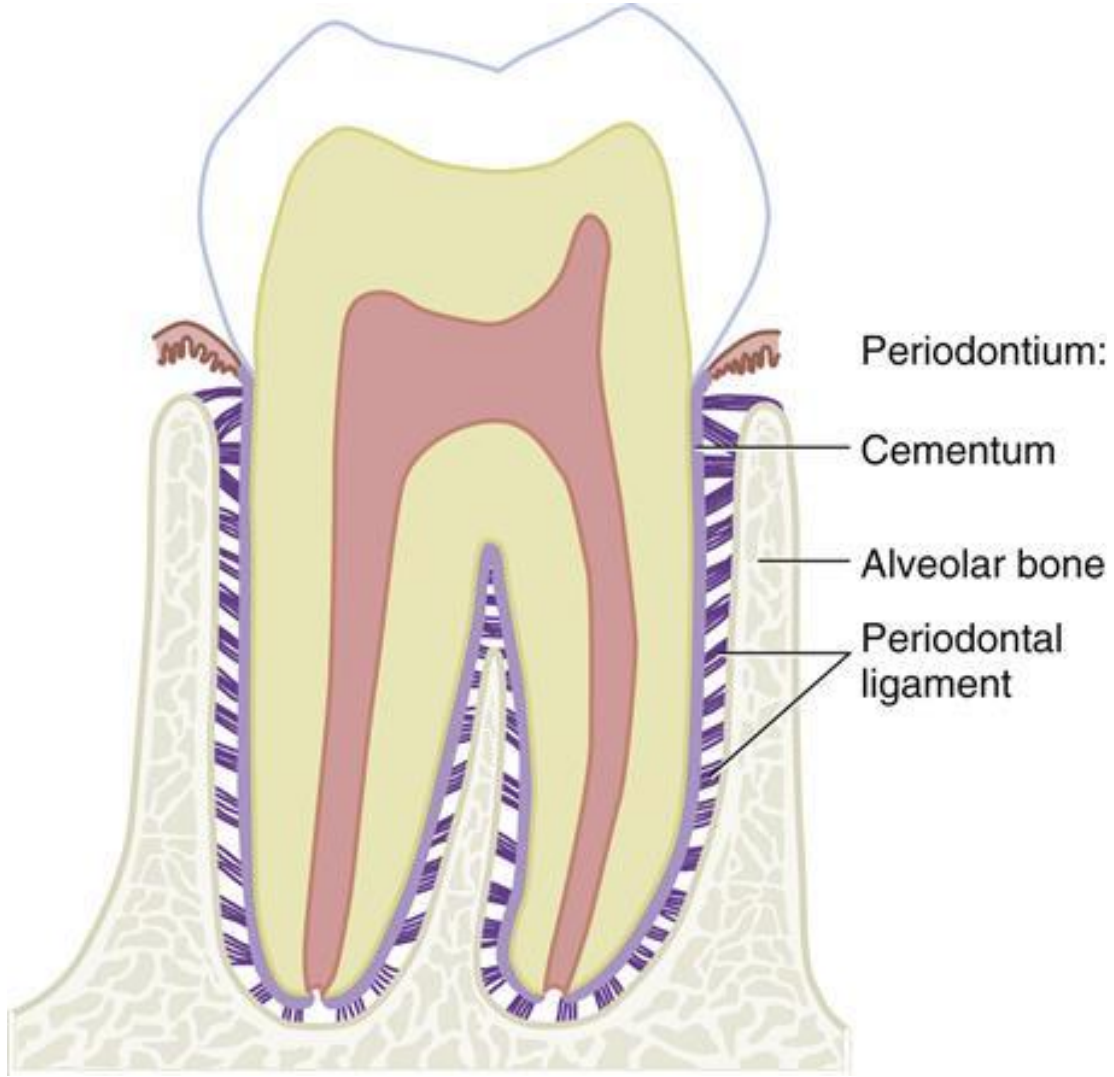
Microscopic structure of alveolar process and clinical aspects of its remodelling

Periodontium



Jan Křivánek

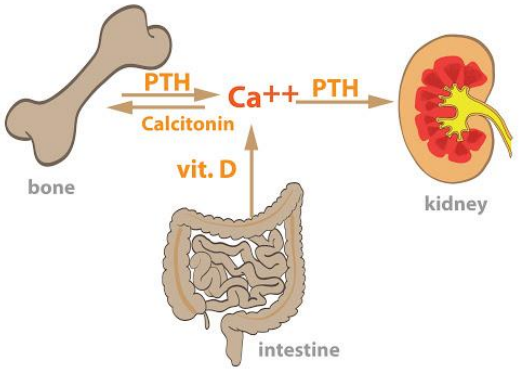
15. 3. 2023

Overview of bone microstructure, and bone plasticity

Two main functions:

Structural – forming skeleton

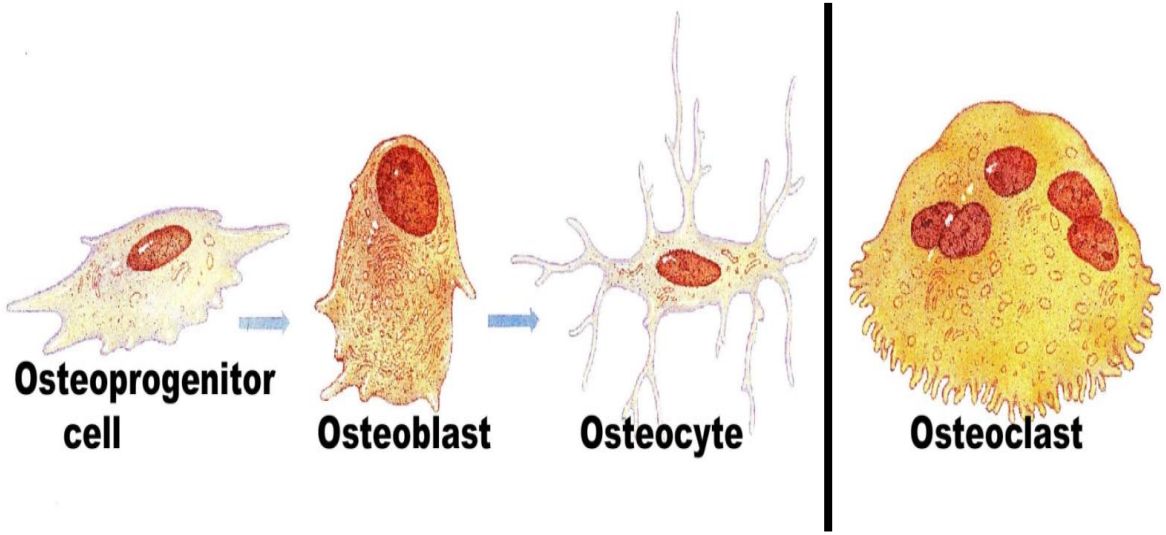
Storage of Ca^{2+} in our bodies (99 %) - releasing calcium from bone into blood and vice versa



Compostion:

Cells

Extracelullar matrix (ECM) - **bone matrix**



Cells in bone

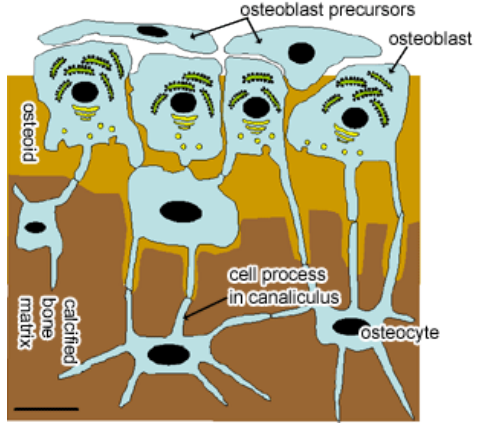
osteoblasts a osteocytes; osteoclasts

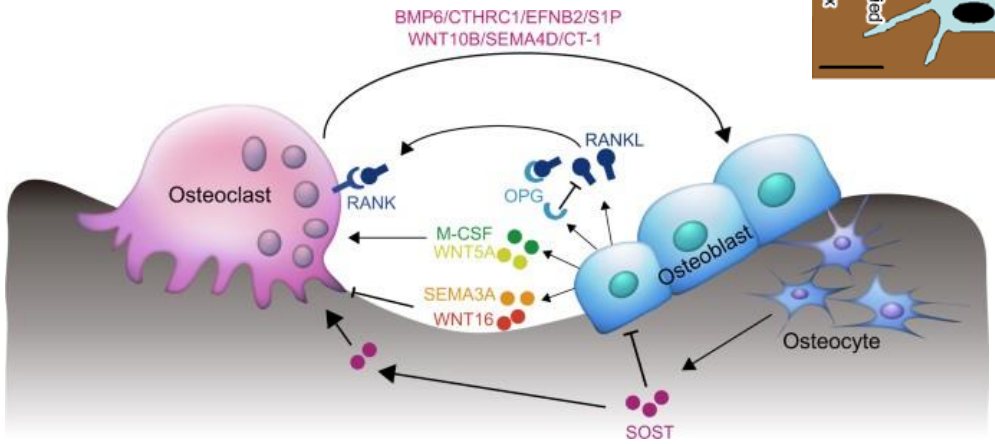
Osteoblasts

Synthesize organic component of extracelullar bone matrix: Collagen I, proteoglycans, glycoproteins

Deposit inorganic salts in matrix

During development forms one layer of cells on the surface





Osteocytes

„Resting“ forms of osteoblasts, have small oval bodies with thin cytoplasmic processes

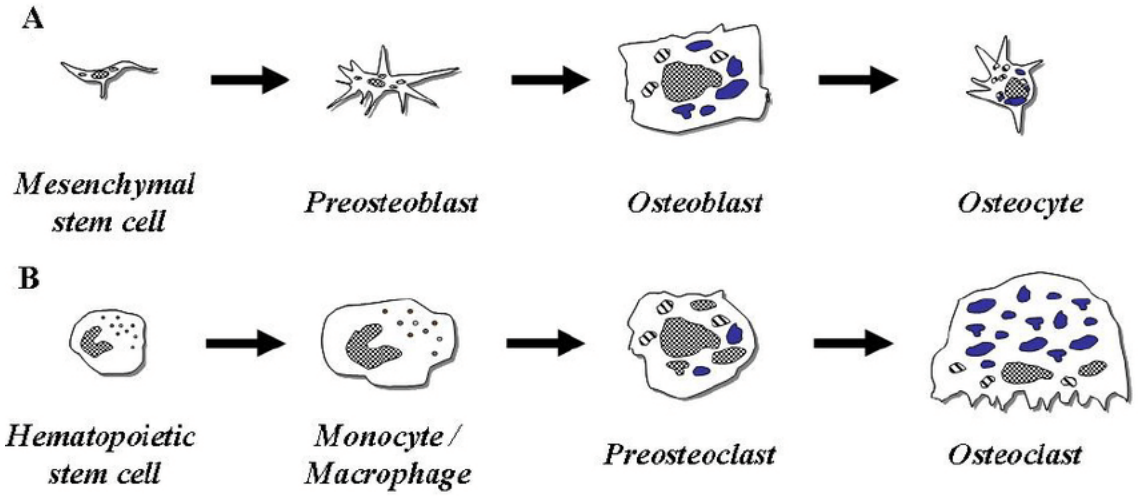
Inhabit bone lacunea and its processess are in **canaliculi ossium**

Osteoclasts

Large cells (diameter around 100 um), with multiple iregular processess

Multinuclear – number of nuclei may be 50 or more, originate by the fusion of monocytes/macrophages

Digest/decompose bone matrix. Essential for bone remodelling



Extracellular matric (ECM) – Bone matrix

Inorganic (+- 45 %) and **Organic** (+- 30 %), rest is Water

Inorganic components are responsible for bone hardness while collagenous fibres determine the resilience and flexibility of bone

The ration bewteen inorganic and organic component is essential for the right mechanical behaviour

Inorganic component

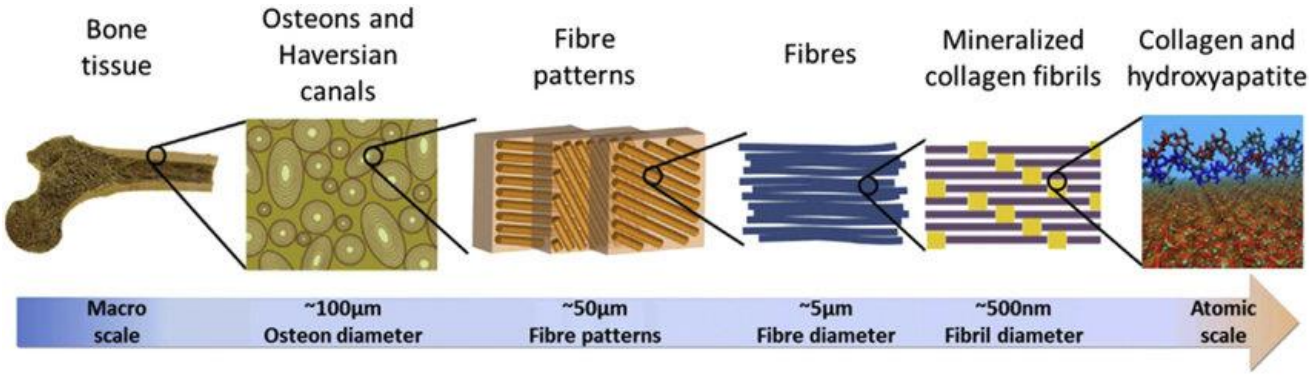
Responsible for hardness and stiffness of bones

Formed by hydroxyapatite crystals – have shape of flat plates of hexagonal profile measuring 40 x 25 x 3 nm, deposited parallel to collagen fibrils

Organic component

Mainly **Collagen I**, then **proteoglycans** (glycosaminoglycans associated with proteins) and **adhesive proteins** – sialoprotein, osteocalcin, osteopontin, osteonectin

Important role in calcium deposition during bone growth and remodelling



Histologically we divide 2 types of bone tissue

Woven bone (primary)

Primitive structure

Resembles calcified fibrous connective tissue

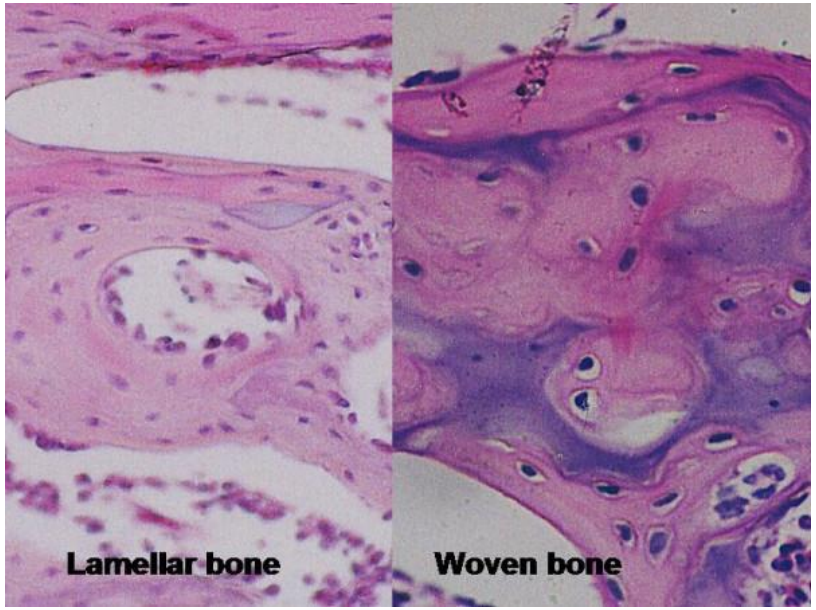
Firstly developer (during growth and remodelling)

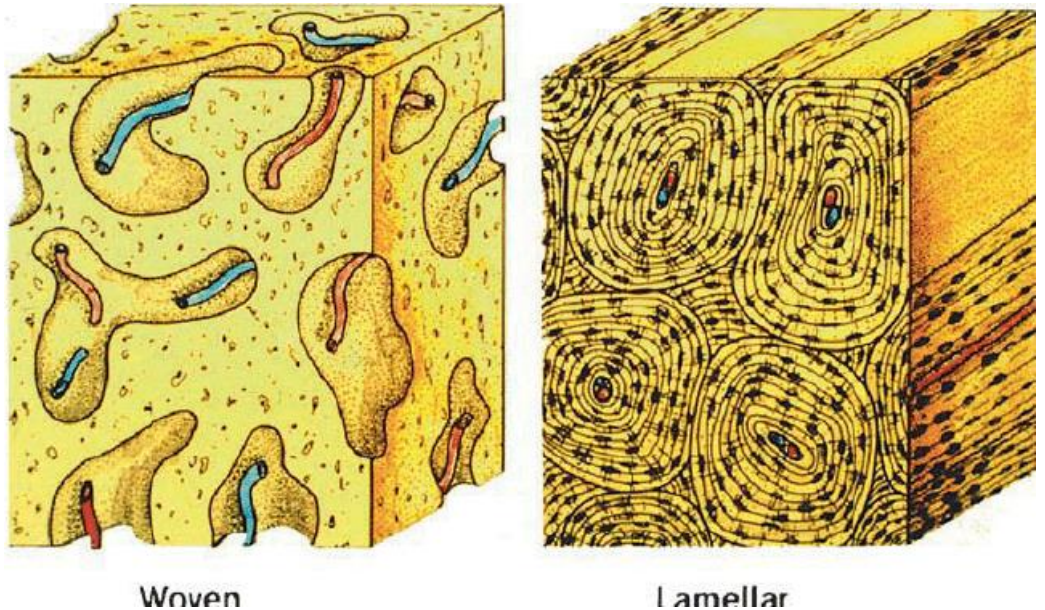
Lamellar bone (secondary)

Developmentally and functionaly better developed

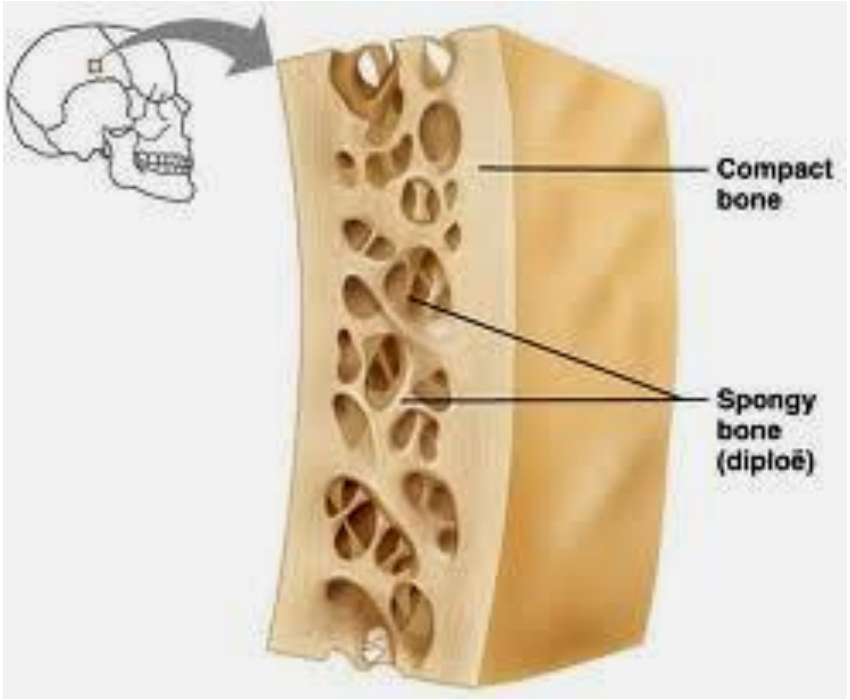
Bone lamellae = 3-7 µm

Collagenous fibres in lamellae always in the same direction
Osteocytes between lamellae

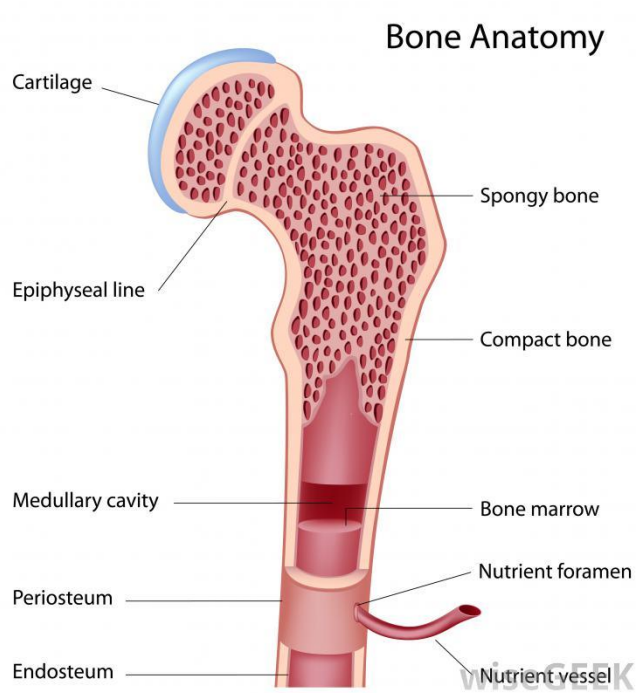




All bones of skeleton (long, short, flat, irregular) **– are composed only by lamellar type**
Lamellae are present in both forms: **Compact (dense) bone and Spongy (cancellous, trabecular)**



Flat bone



Long bone

External and internal surfaces are covered by a connective tissue coats – the periosteum (well developed) and the endosteum (less obvious)

Compact bone consists of **three types** of lamellae

Concentrically arranged lamellae around longitudinal haversian canals, number: 4 to 20

Form cylindrical units called **osteons** that run parallel to longitudinal axis of bone

In cross sections, osteons appear as concentric rings around circular opening (Haversian canal),

In longitudinal sections lamellae resemble closely spaced bands

Interstitial lamellae

Are lamellae without relations to blood vessels

Supposed to be rests of old non-fuctional Haversian systems

which are just being resorbed

Circumferential lamellae

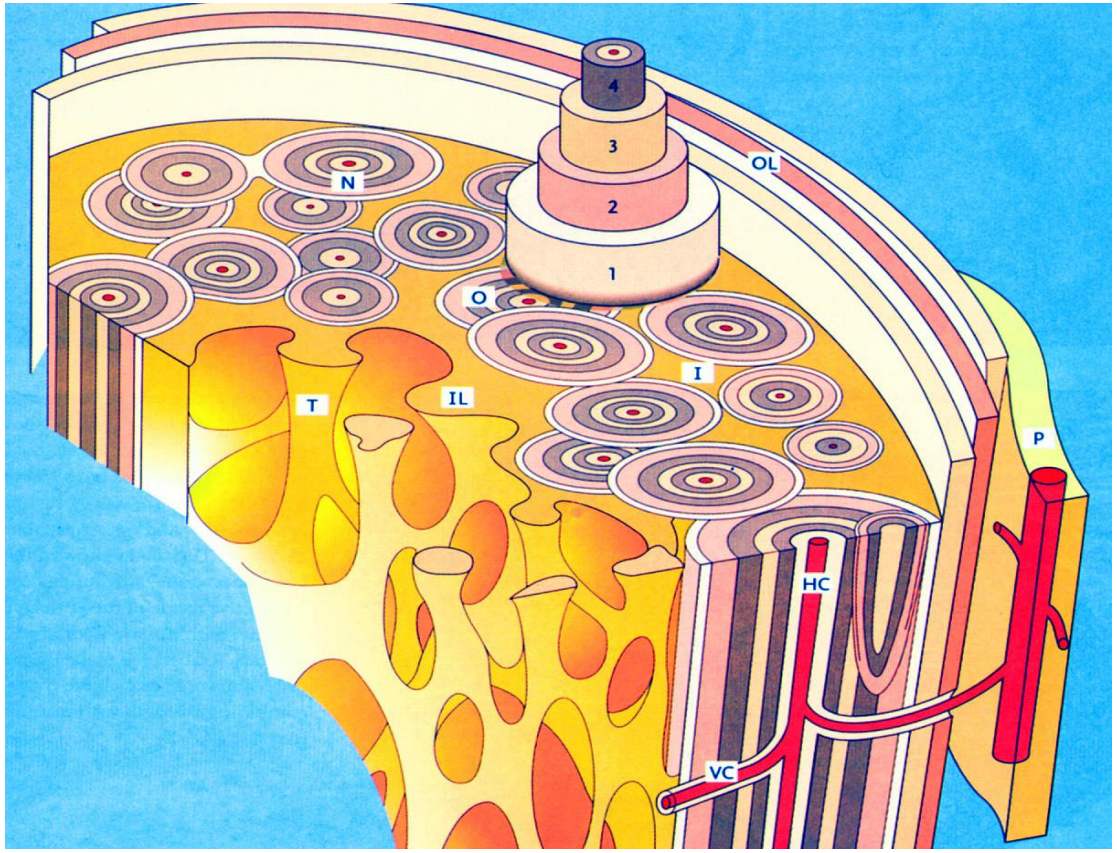
Located at outer and at inner surface of bone

Run in parallel to the periosteum or parallel to endosteum

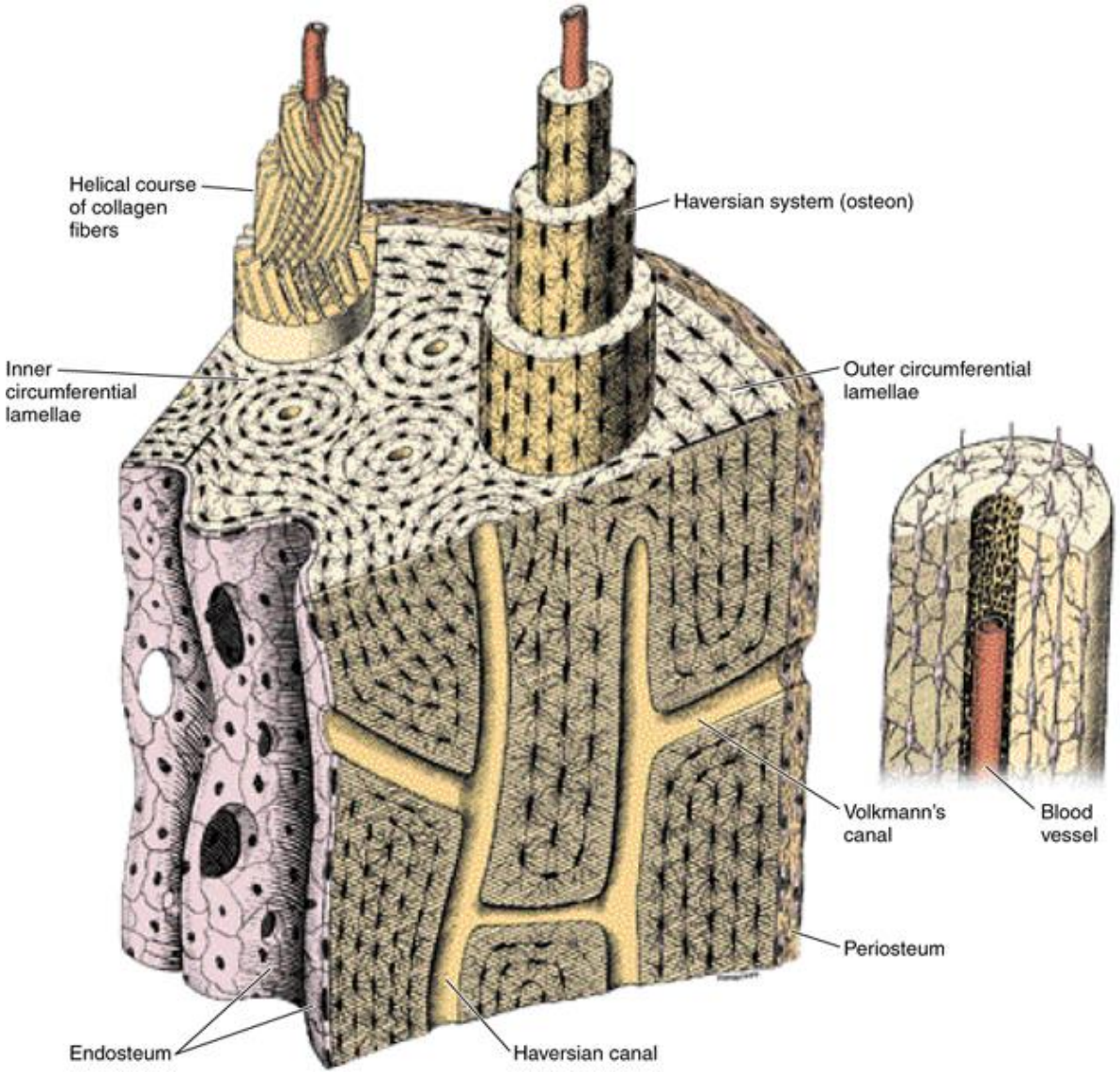
(around the central cavity)

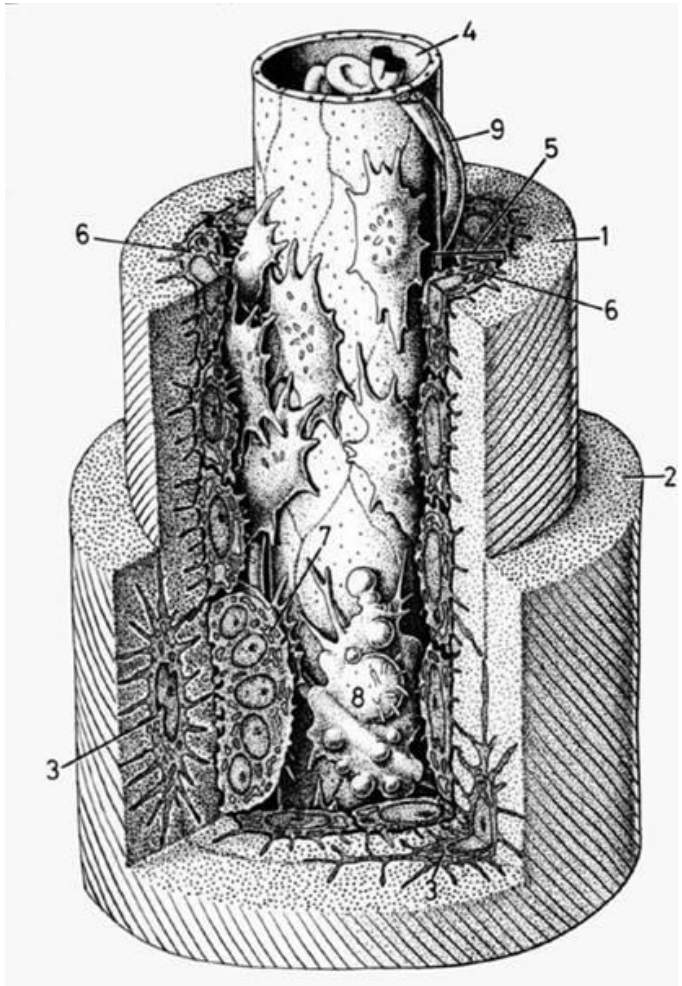
Outer circumferential lamellae

Inner circumferential lamellae

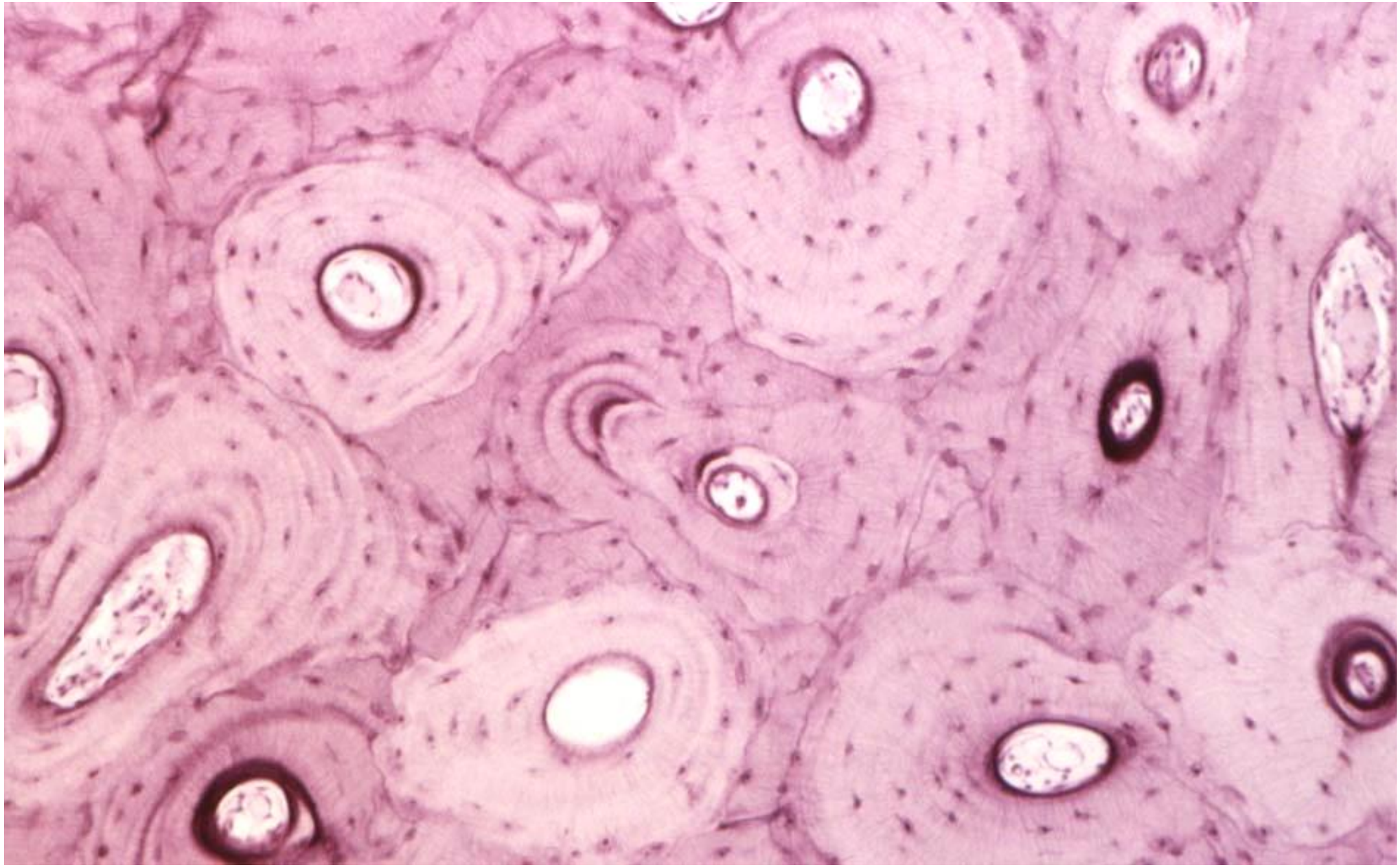


Osteon


Helical course of collagen fibers
Haversian system (osteon)
Inner circumferential lamellae
Outer circumferential lamellae
Volkmann's canal
Blood vessel
Periosteum
Endosteum
Haversian canal


4
9
5
6
1
6
2
7
8
3
3

Diaphysis transversally (HE)



