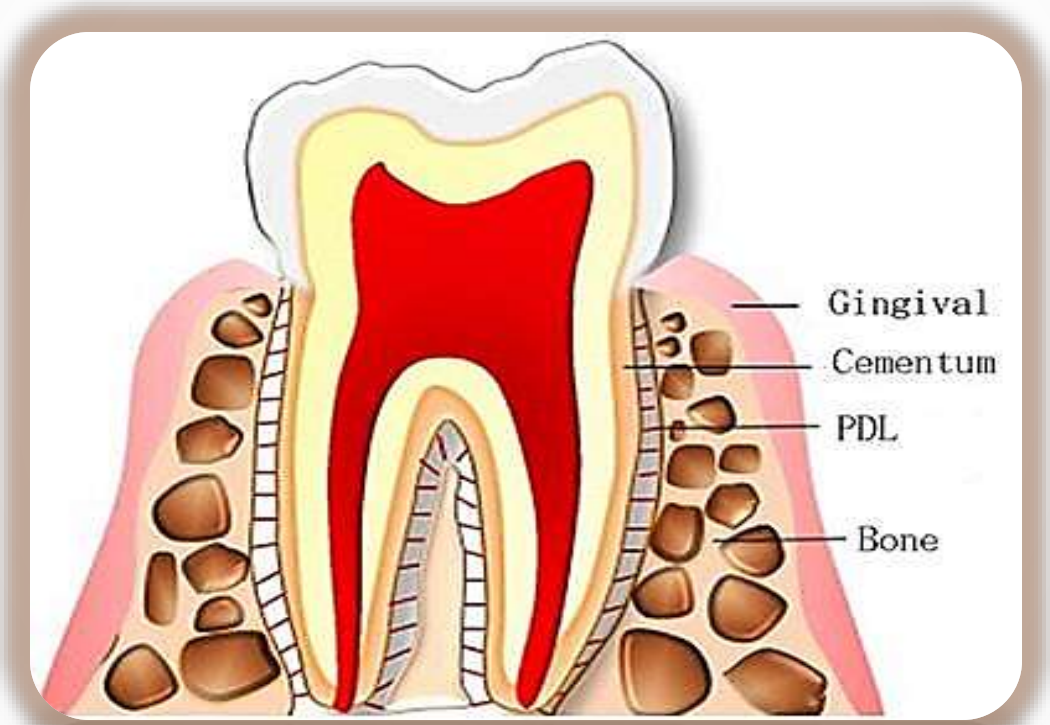
PERIODONTAL LIGAMENT

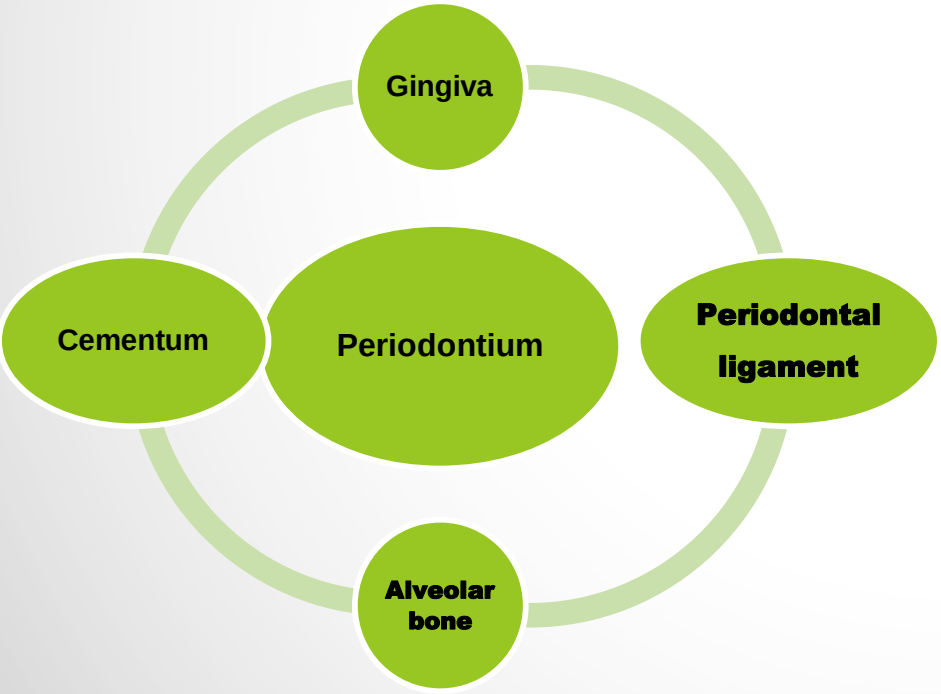


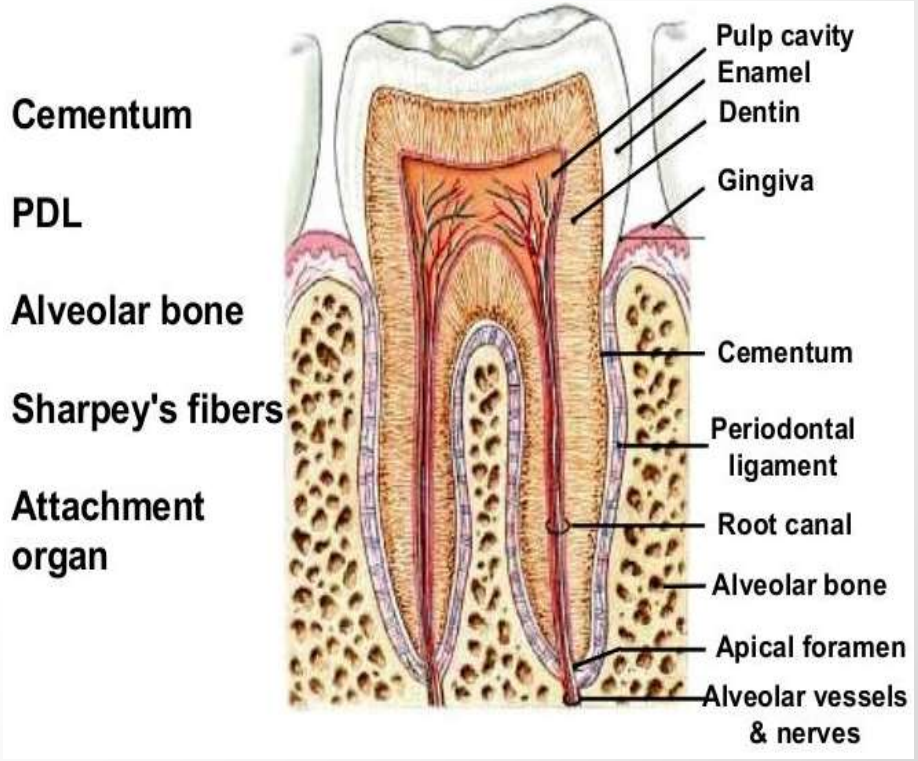
DEPARTMENT OF PERIODONTOLOGY

KARPAGA VINAYAGA INSTITUTE OF DENTAL SCIENCES

INTRODUCTION

- The tissues that invest and support the teeth including the gingiva, alveolar mucosa, cementum, periodontal ligament, and alveolar bone.– **(Glossary of Periodontal terms, 2001).**





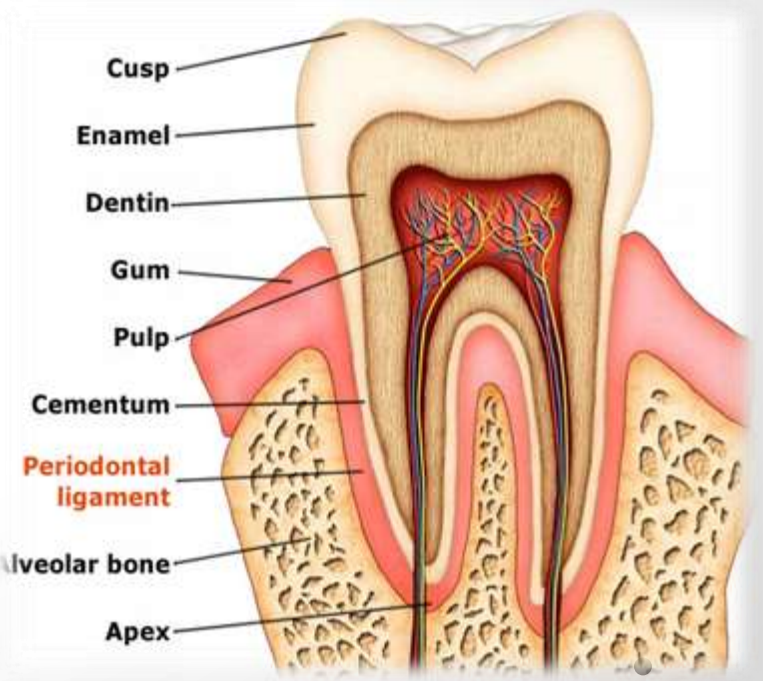
DEFINITION

“ The periodontal ligament is the connective tissue that surrounds the root & connects it to the bone. It is continuous with the connective tissue of the gingiva & communicates with the marrow spaces through vascular channels in the bone.”

Carranza & Bernard

“The periodontal ligament occupies the periodontal space, which is located between the cementum and the periodontal surface of alveolar bone and extends coronally to the most apical part of the lamina propria of the gingiva.”

Orban



SYNONYMS

- Periodontal membrane
- Alveolo-dental ligament
- Desmodont
- Pericementum
- Dental periosteum
- Gomphosis

EXTENT

- In the coronal direction it is continuous with lamina propria of gingiva & is demarcated by the alveolar crest fibers.

- At the root apex it merges with the dental pulp.

- Average width

  - 0.21 mm (11 to 16 yrs)

  - 0.18 mm (32 to 52 yrs)

  - 0.15 mm (51 to 67 yrs) showing a progressive decrease with age.

Width 0.15-0.38 mm

(A.R Ten Cate)

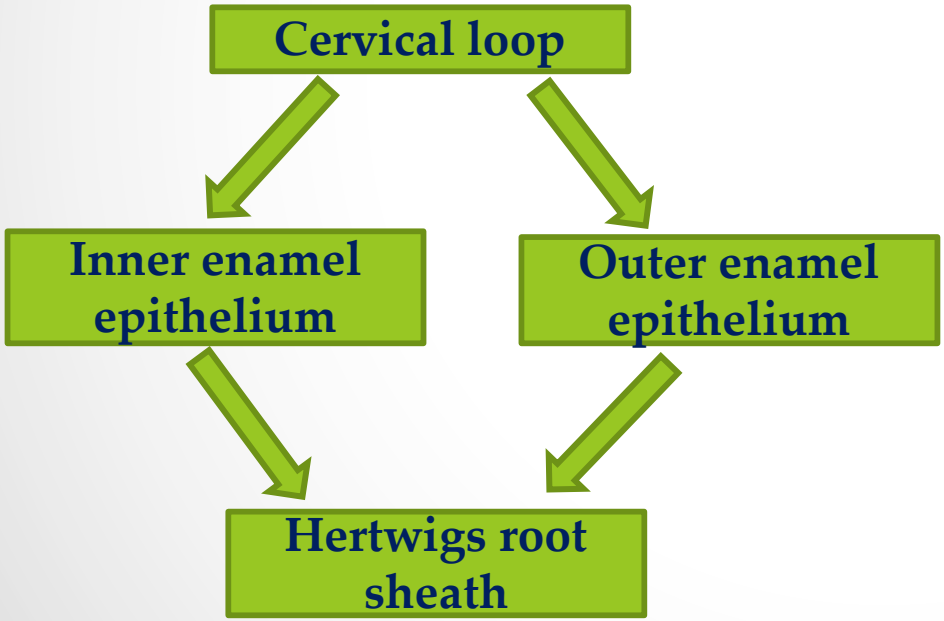
SHAPE:

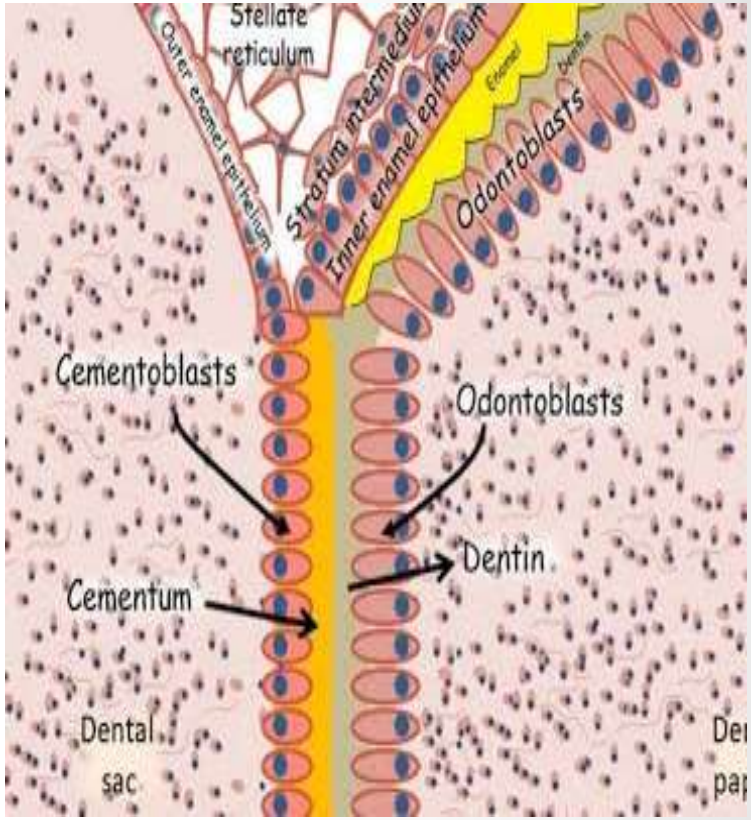
- It is thinnest around the middle third of the root, with an hour glass appearance.

