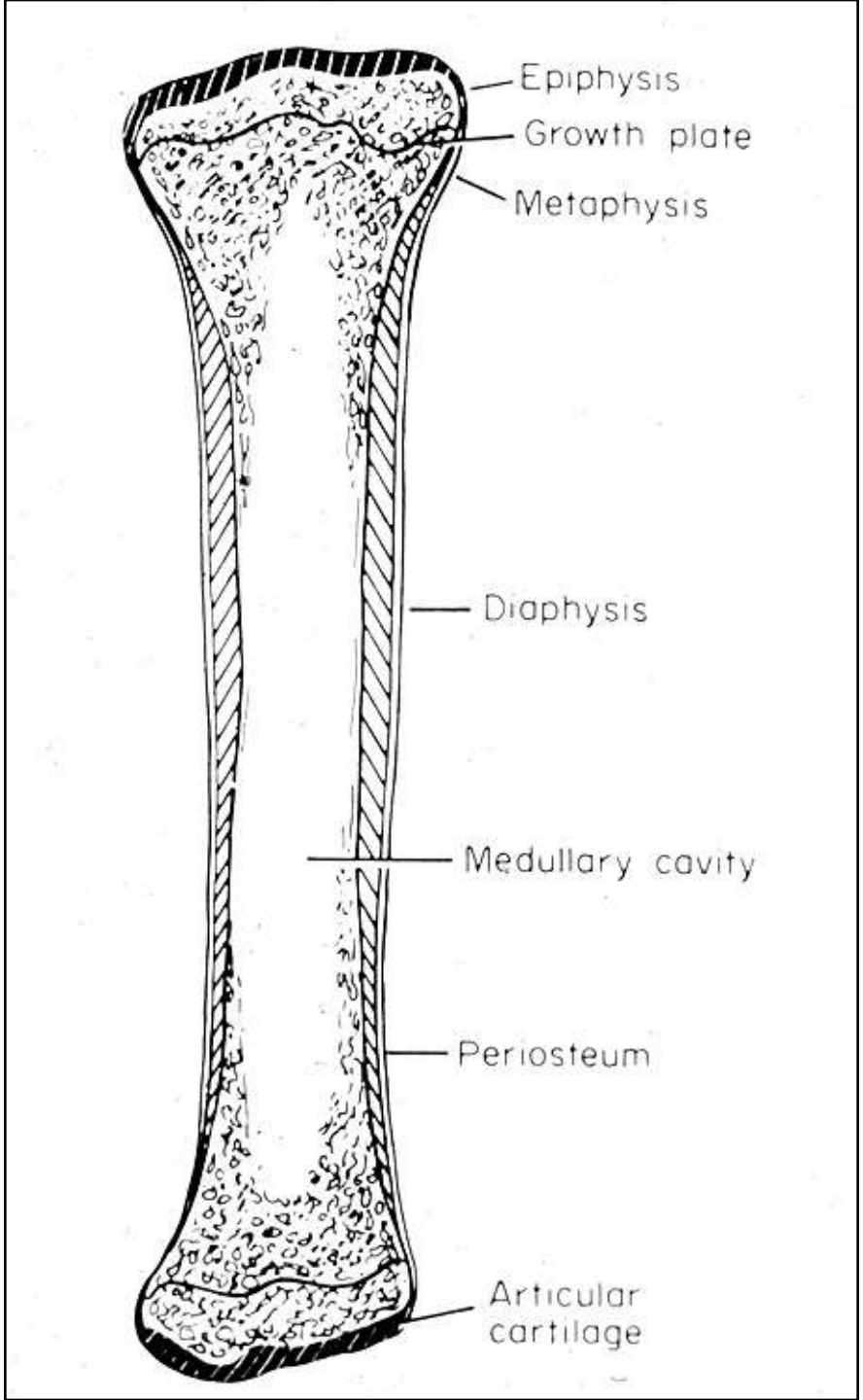
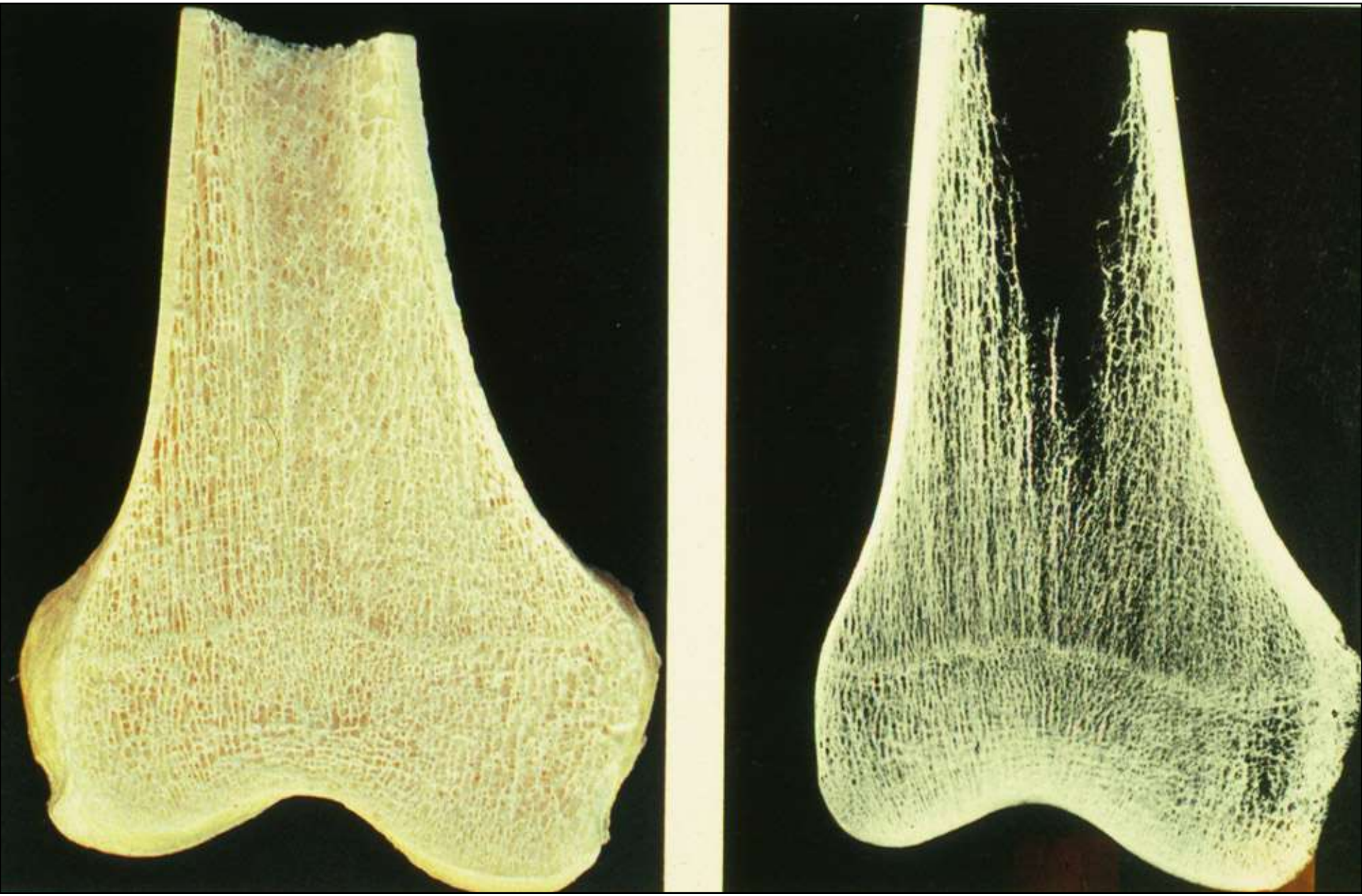
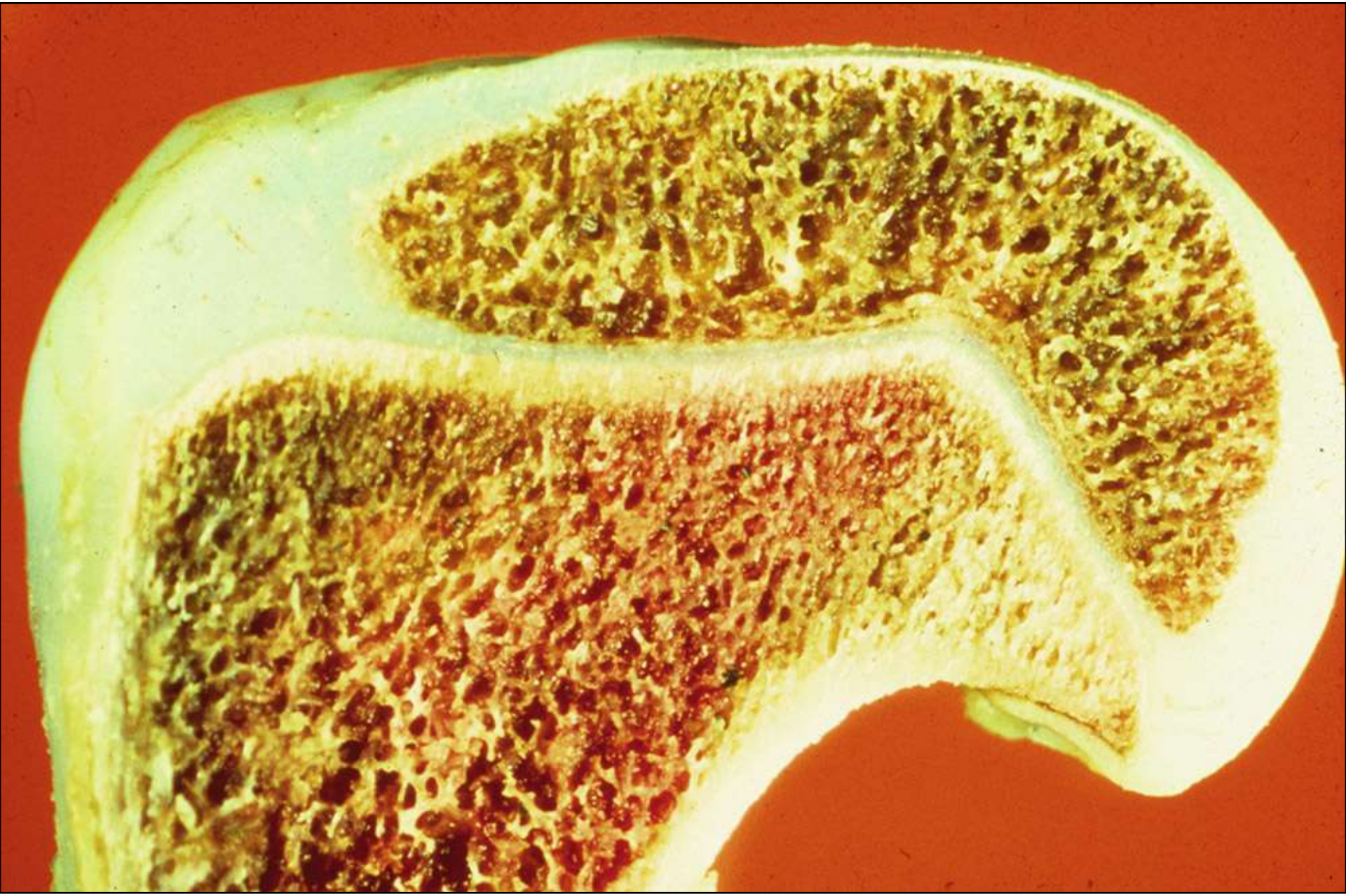
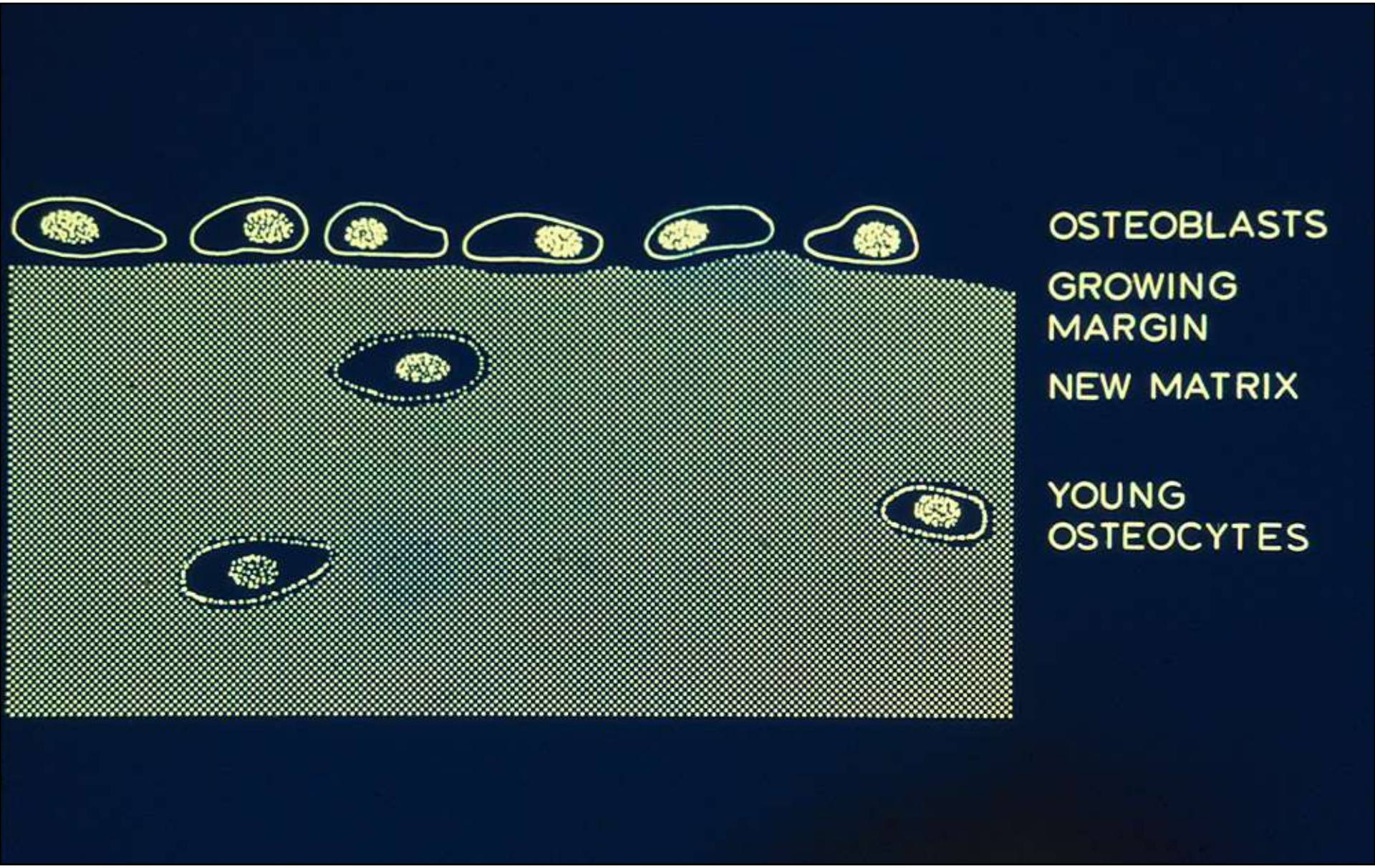
Regions of Endochondral Bones