2 types of vascular channels in the compact bone

Haversian canals

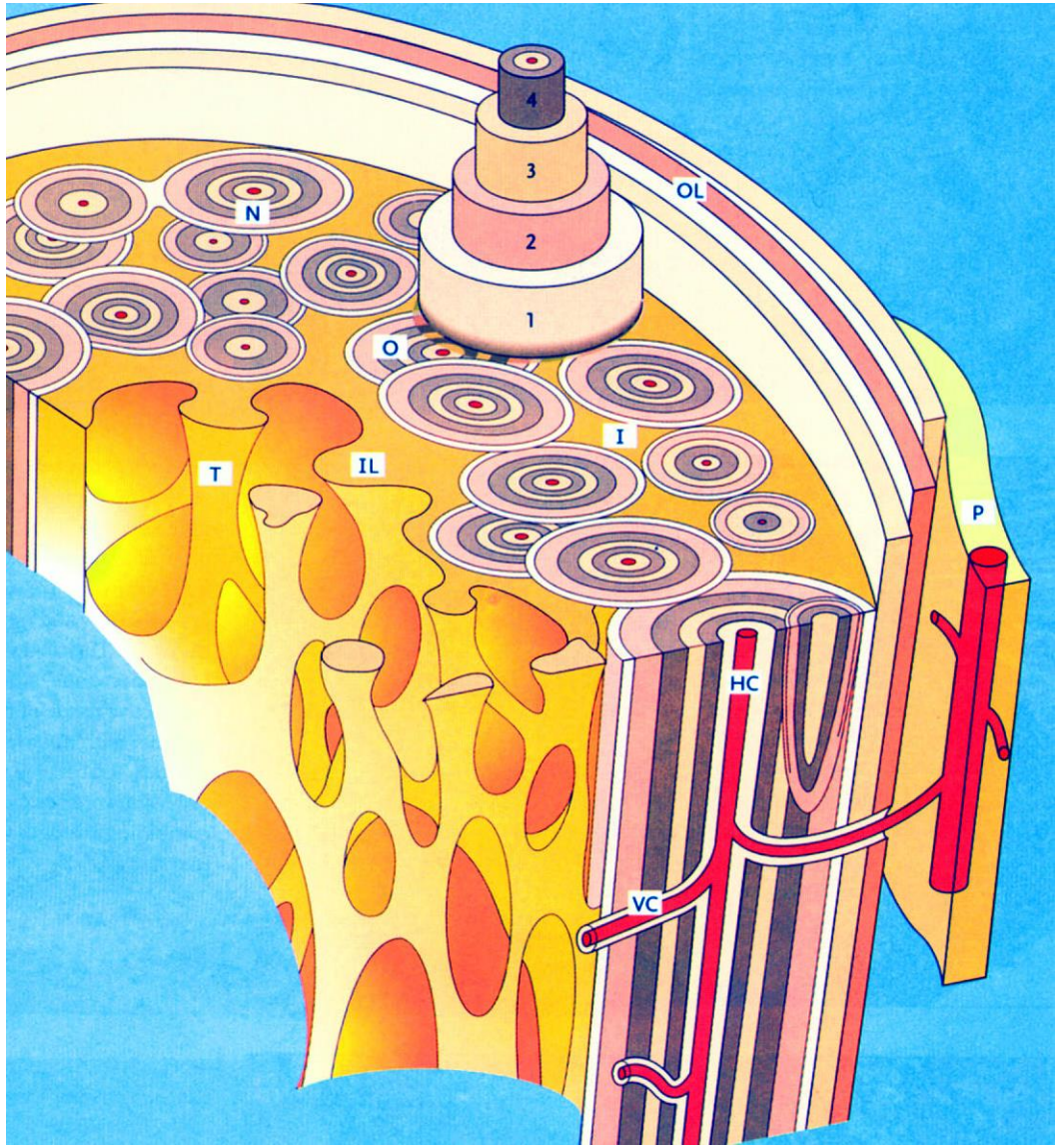
In the centers of Haversian systems

Contain one or two blood vessels

Volkmann's canals

Are not surrounded by lamellae and traverse the bone in perpendicular or oblique direction to the Haversian canals

Function: connect Haversian canals with one other and serve for vessels entering the compact from the periosteum or the marrow cavity



Haversian and Volkmans canals

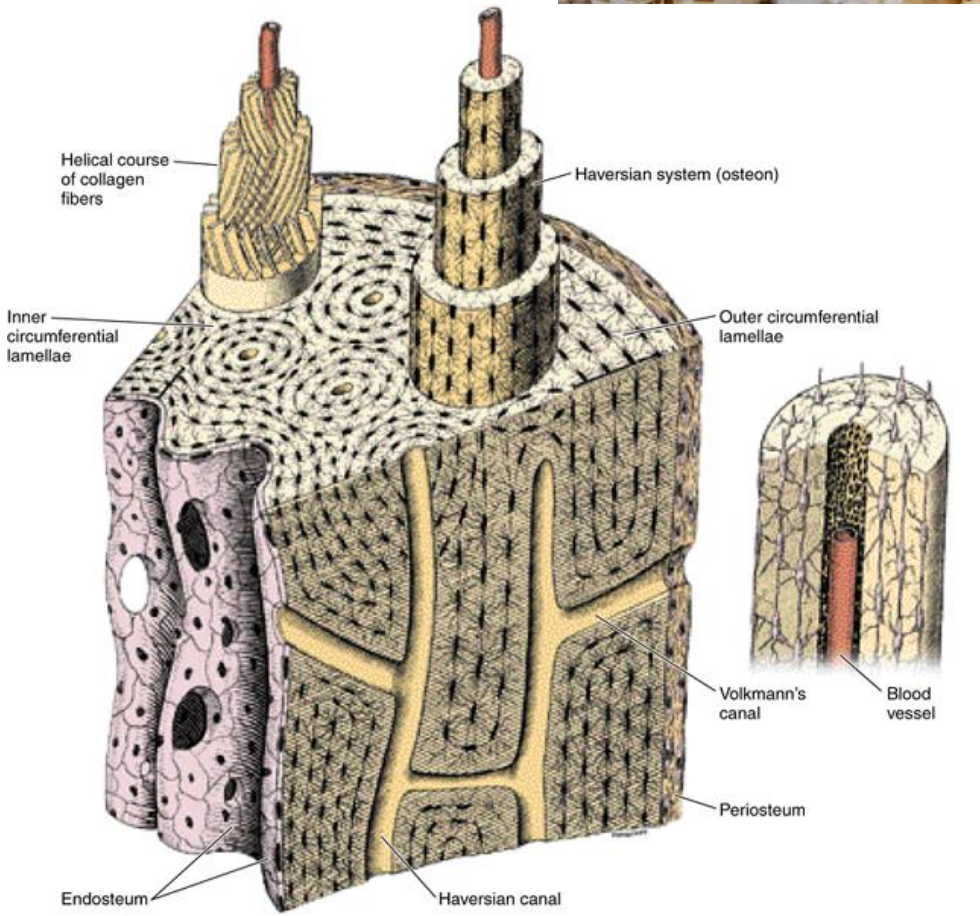
Cancellous/Trabecular bone

composed by trabeculated bone tissue
The course of depends of forces from outer environment

Periostem

Around the bone – from outside
Highly innervated (pain)

2 layers:
Stratum fibrosum, Sharpey‘s fibres
Stratum osteogenicum – osteoprogenitor cells



Endosteum

On the inner surface
Same structure as the periosteum, but thinner

Bone plasticity

Bones as organs can remodel the internal structure to match the actual mechanical load

Remodelling: interaction/equilibrium between osteoblasts and osteoclasts activity

Remodeling is rapid in childhood - it is reported that about 10% of skeletal bones are rebuilt each year

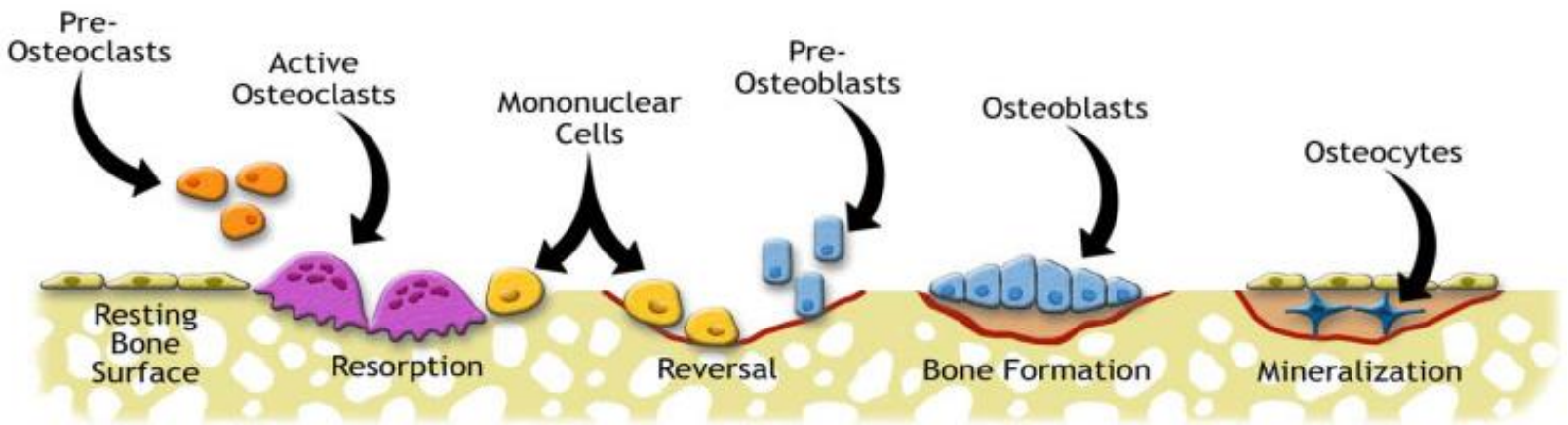
Bone remodeling can be induced by artificial stimuli: by the action of tension or pressure

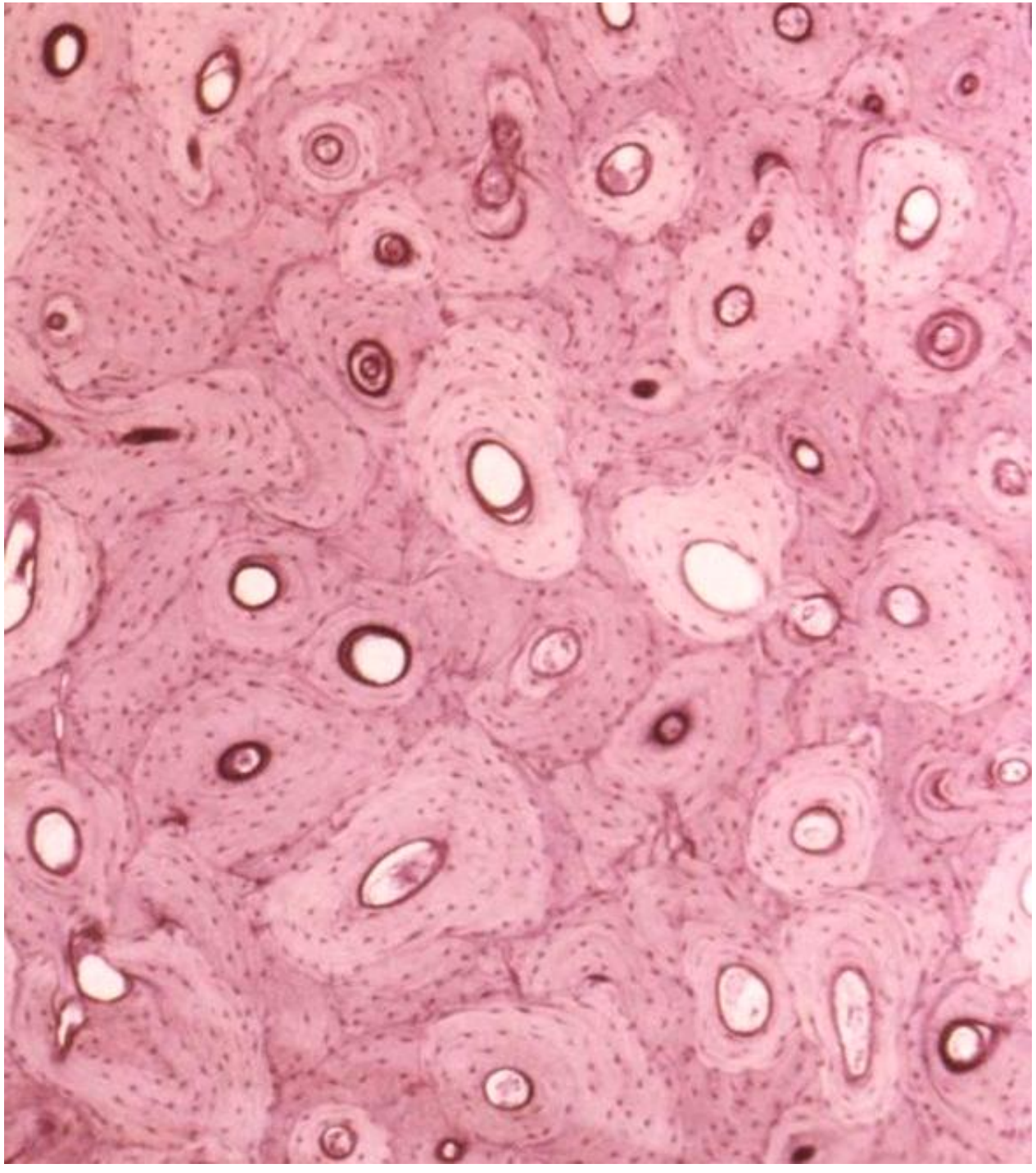
The action of tension creates new bone tissue,

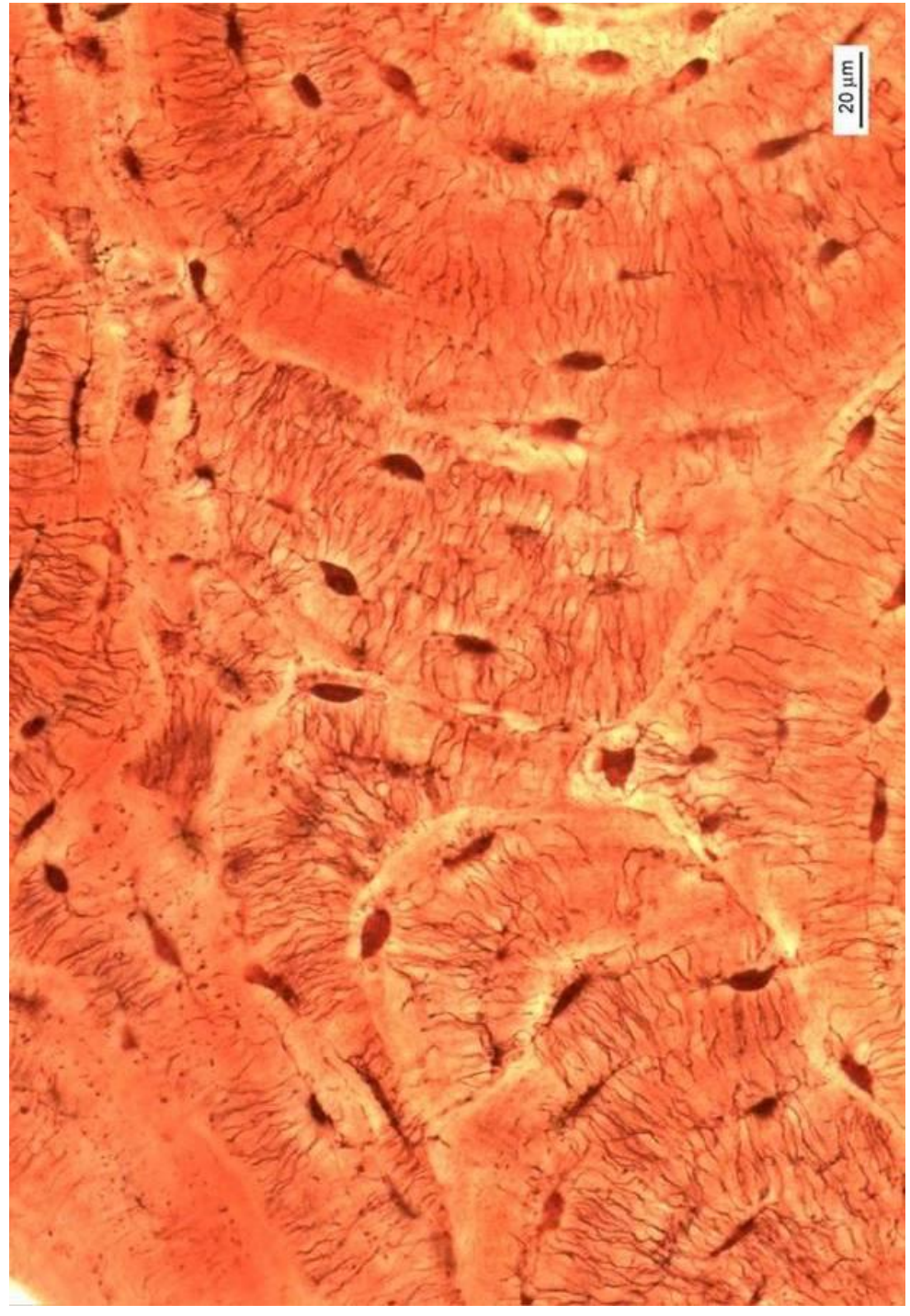
Opposite, it is resorbed under the action of pressure

The role of osteocytes - they act as mechanosensors, they transmit a signal to osteoblasts in the endost or periosteum, and they transmit it to osteoclasts

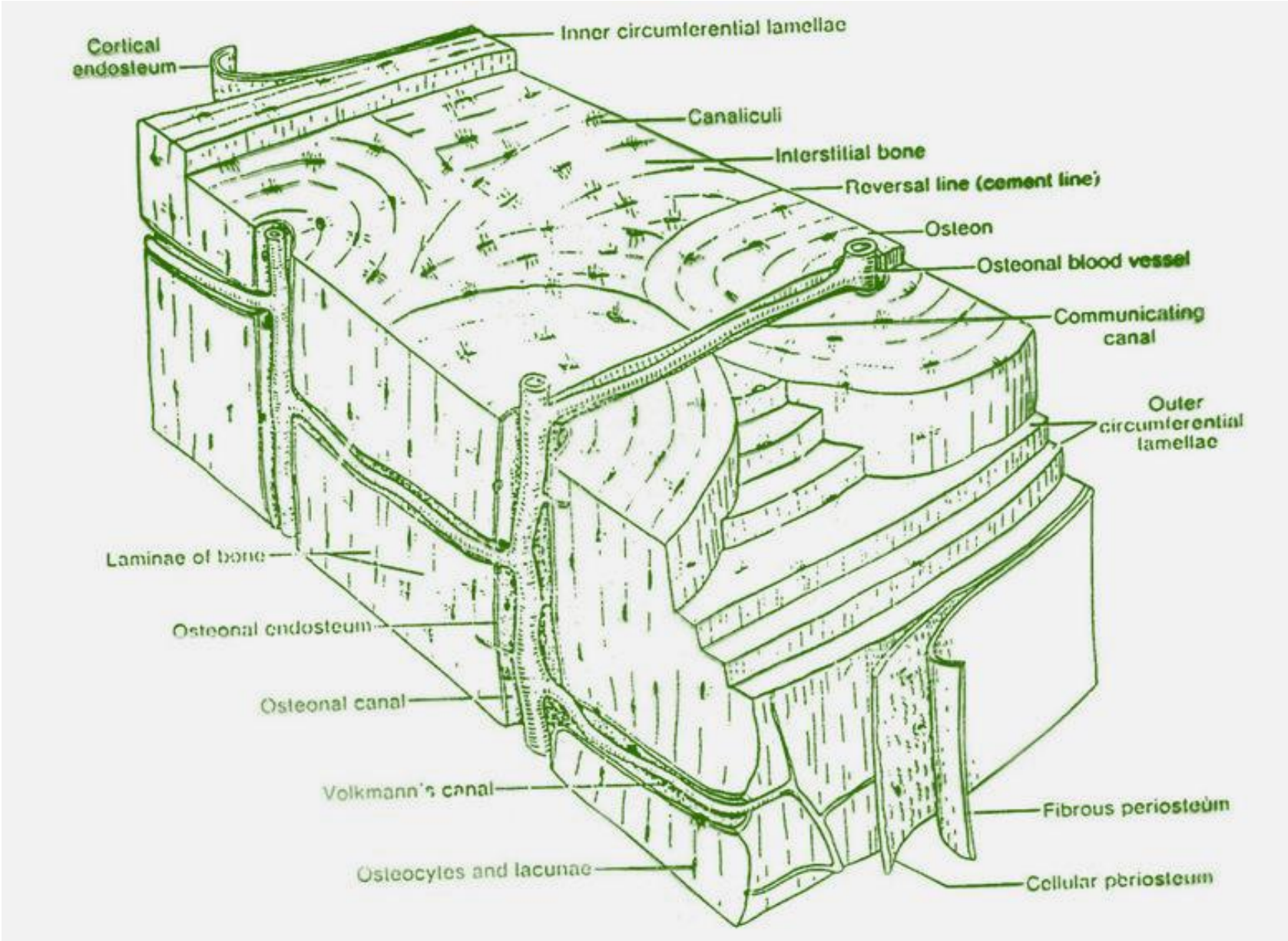
Cycle of bone remodelling






20 µm

Summary

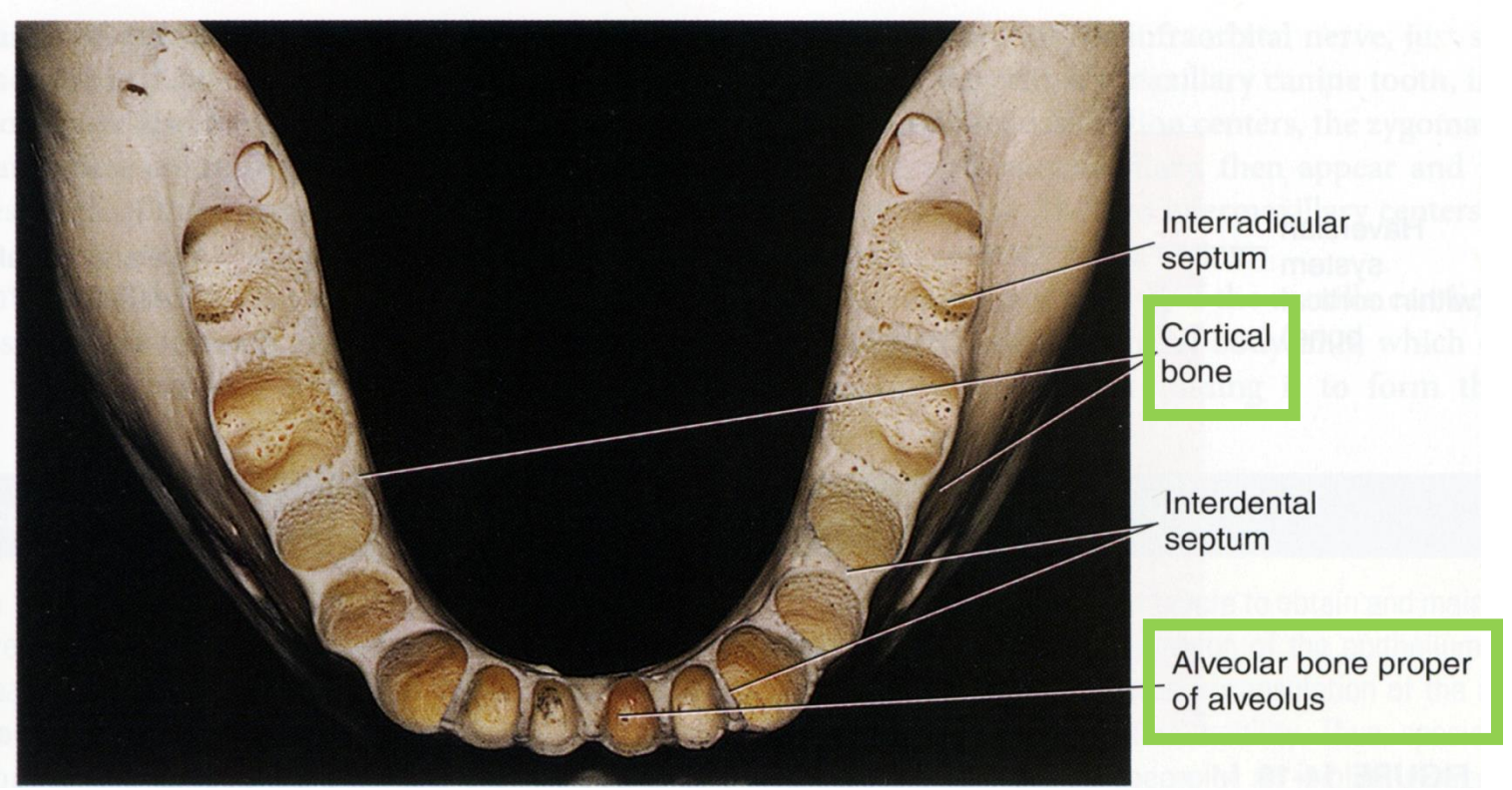

Cortical endosteum
Inner circumferential lamellae
Canaliculi
Interstitial bone
Reversal line (cement line)
Osteon
Osteonal blood vessel
Communicating canal
Outer circumferential lamellae
Laminae of bone
Osteonal endosteum
Osteonal canal
Volkmann's canal
Osteocytes and lacunae
Fibrous periosteum
Cellular periosteum

Alveolar process (*processus alveolaris*)

Part of the jaw which form the bony support for teeth (*alveoli dentales*)
The protrusion, like other anatomical sections of the jaws, is composed of **lamellar-type bone tissue - dense and spongy**

<u>Compact bone</u> structure
2 plates:

- **Cortical (external alveolar)** - forms the vestibular or oral side of the alveoli
- **Cribriform (internal alveolar, os alveolaris, lamina dura)** - forms the wall of alveoli

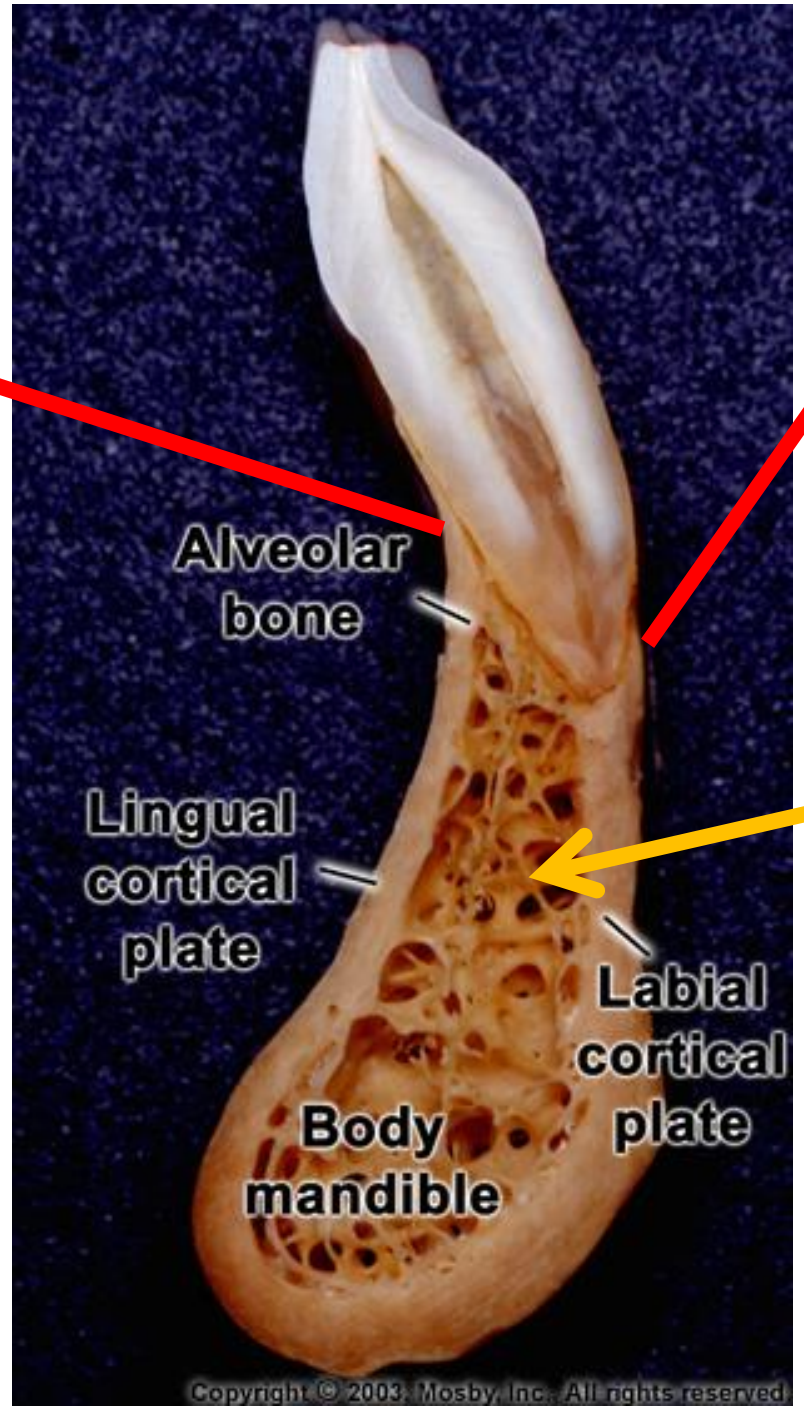


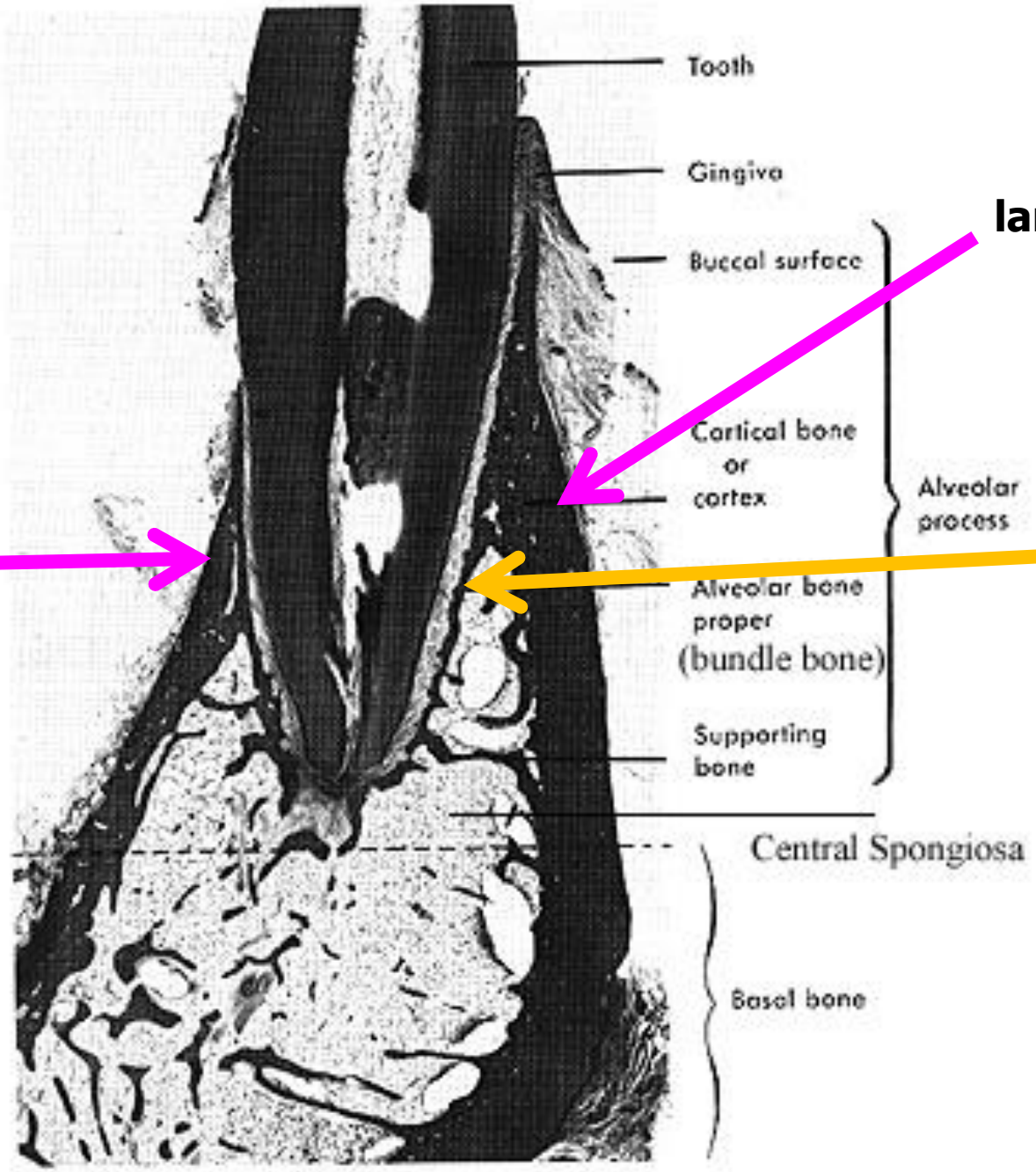
Cortical (outer alveolar) plate
Thicknes: **1,5 - 3,0 mm**

Divided into:
- **Lamina vestibularis**
- **Lamina oralis**

Both are covered by periosteum
Osteons in different directions

In the area of mandibular molars is lamina oralis usually thickened





Cortical lamina vestibularis

Cortical lamina oralis

Cribriform os alveolare

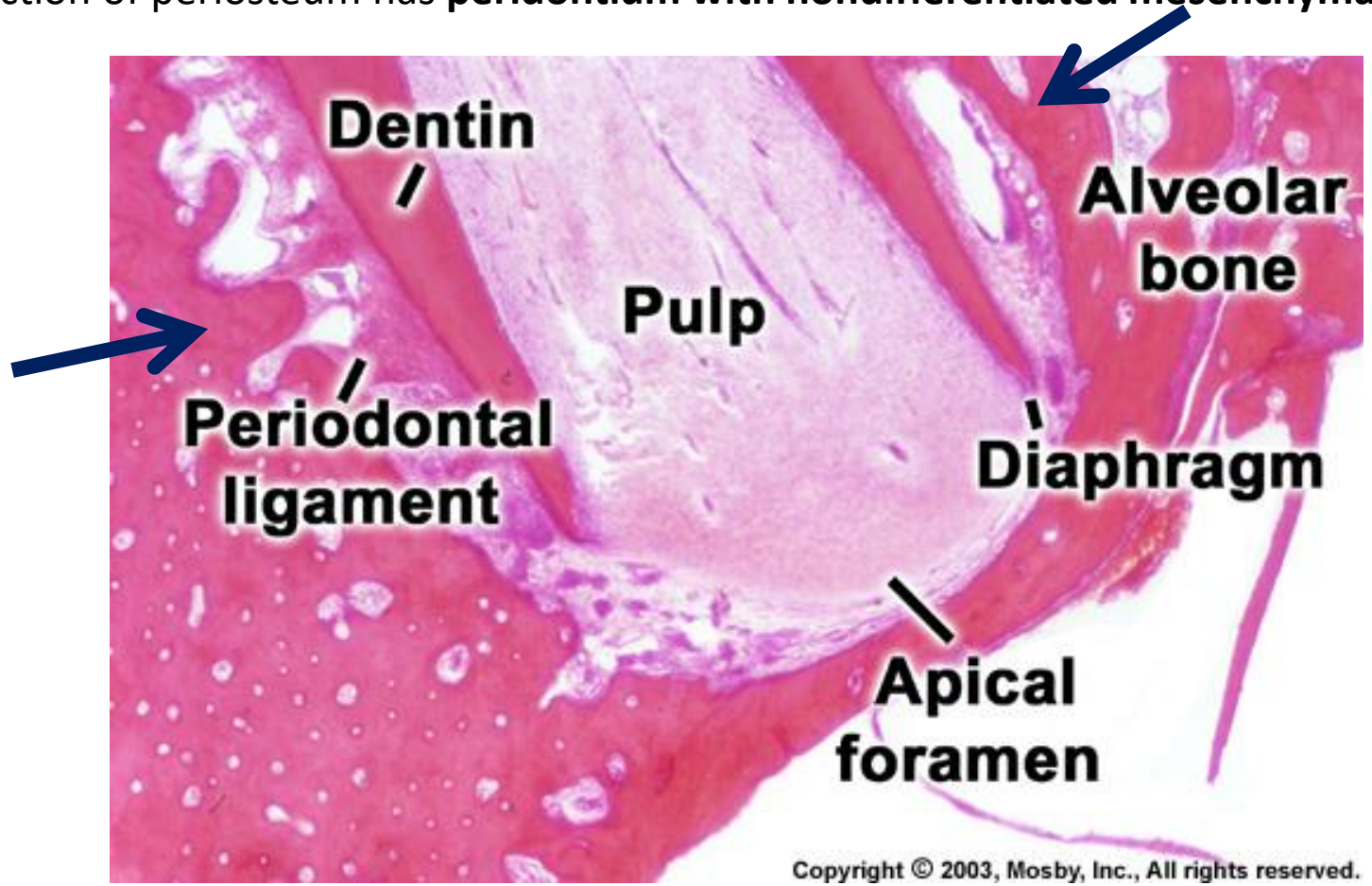
Cribriform plate (inner alveolar plate = os alveolare)