- The ligament appears as a radiolucent area of **0.4- 1.5mm** between the radiopaque lamina dura of the alveolar bone and cementum.(Orbans)

DEVELOPMENT OF PDL:

- The development of the periodontal ligament begins with root formation, prior to tooth eruption.





HERS

Influence

Dental papilla

Differentiates

Odontoblasts

Deposits

Radicular dentin

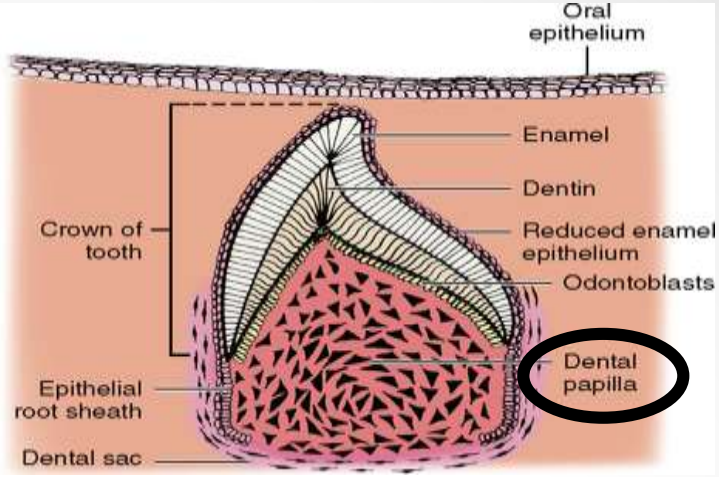
HERS degenerates

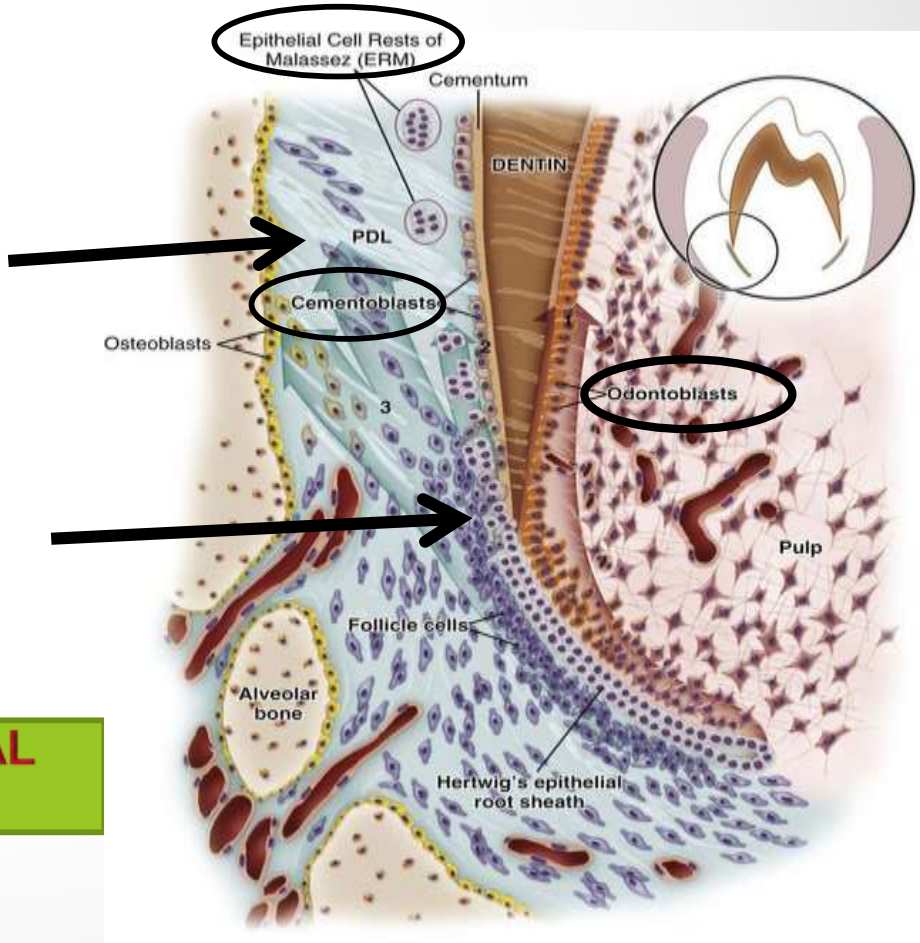
Dental follicle

Dentin

Cementoblasts

PERIODONTAL LIGAMENT





As the root formation continues, cells in the peri follicular mesenchyme gain their polarity, cellular volume & become widely separated

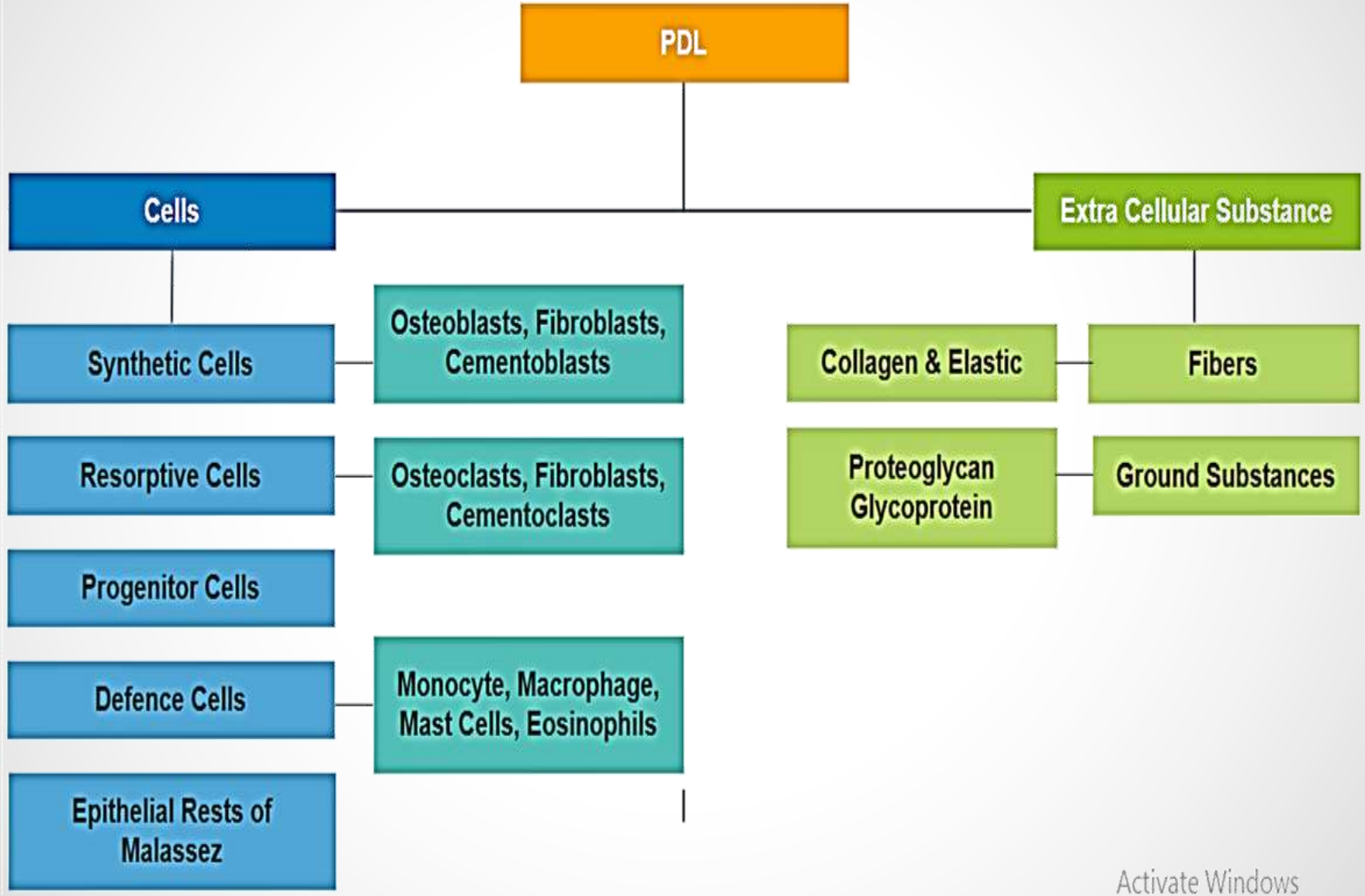
Actively synthesize & deposit collagen fibrils and glycoproteins in developing PDL **(Grant's 1989; Ten Cate's 1971)**

Type I collagen is secreted

Assembles as collagen bundles on the bone and cementum surface

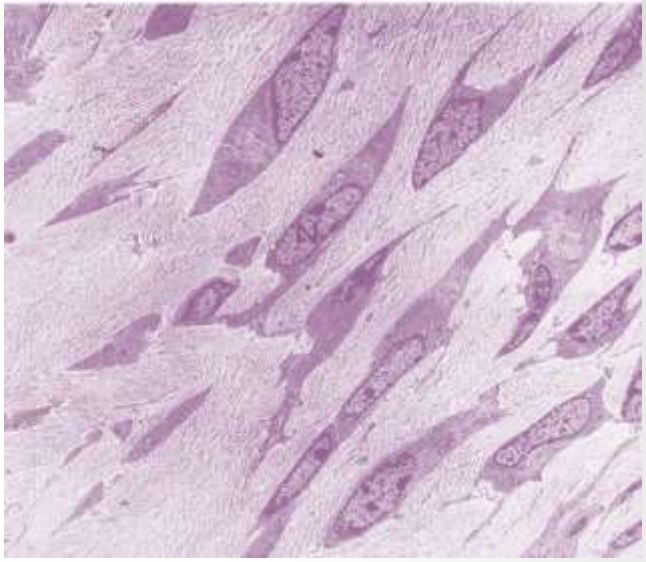
Establish continuity across the ligament space

COMPONENTS OF PDL:



❑ ***SYNTHETIC CELLS:***

FIBROBLASTS



- Principle cell (Tencates) .

- **Origin:**

a) Cementum: Ectomesenchyme of investing layer of dental papilla and the dental follicle

b) Alveolar bone: perivascular mesenchyme.

