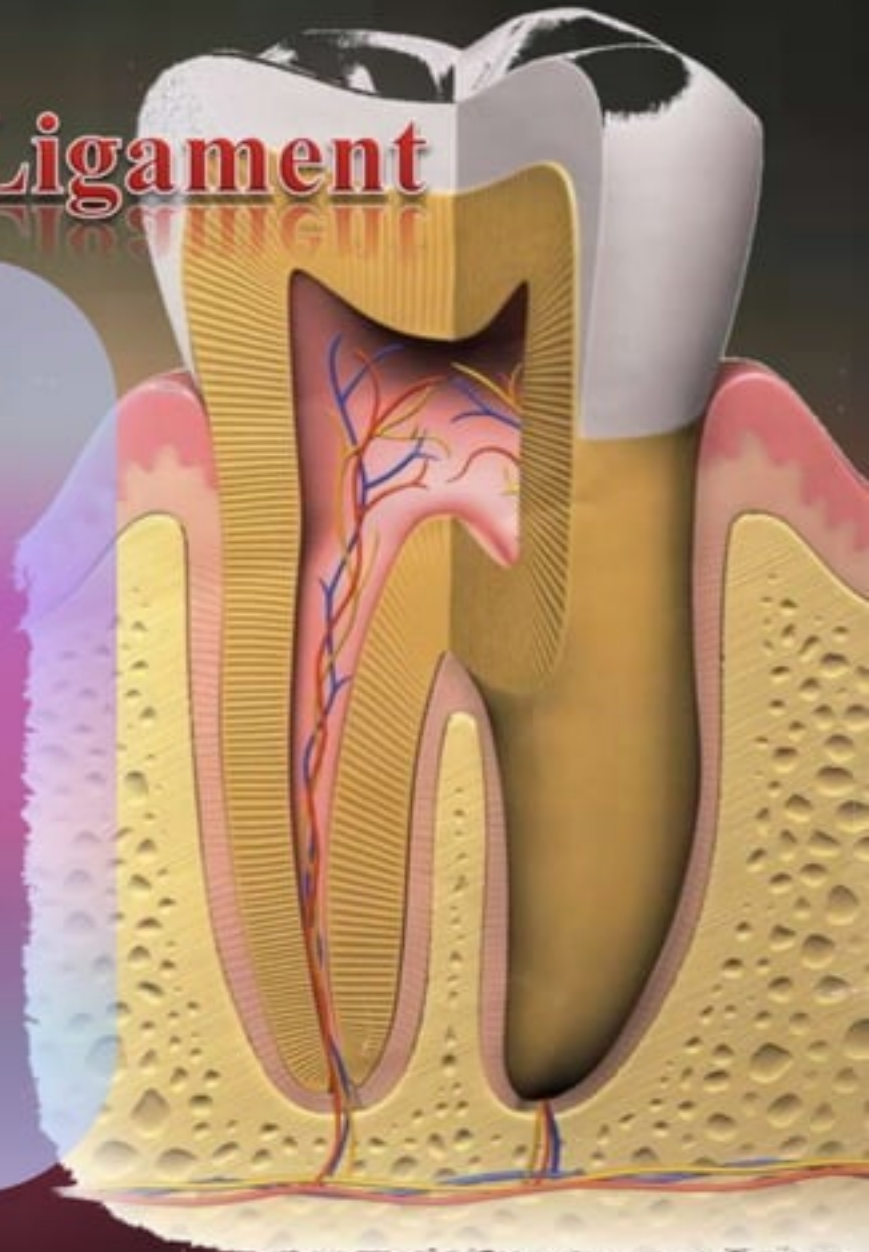
Cementum

- ❑ **Acellular cementum** is deposited first against dentin forming the CDJ, and it covers the cervical and middle thirds of the root.
- ❑ **Cellular cementum** is usually deposited in the apical third of the root, and is deposited at a greater rate, thus entrapping the cementoblasts in the matrix which becomes cementocytes.