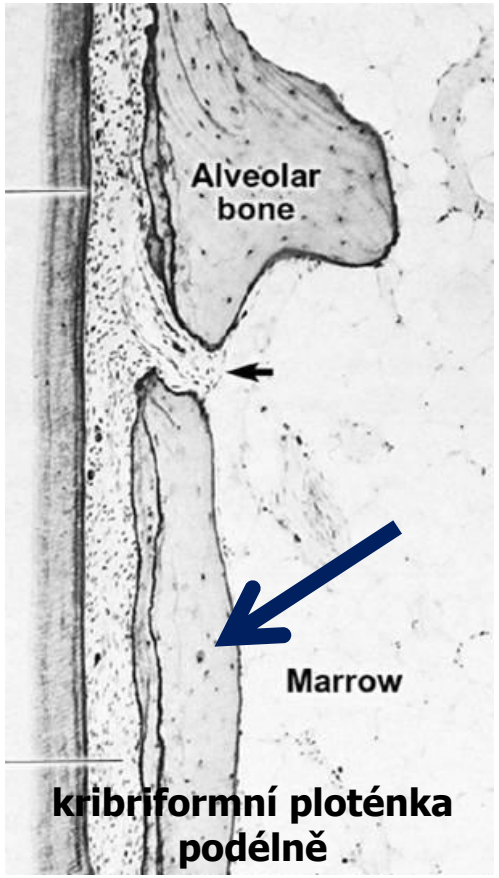
Forms the wall of alveolus, is thinner – **0,5 - 1,0 mm**

Perforated by Volmanns channels (for interalveolar vessels and nerves)

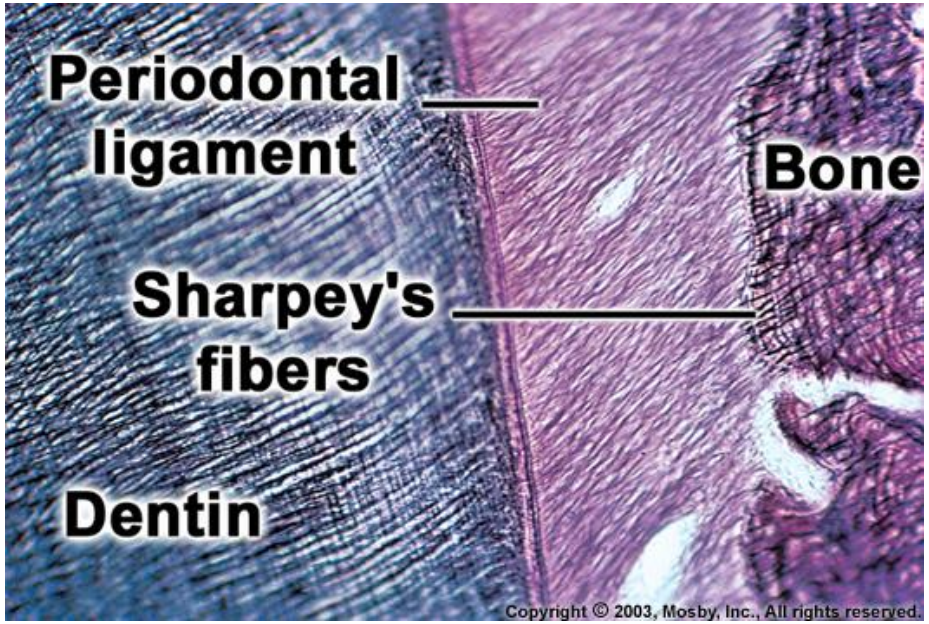
Structure similar as in cortical plate, but no periosteum

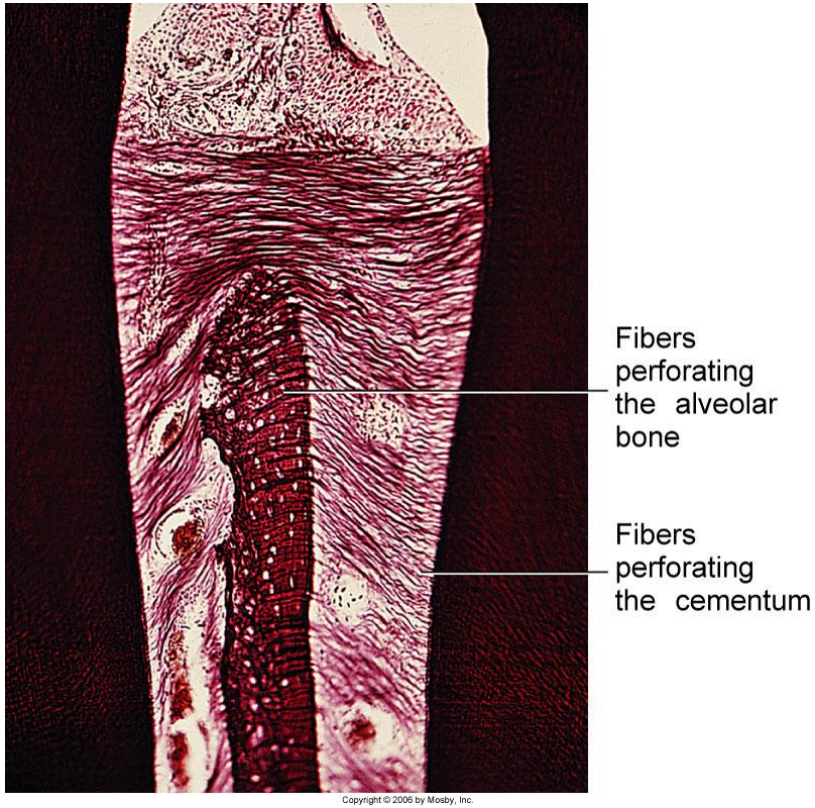
The function of periosteum has **peridontium with nondifferentiated mesenchymal cells** (diferentiate into different -blasts)





In cribriform plate are anchored PDL endings – Sharpey‘s fibres





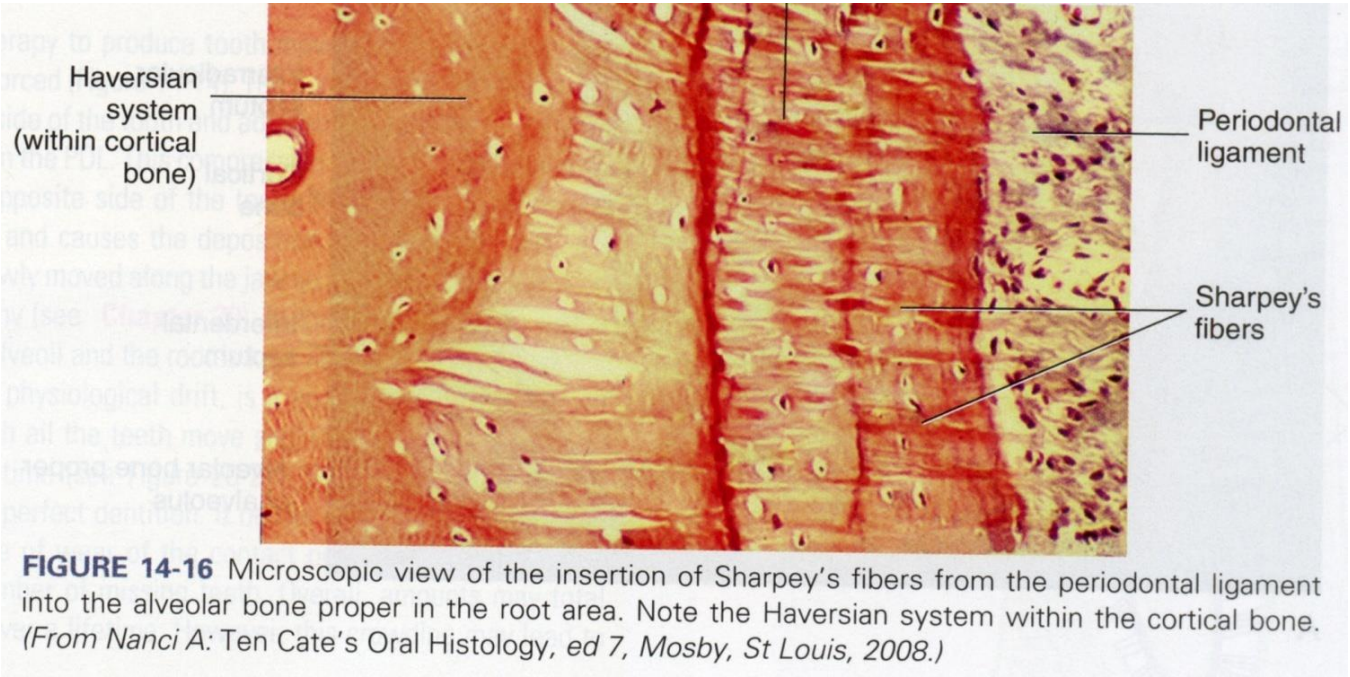
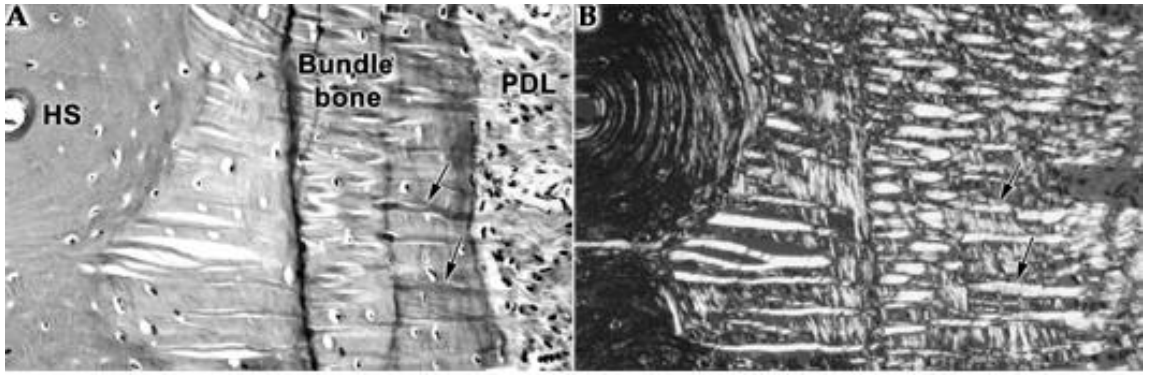


FIGURE 14-16 Microscopic view of the insertion of Sharpey's fibers from the periodontal ligament into the alveolar bone proper in the root area. Note the Haversian system within the cortical bone. *(From Nanci A:* Ten Cate's Oral Histology*, ed 7, Mosby, St Louis, 2008.)*



Cribriform plate is more mineralized – on X-ray has higher density – **lamina dura**

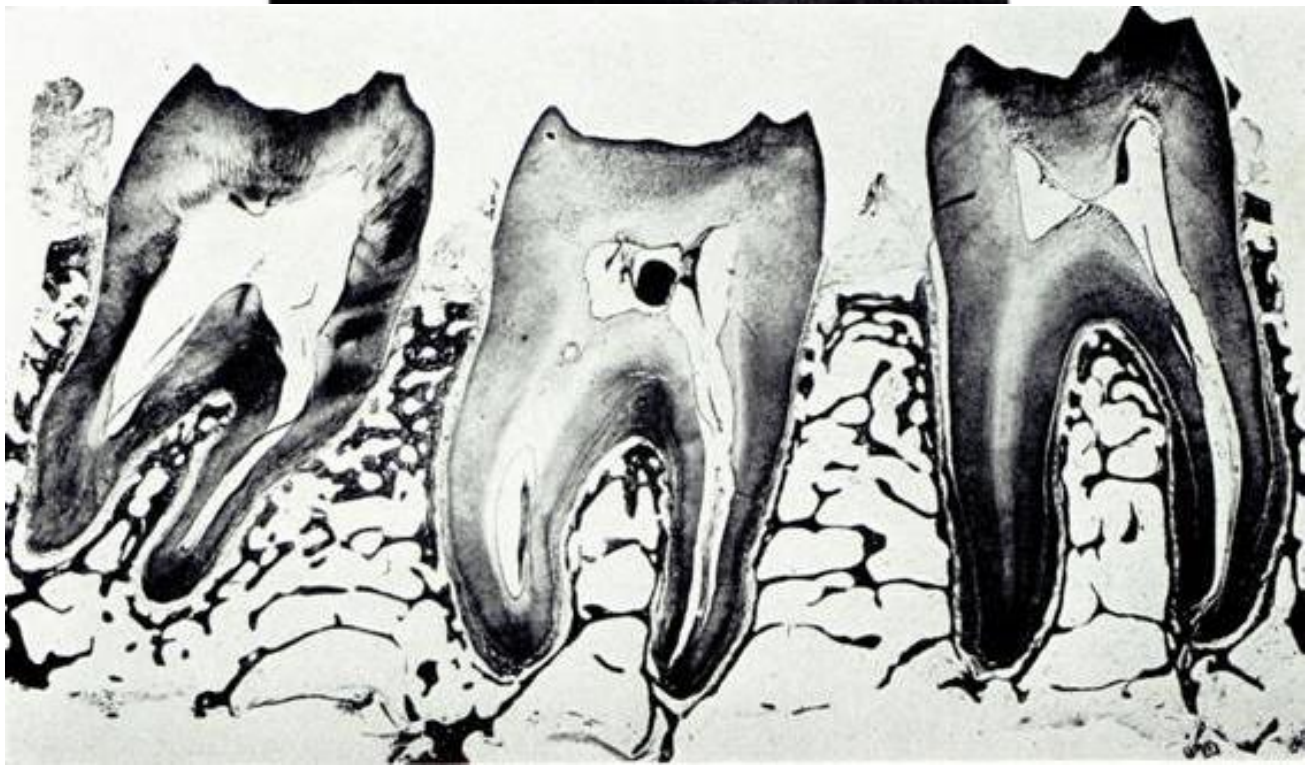
In teeth of primary dentition and young secondary the **lamina dura** is flat, later has wavy structure

Cancellous / Spongy bone

Trabeculae - filling between the plates, high variability in the arrangement of the trabeculae (mostly horizontal direction)

Located between plates and in interdental and interradicular septae

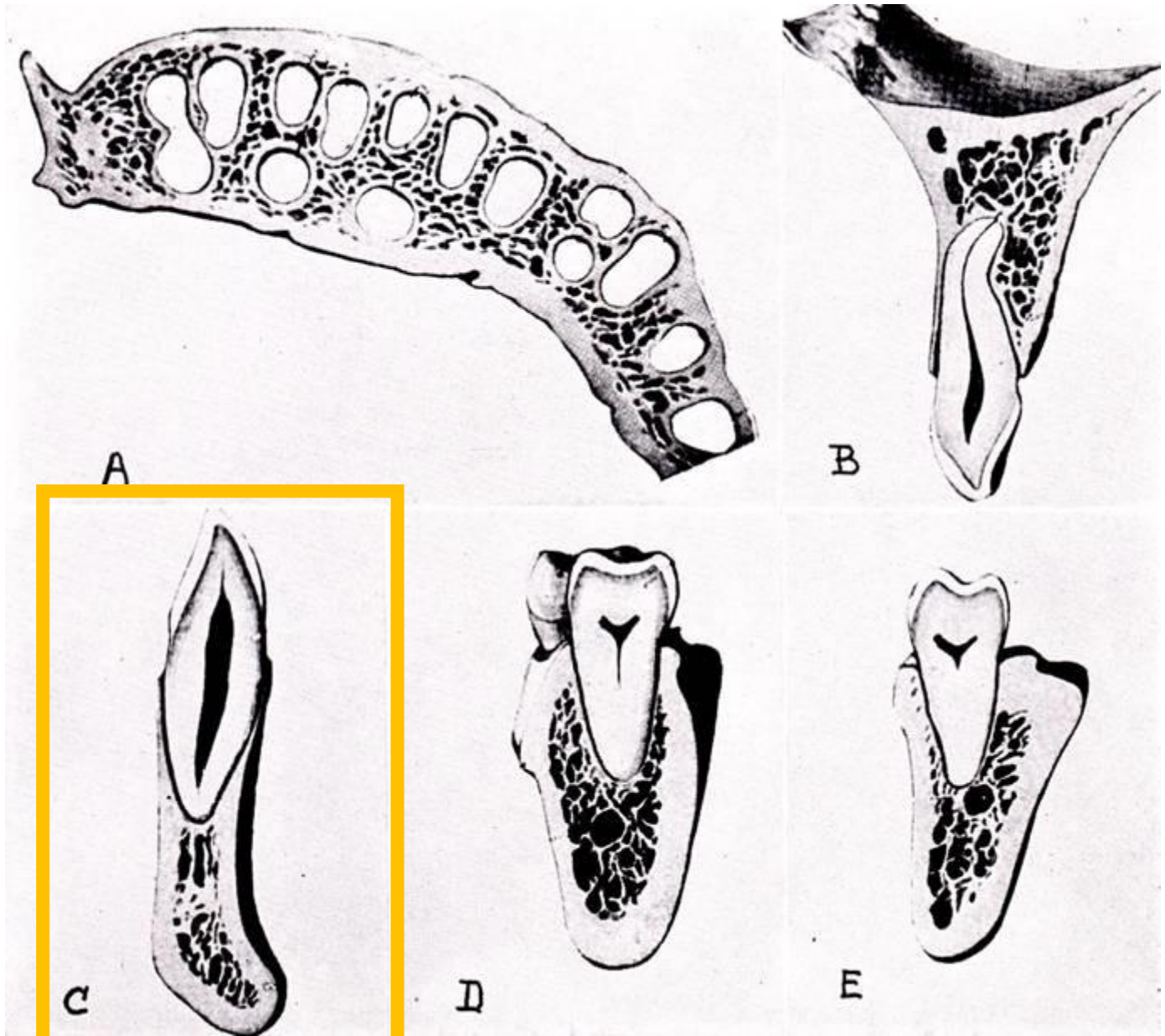
High variability in the arrangement of trabeculae

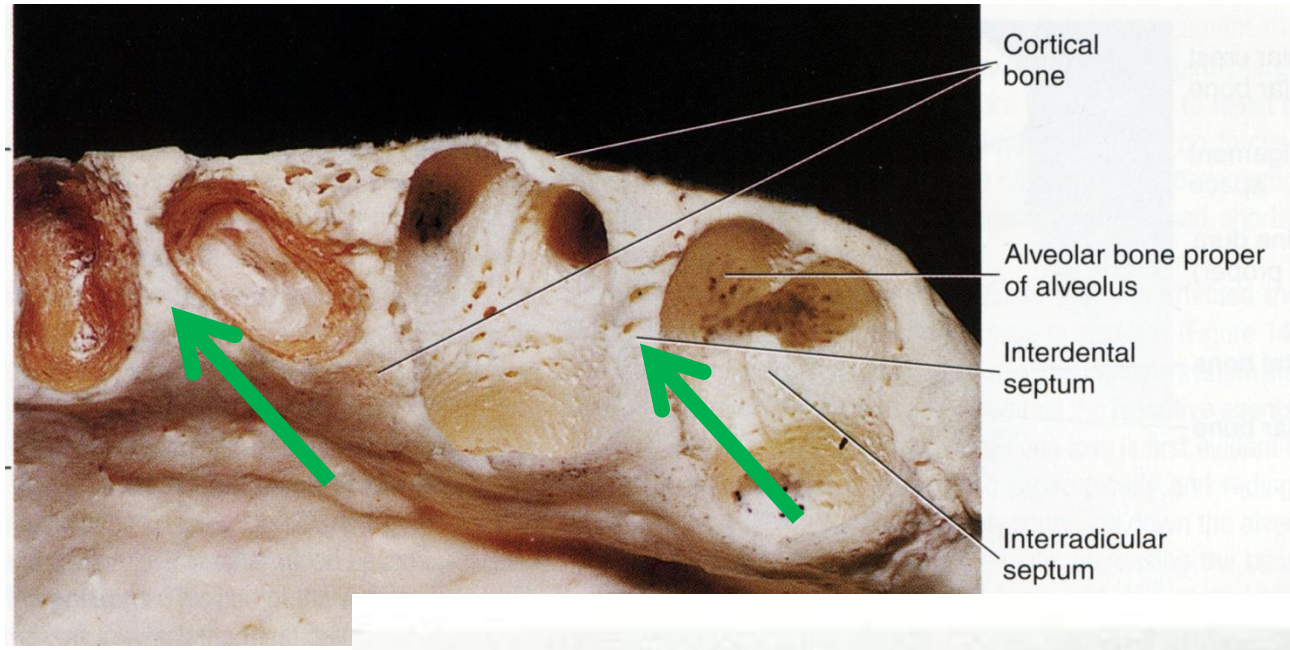


Horizontal course

Between the trabeculae is a hematopoietic bone marrow

In the area of maxillary and mandibular incisors: both lamina oralis and vestibularis fuse with the cribriform plate



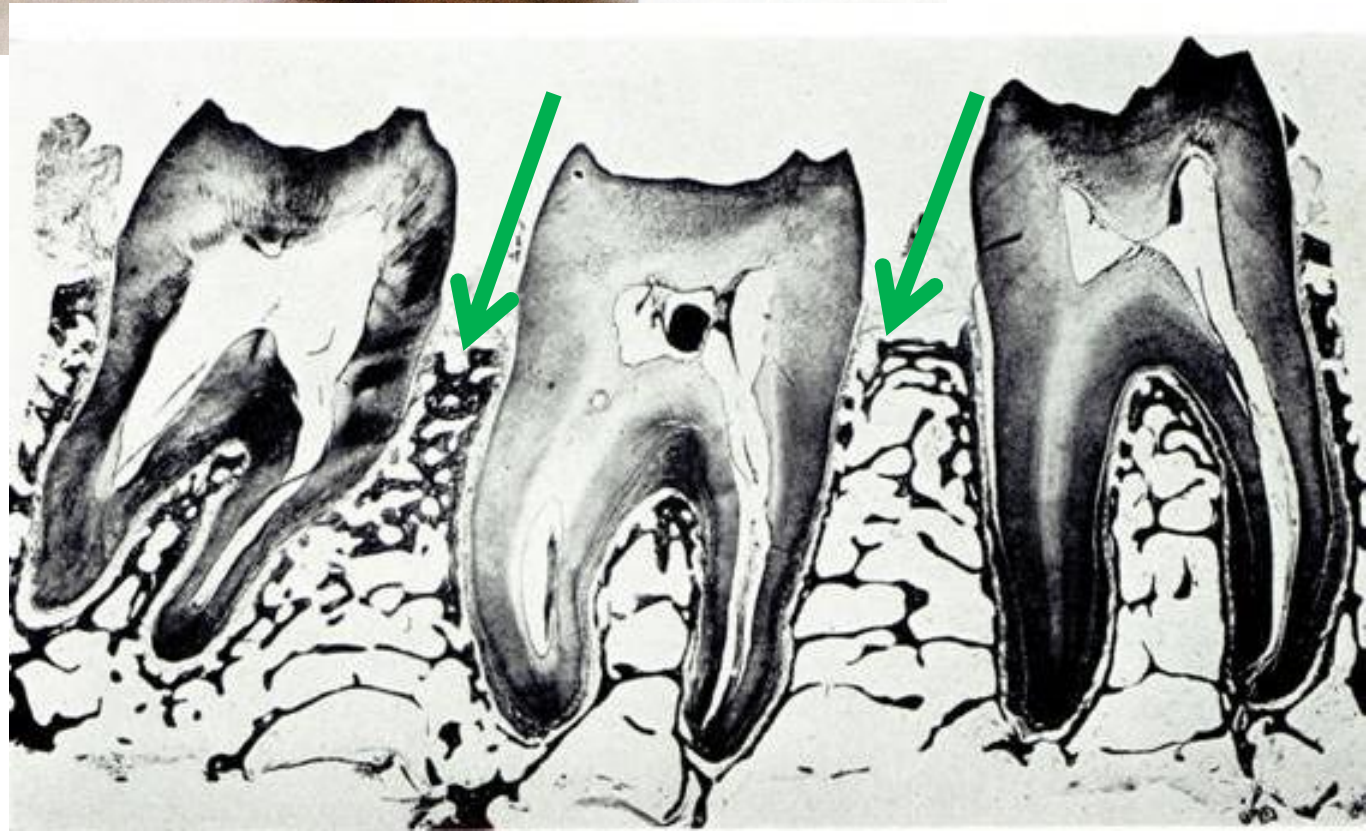


Different alveoli separates:

Interalveolar septae = **septae interdentalia**

Perpendicularly oriented partitions formed by the fusion of mesial and distal parts of cribriform plates of adjacent alveoli

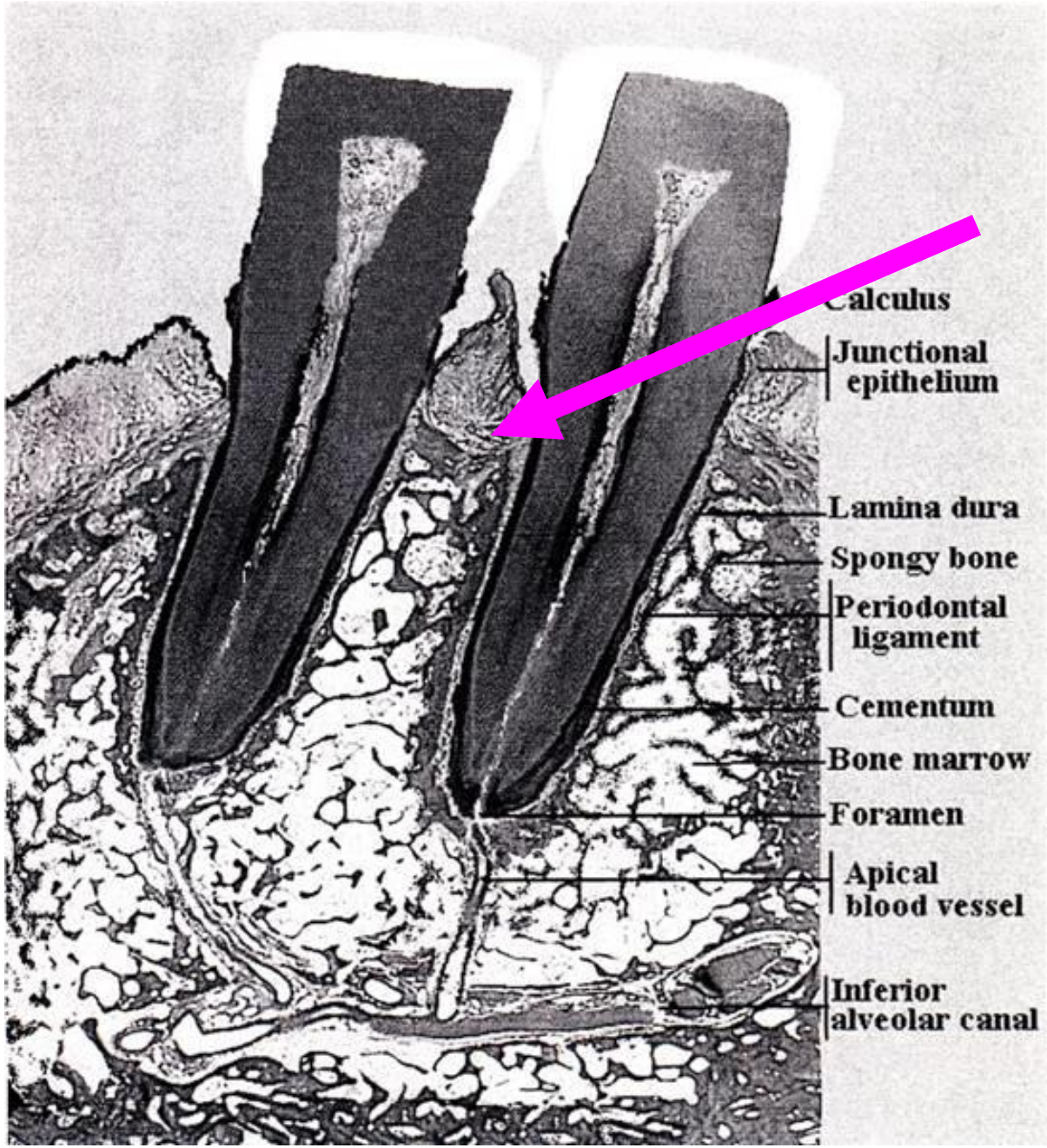
The ridges of the interdental septae are usually rounded and reach the CEJ level



Transseptal fibres

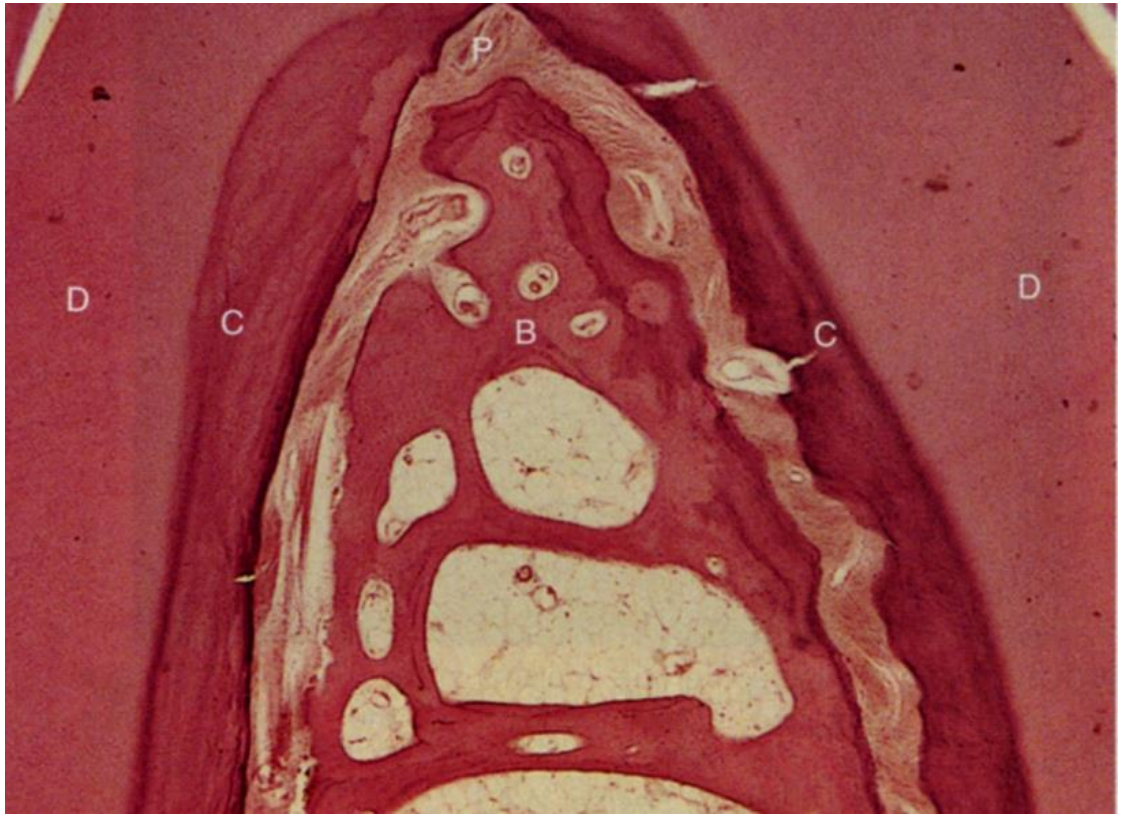
Above interdental septae are **transseptal fibres vlákna** (lig. interdentalia) – forms the shape of crests

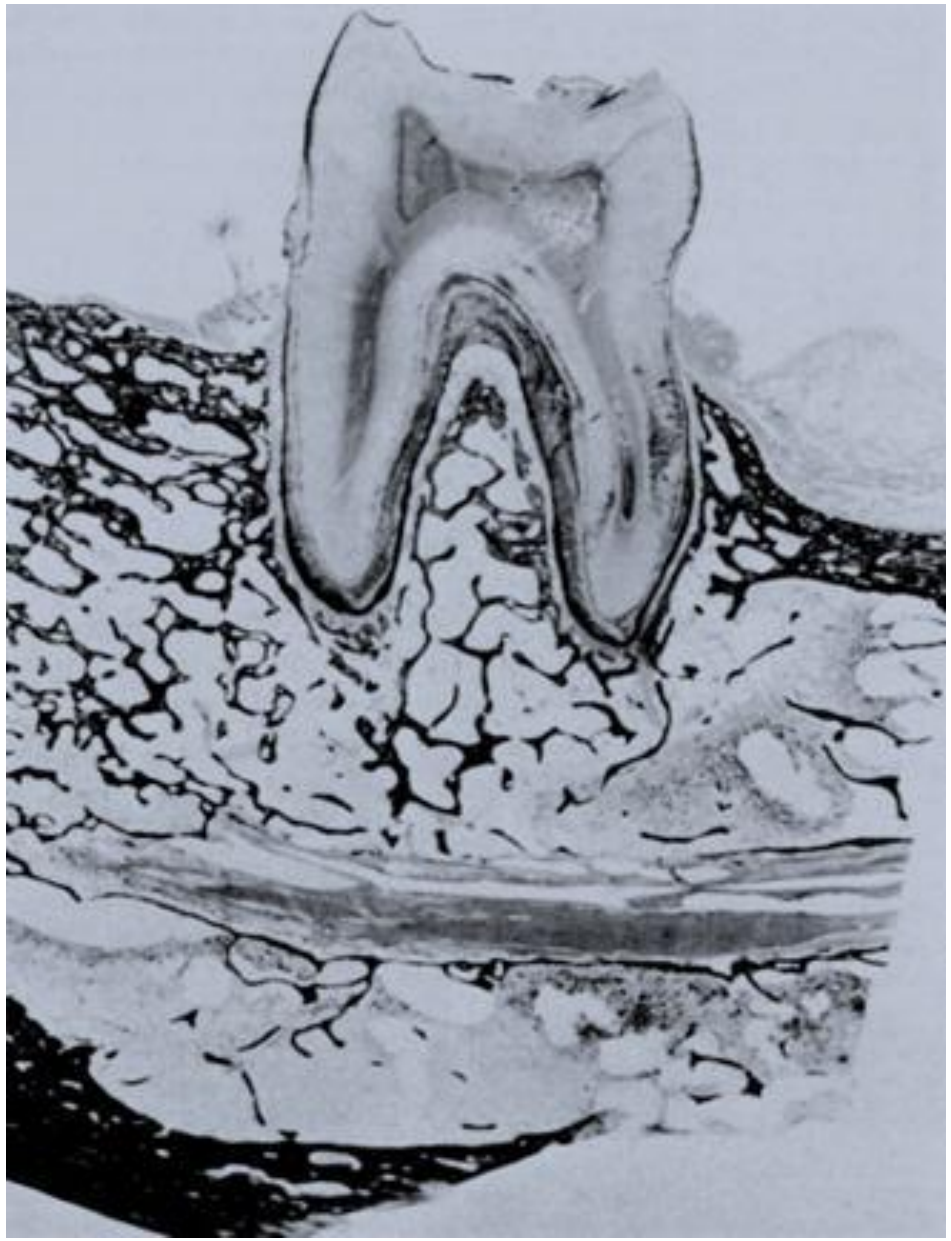
When teeth are inclined the pressure of fibres causes the tilt of crest in the direction of inclination (secondarily, the septum may be shortened)