- **Orientation (Beertsen *et al 1997).***

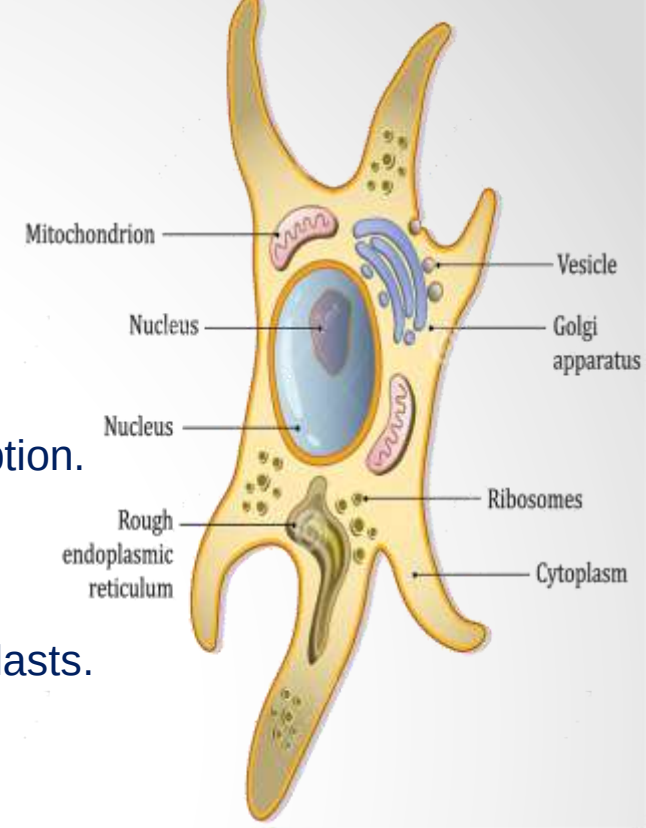
a) Long axis – parallel to collagen fibers

b)Cross sections - exhibit a stellate appearance, with cytoplasmic processes segregating individual bundles of collagen fibers

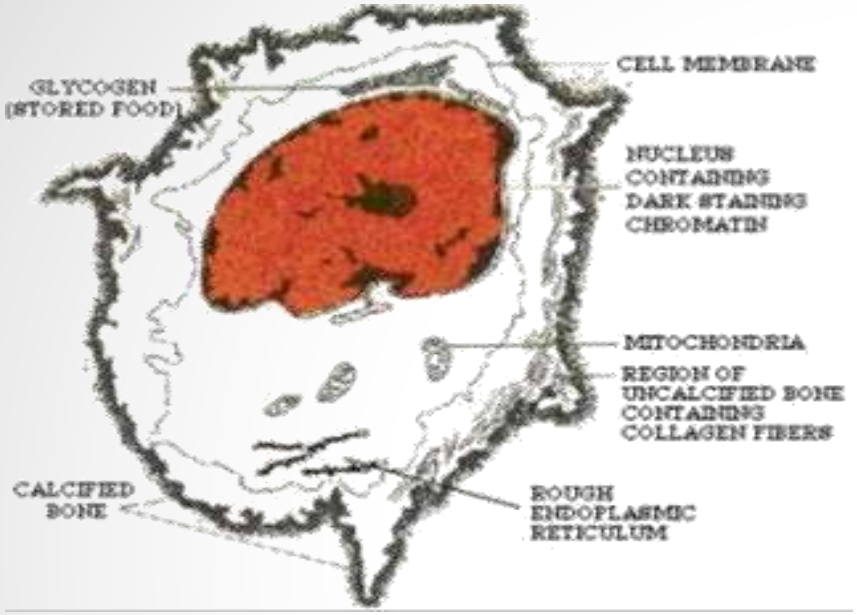
Collagen fiber bundles (blue) are cut transversely and segregated by cytoplasmic processes of connective tissue cells (red).

FUNCTIONS

1. Synthesize Collagen (Esterl 1961)
2. Synthesize fibrils (Stallard 1963).
3. Organize fibrous network & generate force for tooth eruption.
4. Produce extracellular matrix of PDL (Sodek 1977).
5. Have capacity to give rise to cementoblasts and osteoblasts.
6. Maintain normal width of PDL.
7. Regulate collagen turnover by PHAGOCYTOSING old collagen fibers. 30 minutes are taken for the intercellular degradation of collagen
8. Periodontal ligament fibroblasts, as most connective tissue cells, are quite rich in cytoplasmic microfilament systems which are indispensable for contraction and movement (Bellows et al)

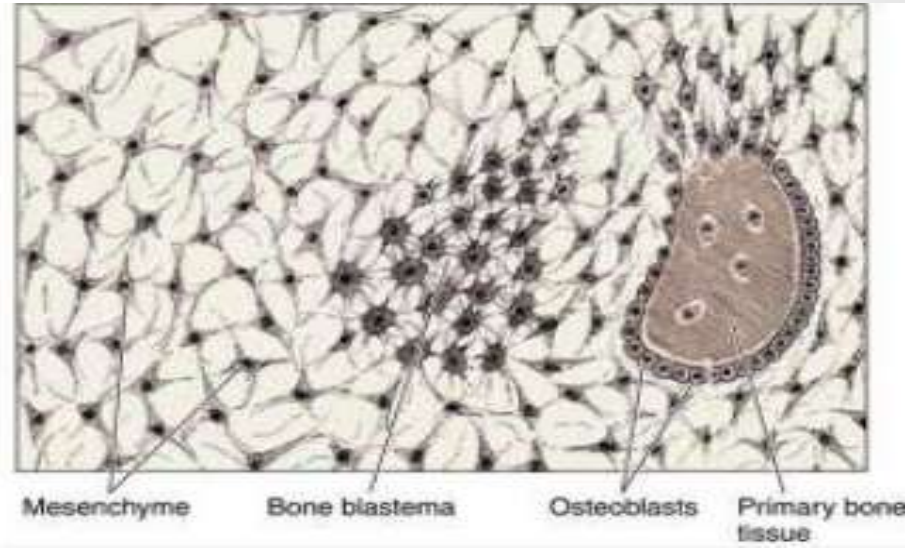


OSTEOBLASTS



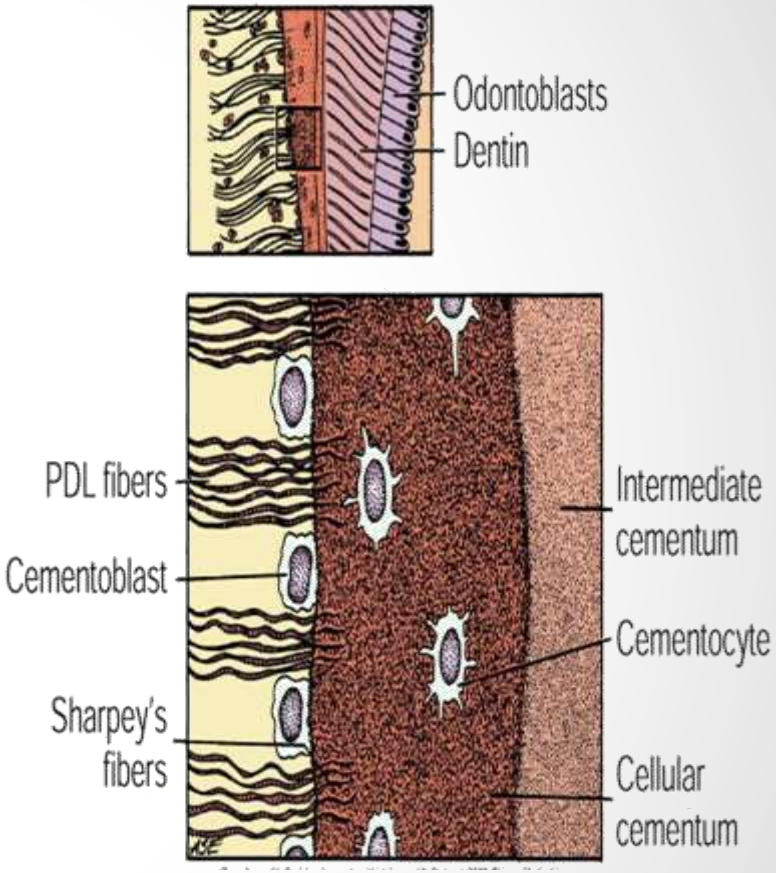
- These cells covers the periodontal surface of the alveolar bone.
- Line the tooth socket and are cuboidal in shape with a prominent round nucleus at the basal end of the cell.
- RER , mitochondria , and vesicles are abundant in active cells.

- Microfilaments are prominent beneath the cell membrane at secreting surface.
- The cells contact one another through desmosomes and tight junctions.



CEMENTOBLASTS

- These cells line the surface of cementum.
- They are cuboidal with a large vesicular nucleus ,with one ore more nucleoli and abundant cytoplasm.
- • All the organelles required for protein synthesis and secretion are present.
- • Cells actively depositing cellular cementum exhibit abundant basophilic cytoplasm and cytoplasmic processes.
- • Acellular cementum- no prominent cytoplasmic processes.



STUTTGART *ET AL* 2002

❑ ***RESORPTIVE CELLS:***

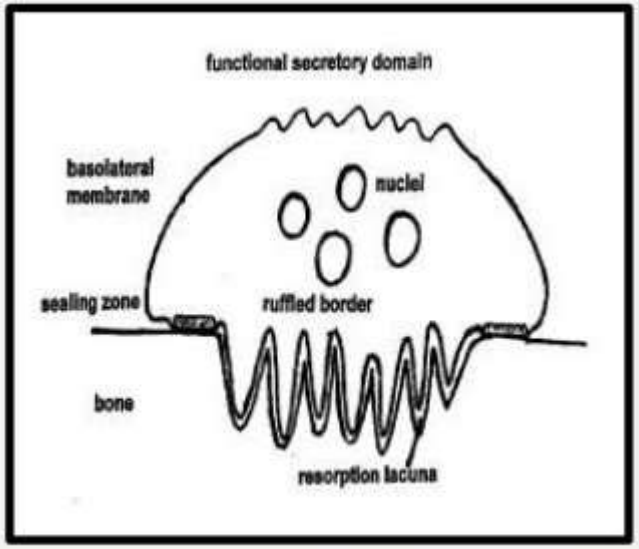
OSTEOCLASTS

- These resorb bone and tend to be large and multinucleated but can also be small and mononuclear .

• Multinucleated Osteoclasts are formed by fusion of precursor cells similar to circulating monocytes.

• The part of plasma membrane lying adjacent to bone that is being resorbed is raised in characteristic folds and is termed the Ruffled or Striated border.

• Are found against the bony surface occupying shallow depression called Howship's lacunae.



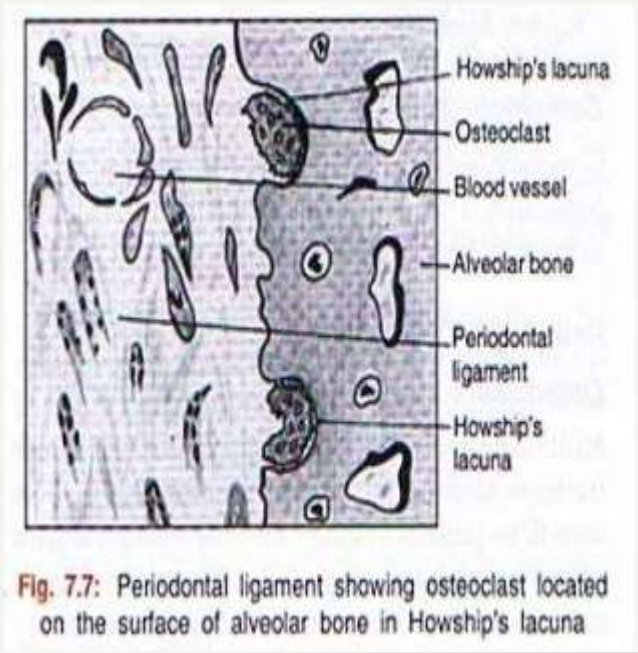


Fig. 7.7: Periodontal ligament showing osteoclast located on the surface of alveolar bone in Howship's lacuna

OSTEOCLASTS

The ruffled border is separated from the rest of plasma membrane by a zone of specialized membrane that is closely applied to the bone, the underlying cytoplasm of which tends to be devoid of organelles and has been called The Clear Zone.

CEMENTOCLASTS

As cementum does not remodel, Cementoclasts are not usually found in the ligament.

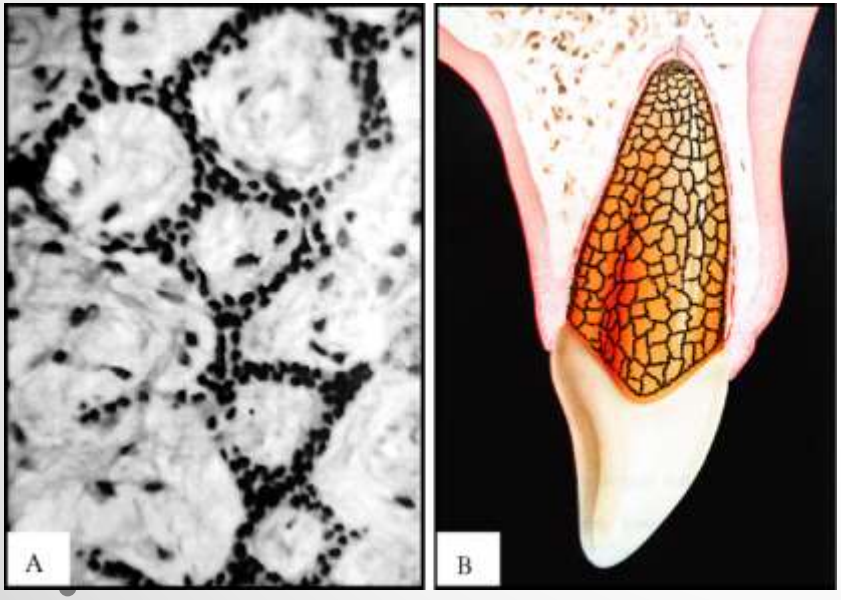
- These cells only occur in certain **pathologic conditions**, during resorption of deciduous teeth and when regressive forces are applied on a tooth such as orthodontic therapy.
- These Cementoclasts resembles Osteoclasts and are located in depressions in cementum resembling **Howship's lacuna.**
- These cells not only resorb cementum, they can destroy dentin and enamel as well thus they are also called **Odontoclasts**

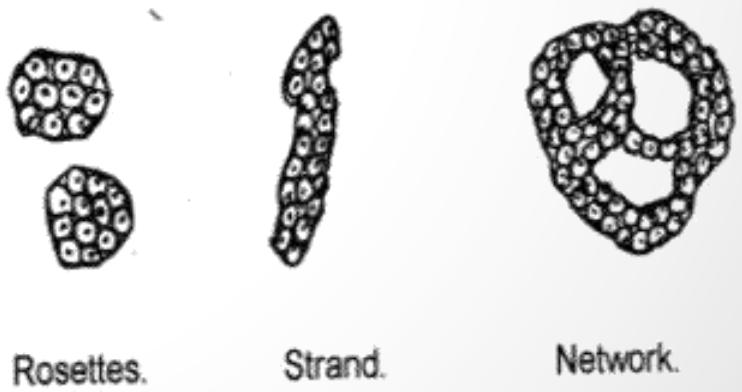
❑ ***PROGENITOR CELLS:***

- All connective tissues including PDL contain progenitors cells that have the capacity to undergo mitotic division .
- Undifferentiated mesenchymal cells that have a perivascular location within 5 micrometres of blood vessels.
- When stimulated appropriately, these cells undergo mitotic division and can differentiate into fibroblast, osteoblast or cementoblast.