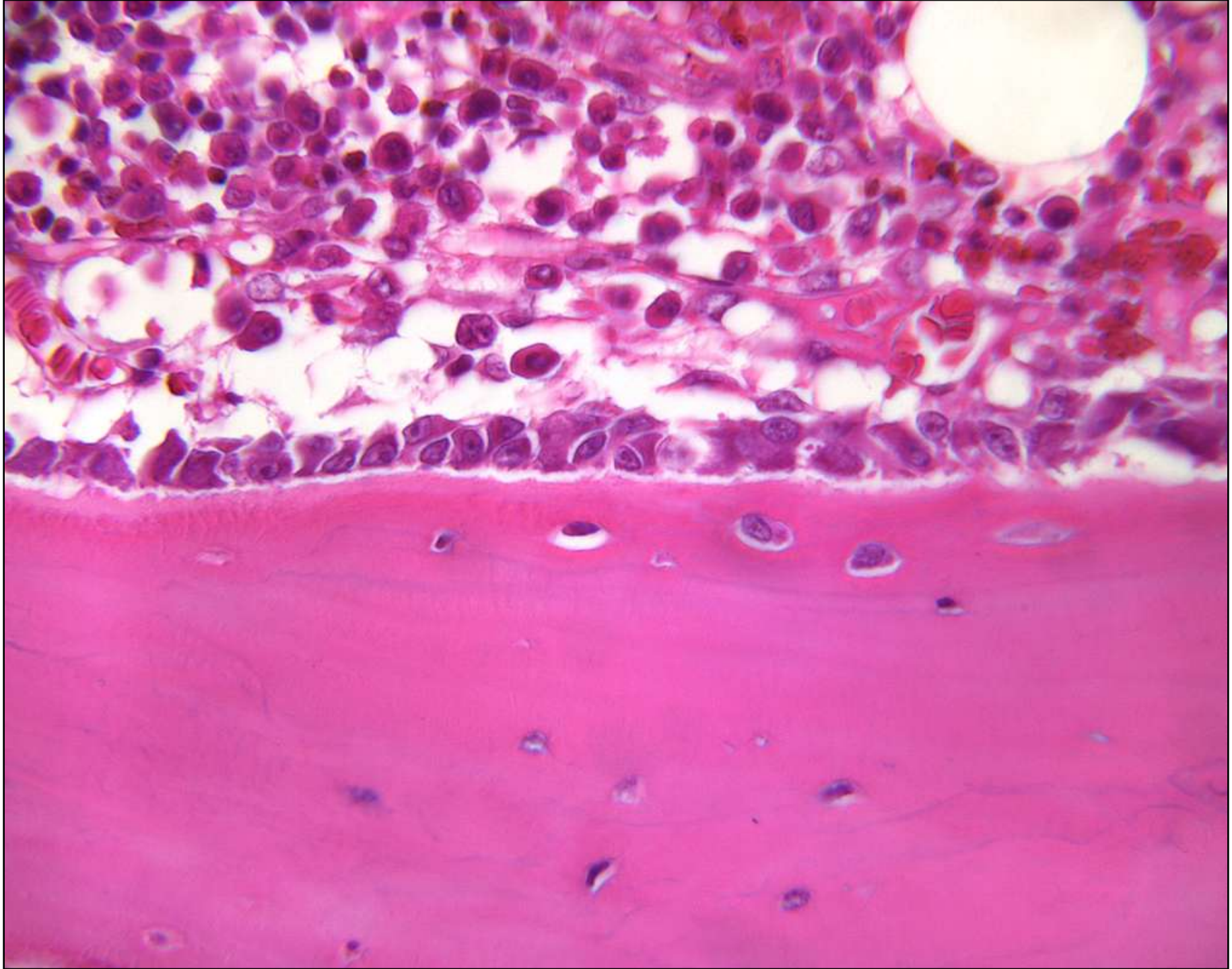

Epiphysis
Growth plate
Metaphysis
Diaphysis
Medullary cavity
Periosteum
Articular cartilage