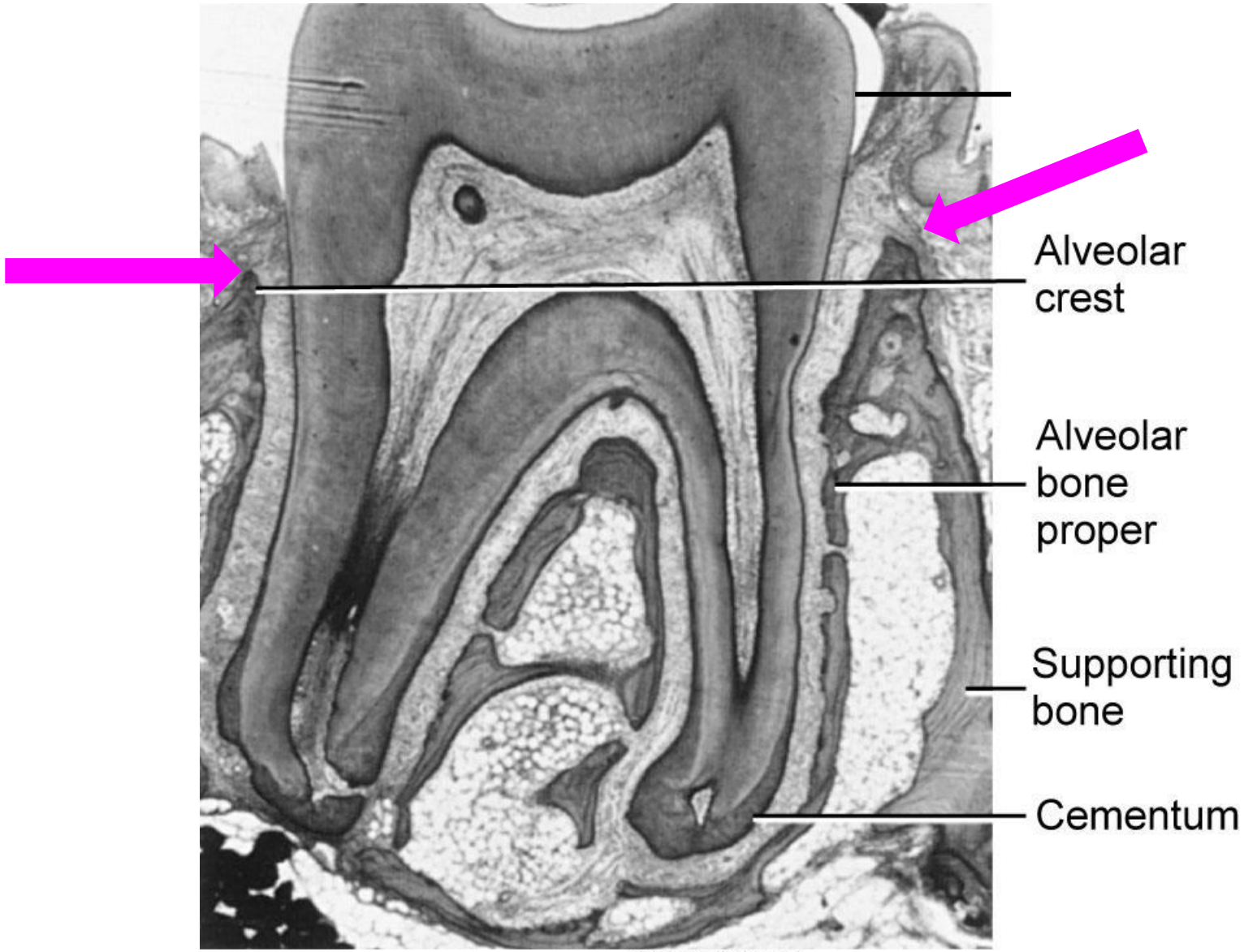
Septa interradicularia

Present only in teeth with more roots
Cribriformn plate together with trabecules of cancellous bone forms interradicular septs - **septa interradicularia**





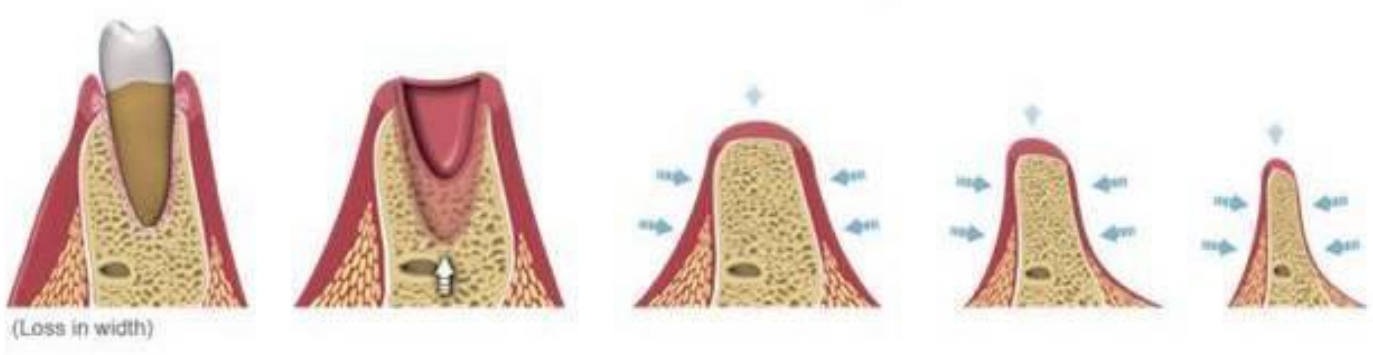
Edge of tooth alveolus – Alveolar crest – is the plase where the coronal end of cribriform plate meets lamina vestibularis or lamina oralis

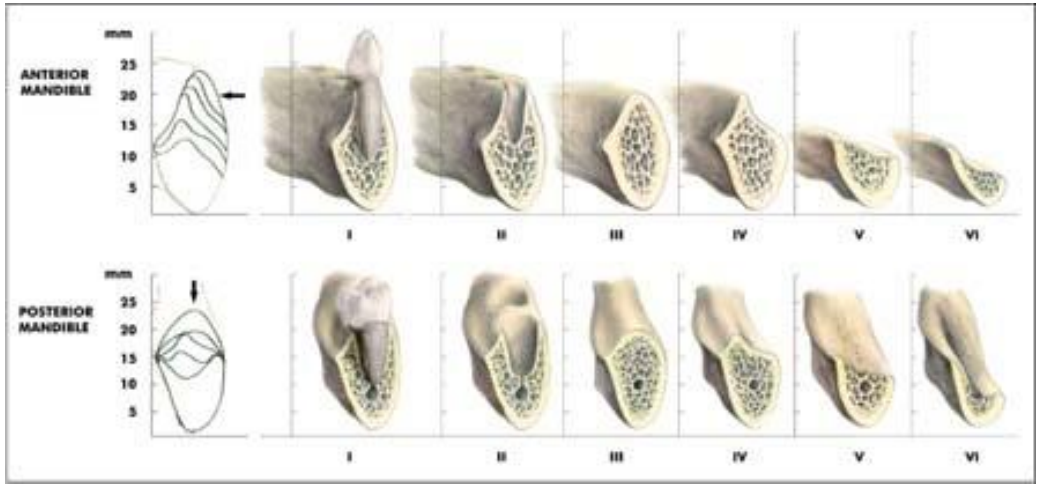


Clinical relevance of alveoli plasticity

The structure and arrangement of the alveolar ridge is affected by a number of factors such as:

- **Overall nutritional status**
- **Hormones (hyper-, hypo- production)**
- **Masticatory forces during food processing**
- **Growth of dental roots and tooth eruption**
- **Infection**
- **Tooth extraction**





Clinical relevance of alveoli plasticity

1. Because of different effect of long-lasting tension and pressure on the bone remodeling the bone structure can be achieved

Long-lasting tension – tooth formation **(tension zone)**

Long-lasting pressure – tooth resorbtion **(pressure zone)**

This is widely used in orthodontics

2. When the bone is not adequately loaded for a long time, structural changes occur

Applies for both the upper and lower jaw

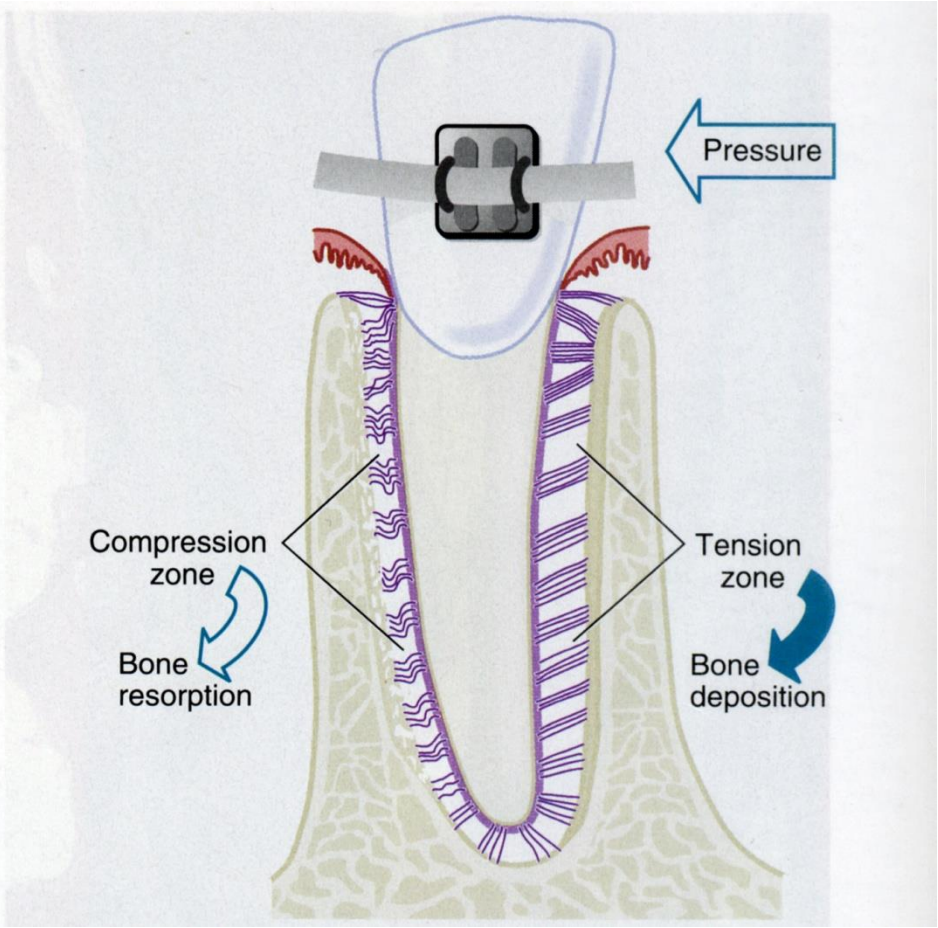
REMEMBER:

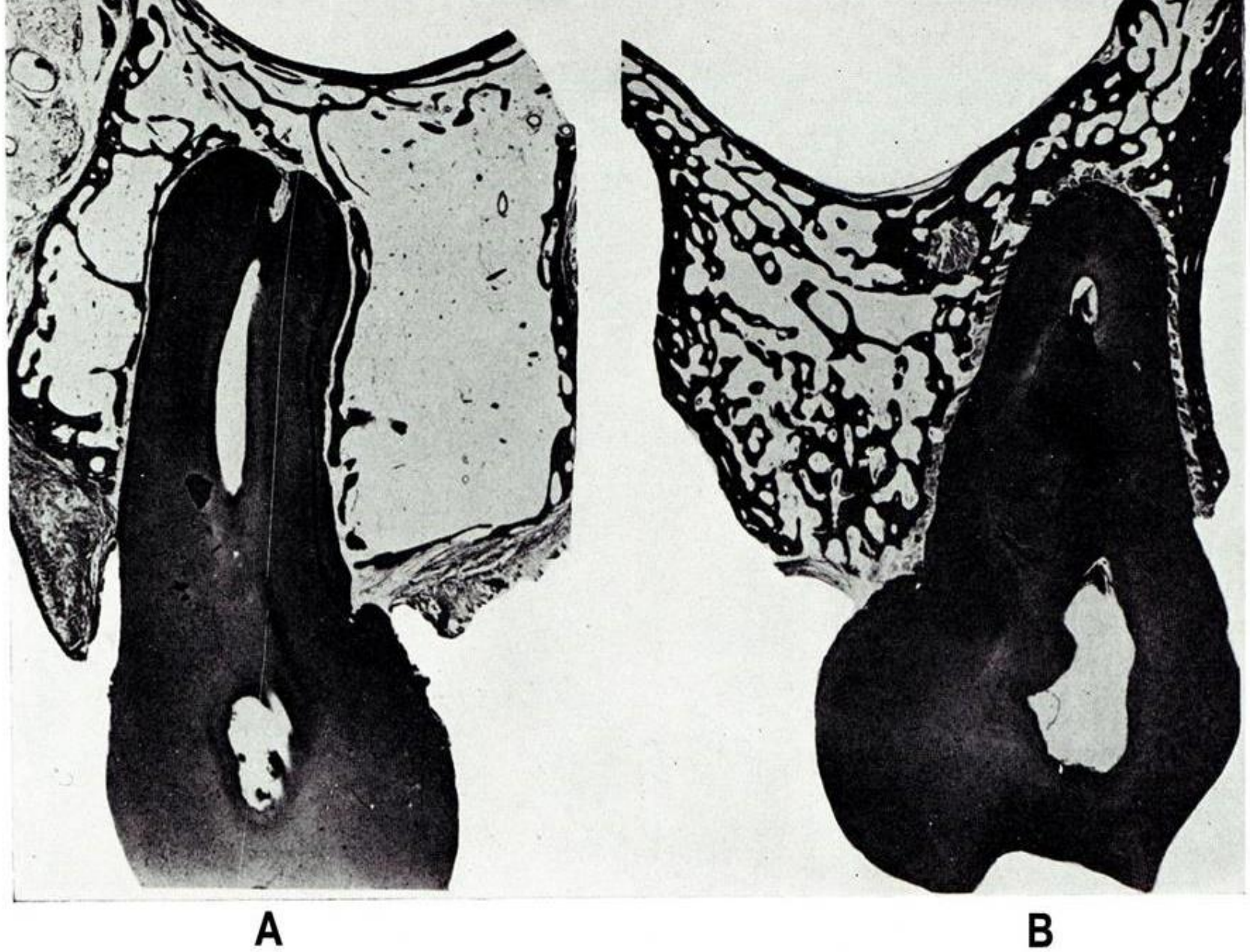
When antagonists are lost – if this condition last for a longer period of time (in the order of months) - there are changes in the alveolus and periodontal ligaments

2 conclusions:

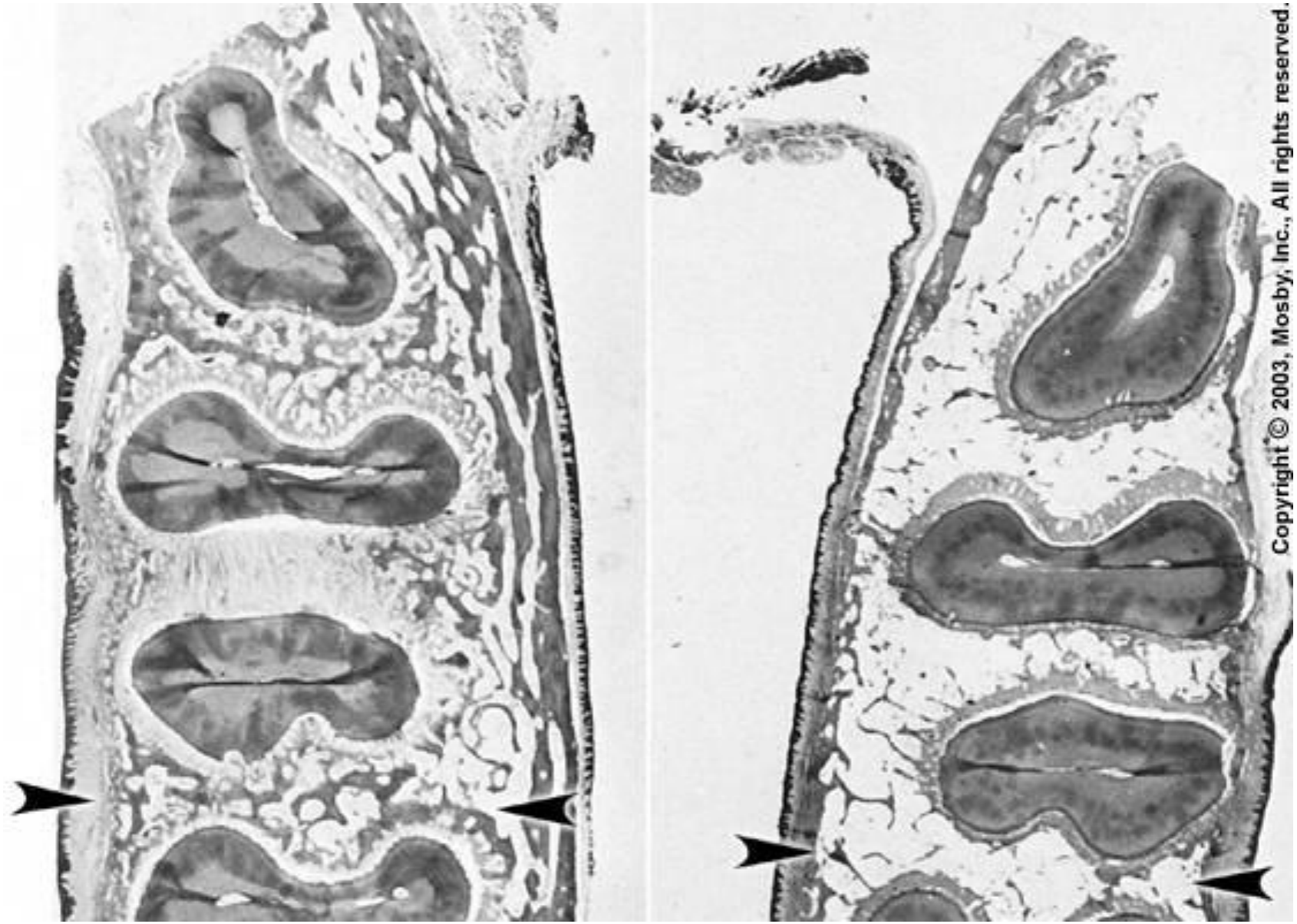
- Carefully indicate teeth extractions

- Fill missing or extracted teeth





A – changes after removal of antogonizing teeth
B – control



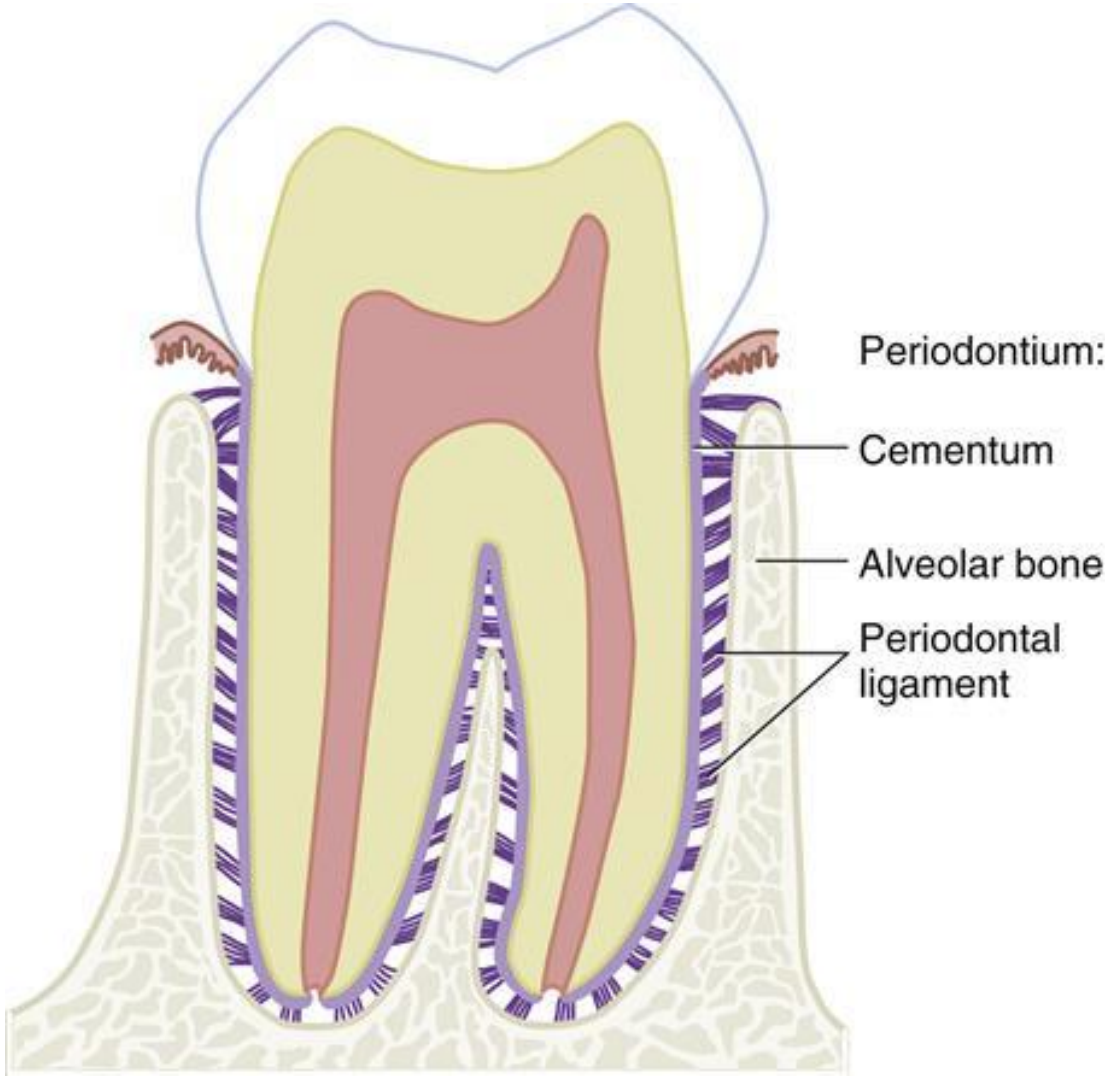
normal loading **changes from inactivity**

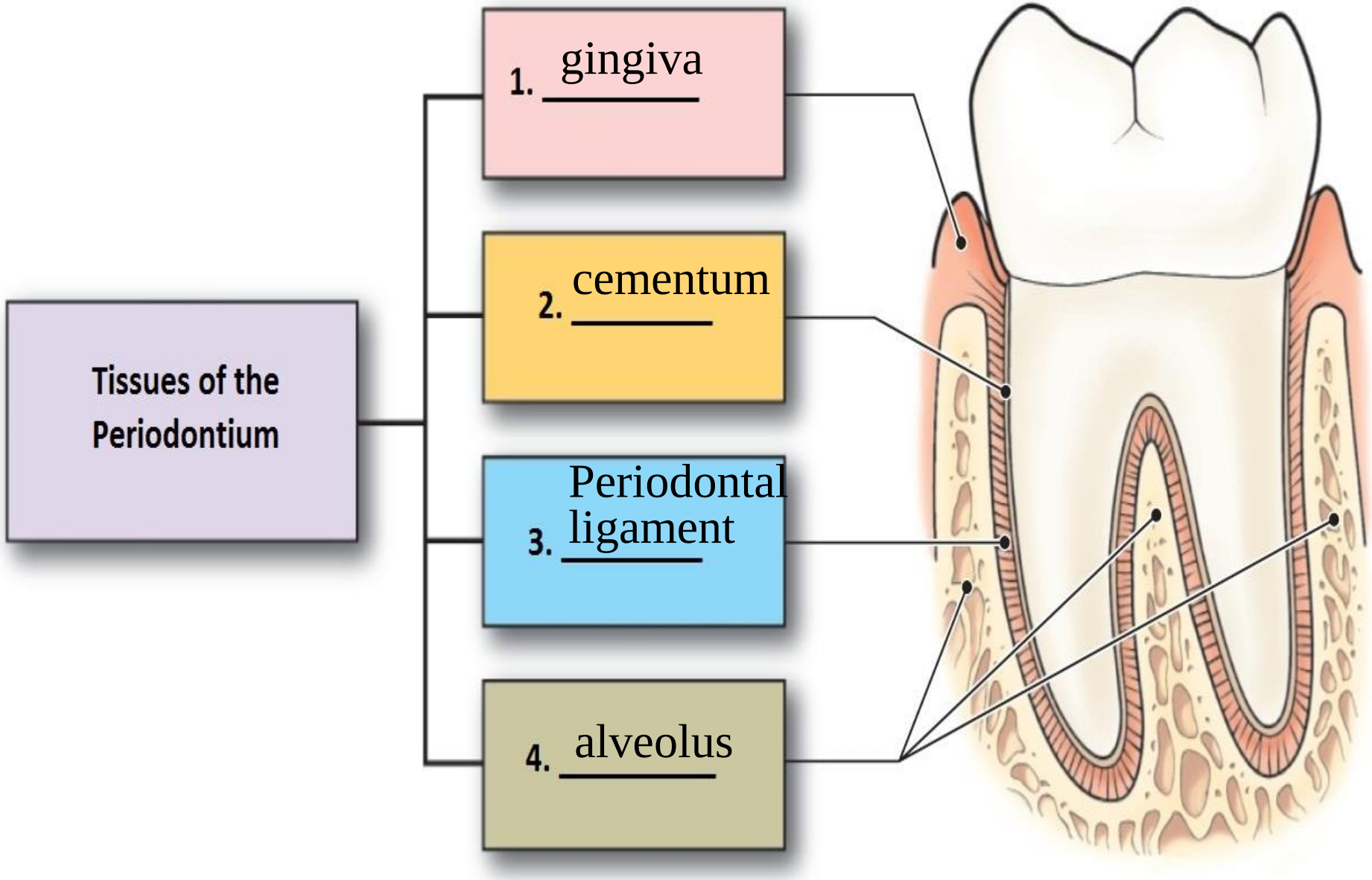
Microscopic structure of the periodontium, its function and clinical significance

Periodontium (in general meaning)

Consists of:

- **Alveolus**
- **Periodontal ligament –** dense collagenous tissue which ensure tooth stability and its attachment inside the alveolus
- **Cementum** – covering roots
- **Gingiva**





Periodontal ligaments

Hold teeth inside the alveolus – Balance and compensate the forces acting during mastication **(thecodontn dentition)**

Transforms compressive forces during chewing into tensile, which the dental bed better resists and is also better adapted to

Fills the space between the cribriform plate of dental socket and root (cementum)

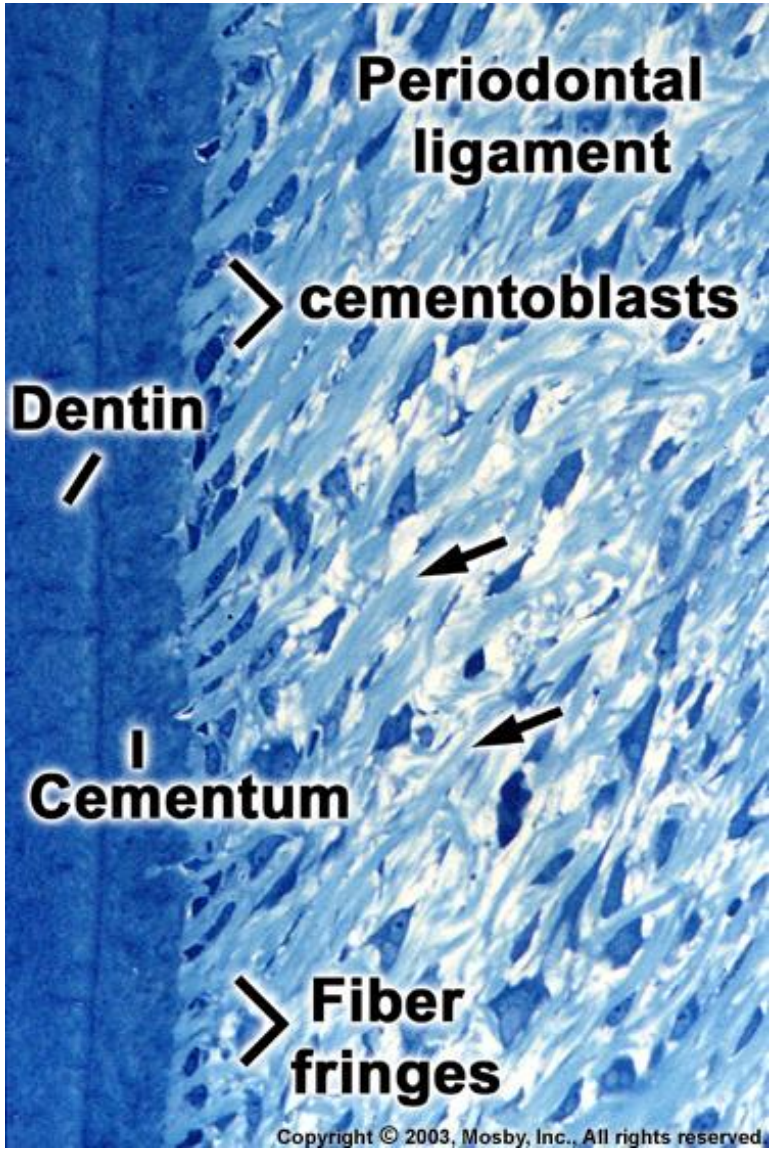
Dense collagenous tissue with higher amount of ECM (extracellular matrix)

Periodontium thickness - 0.18 - 1.0 mm, the thinnest in the middle part of the root

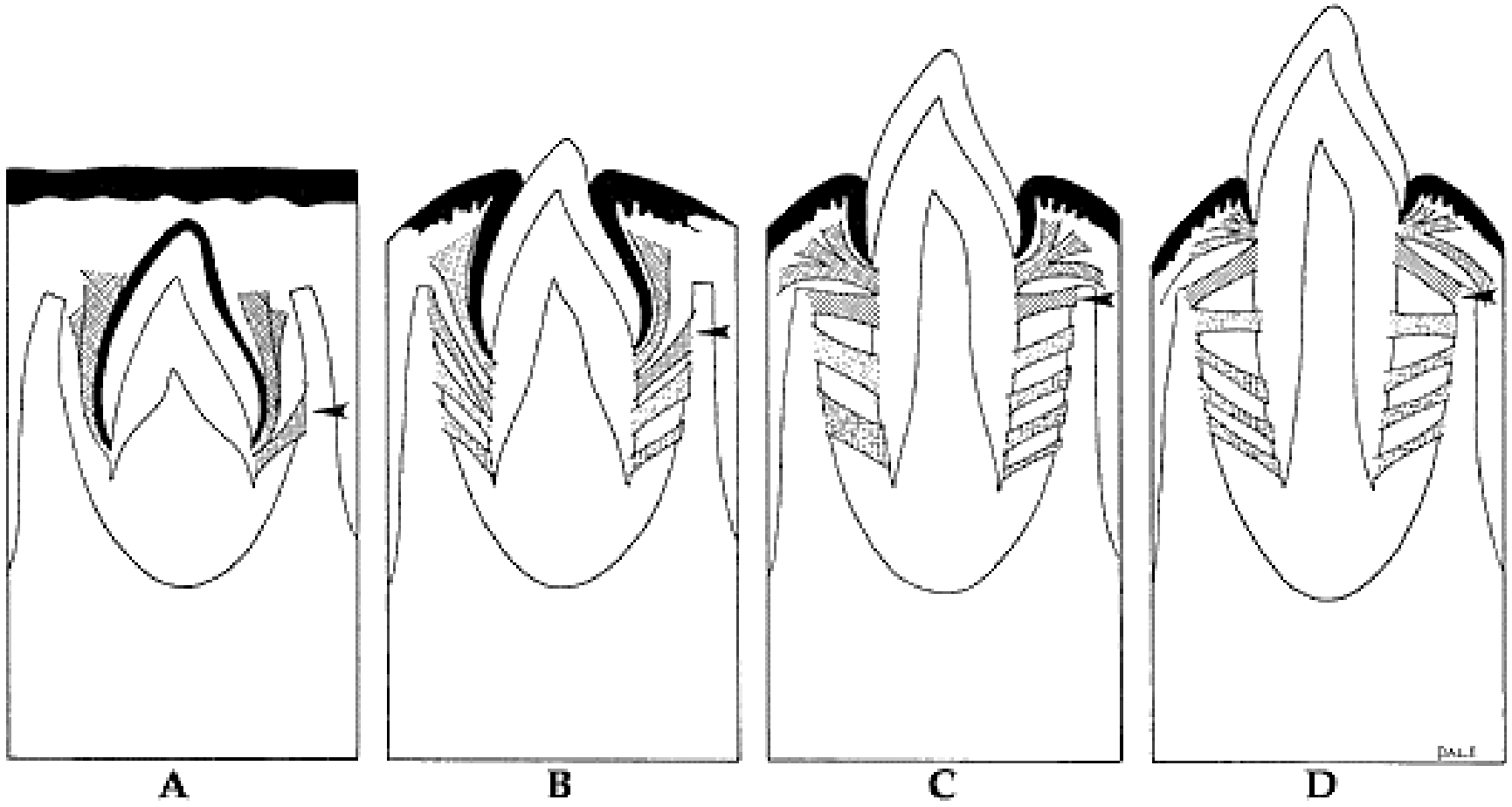
Collagenous fibers - fiber bundles - periodontal ligaments (ligaments)

Ends anchored in dental cementum and lamellar bone of cribriform plate (as Sharpey fibers)

They are of different thicknesses and have a wavy course



Development



Microscopic structure

Cellular: **Fibroblasts a Fibrocytes**

ECM:

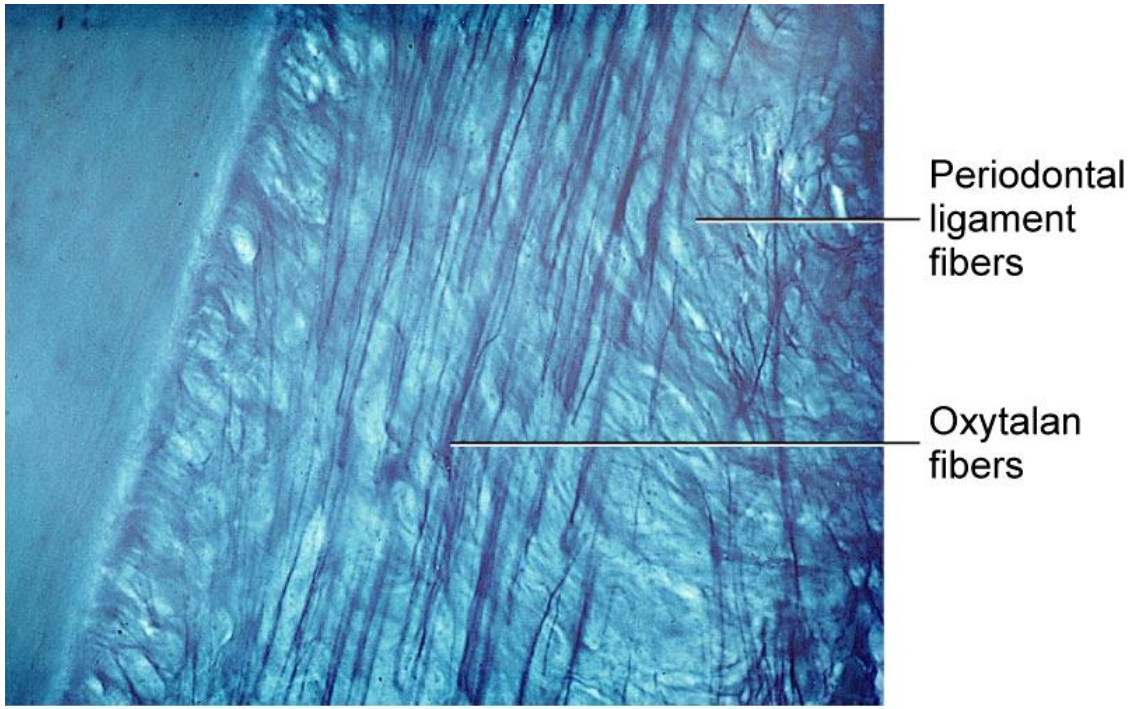
Collagen fibres (I, III a XII)

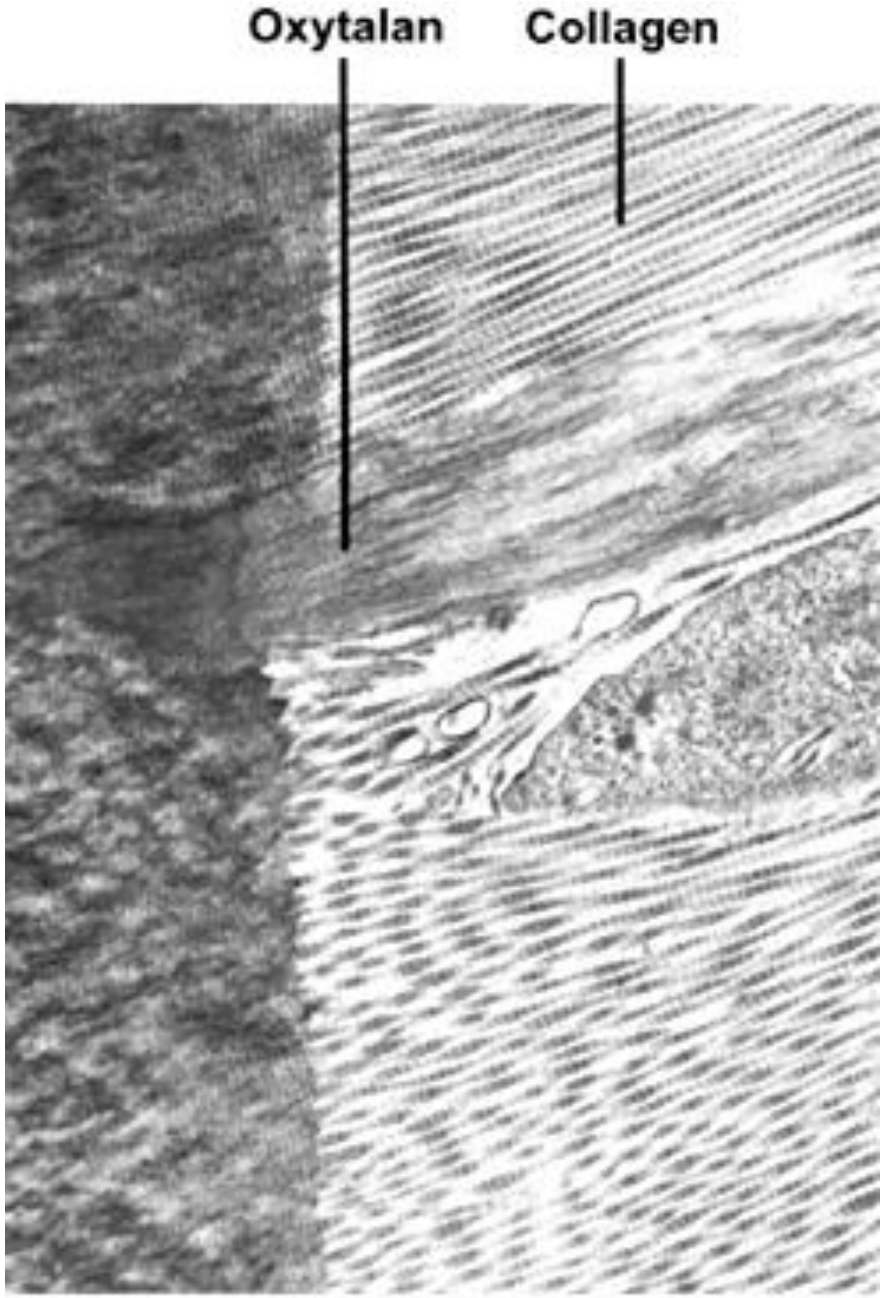
Fast turnover

Organized into bundles

Elastic fibres

Oxytalan fibres (immature elastic fibres)





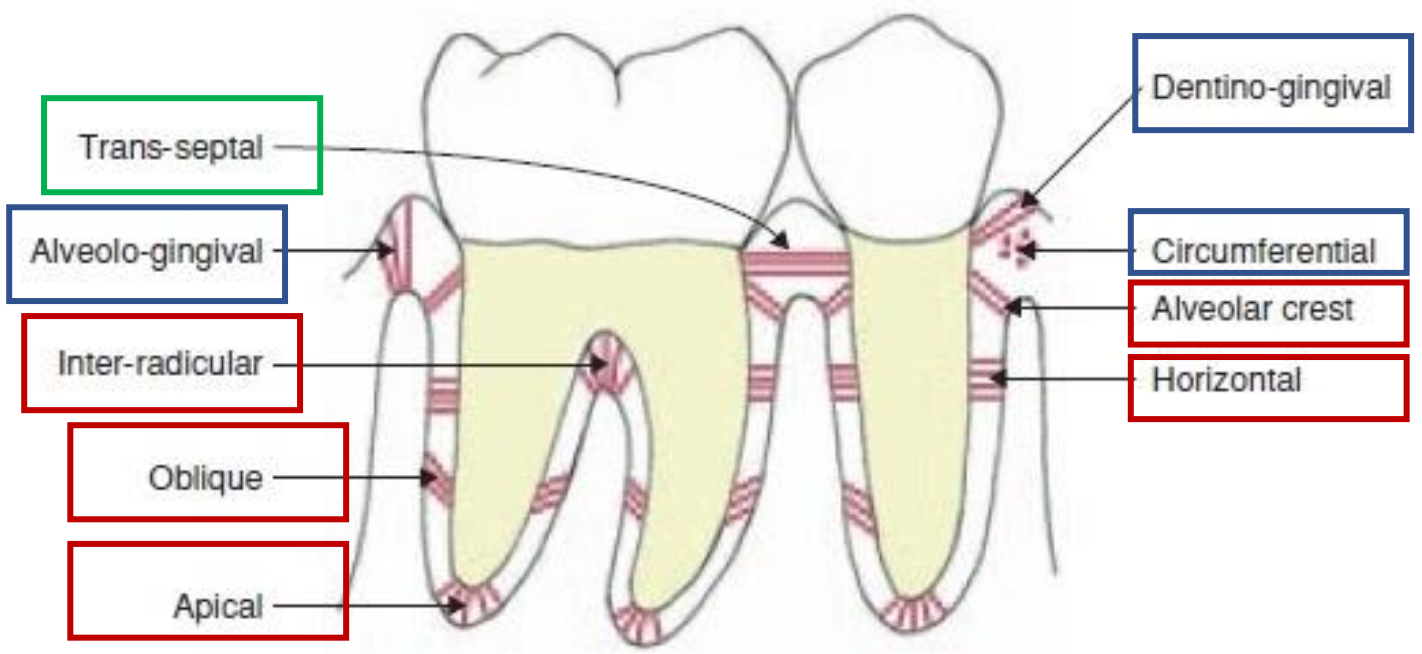
Arrangement of periodontal ligaments

3 main groups:

Gingival fibres

Transseptal (interdental) **fibres**

Alveolar fibres (fibrae principales)



Gingival fibres – attach the gingiva to the neck of the tooth

they are not actually part of the periodontium (they lie in the lamina propria of the gingiva)

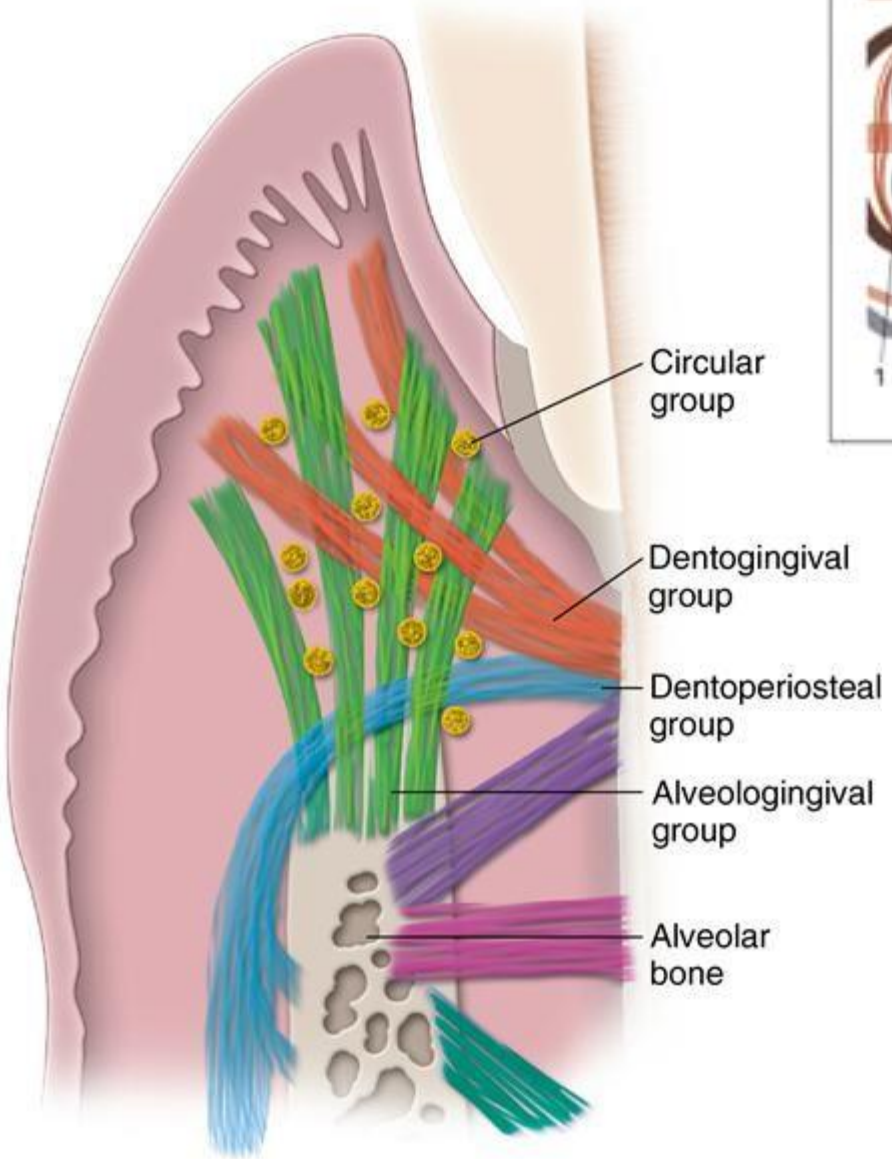
4 directions (groups):

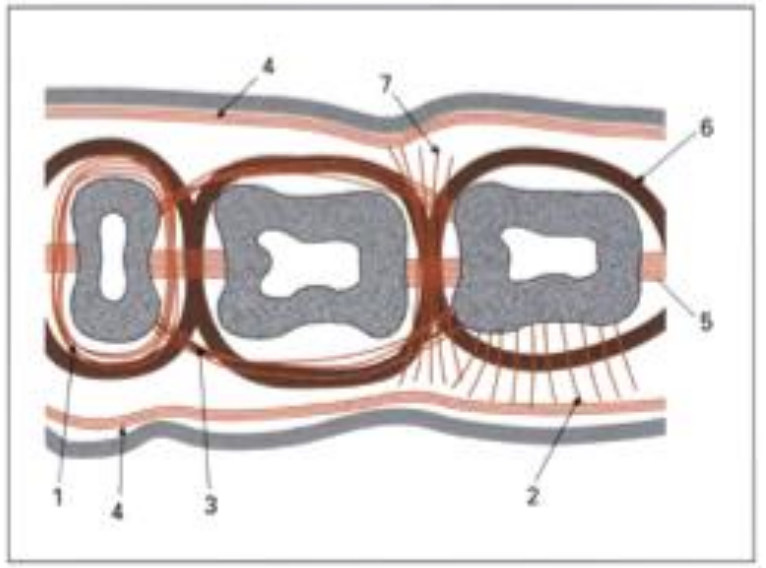
Dentogingival – from cementum at the tooth neck to gingiva afixa and libera. Most abundant

Alveologingival - from the edge of the alveolus gingiva afixa and libera

Circular - placed in free gingiva and they surround the neck of the tooth

Dentoperiostal - from the neck through the edge of the alveolus on the vestibular surface or lingual plate



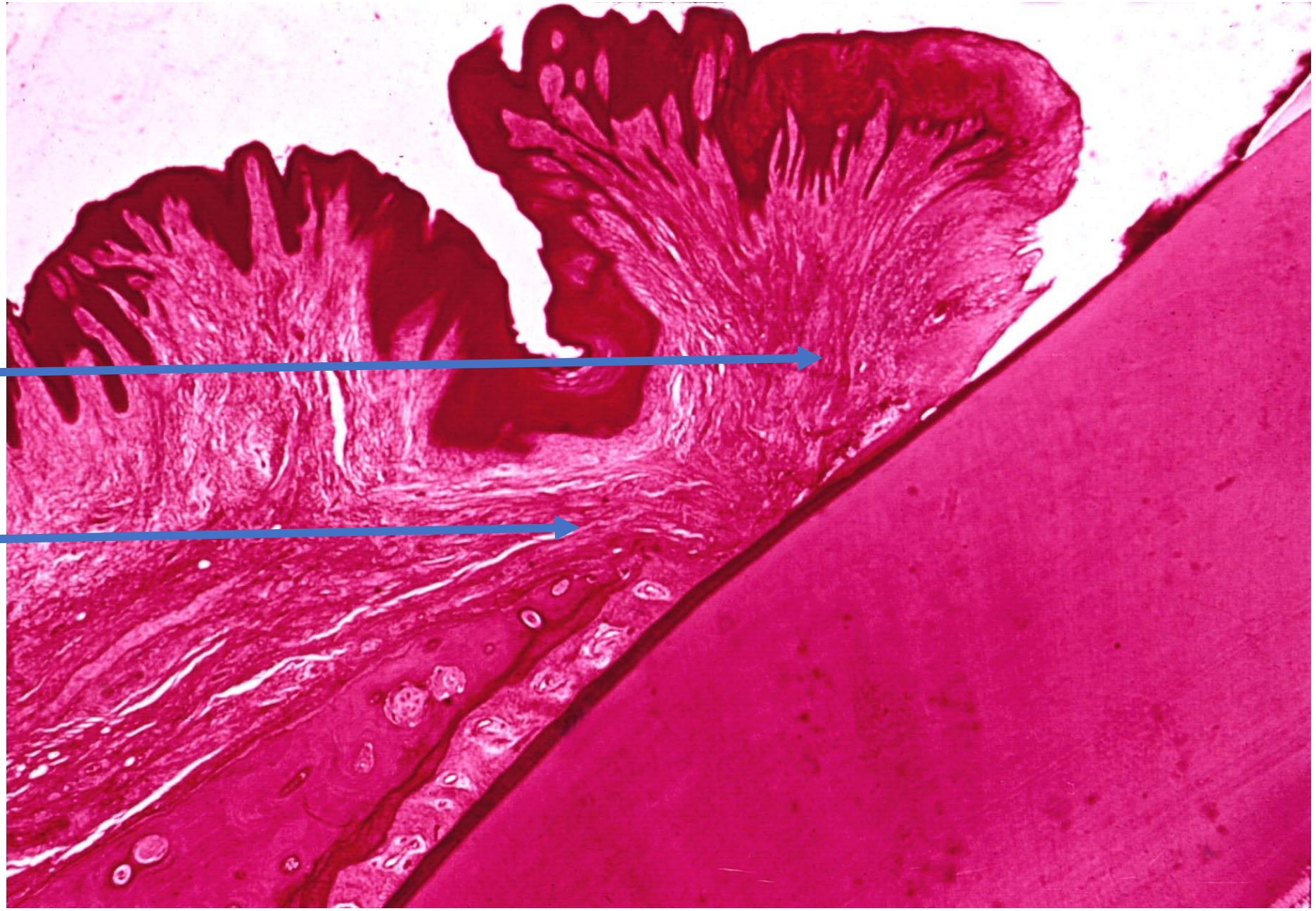


Gingival CT fiber groups in horizontal section:

- (1) circular fibers
- (2) dentogingival fibers
- (3) intercircular fibers
- (4) intergingival fibers
- (5) transseptal fibers
- (6) transgingival fibers
- (7) interpapillary fibers

Dentogingival

Dentoperiostal



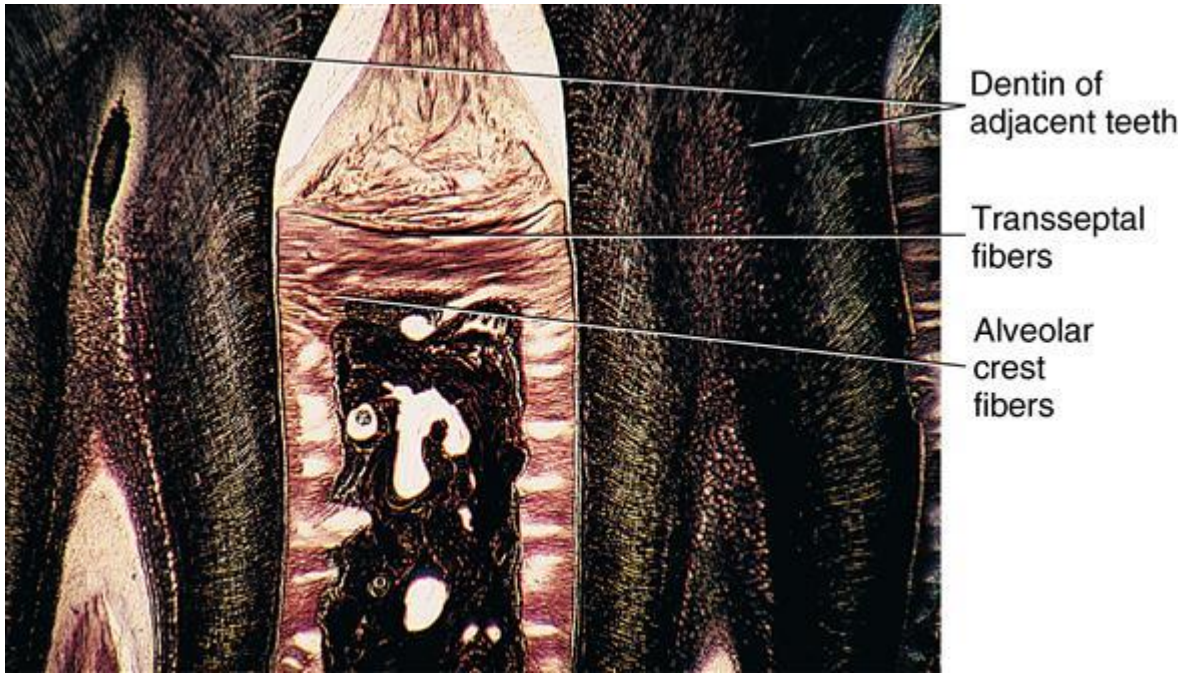
Transseptal fibres – connect necks of neighboring teeth

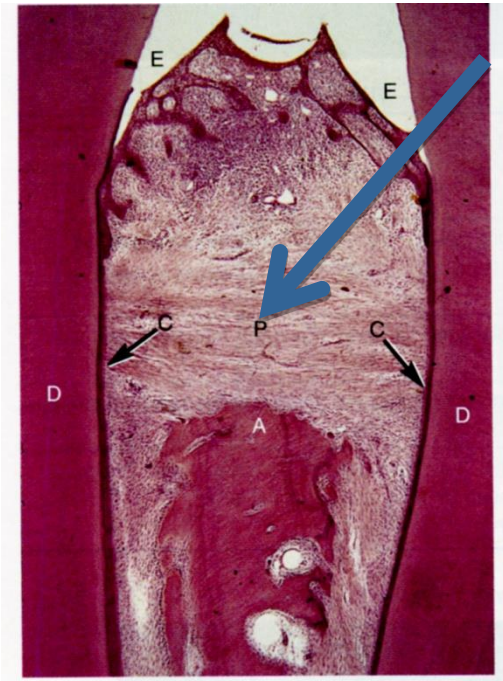
Mesiodistally above the interalveolar septa

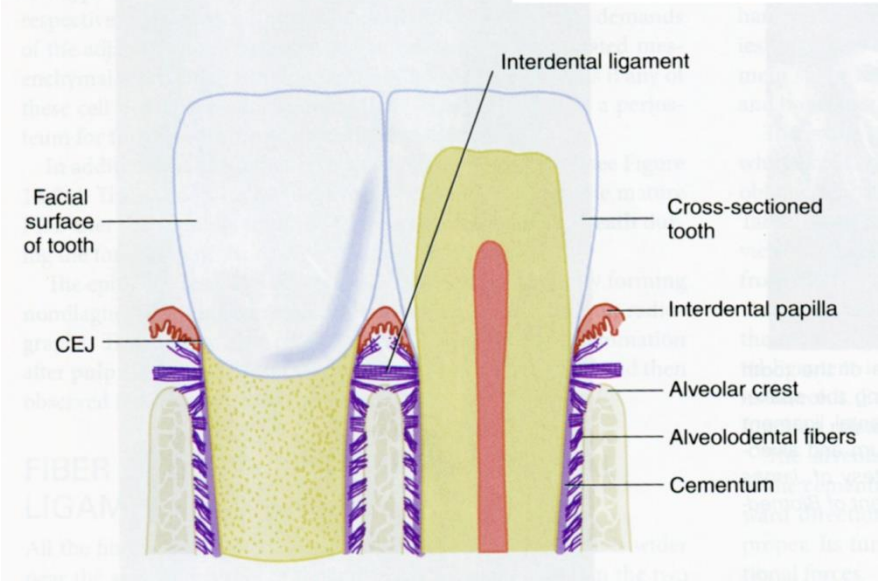
They strengthen the linear alignment of the teeth in the arch and form the basis for interdental papillae

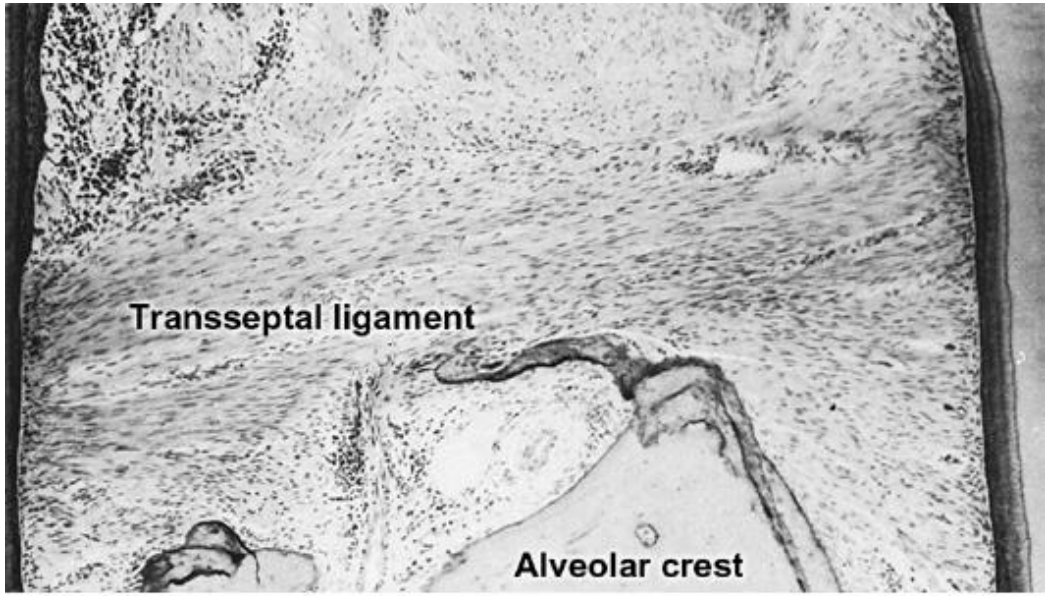
They form the shape of the ridges of theinteralveolar septum

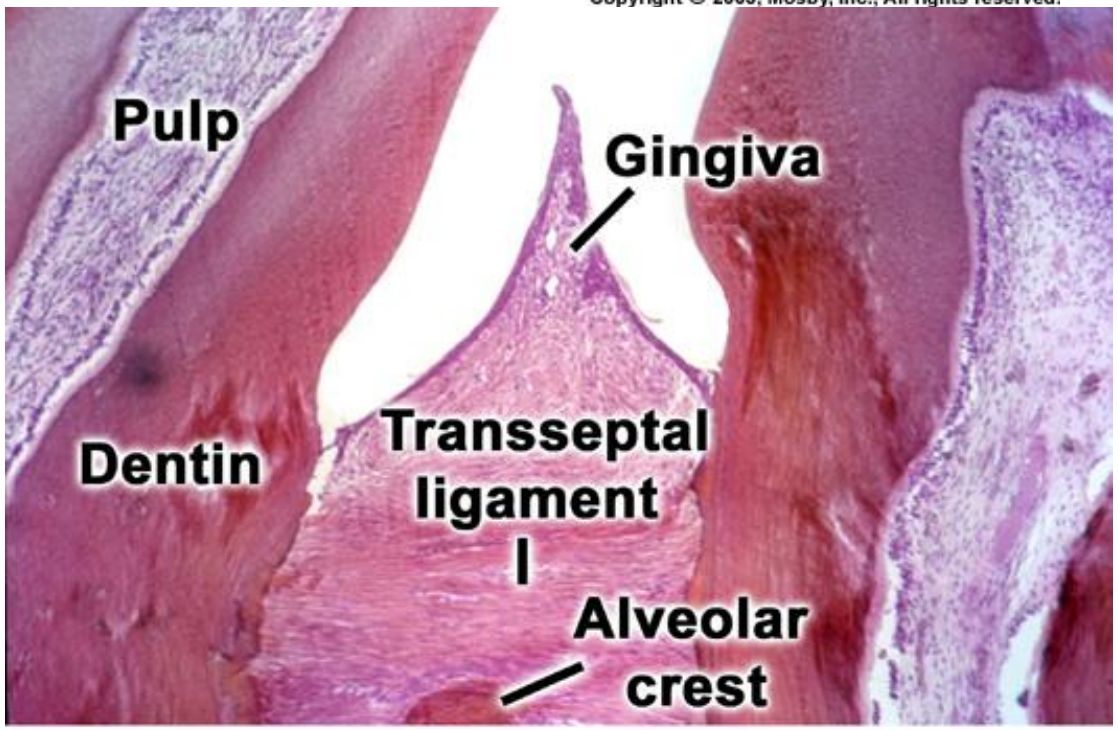
X-ray configuration (with inclination of septal tilt and depression)







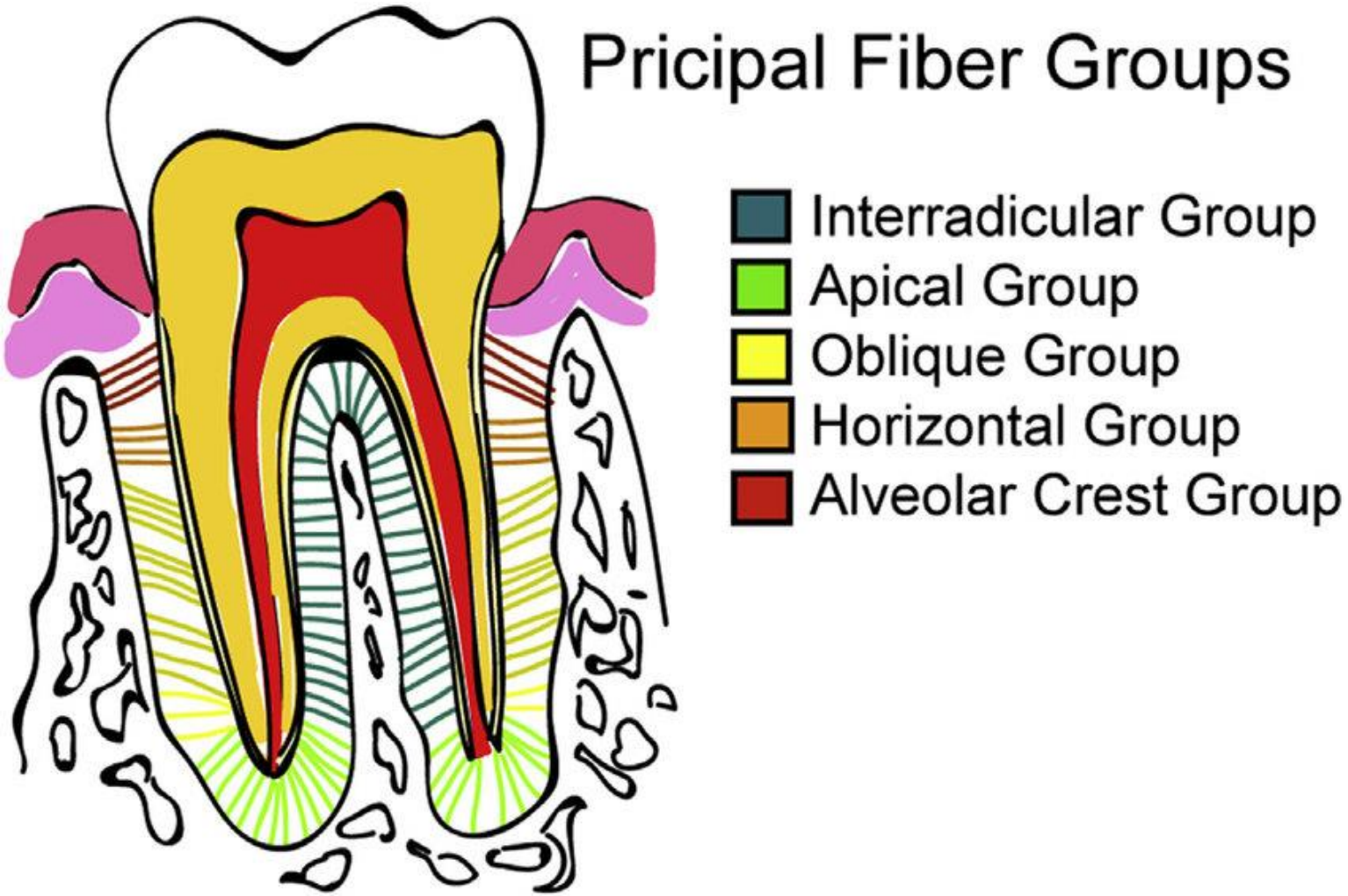




Alveolar fibres

Between root and cribriform plate of alveolus (*os alveolare*)

Most abundant



Alveolar fibres

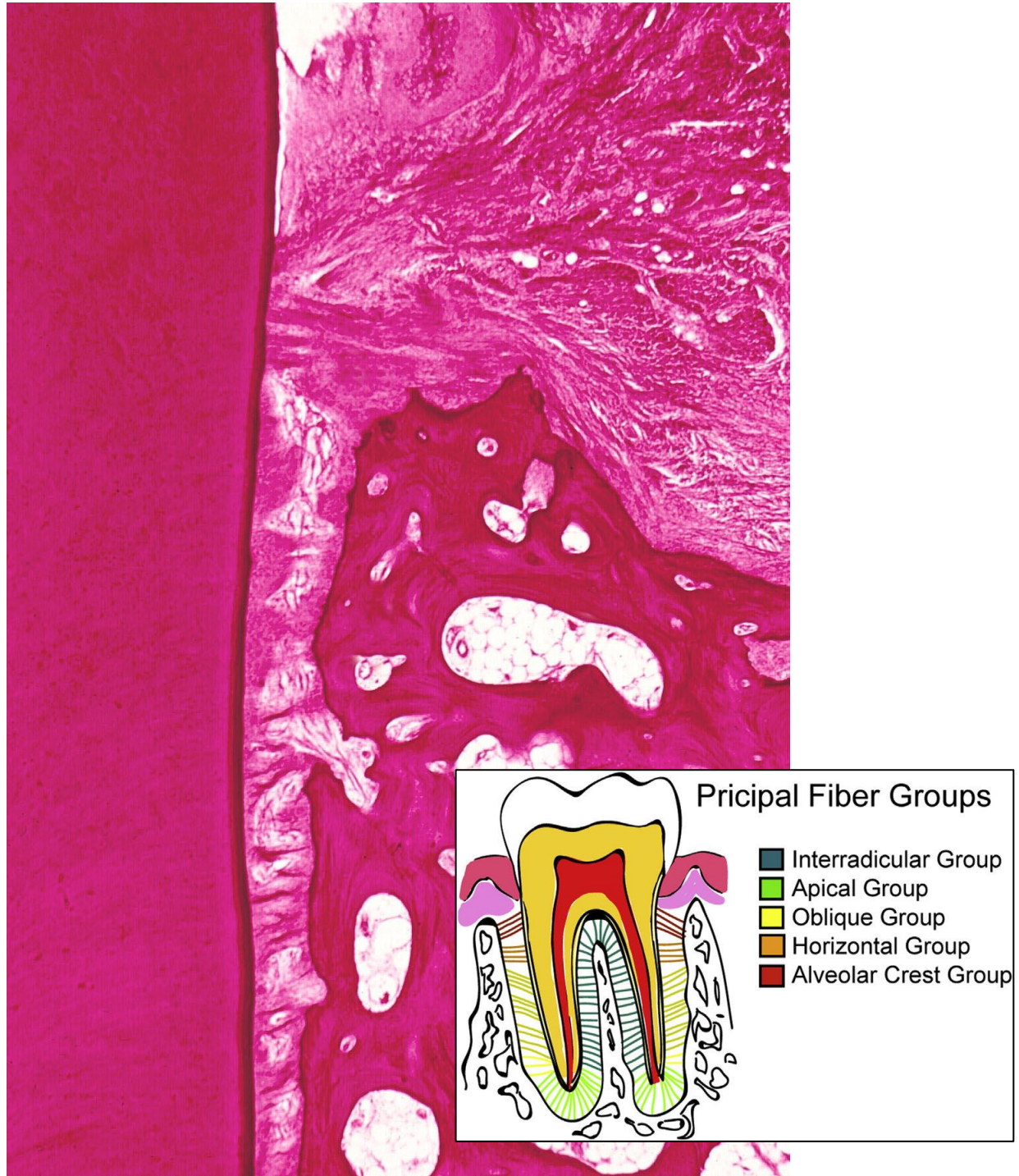
Alveolar crest group – from the neck to periosteum of interalveolar septum or periosteum of coronal edge of alveolus.