❑ EPITHELIAL CELL RESTS OF MALASSEZ:

- These were first described by Malassez in 1884 and are the remnants of the epithelium of Hertwig's epithelial root sheath.
- The PDL contains epithelial cells that lie about 25 m from the cementum surface.
- They persist as networks, strands, islands or tubule-like structures near and parallel to the surface of the root.





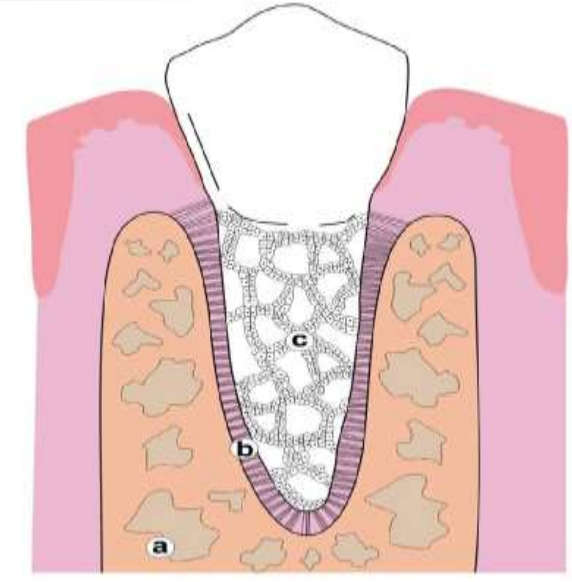
- Most numerous in the apical area & cervical area. **(Xiong J, Gronthos S, Bartold PM)**

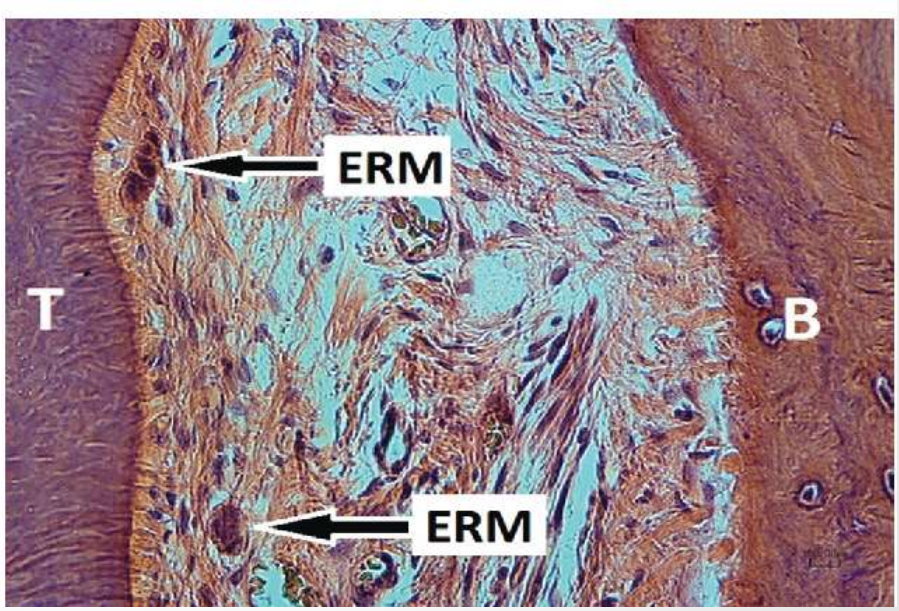
Presence:

children – more numerous

old individuals – less Dimnishes with age **(Simpson HE)**

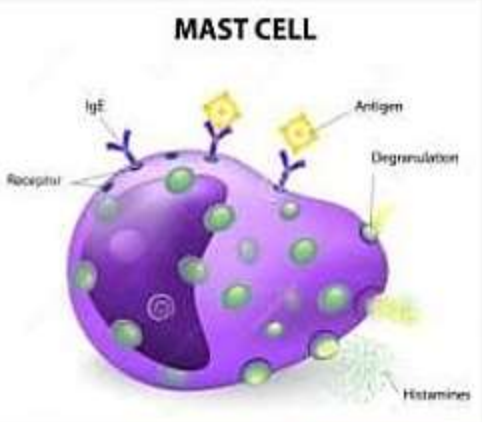
- These cells may proliferate to form cysts and tumors.
- These cells may undergo calcification to become **CEMENTICLES.**



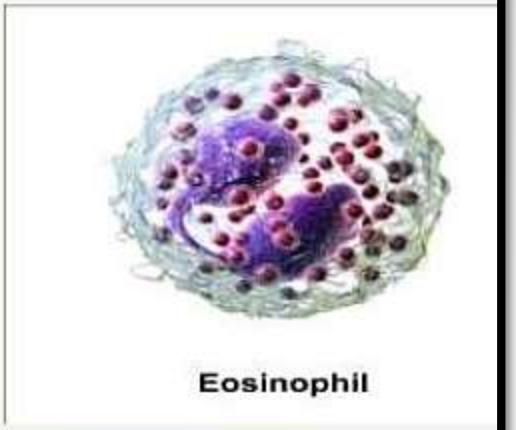


❑ DEFENCE CELLS:

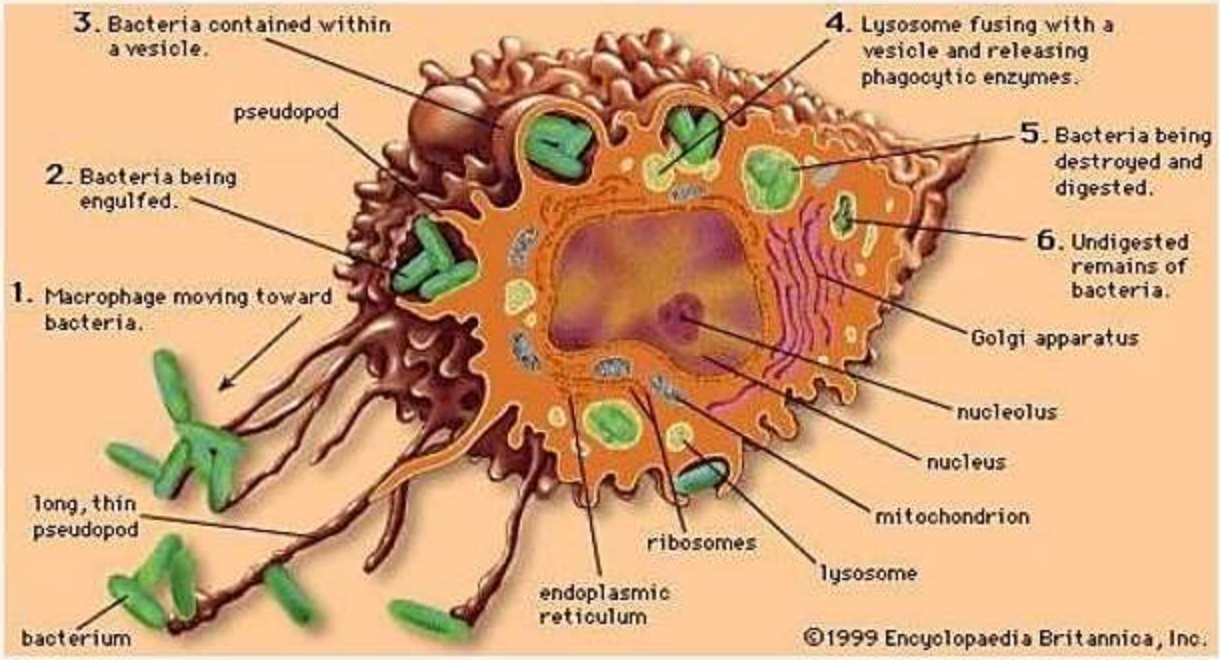
MAST CELLS



EOSINOPHILS



MACROPHAGES



❑ EXTRA CELLULAR SUBSTANCES:

FIBRES

1.COLLAGEN

2.ELASTIC

3.RETICULAR

4.SECONDARY

5.INDIFFERENT FIBER PLEXUS

6.OXYTALAN

GROUND SUBSTANCES

1.PROTEOGLYCANS
2.GLYCOPROTEINS

COLLAGEN:

- Derived from the French word **“collagene”** to designate connective tissue constituents that produce glue.
- Collagen molecule is rigid and resists stretching. Therefore it is utilized in tissues where mechanical forces should be transmitted without loss.
- Organization of collagen depends upon the specific functional requirements in various Collagen.

STRUCTURE:

- All collagens are composed of 3 polypeptide chains coiled around each other to form the typical triple helix configuration.

Variations are brought about by

1. Differences in assembly of the basic polypeptide chains
2. Different lengths of helix
3. Various interruptions in helix
4. Differences in the terminations of the helical mains

COLLAGEN CLASSES:

- There are at least 19 recognized collagen species encoded by at least 25 separate genes, dispersed among 12 chromosomes (Embery et al 2000) Collagen classes.

- a. Interstitial collagens ---- Type I,II,III
- b. Basement membrane type ---- Type IV,VI,VII
- c. Short chain collagens ---- Type IX,X

- The main types of collagen in the PDL are TYPE I and TYPE III.
- More than 70 % of PDL is Type I .

- **Type I** is **uniformly distributed** in the ligament .

- **Type III** collagen accounts for about 20 % of collagen fibers, found in **periphery of Sharpey's fiber** attachments into alveolar bone.

- **Type IV and VII** are associated with **epithelial cell rests and blood vessels.**

- **Type XIII** collagen is believed to occur **within the PDL** only when ligament is fully functional .

- **Collagen V** is associated with these **fibrils** and is either buried within these fibrils or is found in the spaces between the **fiber bundles**.

- **Type VI** - microfibrillar component associated with **oxytalan fiber** system.

- **Type XII** contribute to the **construction of 3-dimensional fibril arrangement**- hence closely associated with regeneration of PDL.

- The collagen is gathered to form bundles approximately 5 um in diameter. These bundles are termed as PRINCIPAL FIBERS.

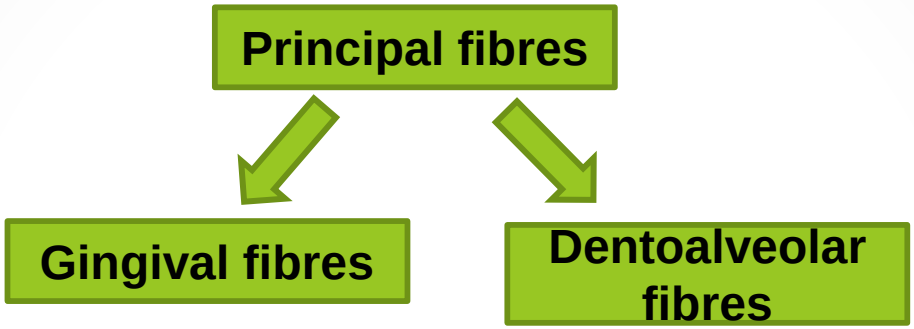
- Within each collagen bundle , subunits are present called collagen fibrils.

TURN OVER RATE OF THE COLLAGEN :

- The rate of turnover of collagen within the PDL is faster than all other connective tissues.
- **Sodek (1977)** found collagen synthesis in PDL of adult rat to be 2 fold greater than that of gingiva, 4 fold greater than that of skin, 6 fold greater than that of bone.
- The rate appears to be highest towards the root apex.
- The collagen on the tooth side has low turnover rate than that on the bone side where it shows high turnover rate.