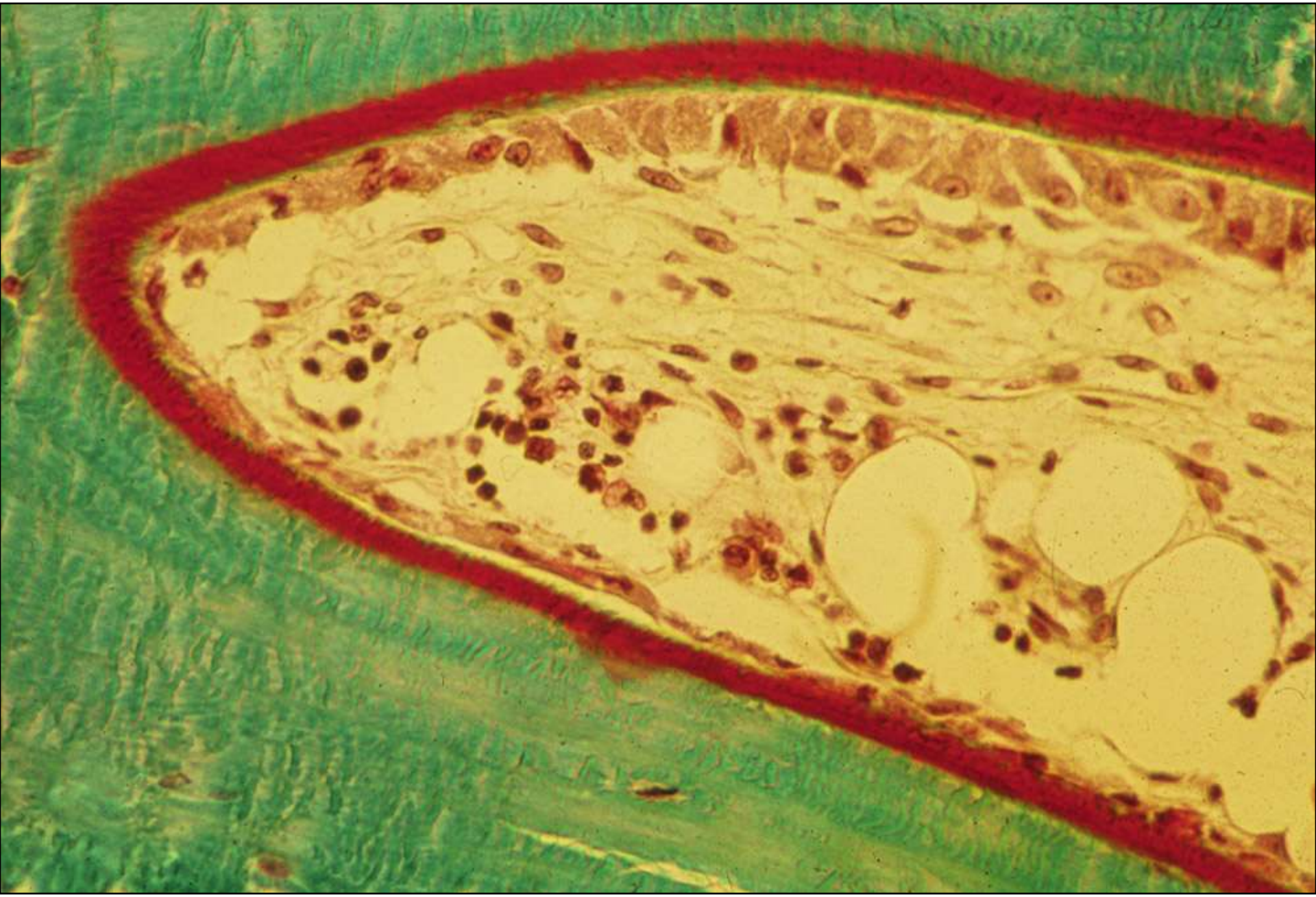
Osteoblasts on a Forming Surface


OSTEOBLASTS
GROWING MARGIN
NEW MATRIX
YOUNG OSTEOCYTES



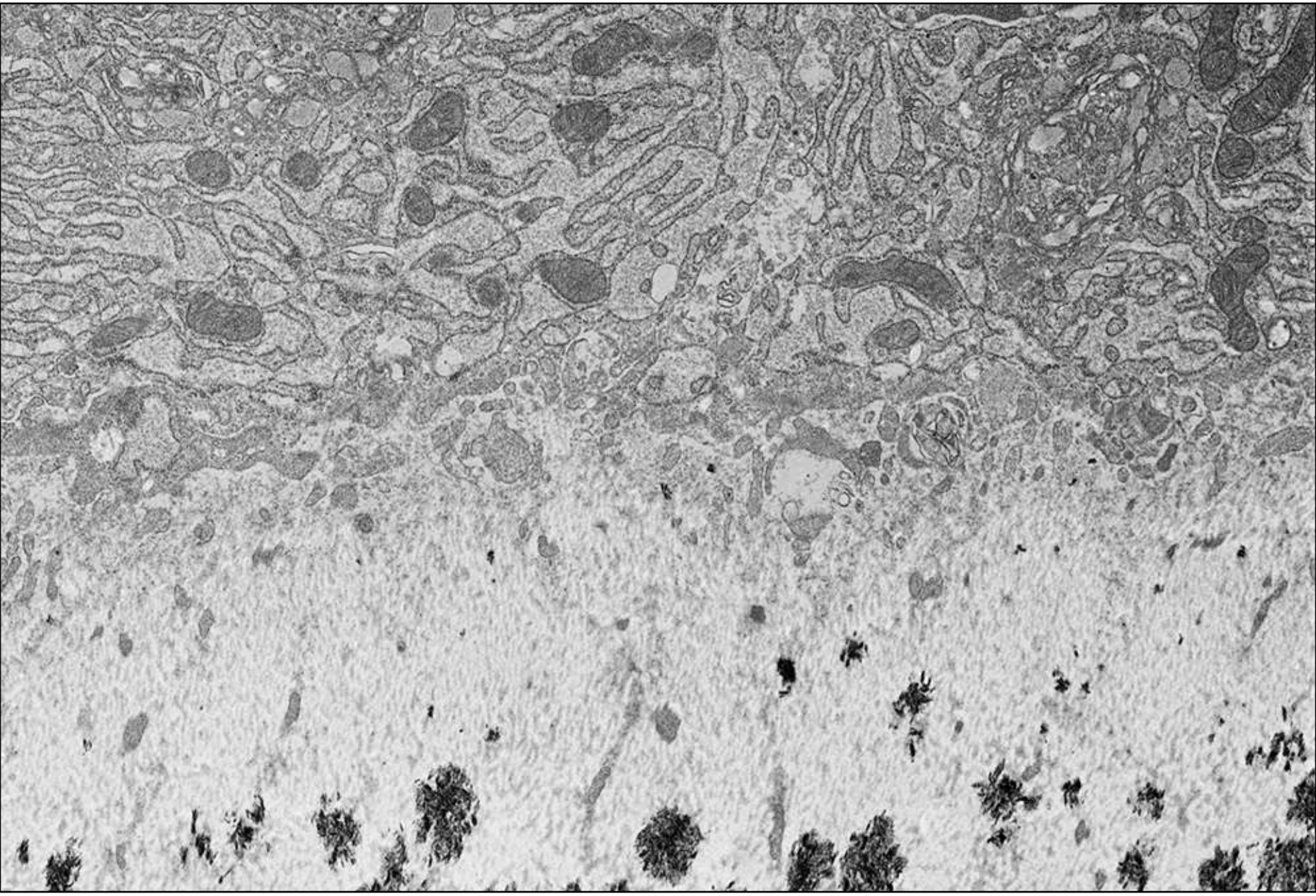
Osteoblasts on a Forming Surface

Fully mineralized section stained with trichrome stain to indicate osteoid.