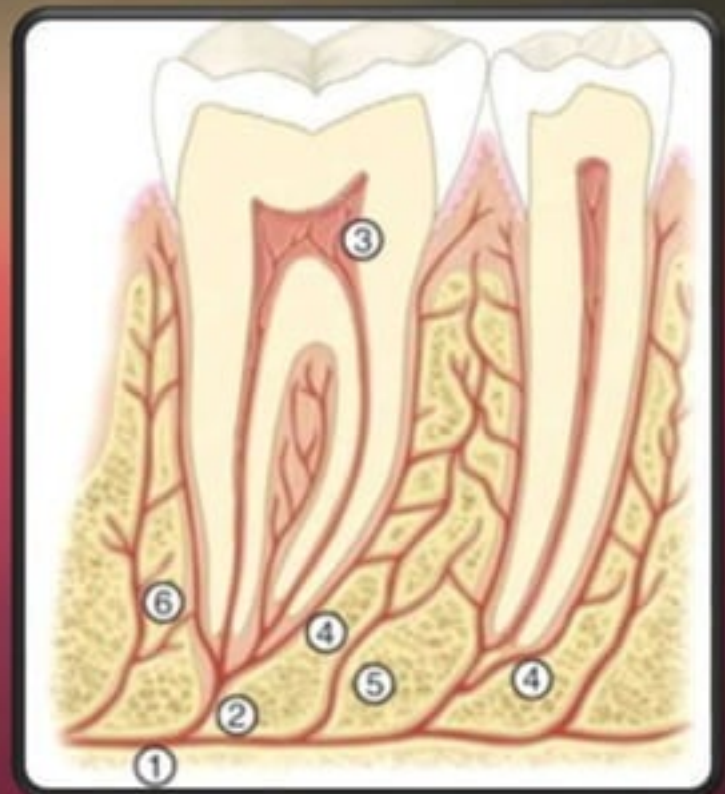
Periodontal Ligament

- ❑ The periodontal ligament is a dense fibrous connective tissue that occupies the space between cementum and alveolar bone.
- ❑ It surrounds the necks and roots of the teeth and is continuous with the pulp.
- ❑ It is composed of ground substance, interstitial tissue, blood and lymph vessels, nerves, cells, and fiber bundles.