Function: **They prevent the tooth from moving out of the alveolus (sometimes missing)**

Horizontal group – in coronal third of tooth root and alveolus

Perpendicular to the longitudinal axis of the tooth

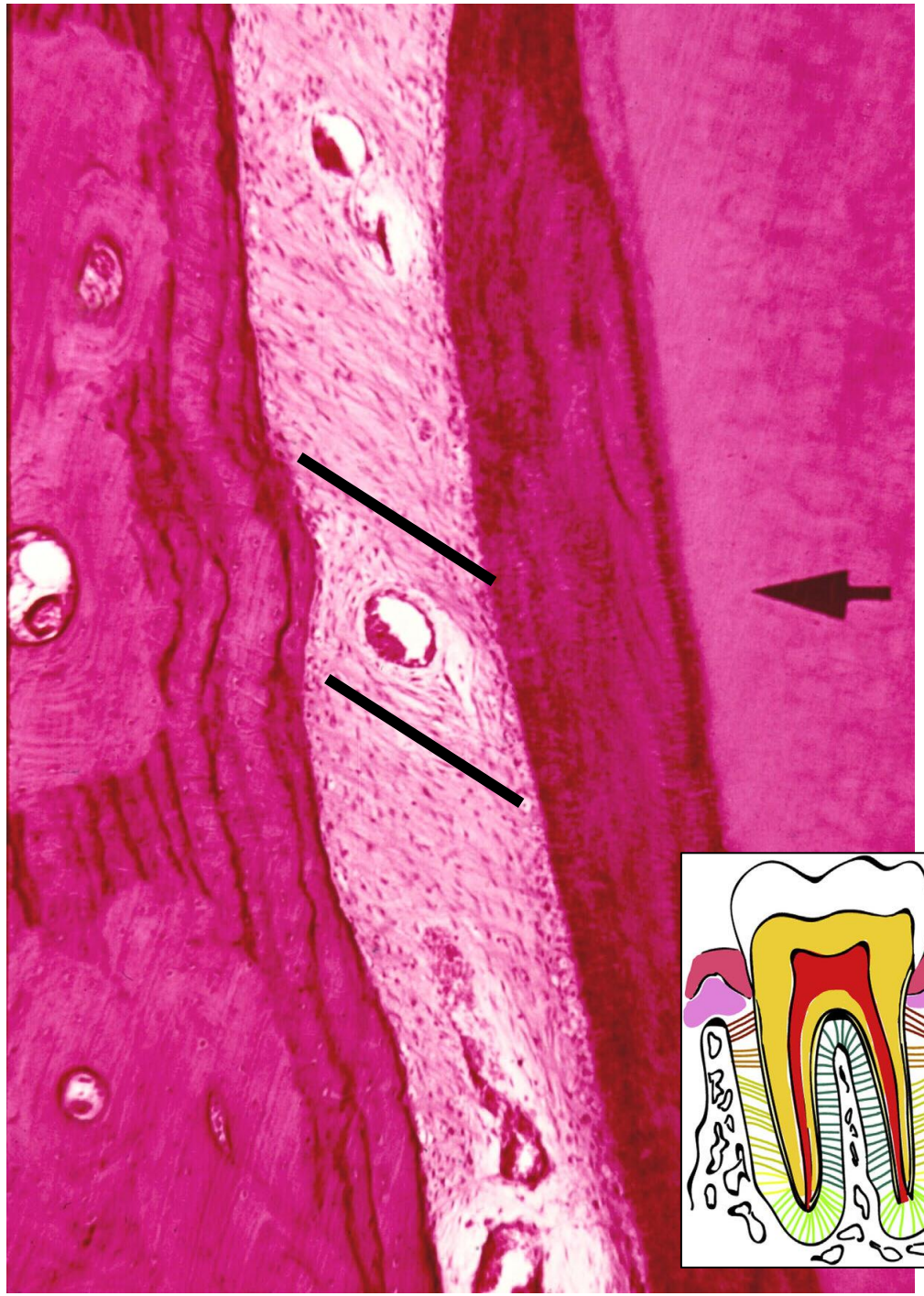
Function - **Prevents lateral (horizontal) movements of the teeth**

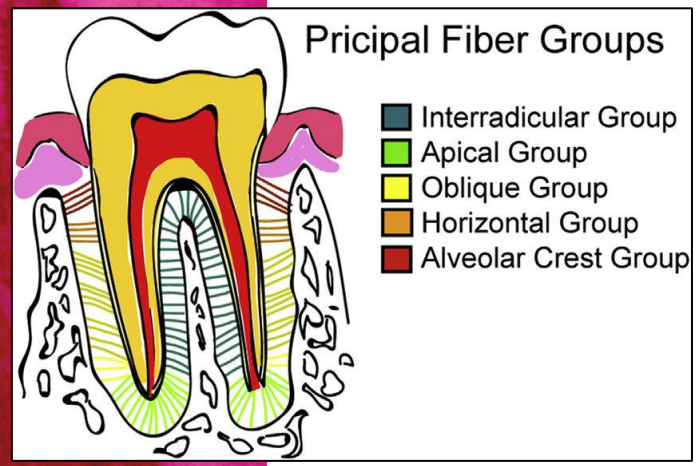


<u>Oblique group</u> – in the middle and apical third of root/alveolus

Diagonal course - the attachments on the cement positioned more apically than the insertion in the cribriform plate

Function - **Prevents the root from being pushed into the bed**

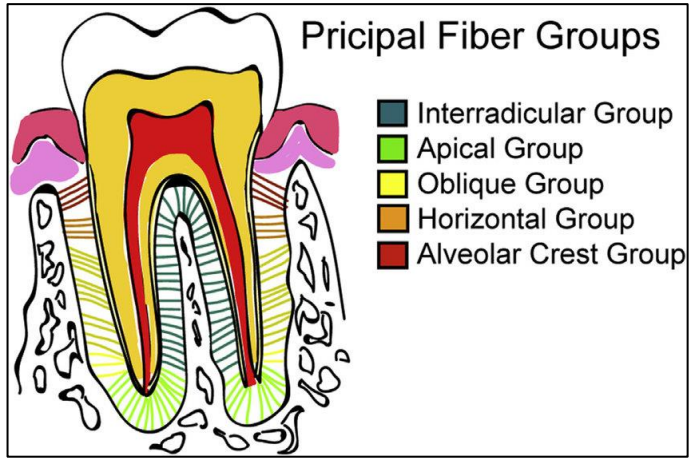


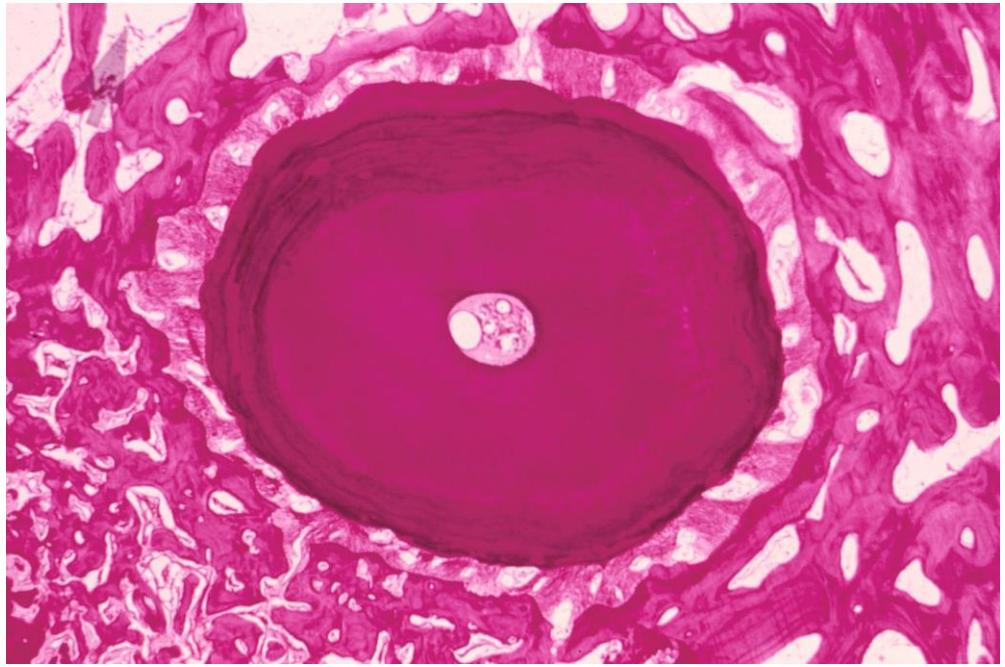


Apical – from the tooth apex to the bottom part of alveolus

Radial course

Function – **Prevent the tooth from moving out of the alveolus (sometimes missing)**



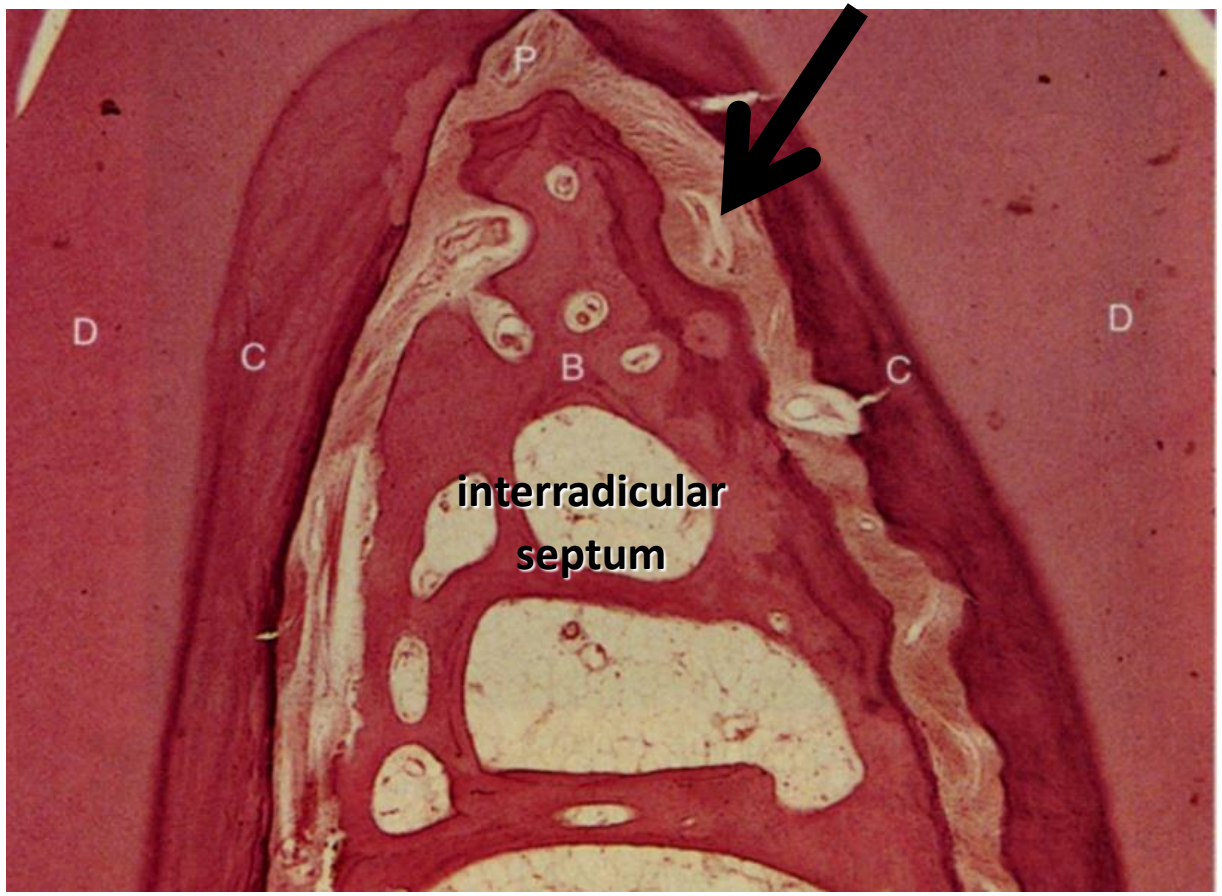


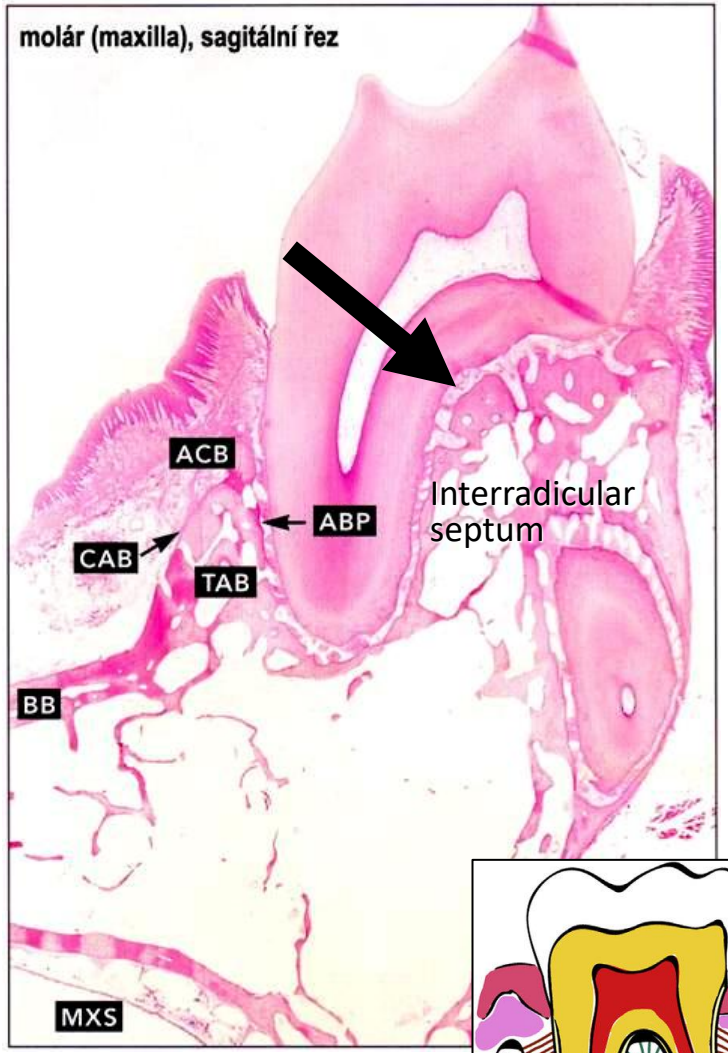
<u>Interradicular</u> – only in teeth with more roots

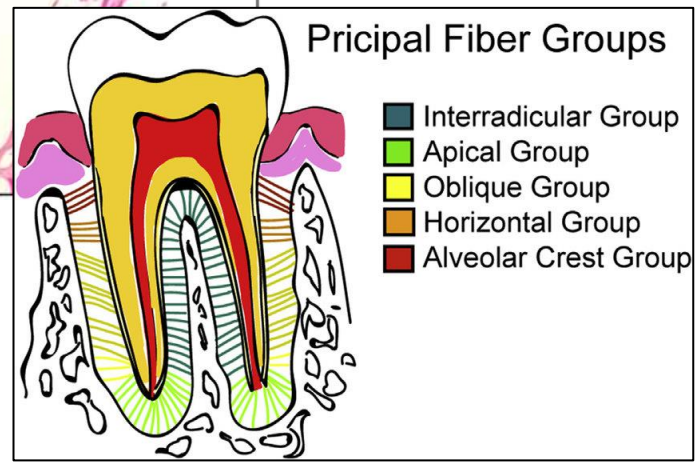
At the place of root branching

Attached to the alveolar septum between roots

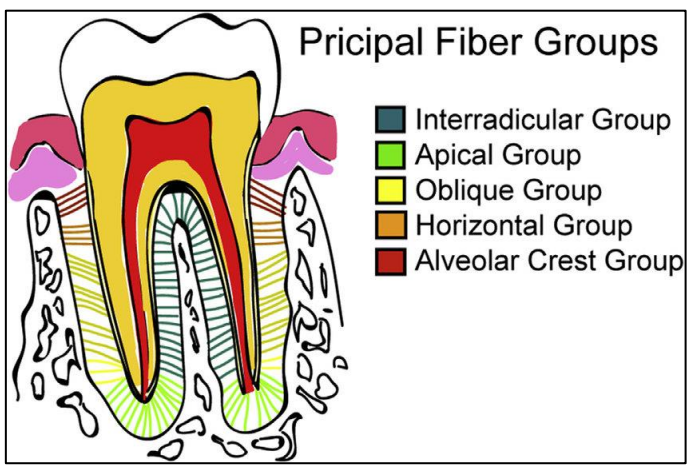
Function – prevent the tooth from moving out of the alveolus and the rotation

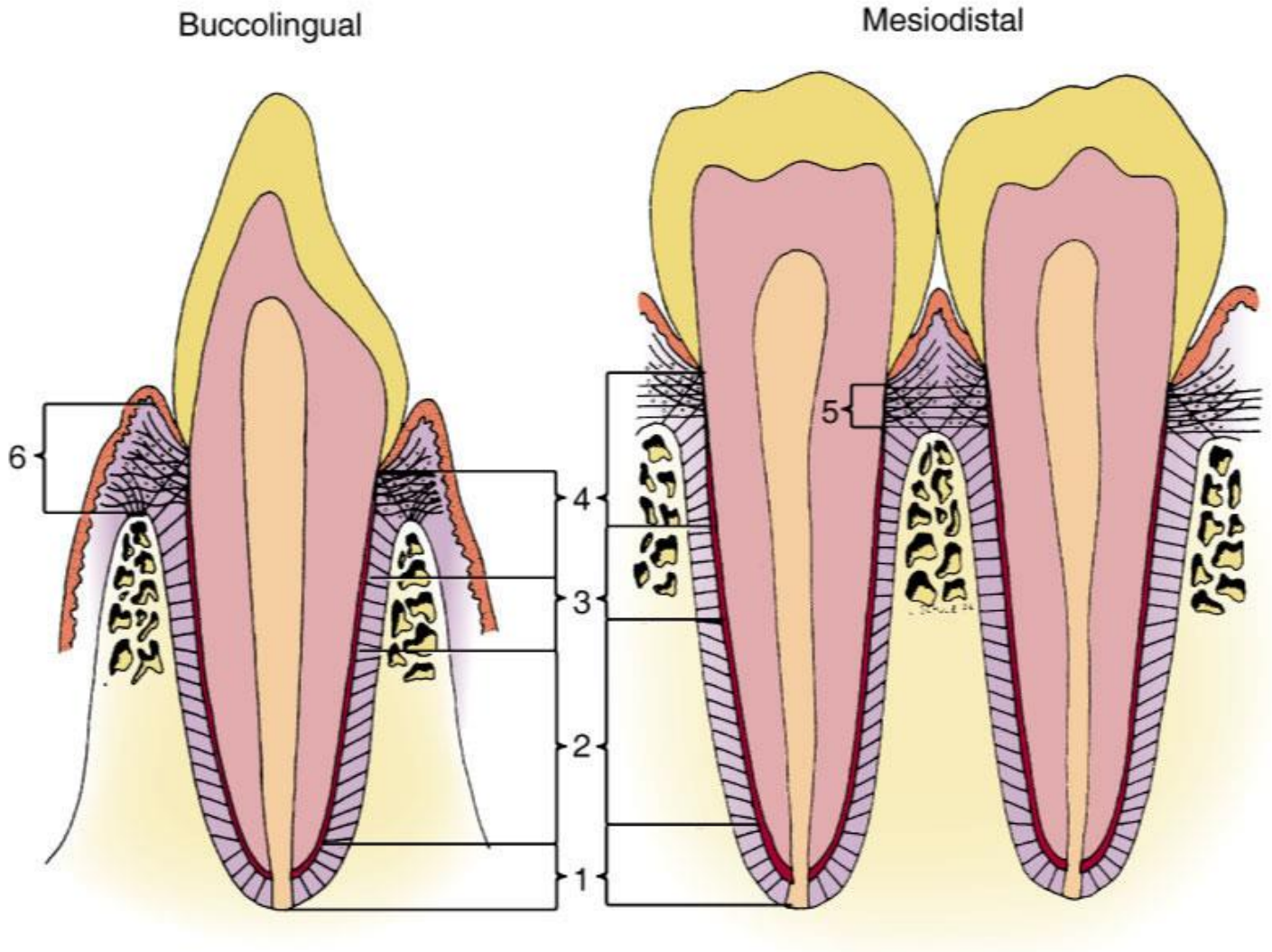






Summarization





1. Aplical
2. Oblique
3. Horizontal
4. Alveolar crest
5. Transseptal
6. Gingival group

Intermediate plexus

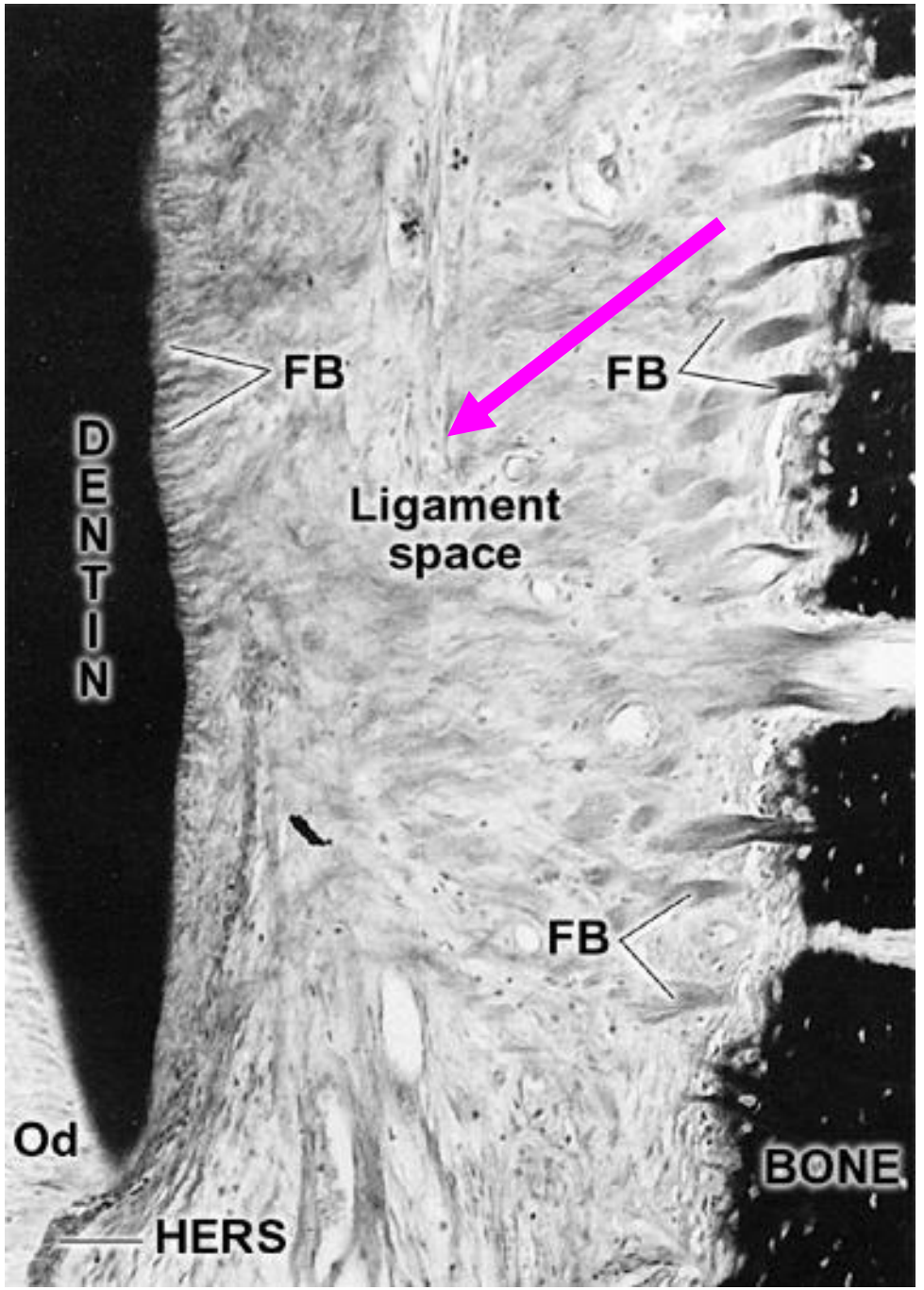
Some fibres has only one attachment – either in cementum or in cribriform plate of alveolar bone and the other is free

From this fibres is constituted

Intermediate plexus

Function:

- Morphological and functional supply for potential reorganization of periodontal ligament
- Support for interstitial areas



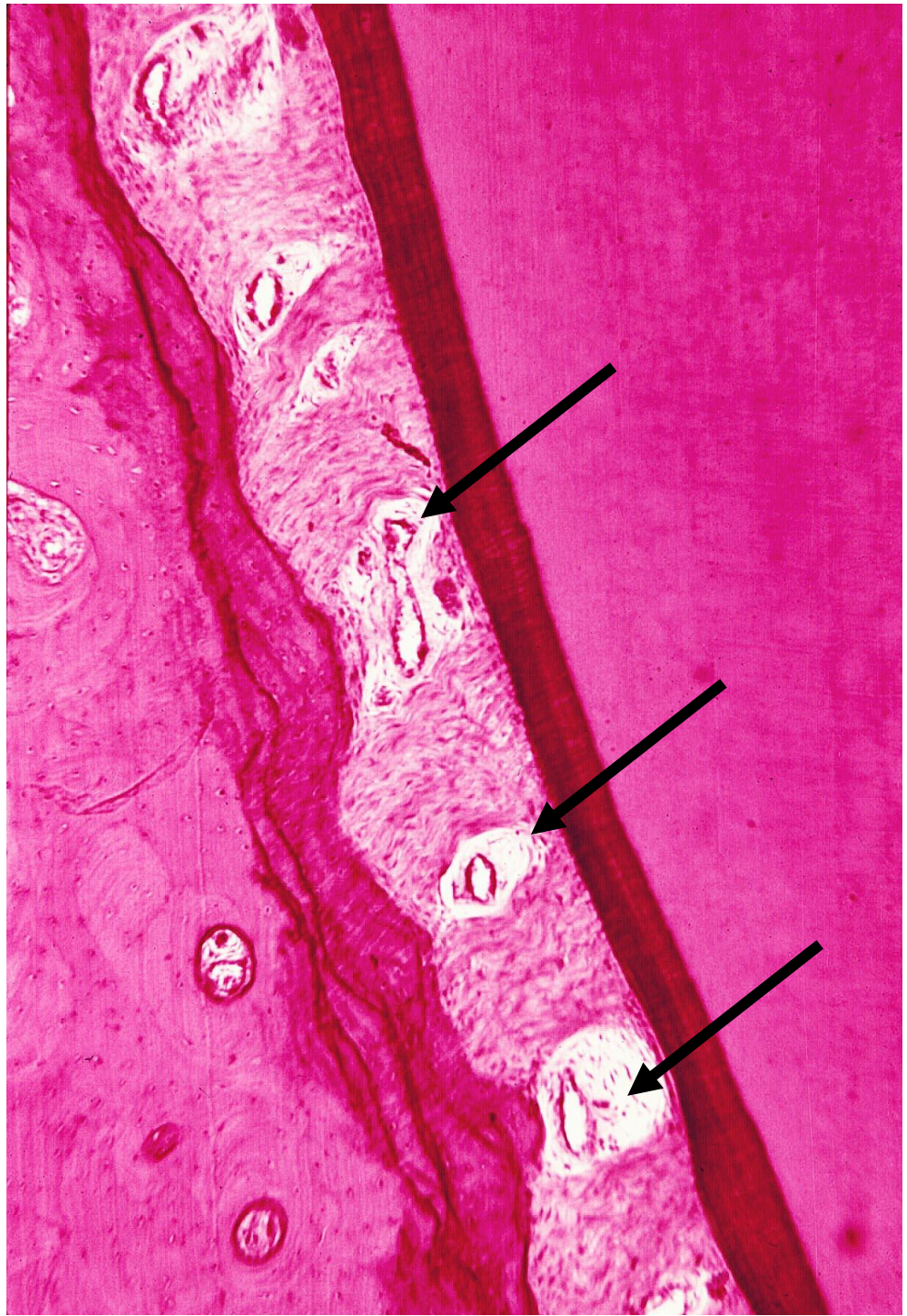
Interstitial areas

Regions of **loose collagenous tissue**

Separate bundles of ligaments

Space for blood vessels and nerves which are responsible for periodontal space vitality

On samples they are paler tissue with obvious blood vessels and surrounded by amorphous tissue



Blood and nervous supply of periodontal space

Highly innervated and numerous blood vessels in this region

Arterioles derived from gingival, „pulpal“ and interalveolar branches

In interstitial areas they form a dense capillary network which branches can be found also between the ligaments

Lymphatic vessels

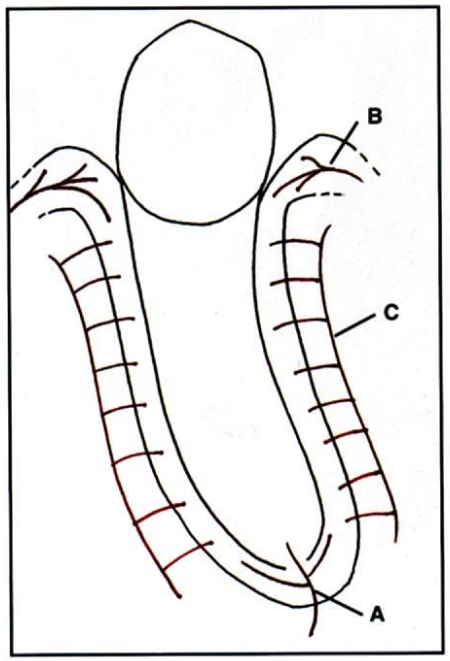
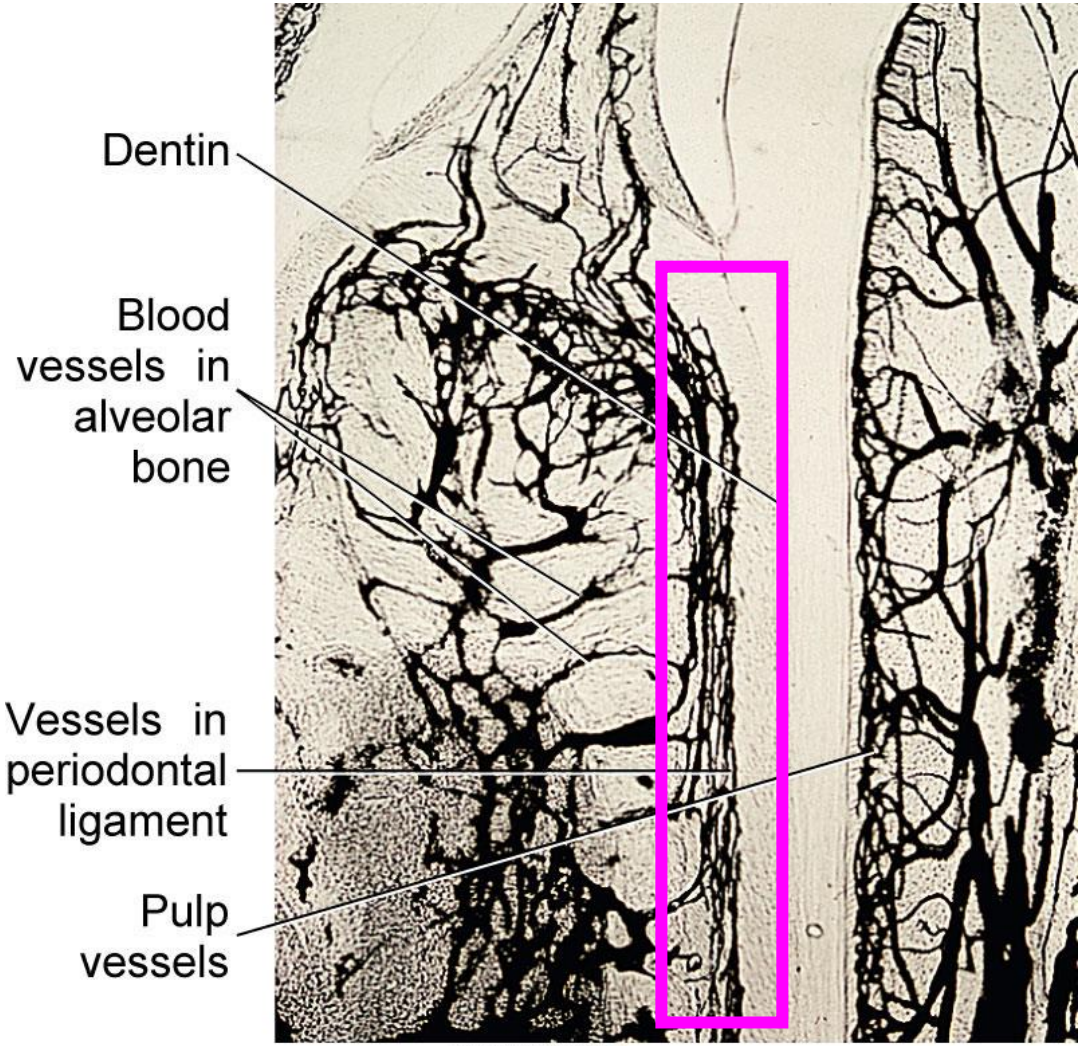


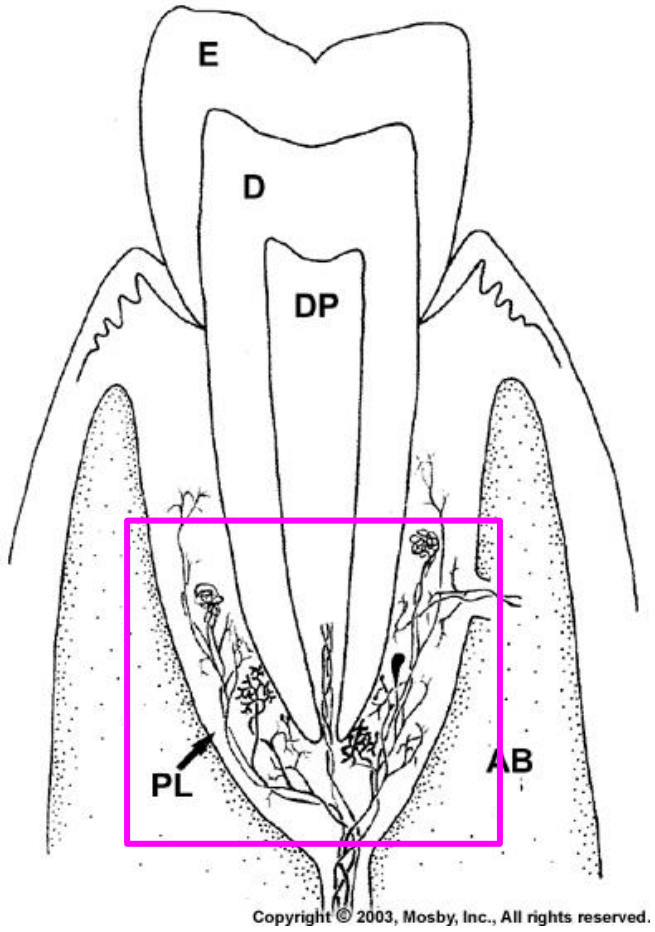
Fig. 12.52 The blood supply to the periodontal ligament. A = Arteries from dental pulp; B = arteries from gingiva; C = arteries from alveolar bone.