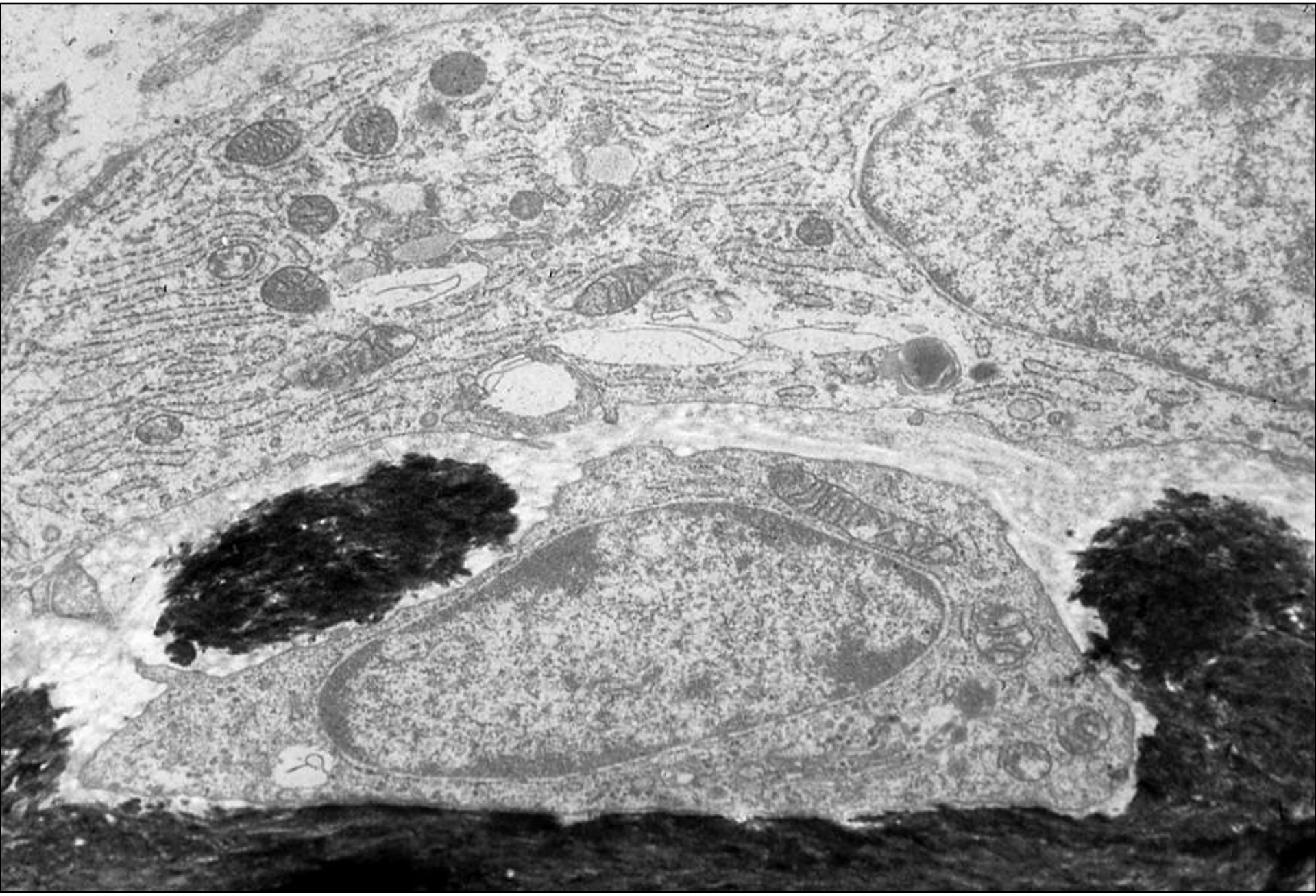


EM Active osteoblasts

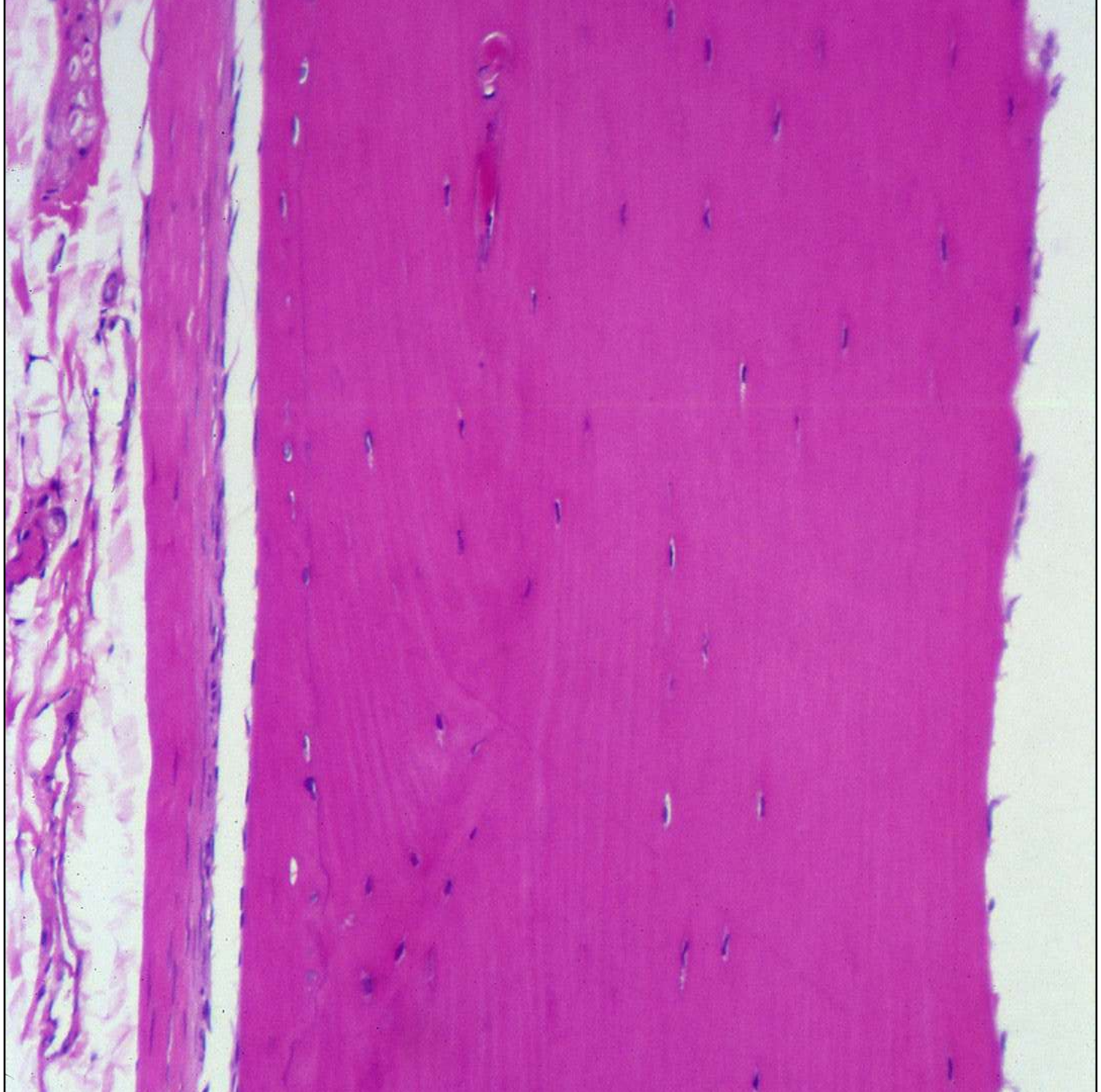
Note: early foci of mineralization (mineral appears black) in the matrix



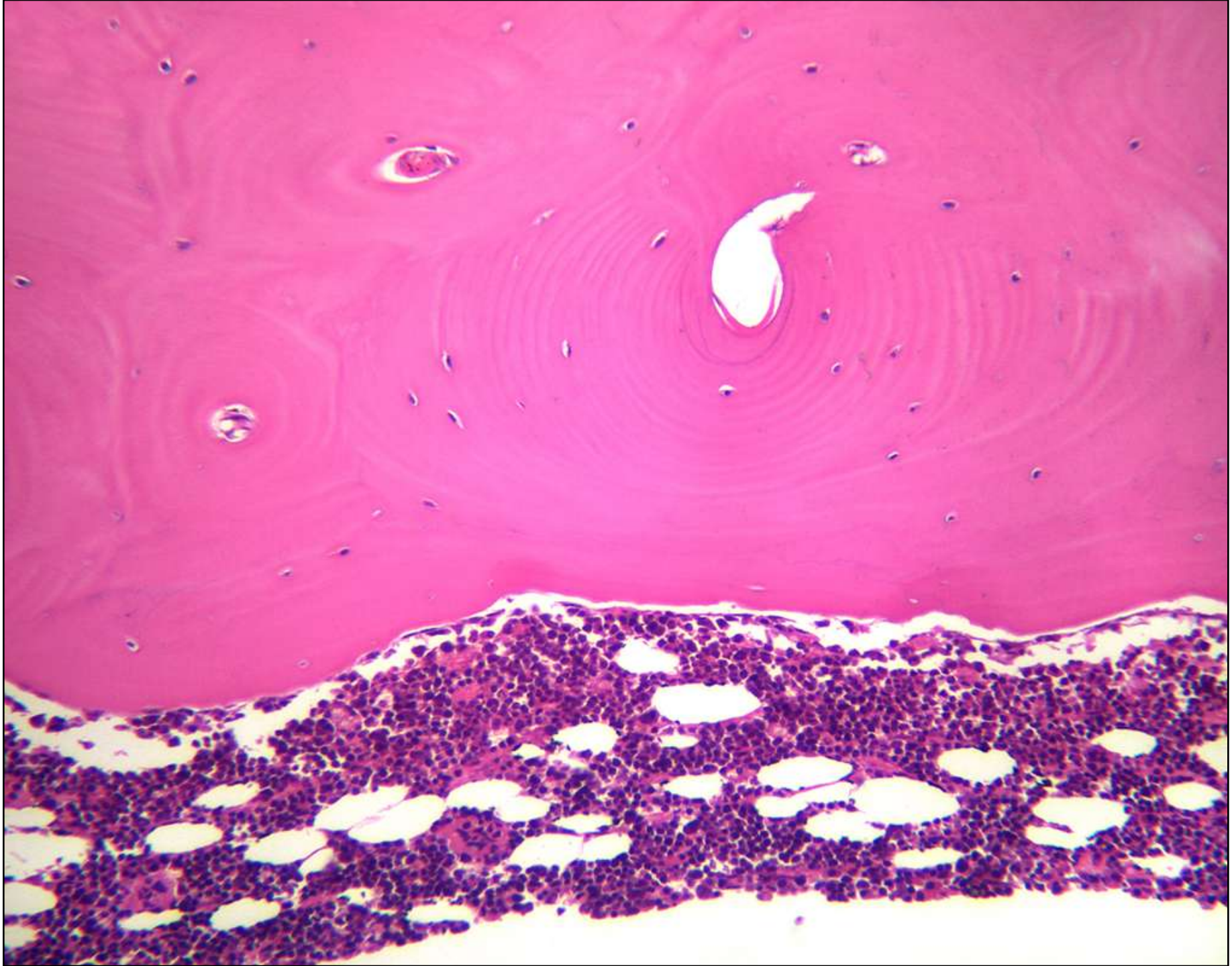
Osteoblast becoming embedded in bone (“pre-osteocyte”)