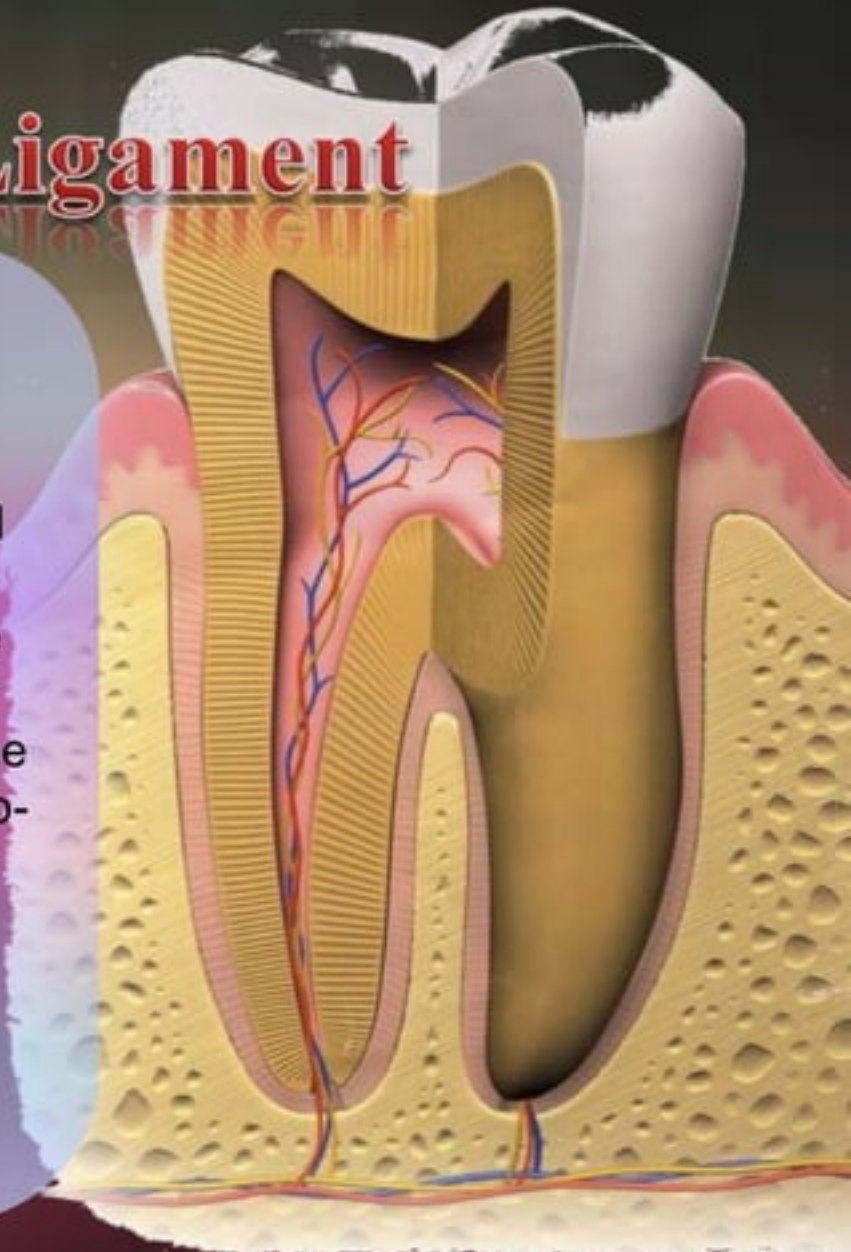
Periodontal Ligament

- ❑ The alveolar artery branches into the dental and interalveolar arteries.
- ❑ The dental artery supplies the apical area of the periodontal ligament.
- ❑ The lateral branches of interalveolar artery, called perforating arteries, enter through the cribriform plate into the lateral periodontal ligament.