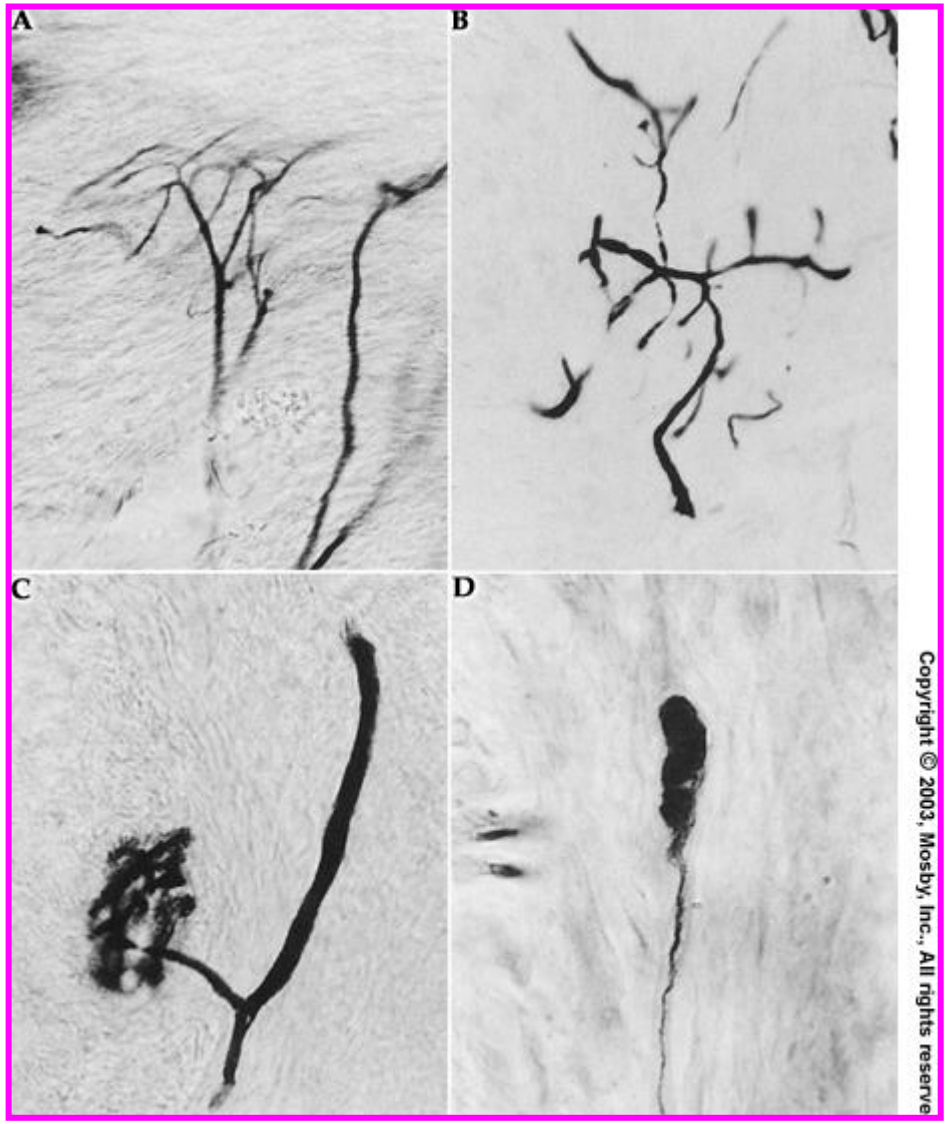


Innervation

Three types of nerve endings

- **Free nerve endings** (pain) – from unmyelinated or from myelinated nerve fibers)
- **Ruffini-like endings** – In apical part of PDL
- **Lamellated corpuscles**





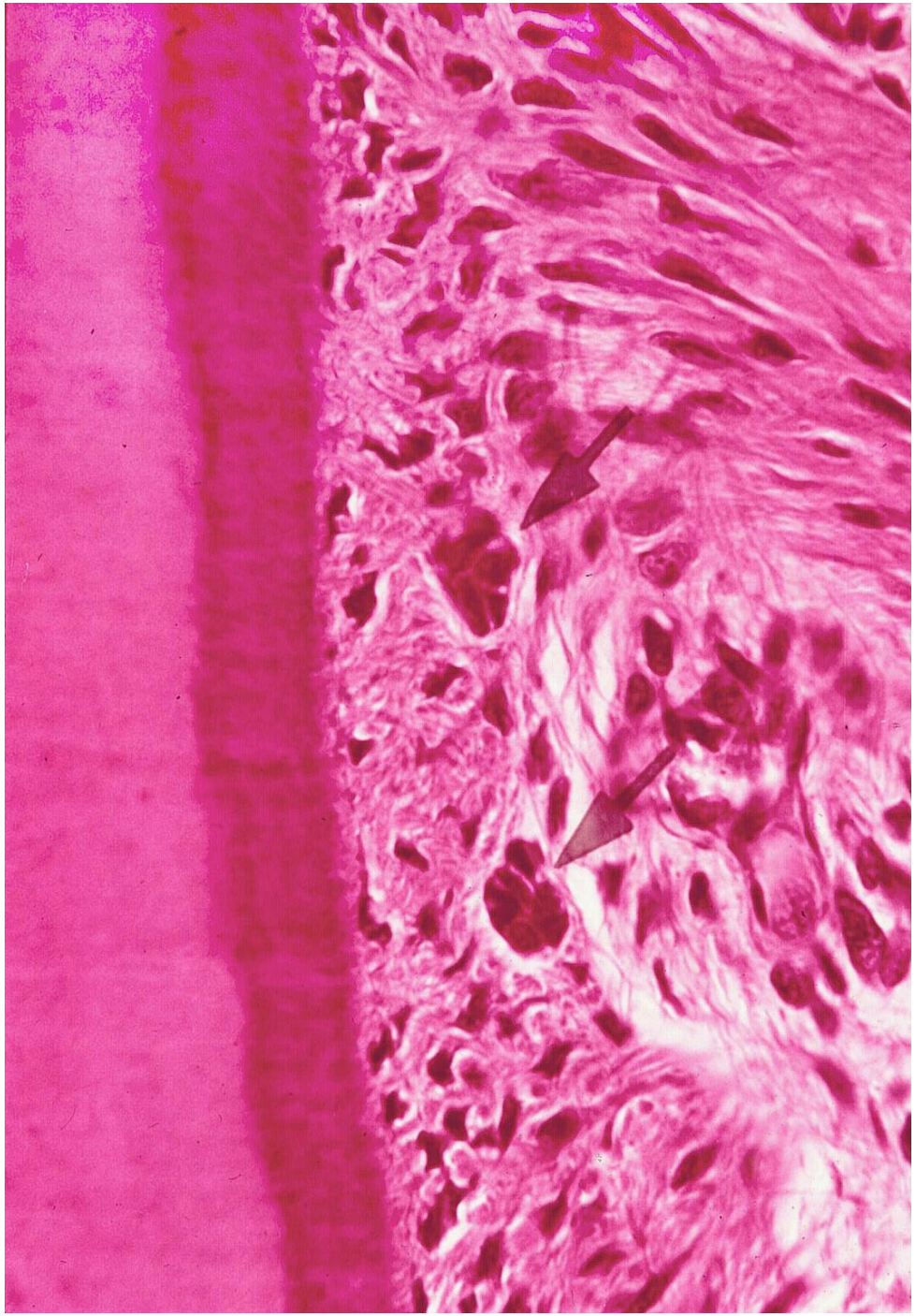
Other structures in periodontal space

ERM (Epithelial rests of Malassez)

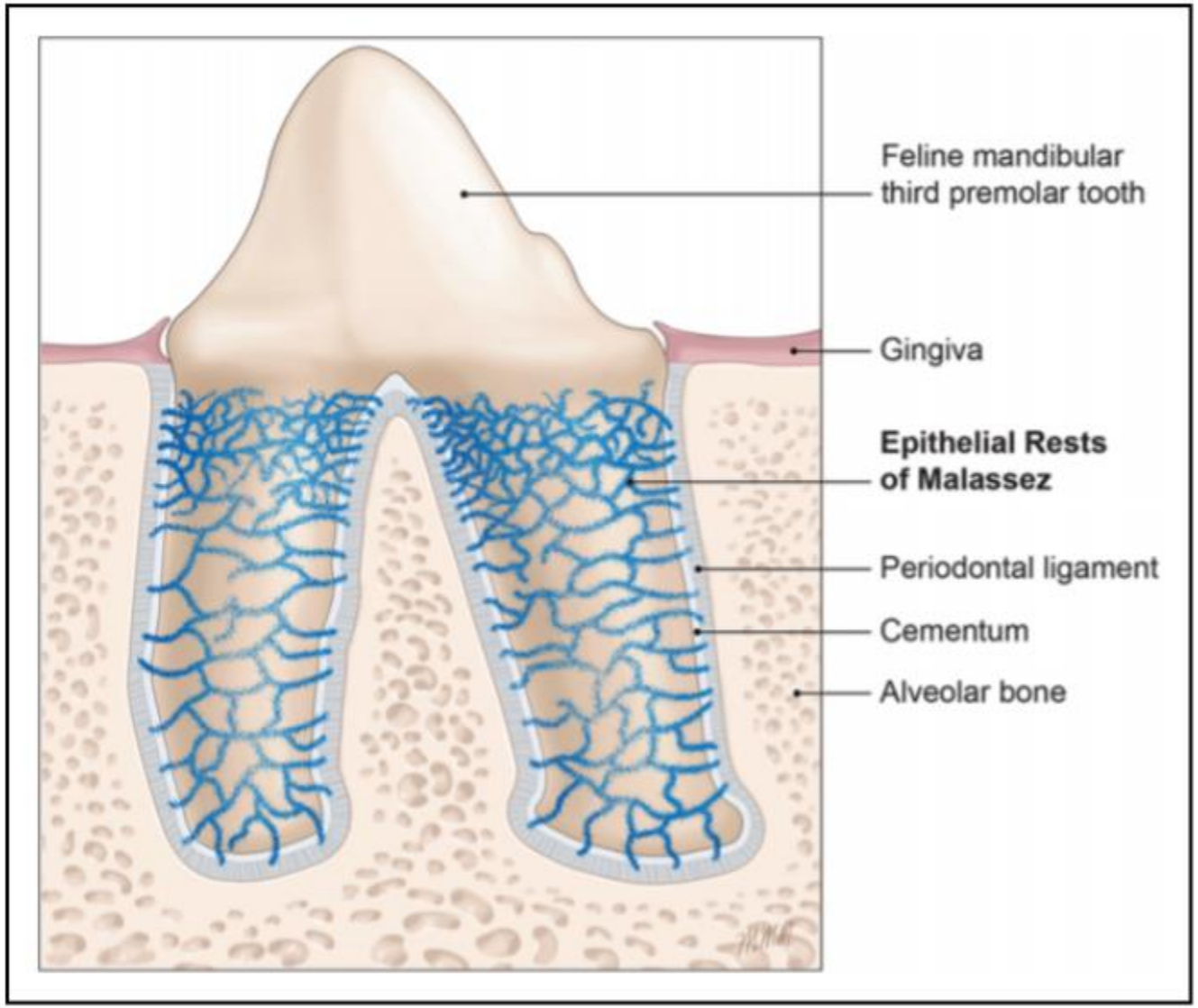
- Epithelial remnants from disintegrated **HERS** (Hertwig Epithelial Root Sheat)
- Pool of stem cells, interactive support for adjacent cells
- Can undergo **EMT** (Epithelial to Mesenchymal Transition)

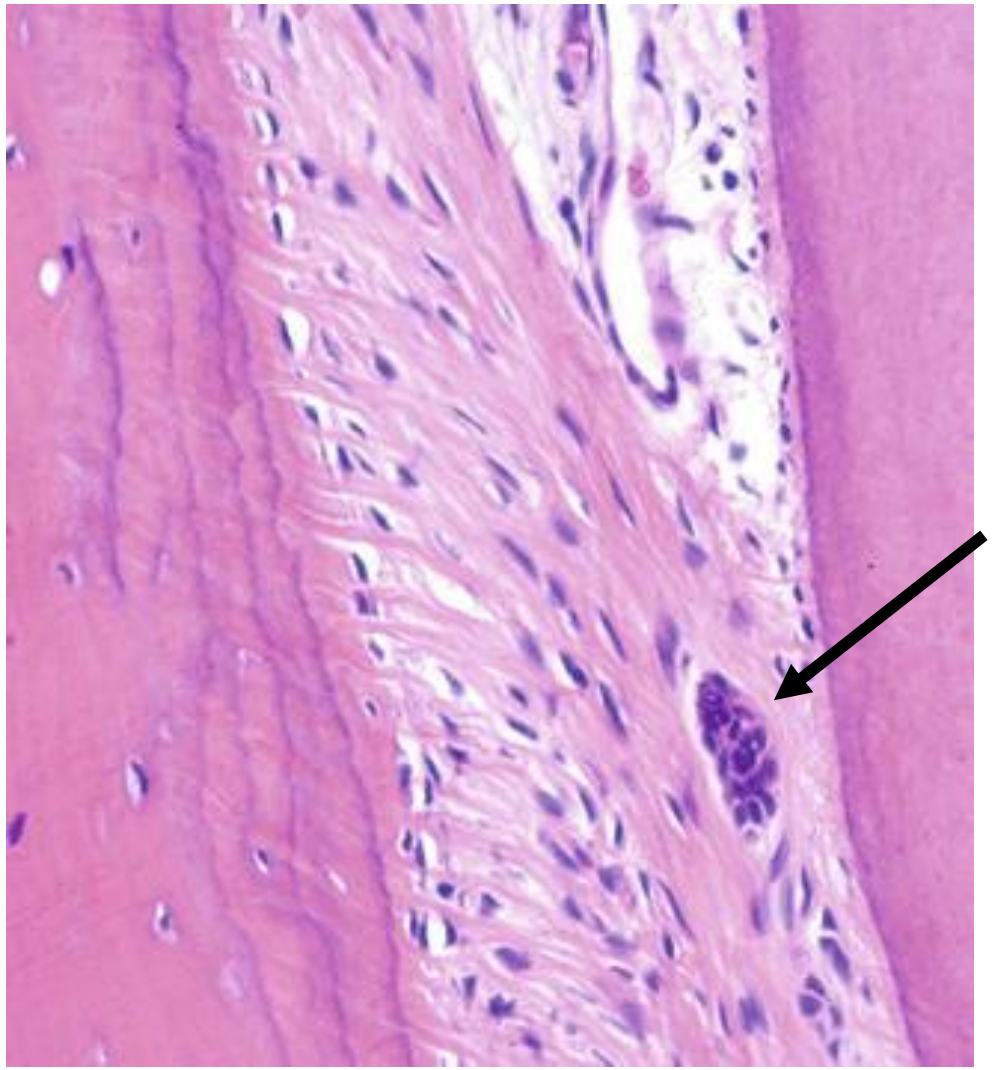
Granulomas and cysts

Cementicles



ERM = Epithelial rests of Malassez





Periodontal changes during ageing

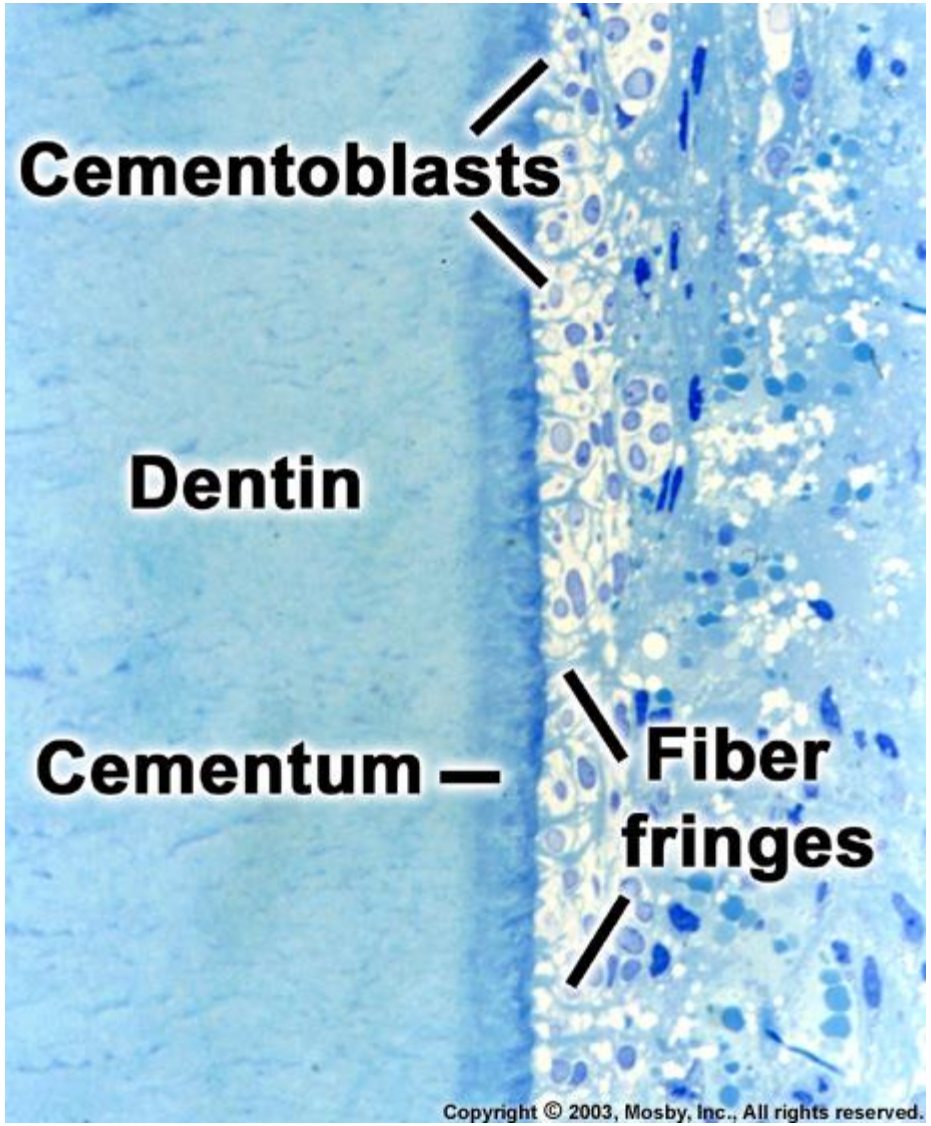
Changes while losing an antagonist – nonfunction

- Periodontal space narrowing
- Weakening and loosening of fibers
- Cementum thickening
- Weakening of the cribriform disc

Changes due to overload

Acute (trauma) – blood effusions, fiber rupture, necrosis and resorption, ankylosis

Chronical – hypercementosis



Periodontal fibres (ligaments) - terminology

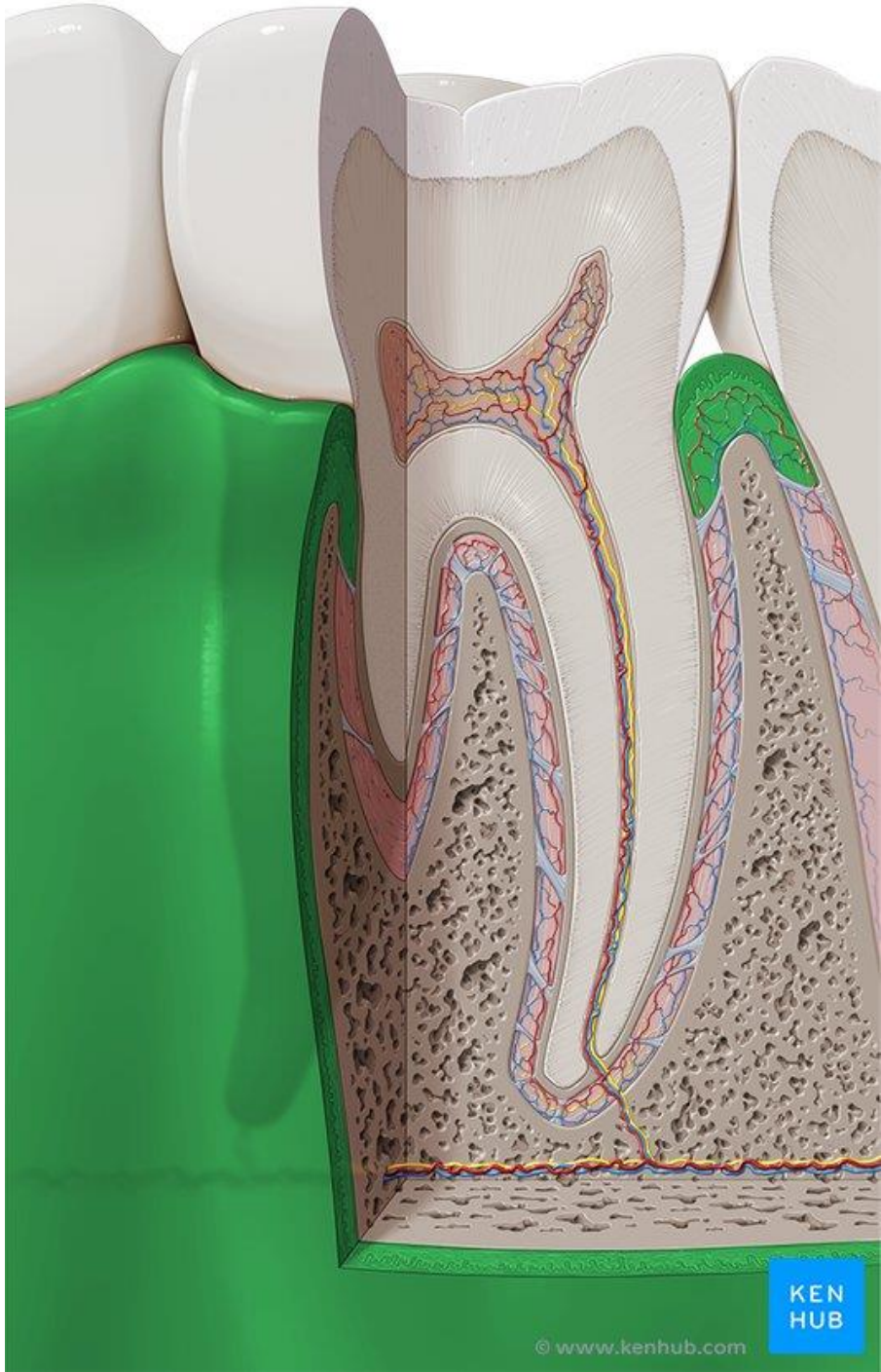
Gingival fibres - fibrae gingivales (fibrae gingivodentales, fibrae gingivales circulares)

Transseptal fibres - fibrae interdentales

Alveolar fibres - fibrae alveolodentales (fibrae principales)

Alveolar cres	-	lig. dentale superius
Horizontal	-	fibrae alveolodentales transversae
Oblique	-	lig. dentale inferius
Apical	-	fibrae apicales
Interradicular	-	fibrae interradiculares

Gingiva

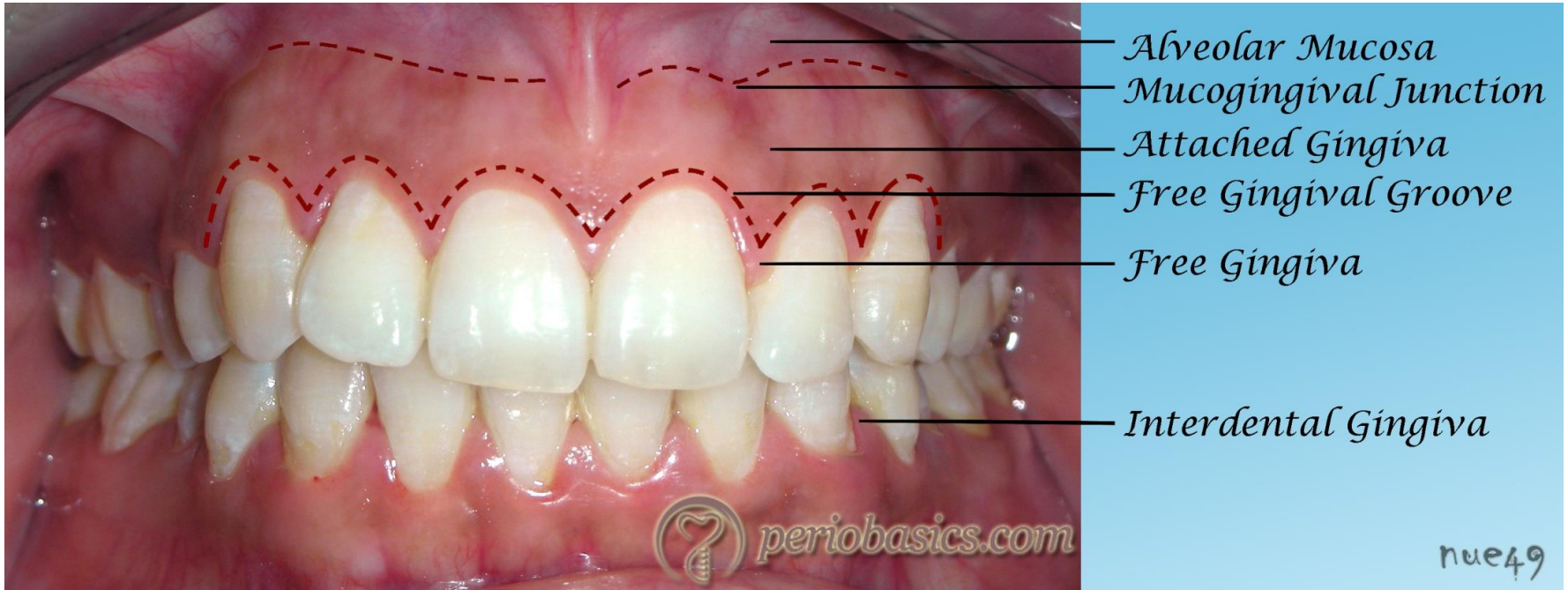


Gingiva

- Masticatory oral mucosa
- Around tooth necks and covering alveolar bone. Firmly attached to adjacent hard tissues
- Very stiff, pale pink color, resistant to pressure and friction
- It is not movable – forming mucoperiosteum

Mucogingival junction (line)

- The border between gingiva and lining mucosa which covers the rest of alveolar process
- Apparent on the vestibular aspect of both mandible and maxilla and on lingual aspect of mandible



Gingiva

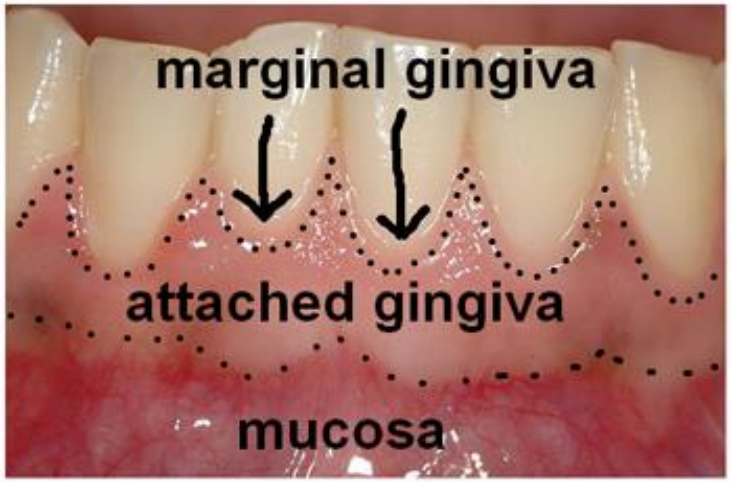
Topography: **2 compartments**

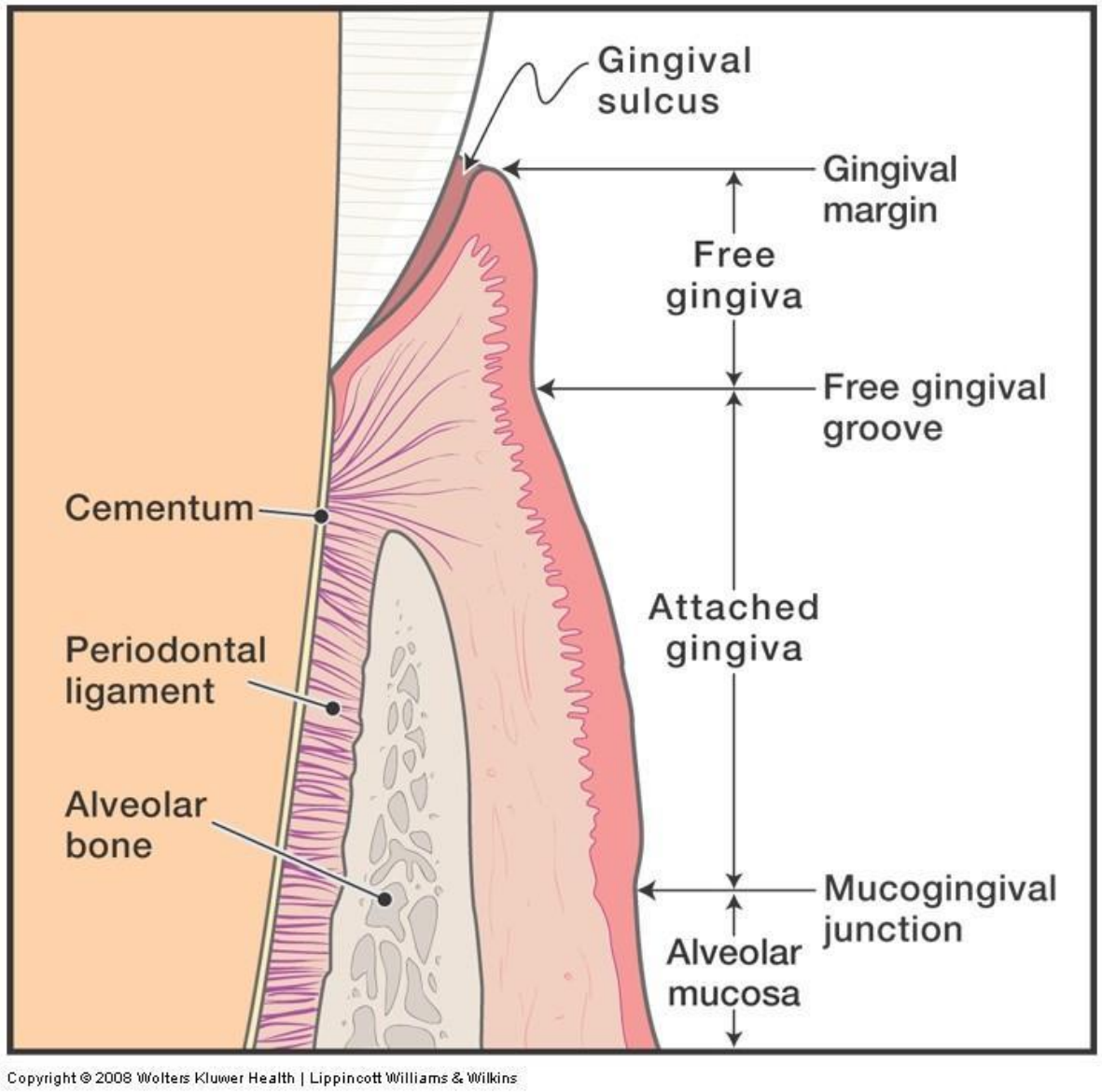
Gingiva libera (Free gingiva)

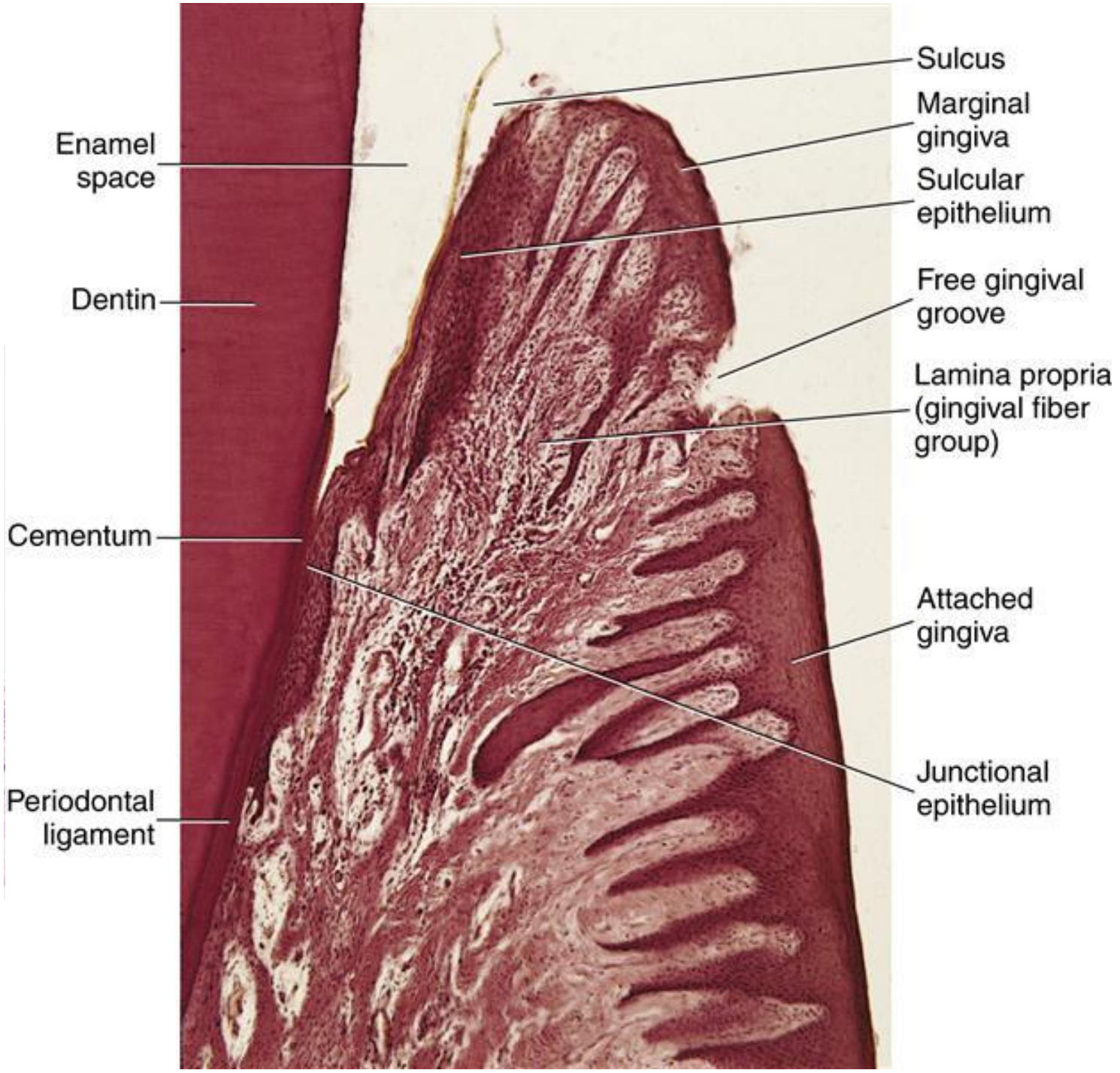
(gingiva supraalveolaris)