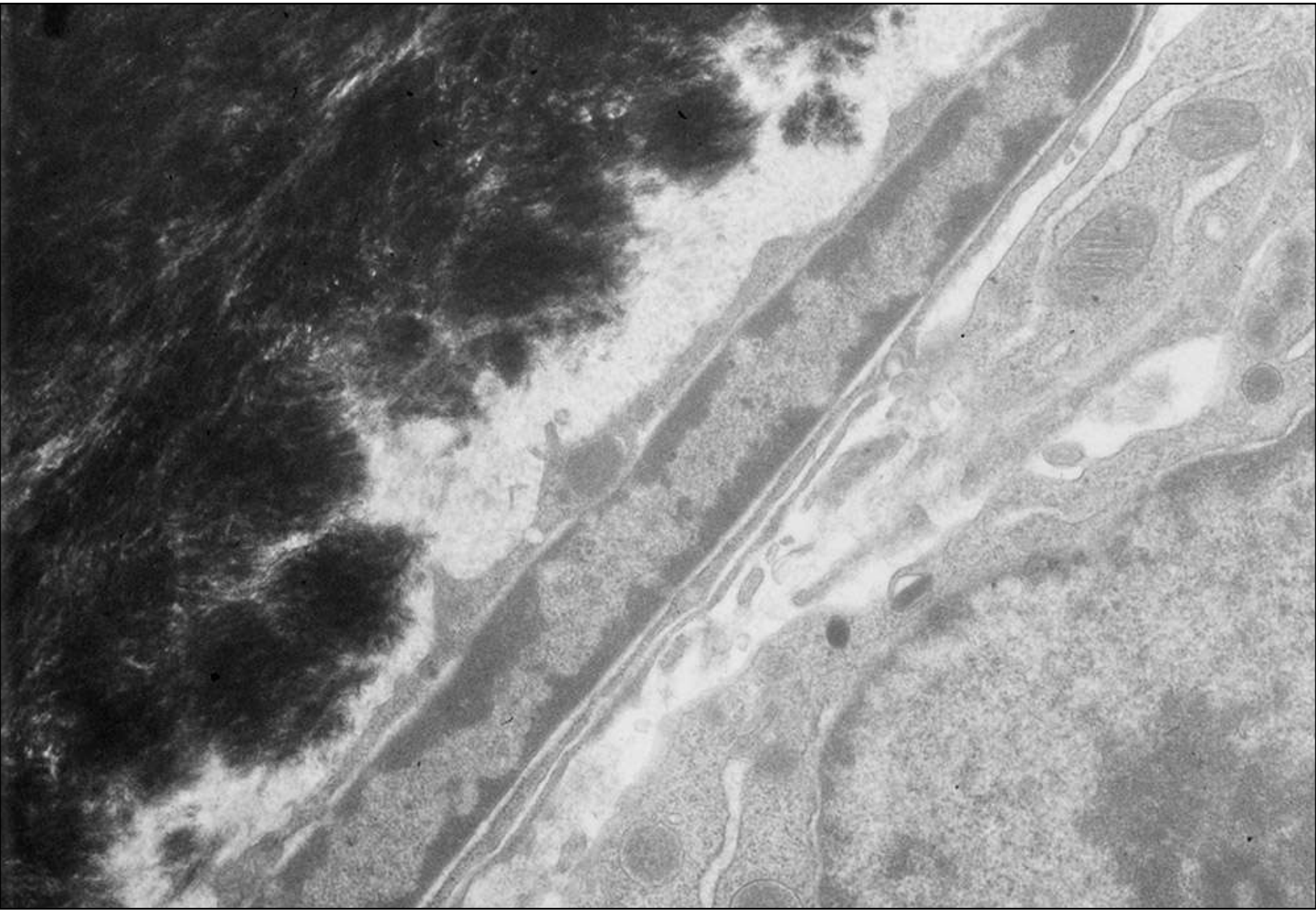
Inactive Osteoblasts (lining cells) on periosteal surface