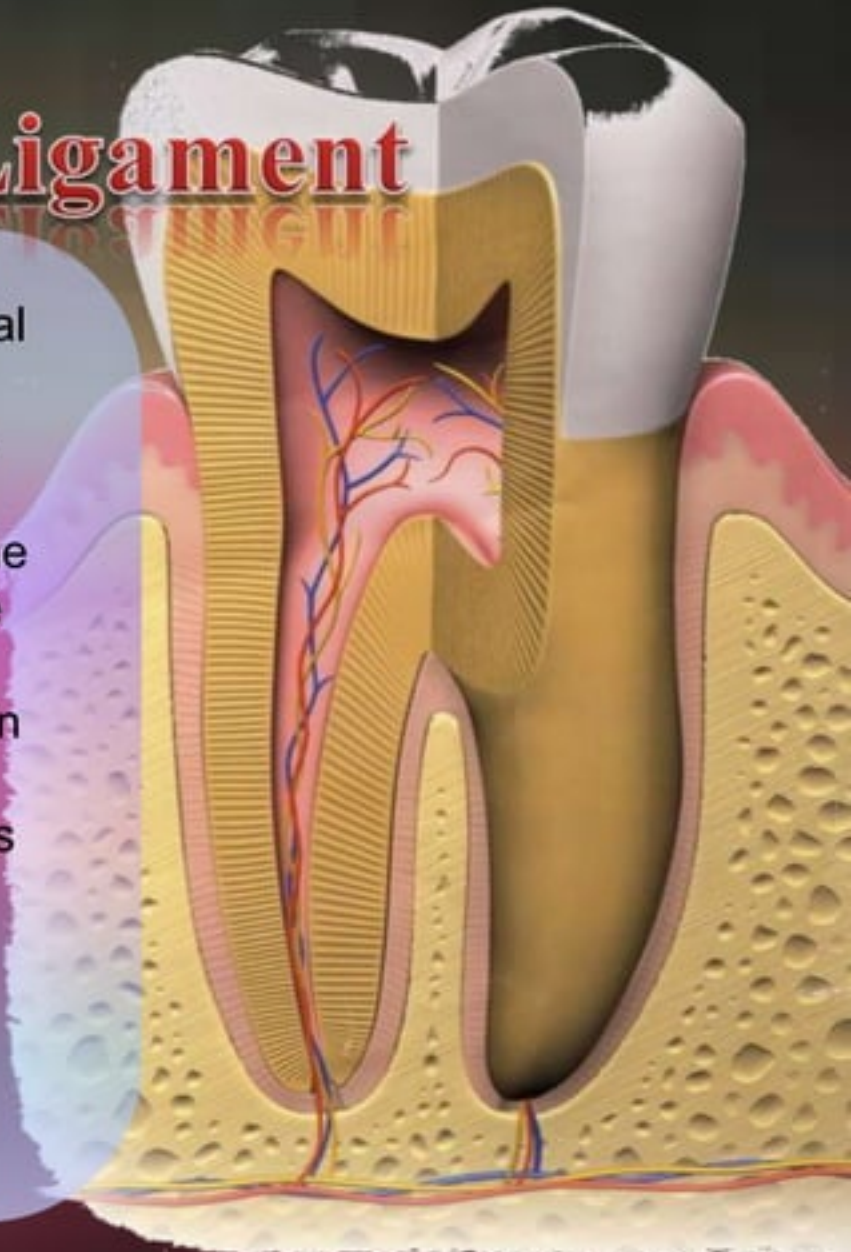
Periodontal Ligament

- ❑ The **alveolar nerves**, which originate in the CNV, innervate the PDL.
- ❑ The nerves end in fibers of small or large diameter. The small-diameter fibers terminate as free endings in the interstitial spaces and are associated with pain. The large-dm fibers terminate in knob-like or spindle-like endings near the principal fibers and are mechanoreceptors associated with touch, pressure, and proprioception.