Gingiva affixa (Attached gingiva)

(gingiva alveolaris)

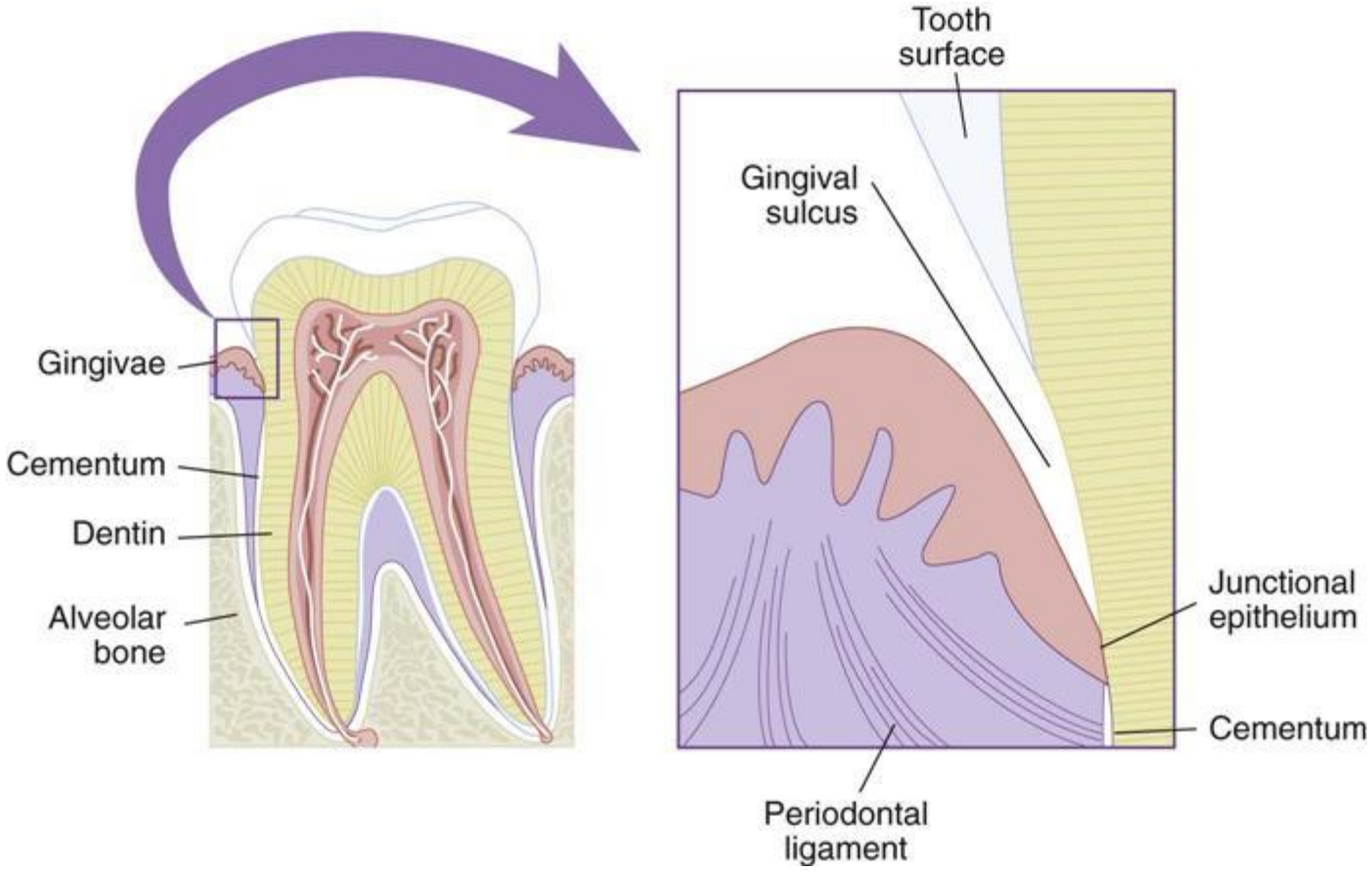





Sulcus
Marginal gingiva
Sulcular epithelium
Free gingival groove
Lamina propria (gingival fiber group)
Attached gingiva
Junctional epithelium
Enamel space
Dentin
Cementum
Periodontal ligament

Sulcus gingivalis (Gingival sulcus)

- Circular groove, physiological depth: 1-2 mm
- **Liquor gingivalis:** plasma-like fluid which leaks from adjacent capillaries. The fluid has antimicrobial and anti-inflammatory properties, contains proteins and carbohydrates



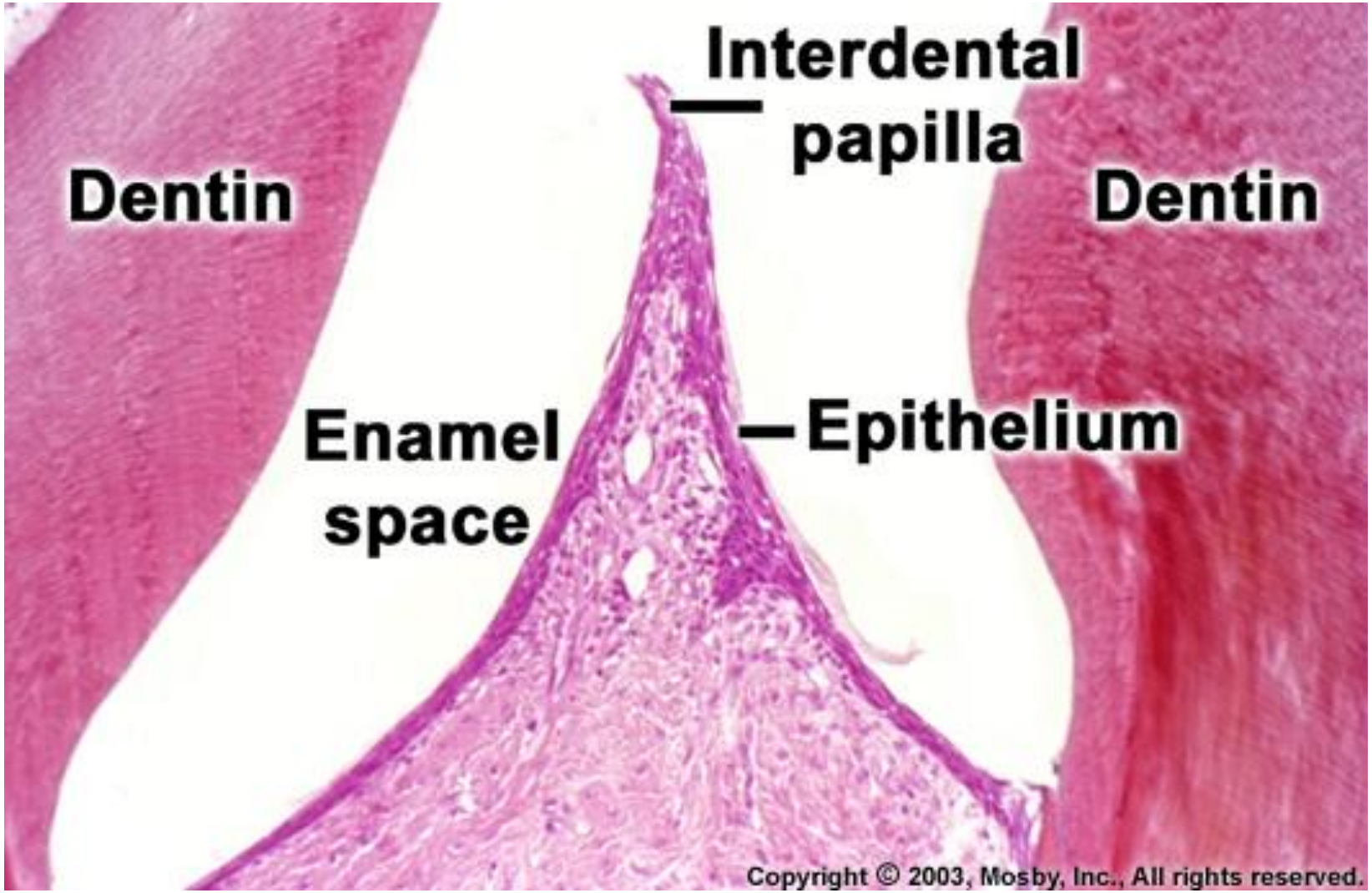
Trigonum interdentale

Interdental papillae, interdental gingiva

Between neighbouring teeth, free gingiva forms a protrusion: **trigonum interdentale**

Vestibular and lingual aspect

Každá má vestibulární a linguální část, connected by intedental saddle



Microscopic structure of gingiva

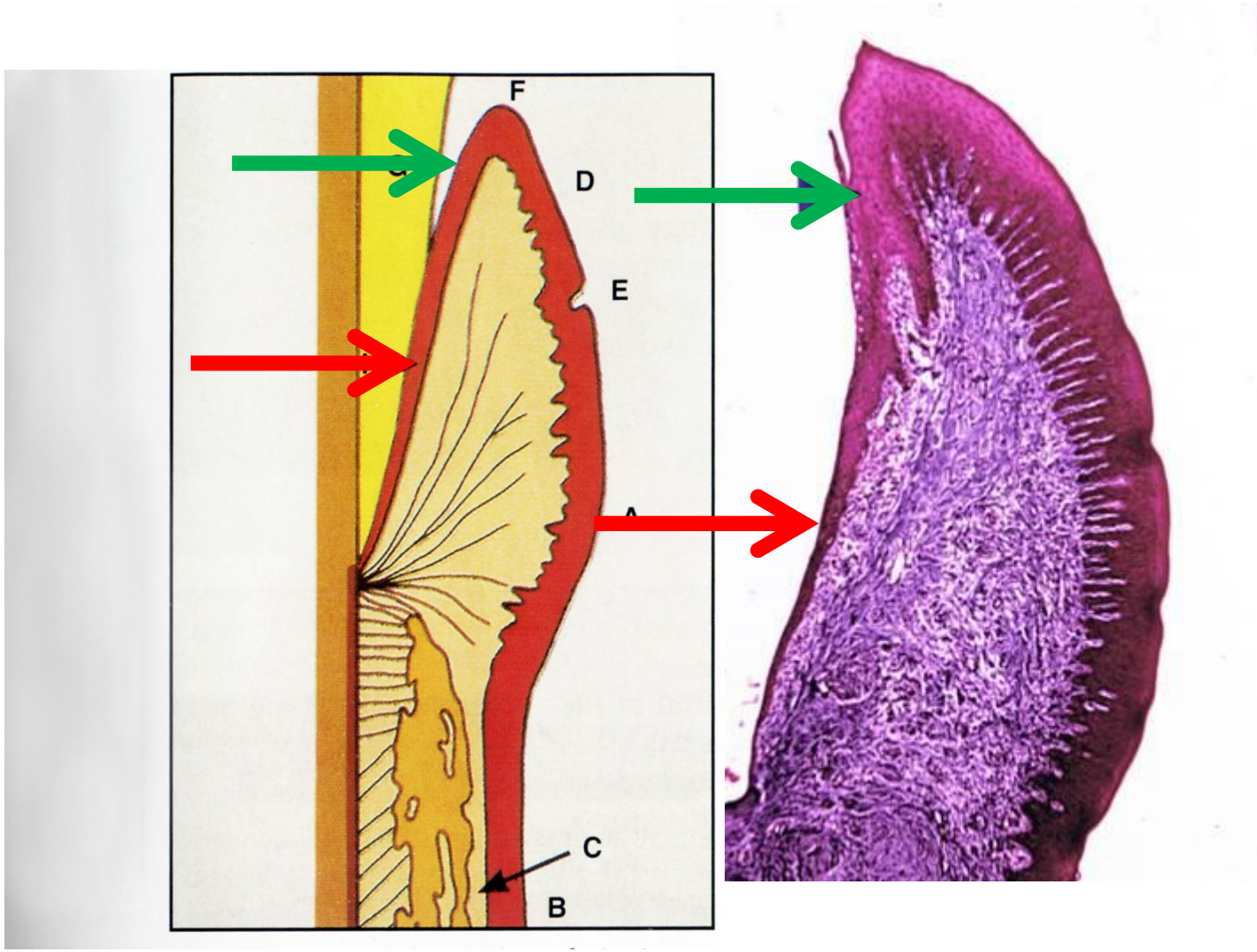
Stratified squamous epithelium

Keratinized at vestibular and palatinal side

No keratinization on the side facing teeth: **Sulcular epithelium**

On the side facing teeth it keeps non-differentiated epithelium characteristics.

Junctional epithelium (epithelial attachment of Gottlieb) is firmly attached to teeth and seal the periodontal space from the environment of oral cavity.



Bath-Balogh,Fehrenbach, 2011

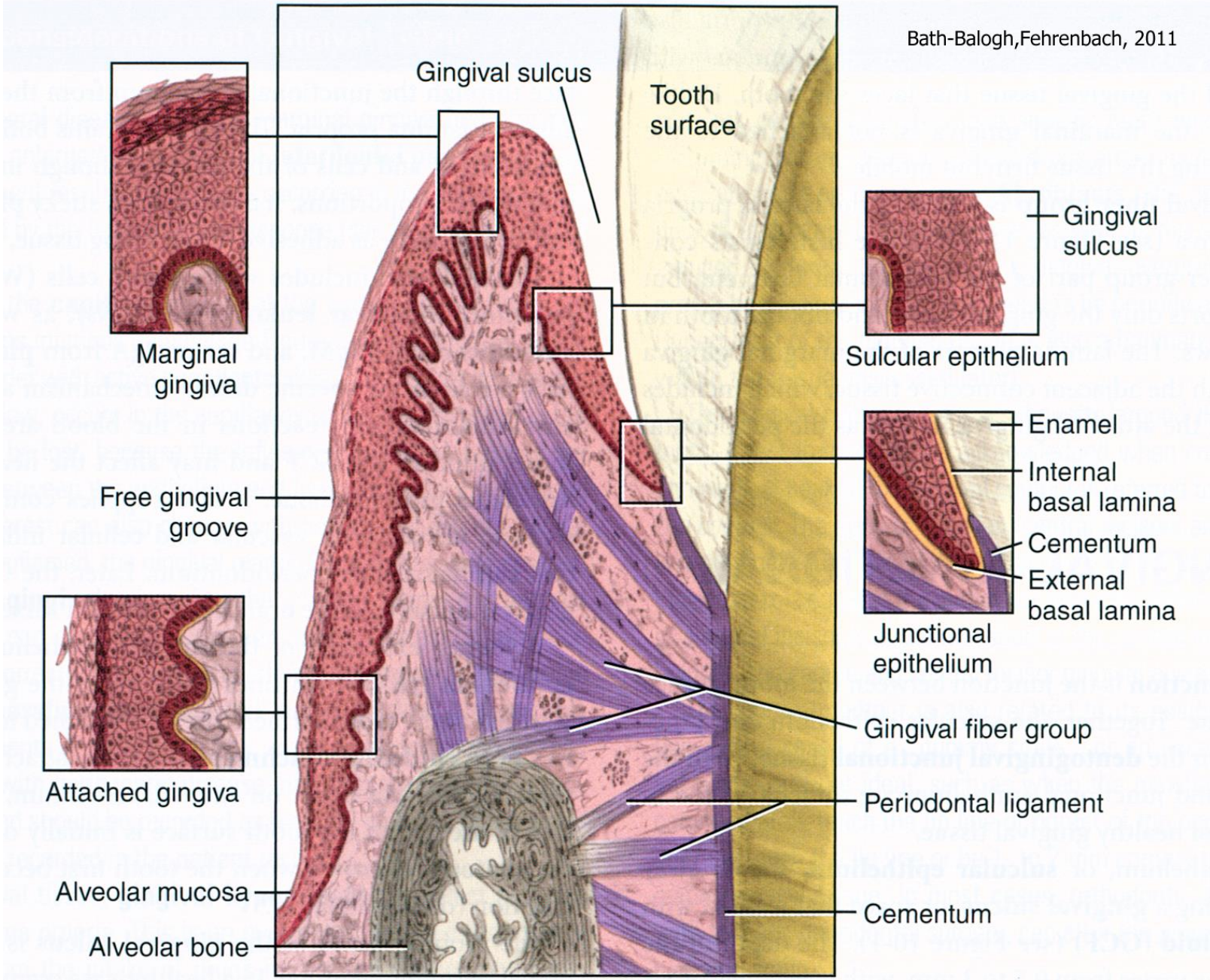


FIGURE 10-1 Gingival and dentogingival junctional tissue: marginal gingiva, attached gingiva, sulcular epithelium, and junctional epithelium.

Lamina propria

Gingiva affixa

Dense collagenous connective tissue with papillas which are numerous and thin. Their presence causes a rough surface

Gingiva libera

Under the epithelium of free gingiva is lower amount of papillas and always missing under epithelium which is facing teeth

Collagenous fibres are ordered into 4 groups:

dentogingival, circular, dentoperiostal and alveologingival

(chapter periodontium)

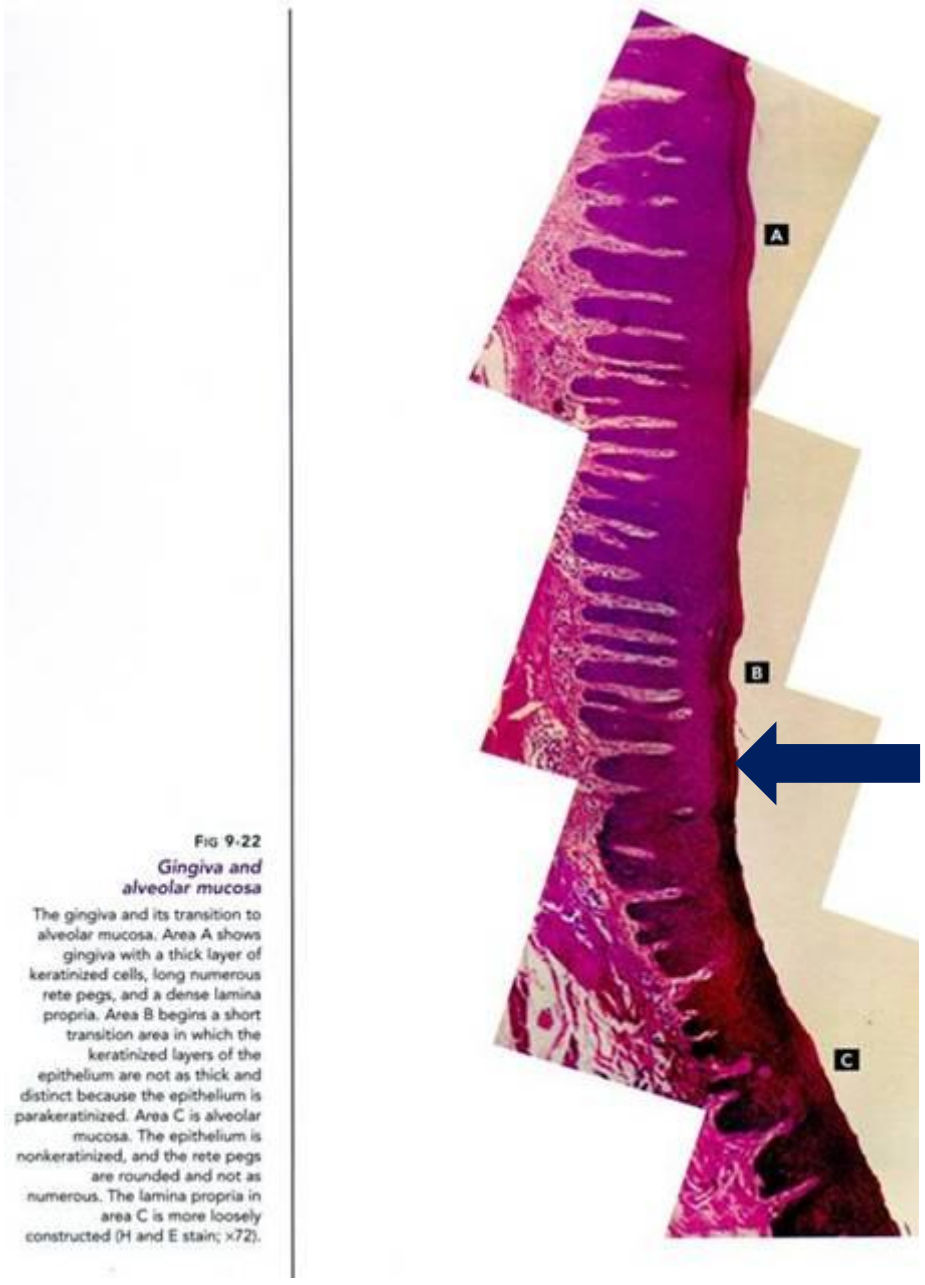


FIG 9-22
Gingiva and alveolar mucosa
The gingiva and its transition to alveolar mucosa. Area A shows gingiva with a thick layer of keratinized cells, long numerous rete pegs, and a dense lamina propria. Area B begins a short transition area in which the keratinized layers of the epithelium are not as thick and distinct because the epithelium is parakeratinized. Area C is alveolar mucosa. The epithelium is nonkeratinized, and the rete pegs are rounded and not as numerous. The lamina propria in area C is more loosely constructed (H and E stain; ×72).

Junctional epithelium

Epithelial attachment, epithelial attachment of Gottlieb,

Protects the periodontal space from aggresive outer environment of oral cavity resp. sulcus gingivalis (against bacteria, toxins, pieces of food)

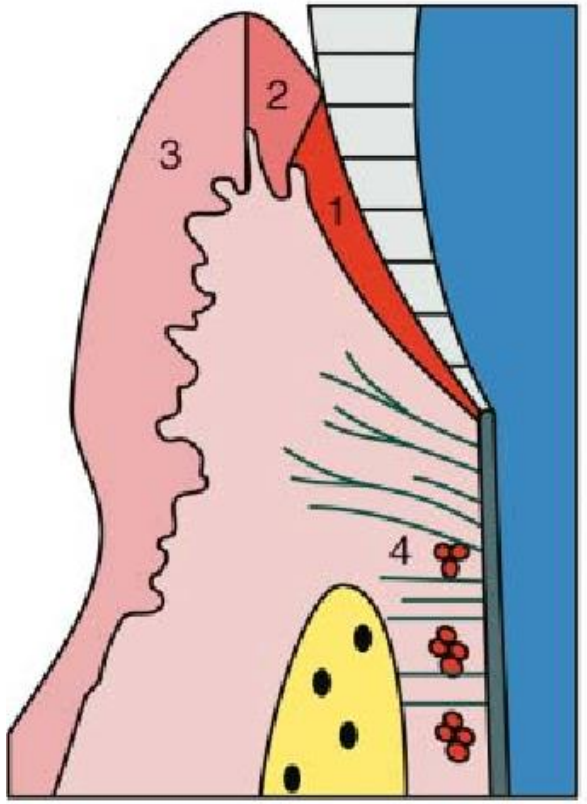
It is characteristic by the **fusion of sulcular epithelium with hard tissues of teeth in the are of the neck**

Zone of fusion is under the sulcus gingivalis

Width: 0,25 - 1 mm

This epithelium is permanently actively regenerated – stem cell activity

Cells are in several layers, flattened



Dento-gingival junction

1. Junctional epithelium (JE)
2. Sulcular epithelium
3. Oral epithelium
4. Epithelial rests of Malassez

JE functions

– attachment to tooth
– barrier
– rapid turnover
– antimicrobial defence
– GCF flow

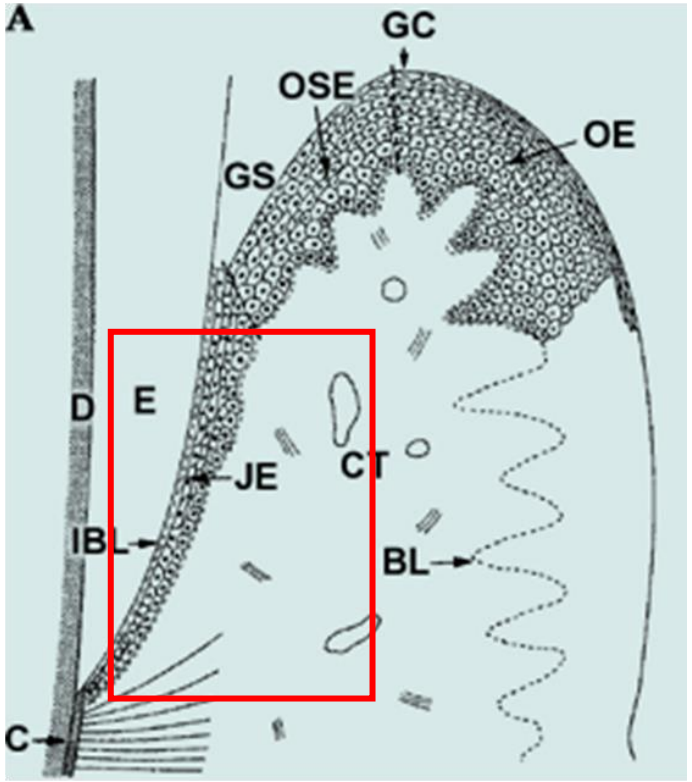
Junctional epithelium

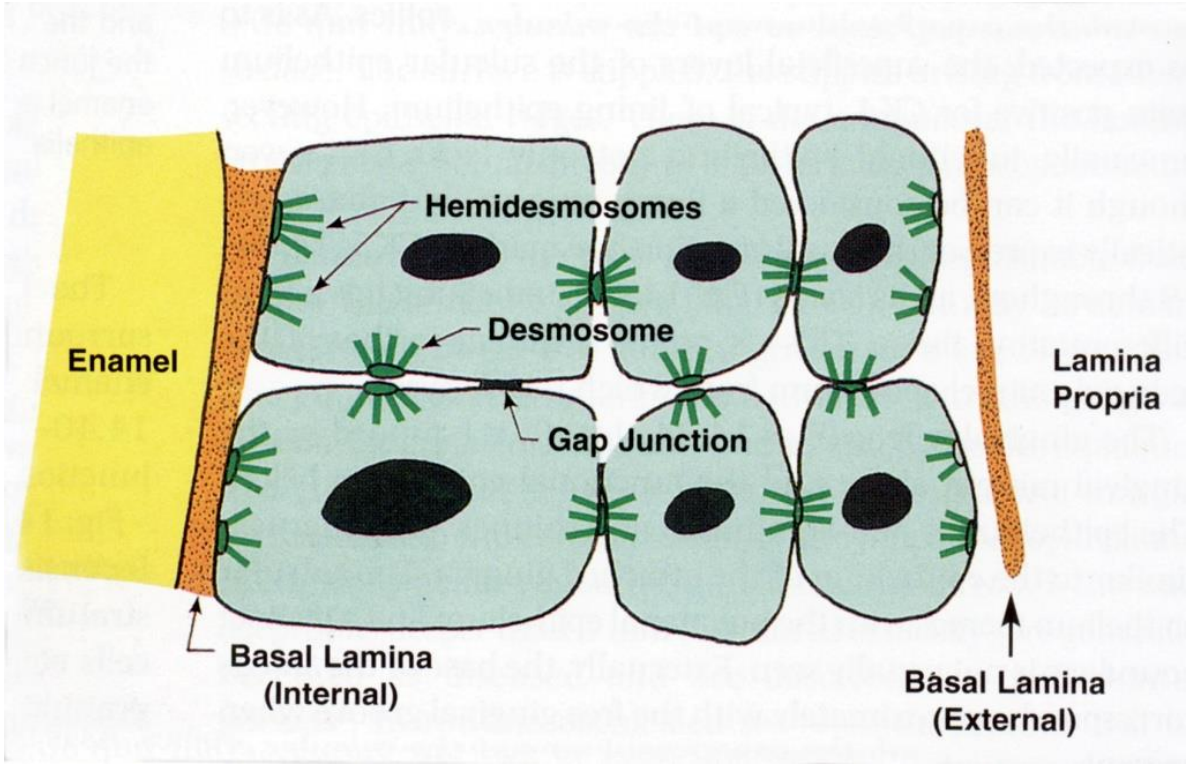
Between the innermost layer of cells and hard tissue are hemidesmosomes, between cells are desmosomes

The line between epithelium and connective tissue is **smooth** (no papillae), connective tissue contains numerous leukocytes and B-lymphocytes, acts as an immunological barrier

Narrowing ath the apical end

Fast turnover: **4-6 days.** Regenerates well after mechanical damage





Gingival recession

Consequence: tooth loosening and ultimately tooth loss

Gingival recession in periodontitis

Normal state: in primary dentition and healthy permanent dentition up to 20‘-30‘ – the apical end of the junctional epithelium at CEJ

Later junctional epithelium moves more apically, until it finally moves to the cementum of the tooth neck

In old age, cementum, can be exposed and a condition in which the clinical crown becomes larger than the anatomical crown

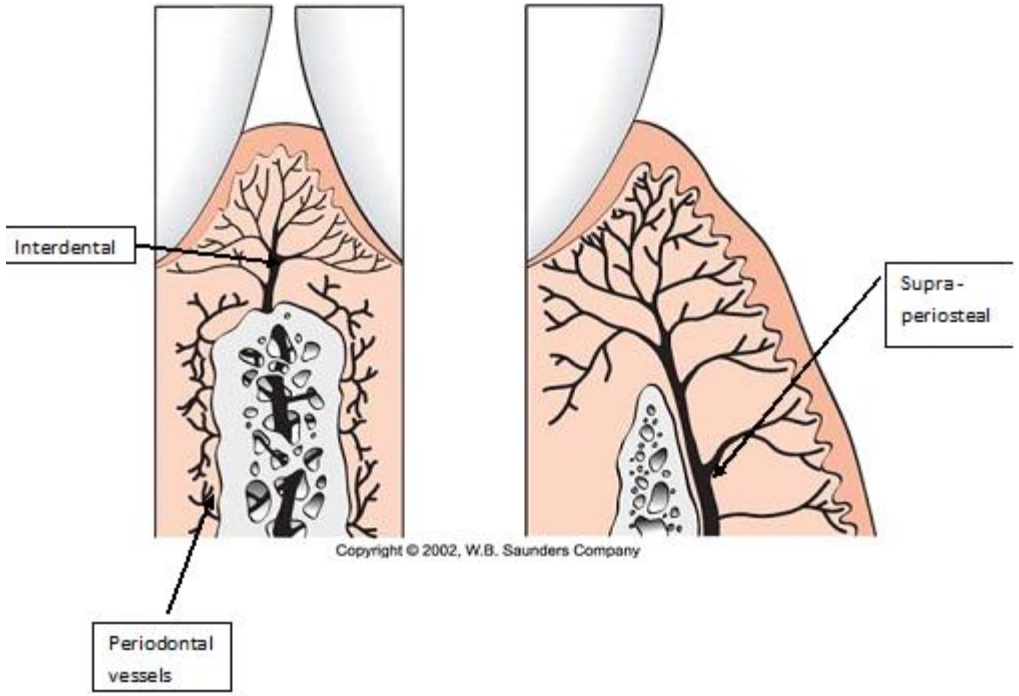
Blood supply and innervation of gingiva

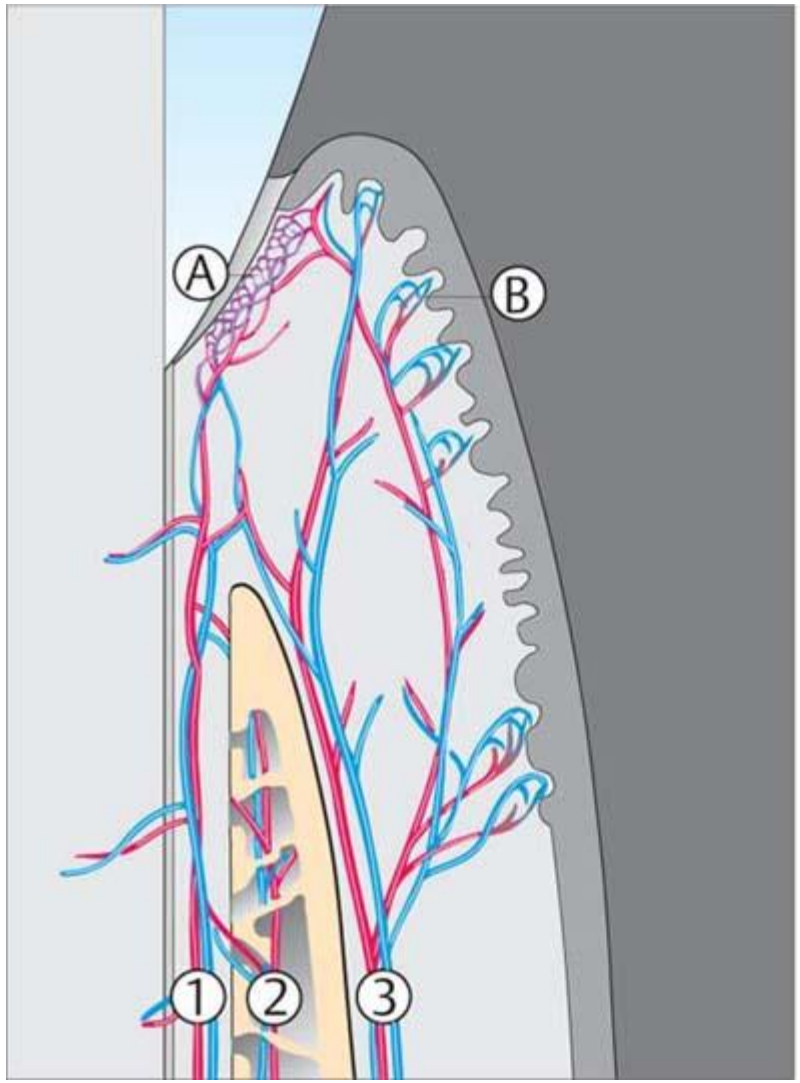
Arterioles from aa. alveolares, a. mentalis, aa. palatinae, a. buccinatoria

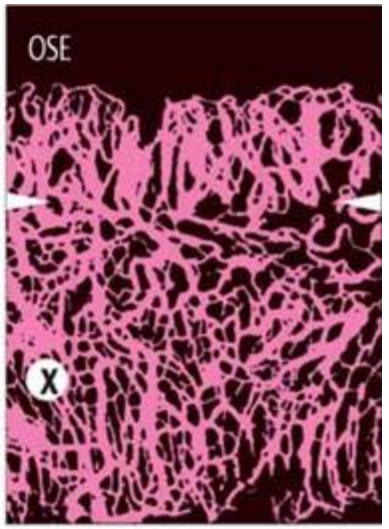
Branch into capillary networks with anastomosis with the periodontal network

Lymphatic vessels and along the blood vessels

Nerve fibres as a free nerve endings and form corpuscles







Blood Supply Pathways

1 Periodontal
2 Alveolar
3 Supraperiostal/mucogingival

A Post-capillary Venous Plexus

B Sub-epithelial Capillary Loops