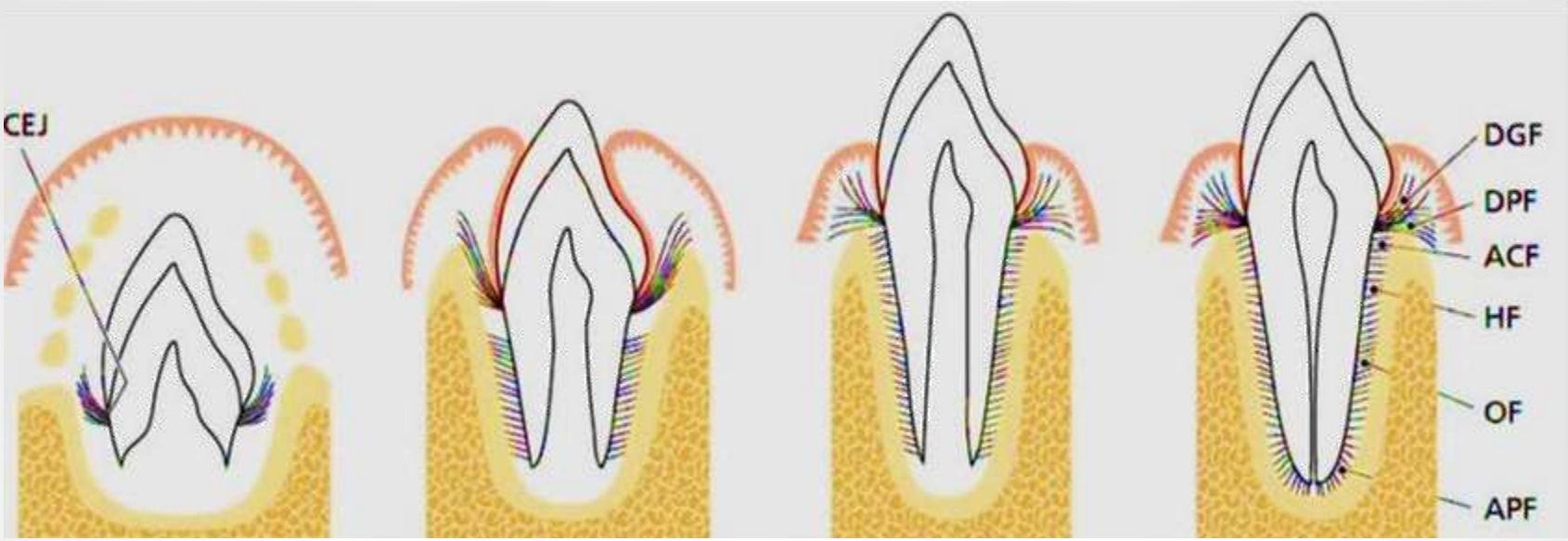
PRINCIPLE FIBRES OF PDL:

- Most of the PDL composition comes from principal fibres,which are oriented bundles of collagen fibres.



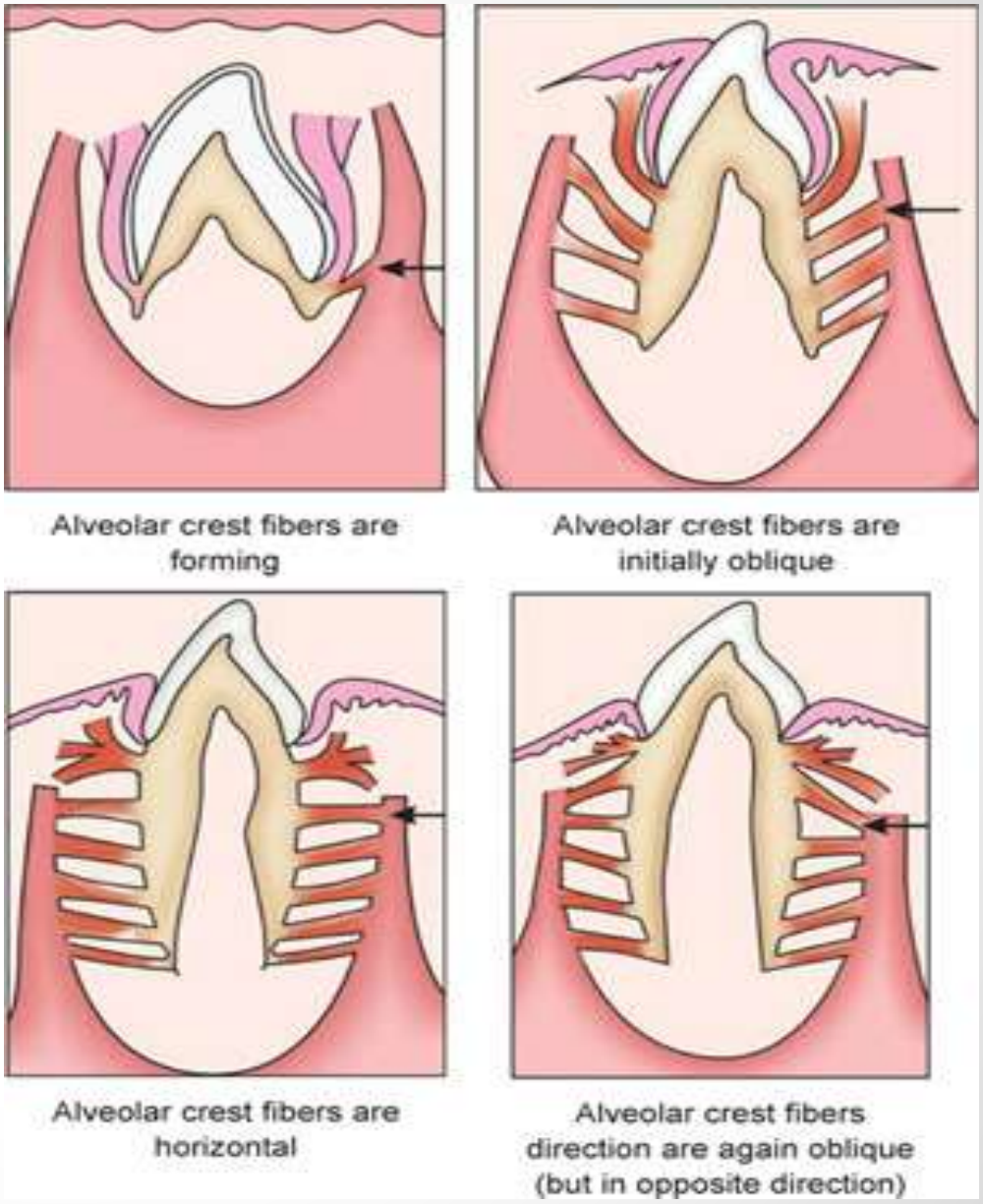
- PDL fibres – WAVY
- Contribute to the regulation of mineralization and to tissue cohesion at sites of increased biomechanical strain **(Zalzal S *et al* 1996).**
- The adult human PDL fibers are slightly thicker than other mammalian species and measure about 54-59 nm in diameter.
- This relatively small diameter reflects the short half-life of ligament collagen, meaning that there is little time for continuous assembly.

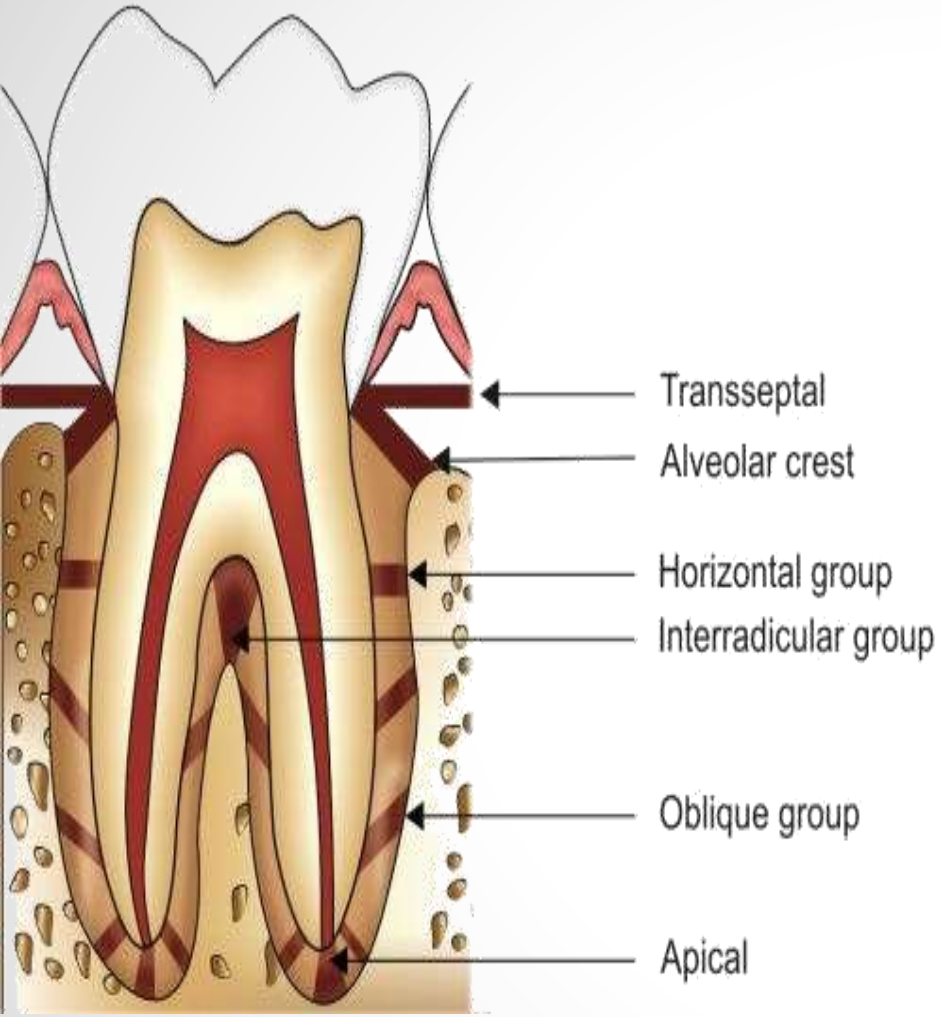
DEVELOPMENT OF PRINCIPLE FIBRES



- As the teeth begin to erupt the orientation of ligament fibres changes according to the stage of eruption (Grant and Bernick 1972)

- By the time of first occlusal contact of the tooth with its antagonist, the principal fibers around the coronal third of the root, the *horizontal* group are almost completely developed.
- The *oblique fibers* in the middle third of the root are still being formed.
- As eruption continues, and definite occlusion is established,there is a progressive apical maturation of *oblique fiber bundles*.
- With the formation of the apical fiber group, the definitive periodontal ligament architecture is established





- **TRANSSEPTAL**

  Extend Inter proximally over the alveolar bone crest and are embedded in the cementum of adjacent tooth

- **ALVEOLAR CREST**

  Fibers also run from the cementum over the alveolar crest and to the fibrous layer of the periodontium covering alveolar bone.

- **HORIZONTAL**

  Extend at right angles to the long axis of tooth from cementum to the alveolar bone

- **OBLIQUE**

  Largest group in the PDL.

  Extend from the cementum in a coronal directing obliquely to the bone.

- **APICAL**

  Radiate in a rather irregular fashion from the cementum to the bone at the apical region of the socket .