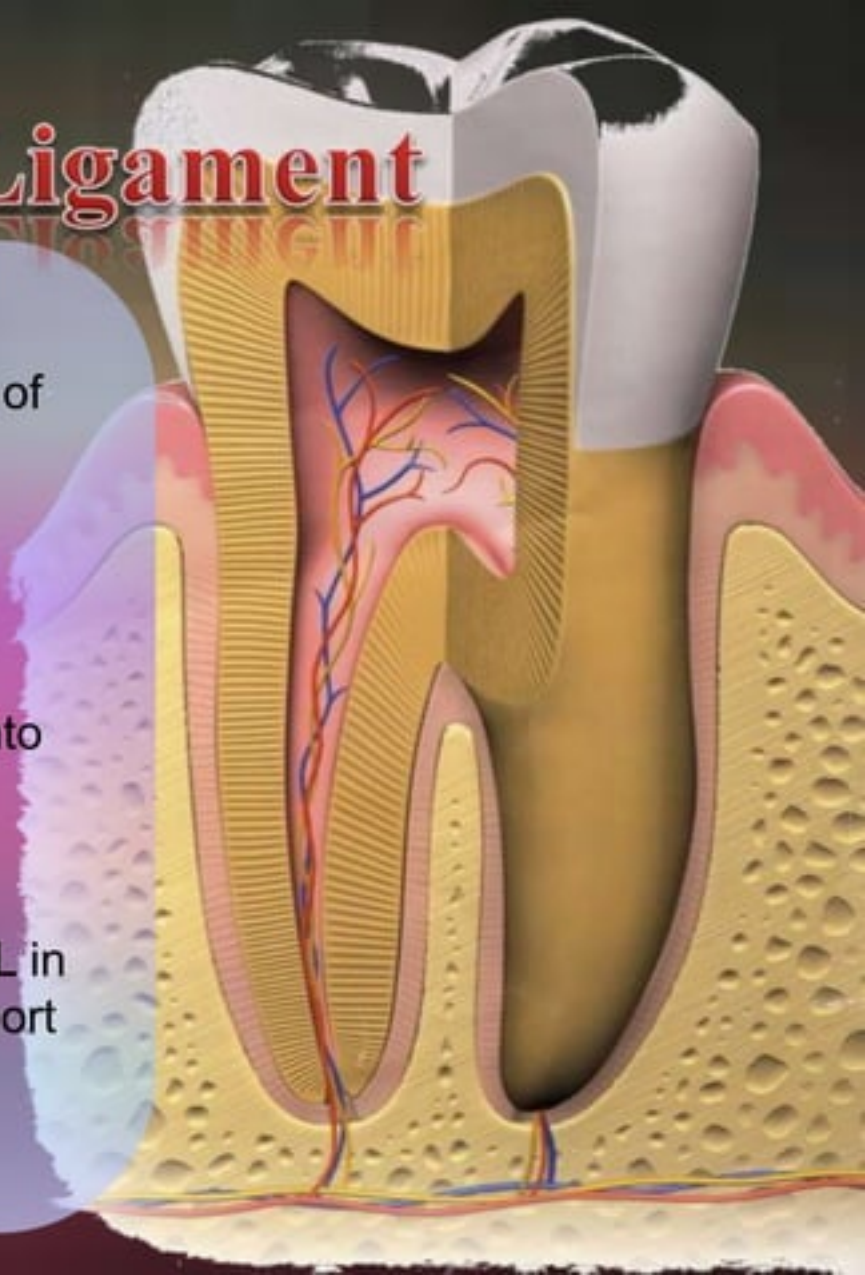
Periodontal Ligament

- ❑ The active cells of the periodontal ligament are the fibroblasts, osteoblasts, and cementoblasts.
- ❑ Osteoclasts are found in the bone periphery during periods of bone remodeling. Cementoclasts are only found in patients with certain pathologic conditions.
- ❑ Other cells are the epithelial cells of Malassez, undifferentiated mesenchymal cells, mast cells, and macrophages.