Inactive osteoblasts on an eroded endosteal surface

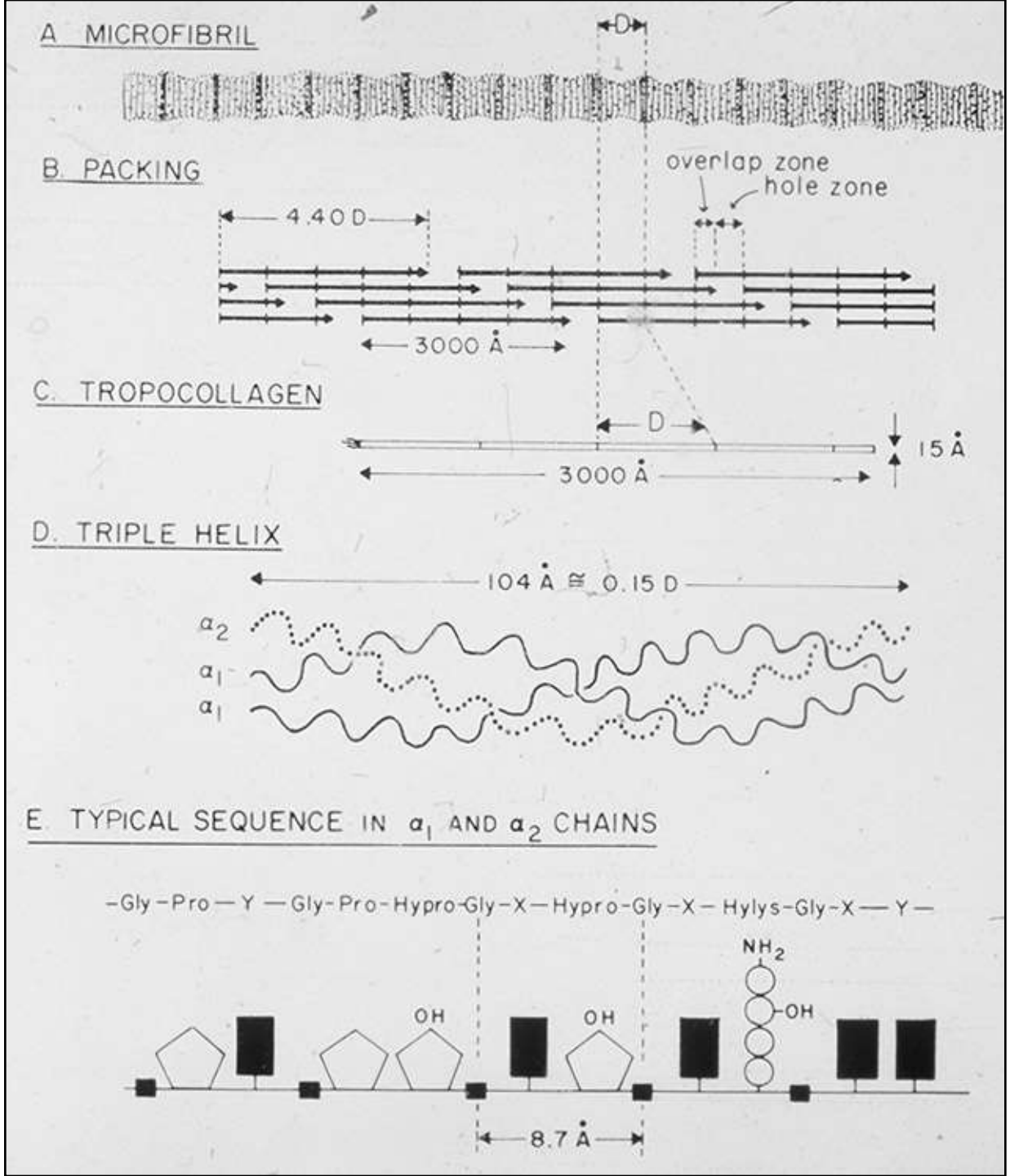


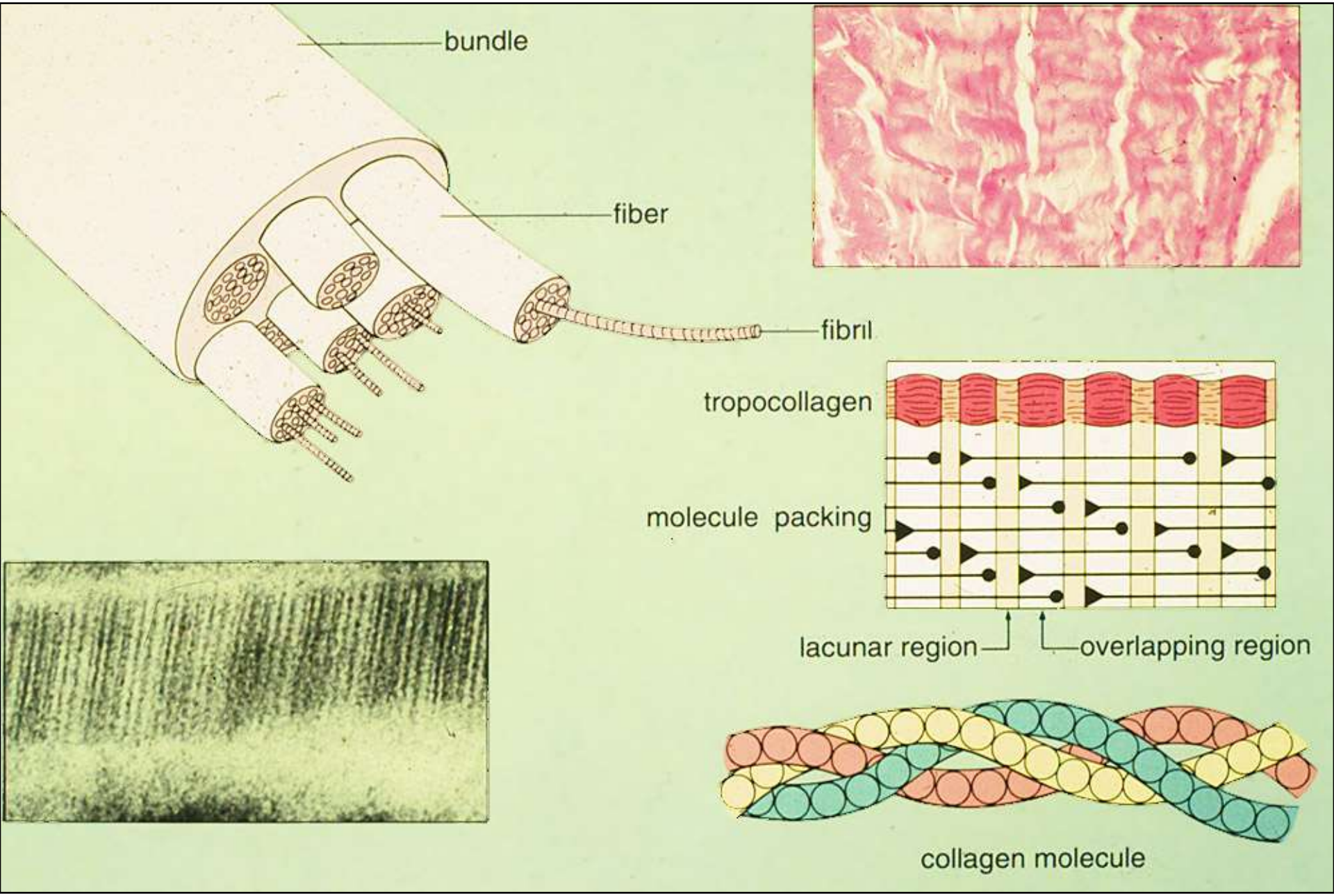
EM of Inactive osteoblast (lining cell). Note: lamina limitans on the completed mineralized surface.