- **INTER RADICULAR**

  Fan out from cementum to the tooth in the furcation areas of multi rooted teeth

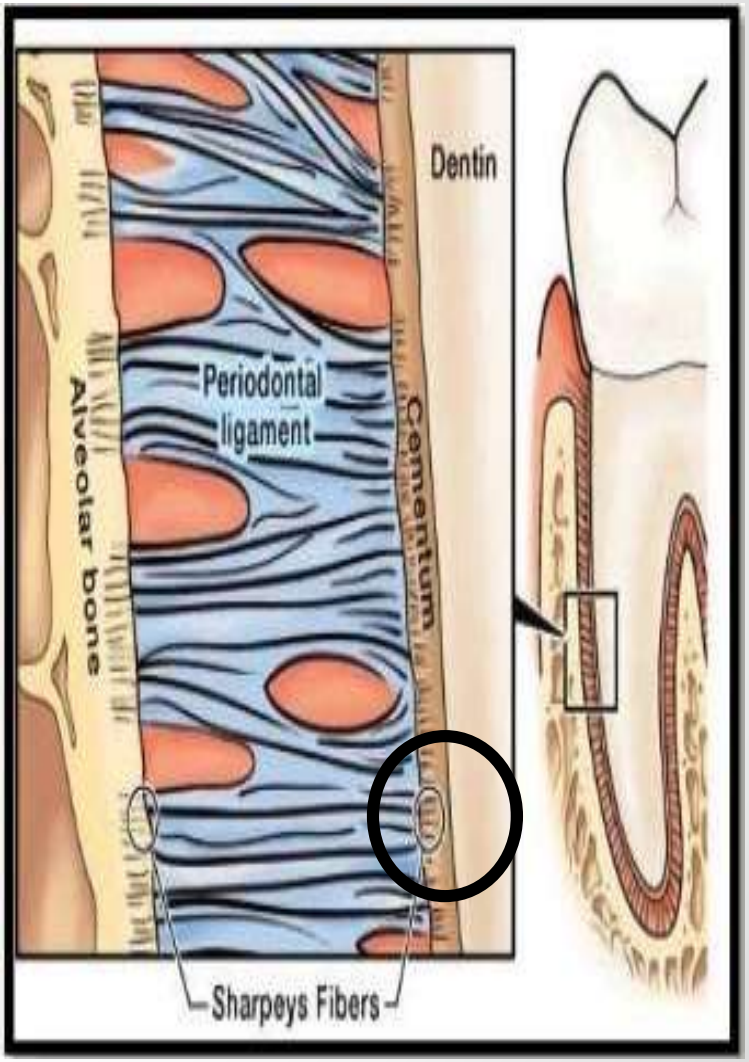
Fibre Group	Origin and insertion	Supposed function
1) Alveolar crest	Extend obliquely from the cementum just beneath the junctional epithelium to the alveolar crest and to the fibrous layer of the periosteum covering the alveolar bone.	Retains tooth in the socket Oppose lateral forces Prevents extrusion & intrusion of tooth. Protects deeper periodontal ligament structures
2) Horizontal group	They extend from cementum to alveolar bone in horizontal direction at right angles to long axis of tooth. Occupy 10-15 % of coronal root surface.	Restrain lateral tooth movements.
3) Oblique group	Largest group of PDL fibers. Occupy 80-85% of root surface. Extend from cementum in a coronal direction obliquely to the bone.	They bear the brunt of vertical masticatory stresses and transform them into tension on alveolar bone and resist intrusive forces.
4) Apical group	The apical fibres radiate in a rather irregular fashion from cementum to the apical region of the socket They donot occur in incompletely formed roots.	Prevent tooth tipping Resist luxation. Protect blood, lymph and nerve supplies to tooth.
5) Inter radicular group.	They fan out from the cementum to the tooth in the furcation areas of multirooted teeth.	Aid in resisting tipping torquing and luxation.

SHARPEY'S FIBRES

- The terminal portion of principal fibers of periodontal ligament, that are inserted into cementum and alveolar bone are called Sharpey's fibers.

- Acellular cementum- fully mineralized. Cellular cementum & AB – partially mineralized.

- Few Sharpey's fibers pass uninterruptedly through bone of alveolar process – **Transalveolar fibers.**



ELASTIC FIBERS

- There are three types of elastic fibers which are histochemically and ultrastructurally different.

1. Mature Elastic fibers
2. Eulanin fibers
3. Oxytalan fibers .

EULANIN FIBERS and OXYTALAN FIBERS have been described as immature elastic fibers.

MATURE ELASTIC FIBERS

• Consist of microfibrillar component surrounding an amorphous core of elastin protein .

- Restricted to walls of blood vessels in humans.

- PDL fibers do not contain mature elastin but two immature forms are found oxytalan and eulanin.

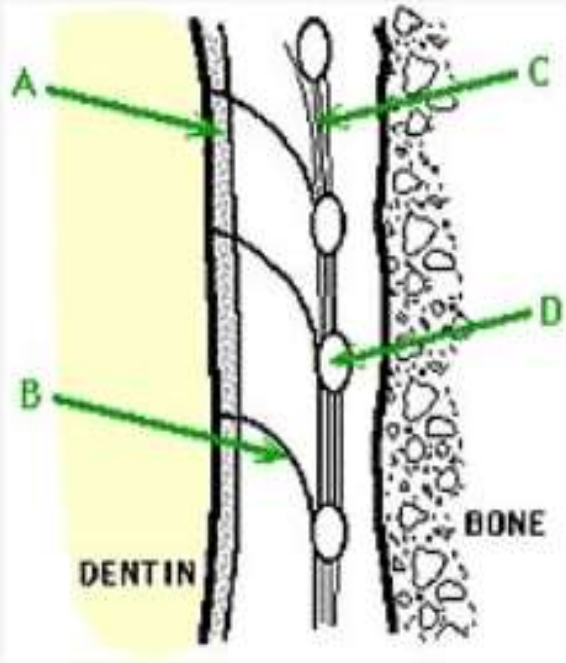
OXYTALAN FIBERS

- Are micro fibrils
- Run in apico-coronal direction to bend and attach at cervical third of root (Fulmer et al. 1974)
- Diameter – 0.5-2.5um
- Volume – 3%

Function

- supporting blood vessels of PDL.

- tooth support (abutments/ Orthodontically moved teeth)



Oxytalan fibers. (A) Cementum, (B) Principal oxytalan fiber, (C) Oxytalan tract, and (D) Periodontal vessel.

EULANIN FIBERS

- Are bundles of microfibrils embedded in a small amount of amorphous elastin.

- An elastic meshwork has been described in the PDL as being composed of many elastin lamellae with peripheral oxytalan & eulanin fibers

- Functions

- Regulate vascular flow
- Role in tooth support
- Facilitate fibroblast attachment and migration

RETICULAR FIBERS

- Immature collagen fibers
- Argyrophilic staining properties
- Related to basement membrane of blood vessels and epithelial cells
- Lie within the periodontal ligament.

SECONDARY FIBERS

- Represent the newly formed collagenous elements, not yet incorporated into principal fiber bundle.
- Located between and among the principal fibers.
- These are relatively non-directional and randomly oriented.
- Appear to transverse the periodontal ligament space corono-apically and are often associated with path of vasculature and nervous elements.

INDIFFERENT FIBER PLEXUS

- Described by **Shackleford, 1971**
- Small Collagen fibers in association with the larger principal collagen fiber
- Run in all directions forming a plexus.
- Once the tooth has erupted into clinical occlusion such an intermediate plexus is no longer demonstrable.
- **Intermediate plexus** has been reinterpreted by **Sloan** as representing merely an optical effect explained entirely by the arrangement of middle layer collagen into sheets rather than bundles.

GROUND SUBSTANCE

- The ground substance is the **Gel like matrix** synthesized by the fibroblast family & fills the space between the fibers and cells.

COMPOSITION

- Consists of a biochemically complex, highly hydrated, semisolid gel.
- Water content of 70%
- Glycosaminoglycan's – hyaluronic acid, Proteoglycans(versican , decorin)
- Glycoproteins -fibronectin , laminin, vibronectin , tenascin

PROTEOGLYCANS

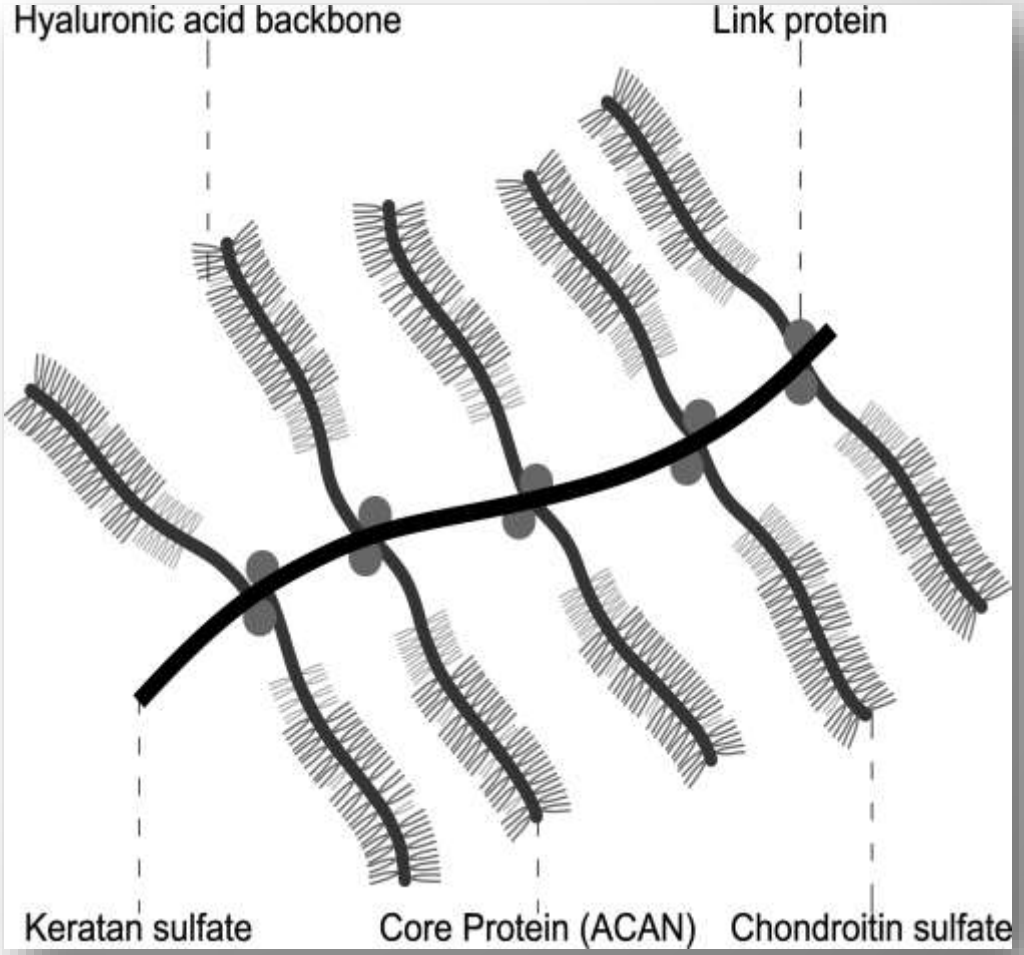
Large group of anionic macromolecules that consists of a protein core to which are attached hexose amine containing polysaccharides called **GAG chains.**

1. Decorin – regulates growth of collagen fibrils.
2. Versican – binds cell surface glycoproteins to ECM.
3. Prelecan - binds to fibronectin & helps anchor fibroblast to ECM.
4. Syndecan - binds to collagen & other glycoproteins.
5. CD44 – binds to glycoproteins.

With the exception of hyaluronic acid, the other glycosaminoglycans are sulphated and covalently attached to the core proteins at the reducing terminus of PG.

The major GAGs are:

1. Chondroitin Sulphate
2. Dermatan Sulphate
3. Heparin Sulphate
4. Hyaluronic Acid
5. Keratan Sulphate



GLYCOPROTEINS

Three distinctly related glycoprotiens of the extra cellular matrix have been localized in the decalcified sections of human periodontal ligament.

1. FIBRONECTIN

- It promotes the attachment of cells to the substratum especially to collagen.
- It is expressed strongly along attachment sites of the PDL collagen fibers to cementum but not bone.
- In addition to its function as an adhesion protein it is also involved in blood coagulation, wound healing and chemotaxis.

2. TENASCIN :

- Also known as cytotactin
- It is found mostly in healing wounds.
- Unlike fibronectin it is not uniformly distributed through out the PDL.
- But is concentrated in between the less densely packed collagen fibrils near cementum and alveolar bone.
- Present in the glycoproteins of periodontal ligament with a smaller role in cell attachment and organization of basement membrane.