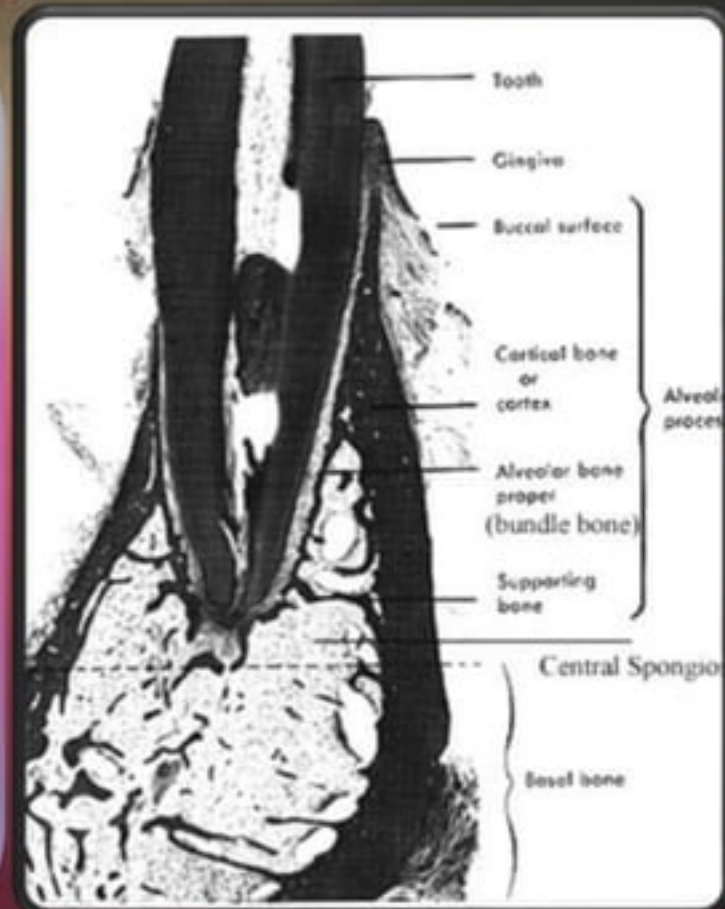
Periodontal Ligament

- ❑ The periodontal fibers are the principal structural components of the periodontal ligament.
- ❑ Two types are known: collagen and oxytalan fibers.
- ❑ Collagen fibers are organized into bundles which is arranged into principal fiber groups.
- ❑ Oxytalan fibers traverse the PDL in an axial direction and may support the blood vessels.



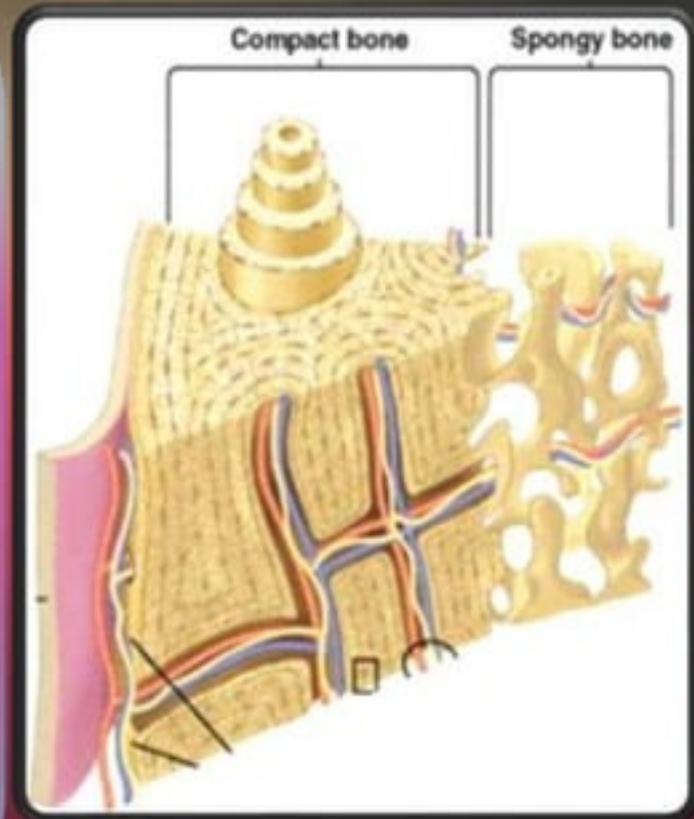
Alveolar Process

- ❑ The alveolar process is divided into the alveolar bone proper and supporting alveolar bone.
- ❑ The **alveolar bone proper** is the bone that lines the alveolus or the bony sockets that house the roots of the teeth. It consists of bundle bone in the periphery of the alveoli and lamellated bone toward the center of alveolar process.
- ❑ It can be referred to as cribriform plate and its radiographic image is called lamina dura.



Alveolar Process

- ❑ Adjacent to the alveolar bone proper is the **supporting alveolar bone** which is a diploe of cancellous bone covered by two outer layers of compact bone.
- ❑ The cancellous bone consists of lamellated bone arranged in branches called trabeculae. Between trabeculae are medullary spaces, filled with marrow.
- ❑ In adults, the marrow in the mand. and max. is usually fatty, but hematopoietic tissue is found in max. tuberosity, max. and mand. molar periradicular, and premolar periradicular areas.



Thank you!

Sources:

- ❑ Cohen, Stephen. Burns, Richard. Pathways of the Pulp. 6th ed.
- ❑ Grossman, Louis. Root Canal Therapy.