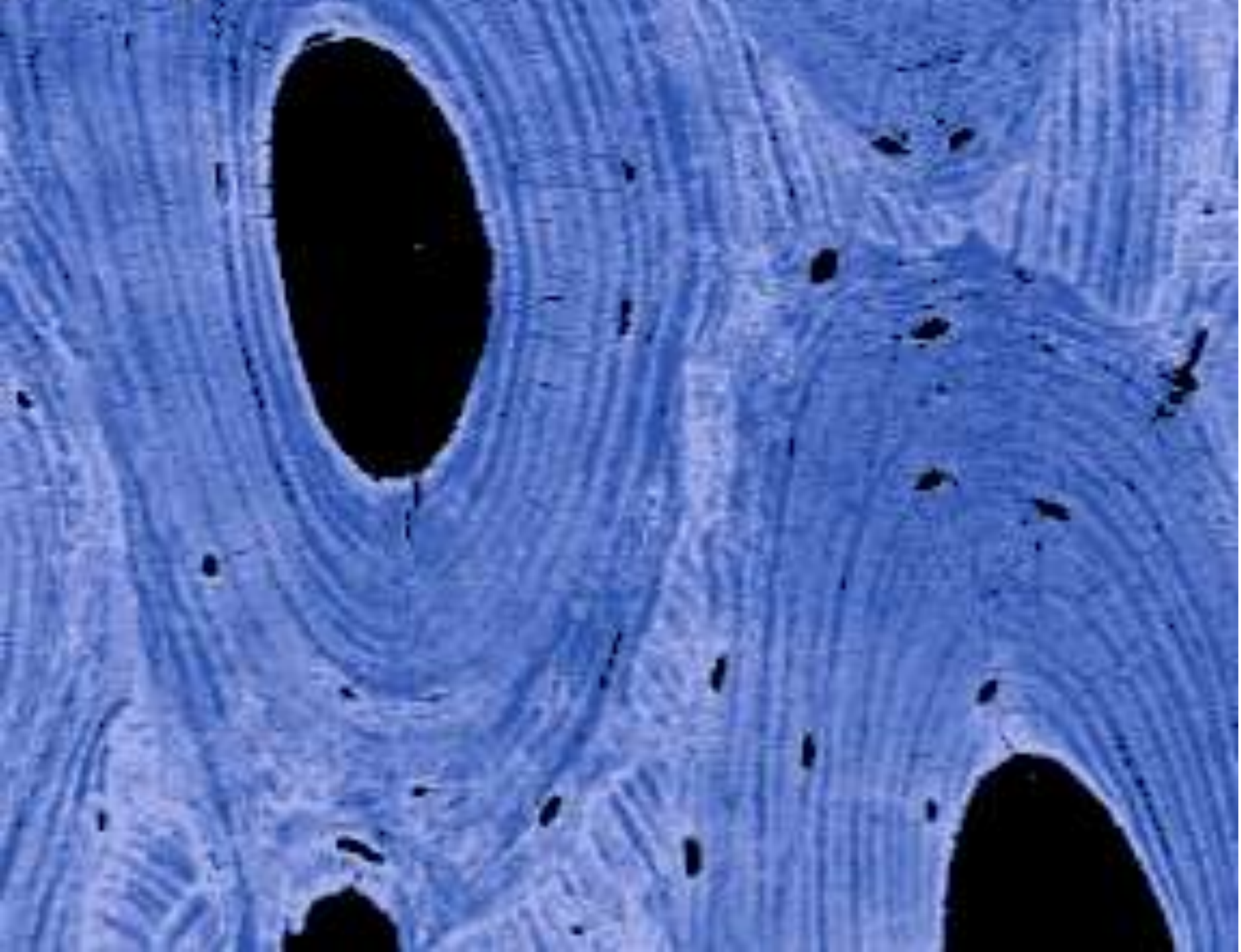
Organic Bone Matrix

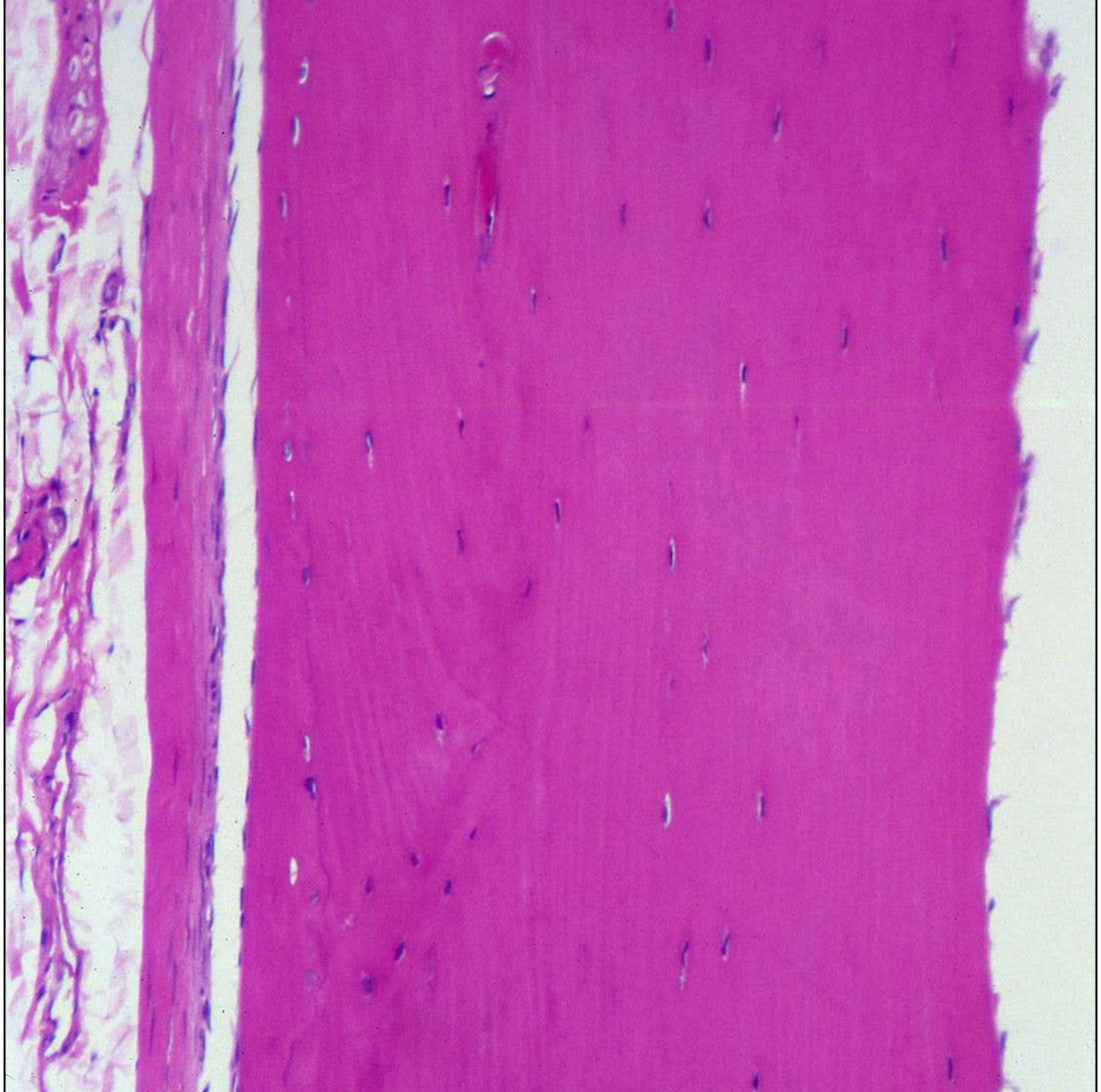
Formation of Type II collagen

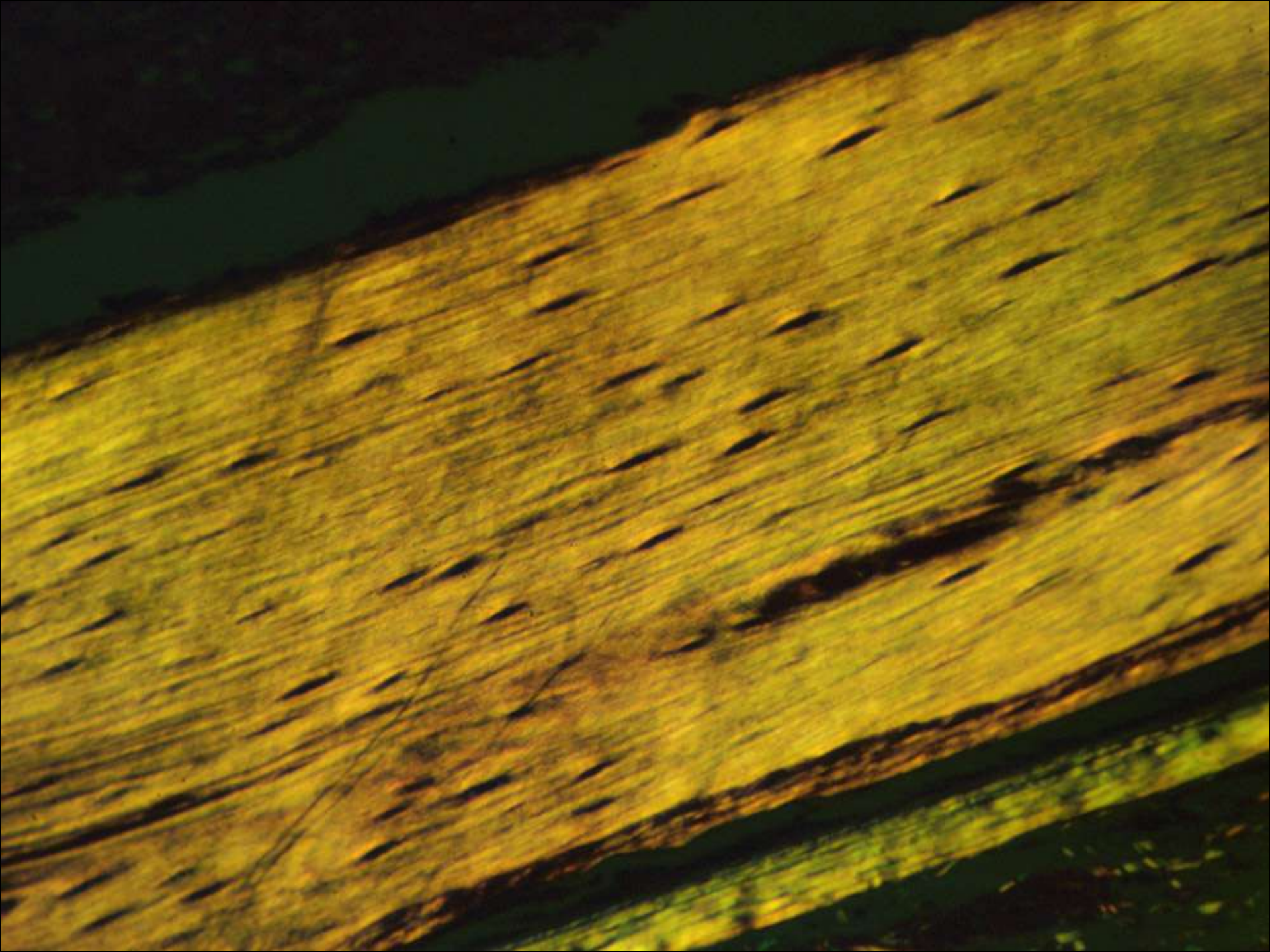

A MICROFIBRIL
D
B. PACKING
overlap zone
hole zone
4.40 D
3000 Å
C. TROPOCOLLAGEN
D
15 Å
3000 Å
D. TRIPLE HELIX
104 Å ≅ 0.15 D
α2
α1
α1
E. TYPICAL SEQUENCE IN α1 AND α2 CHAINS
-Gly-Pro-Y-Gly-Pro-Hypro-Gly-X-Hypro-Gly-X-Hylys-Gly-X-Y-
NH2
OH
OH
OH
8.7 Å


bundle
fiber
fibril
tropocollagen
molecule packing
lacunar region
overlapping region
collagen molecule