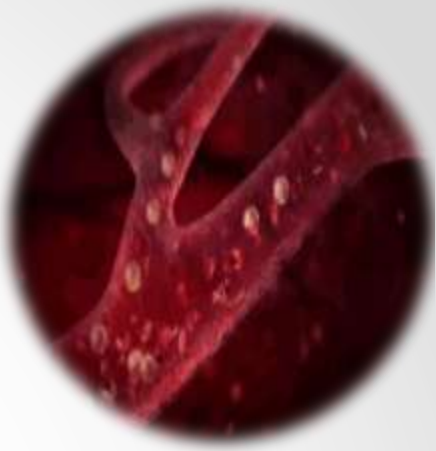
3. LAMININ :

- Implicated in variety of functions including.
- Cell adhesion
- Migration
- Differentiation

Other glycoproteins like

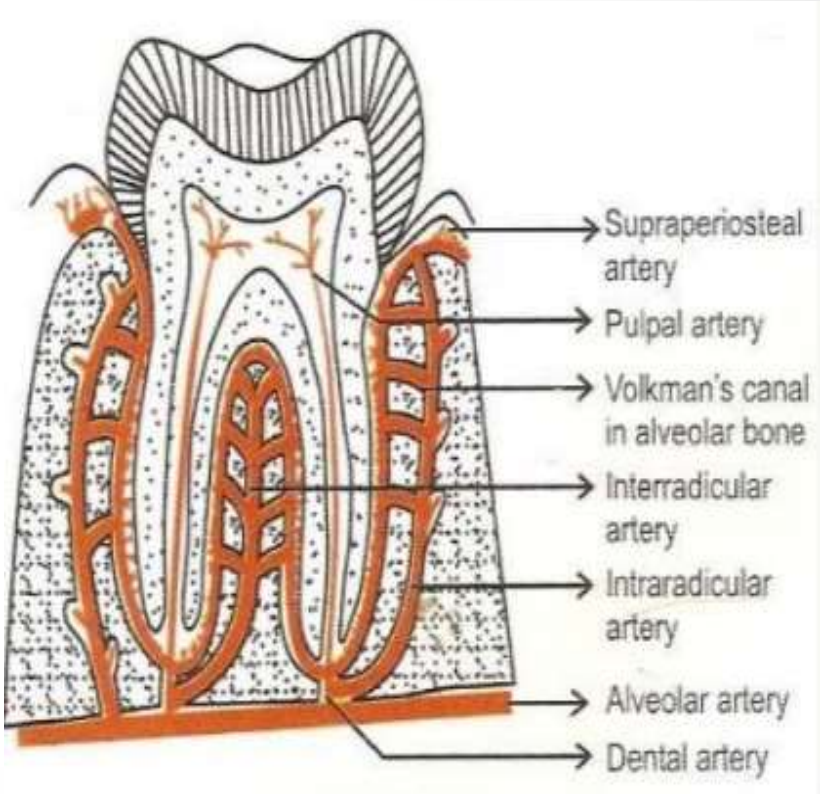
- Entactin (Nidogen) – dumb bell shaped glycoproteins Vitronectin
- Thrombospondin
- May also be present in the glycoproteins of PDL with a smaller role in cell attachment and organization of basement membrane.

BLOOD SUPPLY



- Derived mainly from :
- Inferior alveolar arteries
- superior alveolar arteries

1. Apical vessels (Dental artery) supply dental pulp
2. Transalveolar vessels (rami perforates-penetrating vessels from alveolar bone)
3. Intraseptal vessels (anastomosing vessels from the gingiva)

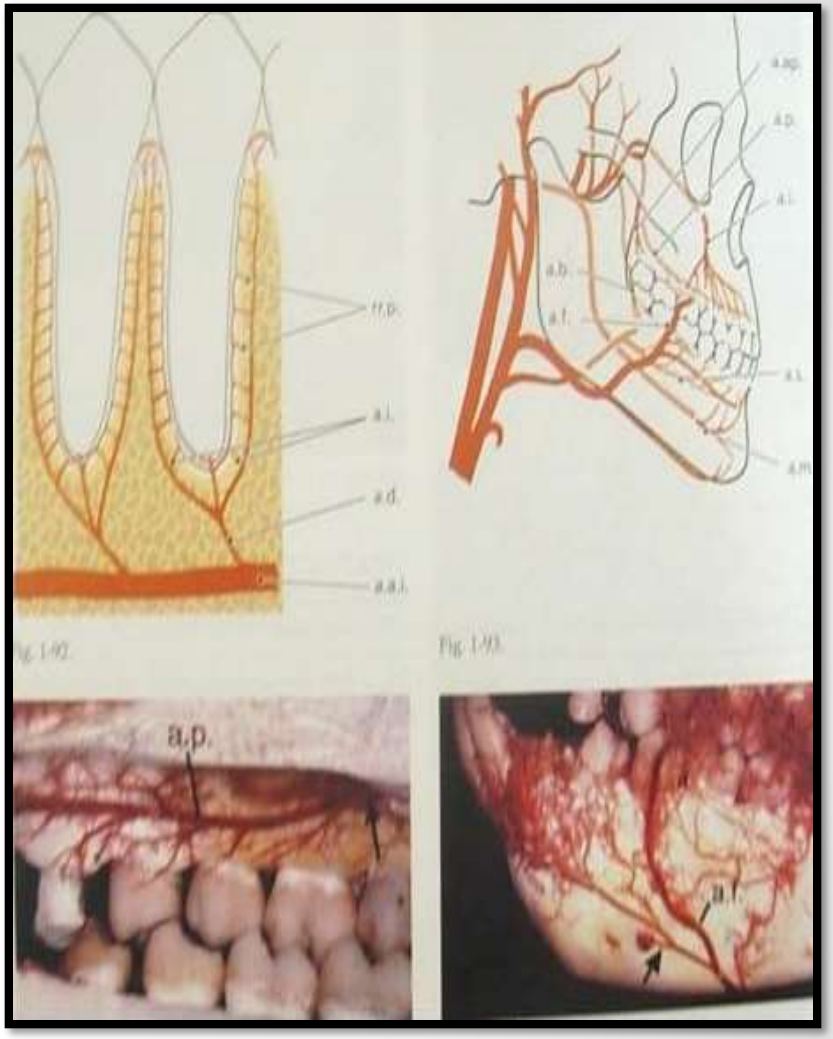


- Ramify and form a rich network of arcades more evident adjacent to bone than cementum.

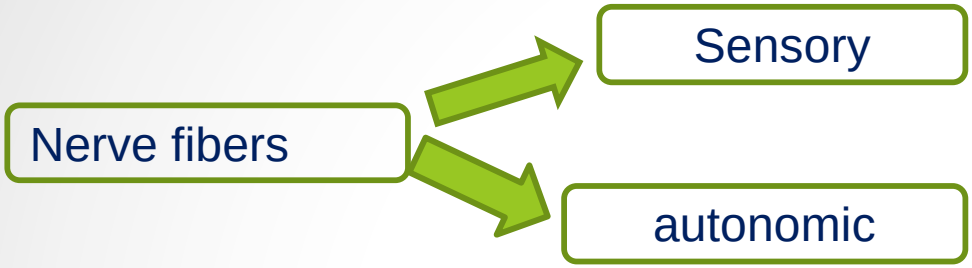
Blood Supply:

- Posterior teeth > Anterior teeth

- Gingival third > Apical third > Middle third



Nerve SUPPLY



- The nerve follow almost the same course as the blood vessels.
- Nerve bundle divide → myelinated fibers → lose their myelin sheath → end in one of the 4 types of neural terminations

Free endings with tree like ramifications :

- terminal branching of myelinated fibers
- 0.2-1 um in diameter
- fine, non myelinated fibers only type of ending in tooth pulp → classic model of pure nociception.
- Located at regular intervals along the length of the root

Ruffini's endings :

- Found around the root apex.
- Appear dendritic and end in terminal expansions among the PDL fiber bundles.
- Are mechanoreceptors.
- Meissner's corpuscles : mid-root, for tactile perception
- Encapsulated spindle type : temperature receptor, associated with root apex.

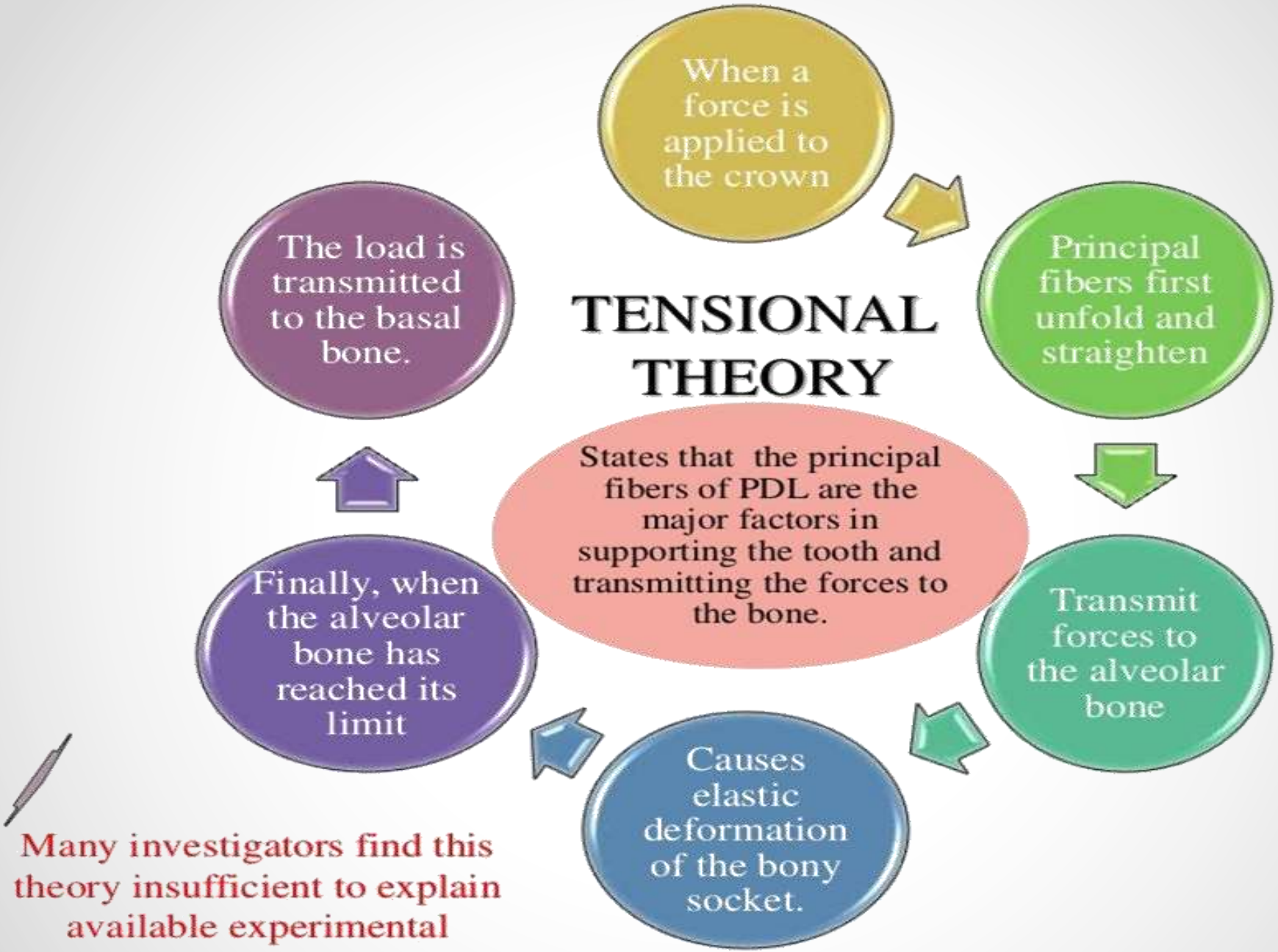
Lymphatic drainage

- Lymph vessels - Follow the course of blood vessels.
- Course apically - pass through the fundus of the socket or they may pass through the cribriform plate to empty into larger channels pursuing intraosseous paths.

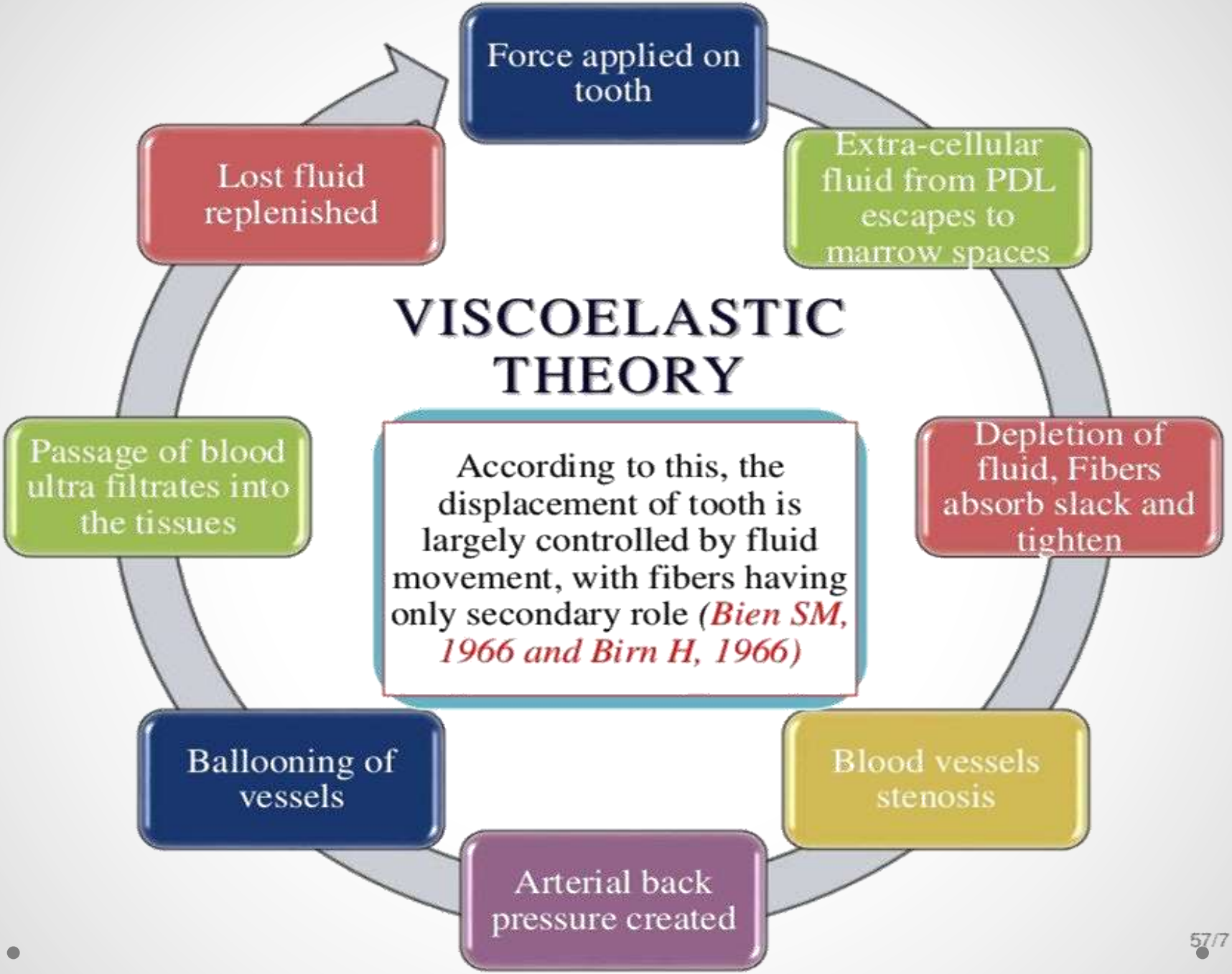
Functions of pdl

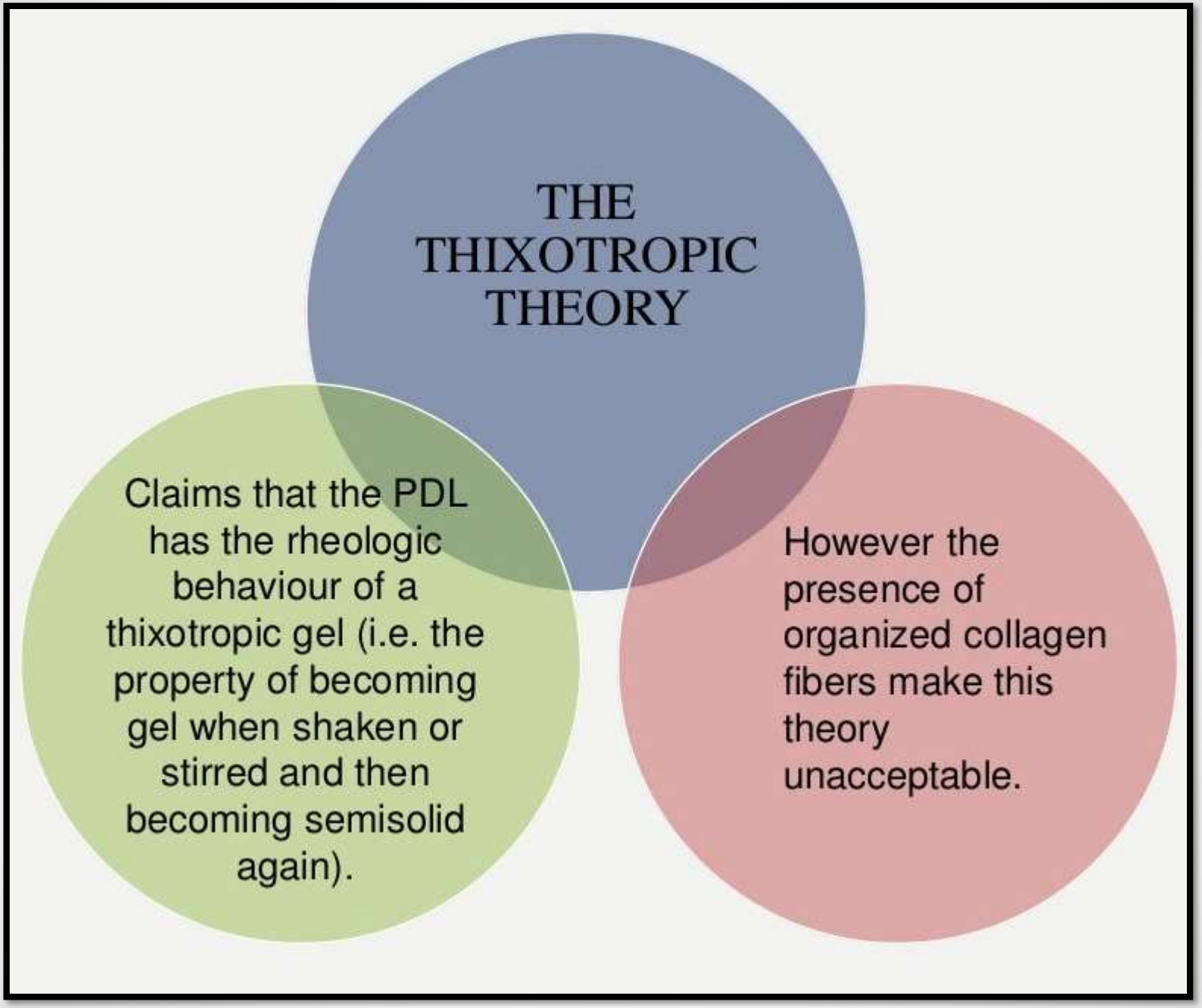
I. PHYSICAL FUNCTION :

- Provision of a soft tissue ‘casing’ to protect the vessels and nerves from injury by mechanical forces.
- Transmission of occlusal forces to the bone.
- Attachment of the teeth to the bone.
- Maintenance of the gingival tissues in their proper relationship to the teeth.
- Resistance to the impact of occlusal forces (Shock absorption).



Many investigators find this theory insufficient to explain available experimental evidence.


Force applied on tooth
Extra-cellular fluid from PDL escapes to marrow spaces
Depletion of fluid, Fibers absorb slack and tighten
Blood vessels stenosis
Arterial back pressure created
Ballooning of vessels
Passage of blood ultra filtrates into the tissues
Lost fluid replenished
VISCOELASTIC THEORY
According to this, the displacement of tooth is largely controlled by fluid movement, with fibers having only secondary role (Bien SM, 1966 and Birn H, 1966)


THE THIXOTROPIC THEORY
Claims that the PDL has the rheologic behaviour of a thixotropic gel (i.e. the property of becoming gel when shaken or stirred and then becoming semisolid again).
However the presence of organized collagen fibers make this theory unacceptable.

II. FORMATIVE AND REMODELING FUNCTION :

- Cells of the PDL participate in the formation and resorption of cementum and bone, which occur in physiologic tooth movement,
- Accommodation of the periodontium to occlusal forces in the repair of injures.

- Remodeling : The 3-D organization of the fiber meshwork is adapted to accommodate for positional changes of the tooth in its socket or changes in functional state (such as hypofunction).
  - It relates to adaptability of PDL tissues.
  - Both these processes can occur simultaneously and may therefore be indistinguishable.

III. NUTRITIONAL:

- PDL supplies nutrients to the cementum , bone, and gingiva by way of blood vessels and provides lymphatic drainage.
- The PDL contains blood vessels, which provide anabolites and other substance to the cementum, bone and gingiva. & removes catabolites.

IV. HOMEOSTATIC:

- Adaptability to rapidly changing applied forces and its capacity to maintain its width at constant diameter throughout life.
- It is evident that the cells of PDL have the ability to resorb and synthesize the extracellular substance of the connective tissue of the ligament , alveolar bone and cementum

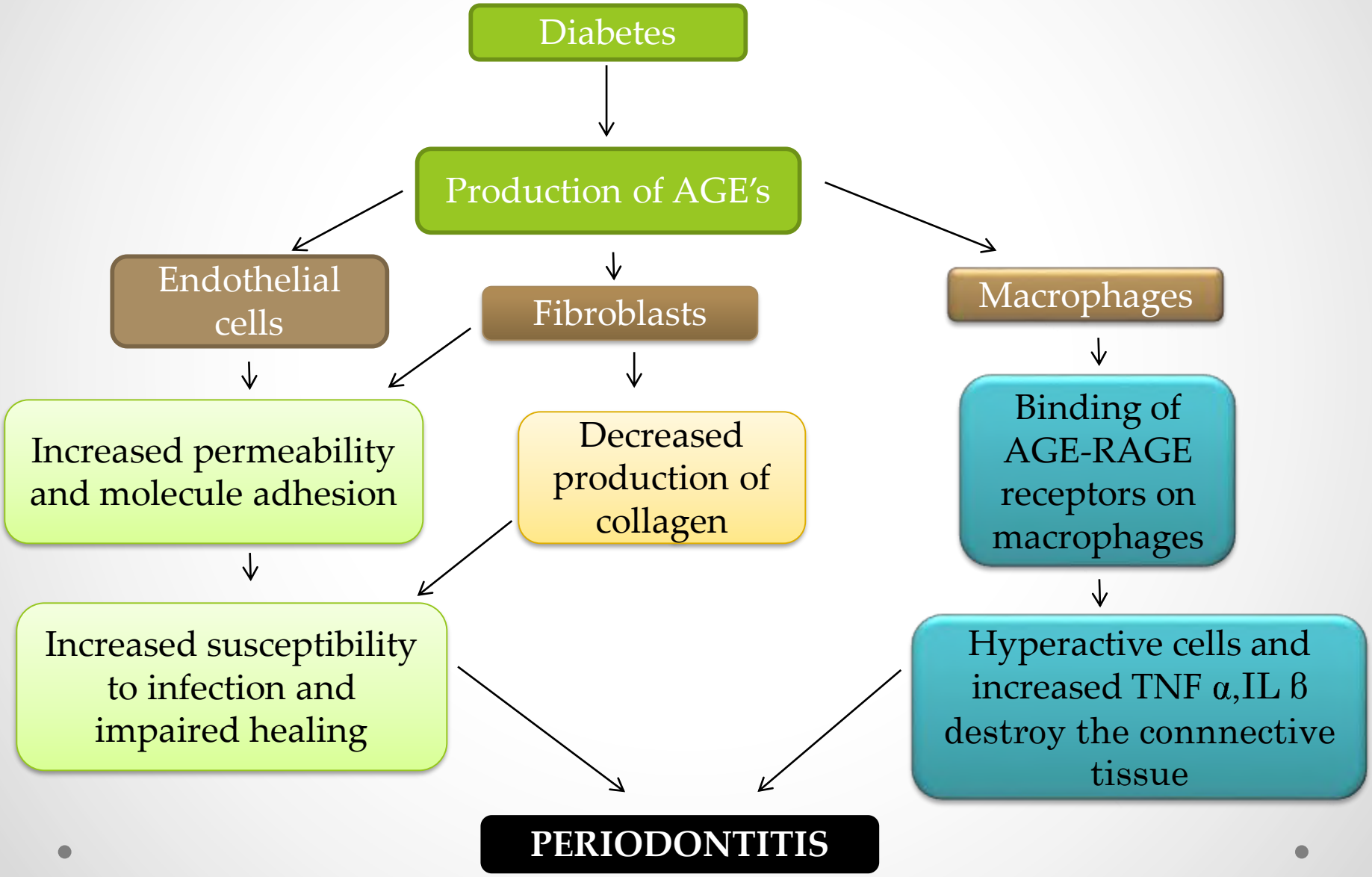
V. SENSORY FUNCTION

- The PDL is abundantly supplied with sensory nerve fibers capable of the repair of transmitting tactile, pressure and pain sensations by the trigeminal pathway.
- The PDL provides a most efficient proprioceptive mechanism.

4 types of neural terminations are seen

- 1. Free nerve endings –pain(at regular intervals along the length of the root.
- 2. Ruffini like mechanoreceptors (apical area)
- 3. Meissner’s corpuscles - mechanoreceptors (middle 3rd)
- 4. Spindle like pressure and vibration endings (apex)

Effect of diabetes in PDL



CONCLUSION

- The periodontal ligament is a fibrous connective tissue forming important part of the Periodontium.
- The PDL is a physically small, but functionally important tissue in tooth support, proprioception and regulation of alveolar bone volume.
- The PDL is an absolute requirement for rapid remodeling of alveolar bone when forces are applied to teeth.
- Cell of the PDL are Pluri-potent and helps in the regeneration of all the components of Periodontium lost in the periodontal disease process.

- •A better understanding of cell and molecular biology of developing and regenerating periodontium offers newer avenues to regenerate the PDL.

- Yet safeguarding the integrity of the PDL and alveolar bone is still one of the most important challenge

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Thank
You