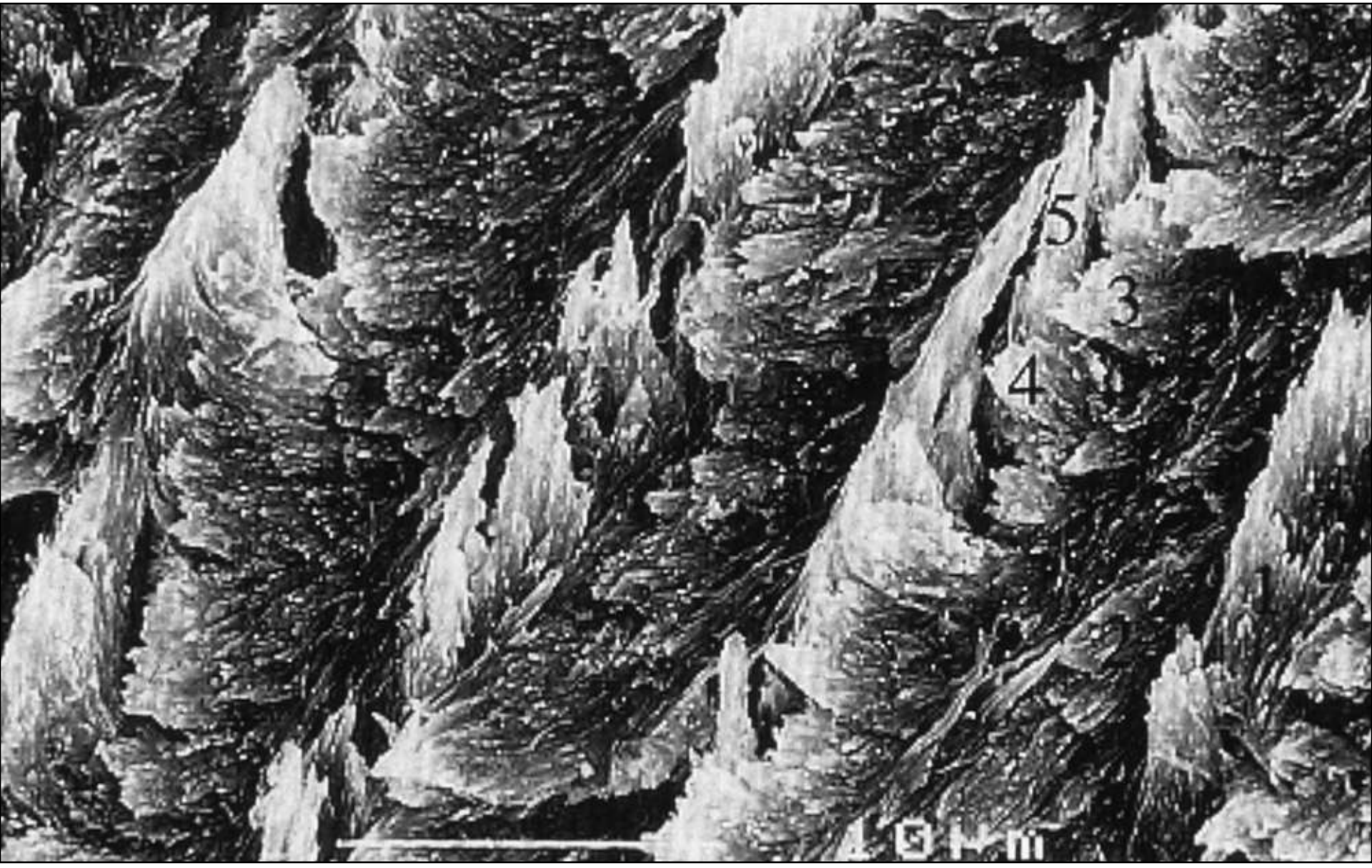
Lamellar Bone



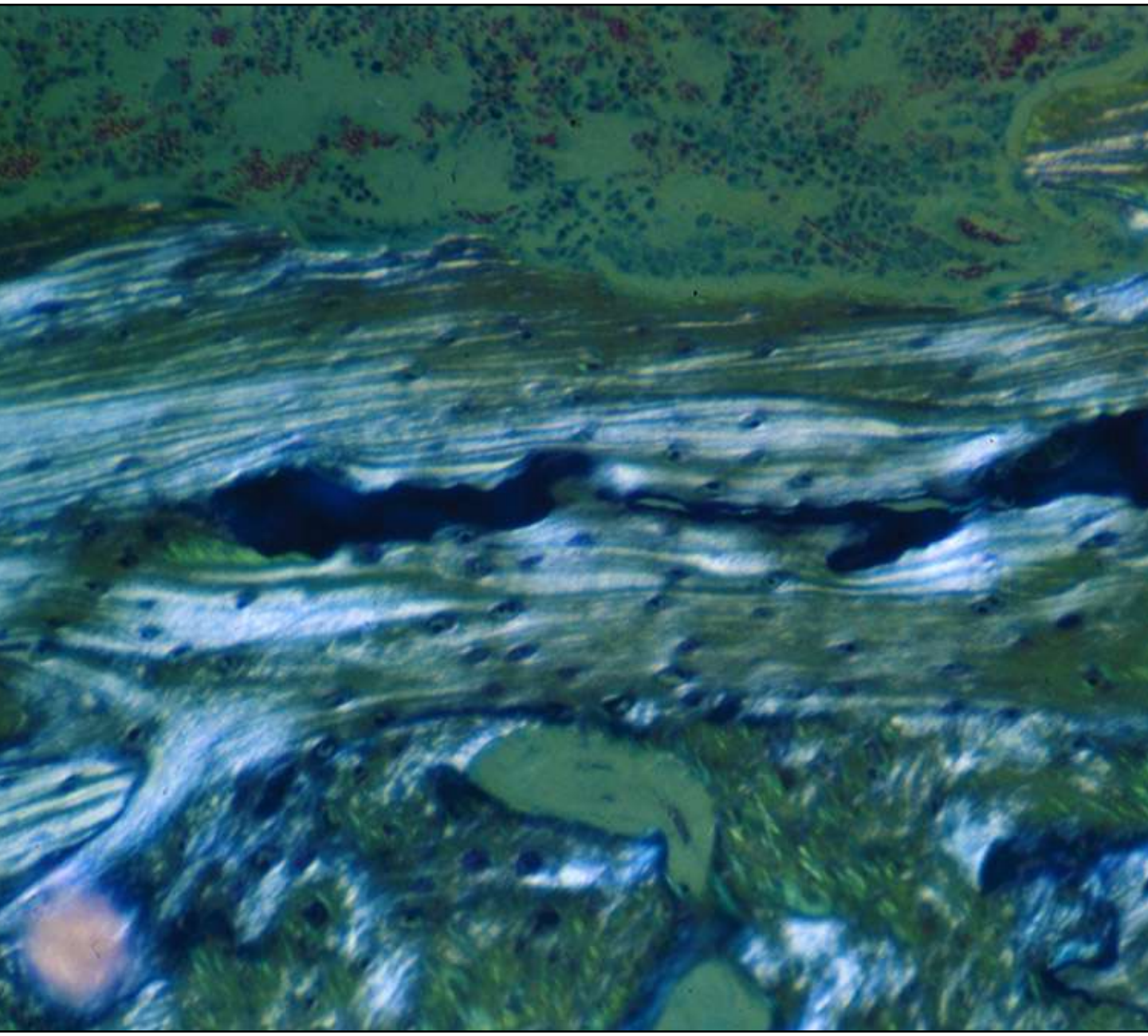


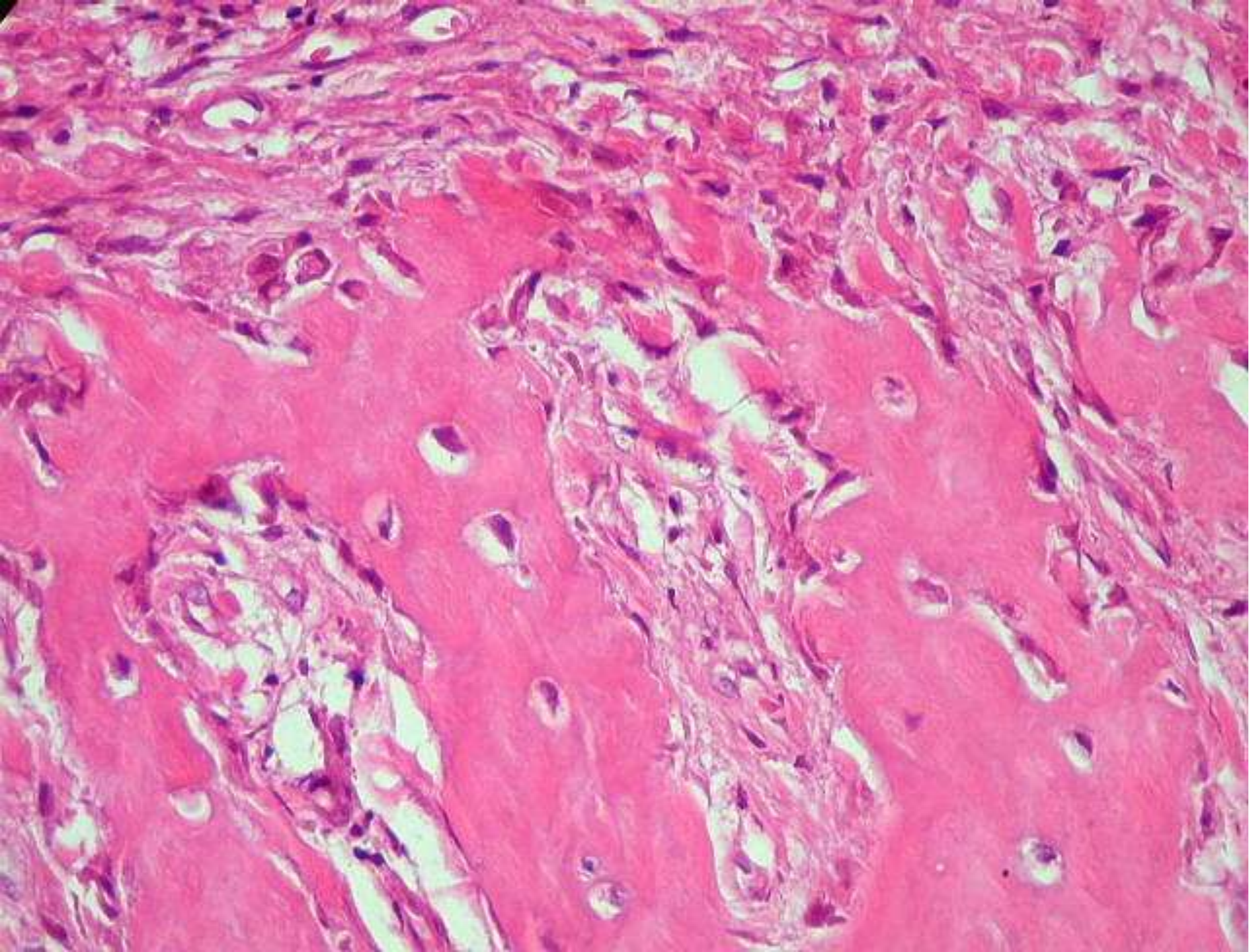


Scanning electron micrograph of lamellar bone


5
3
4
1.5 mm

Woven Bone



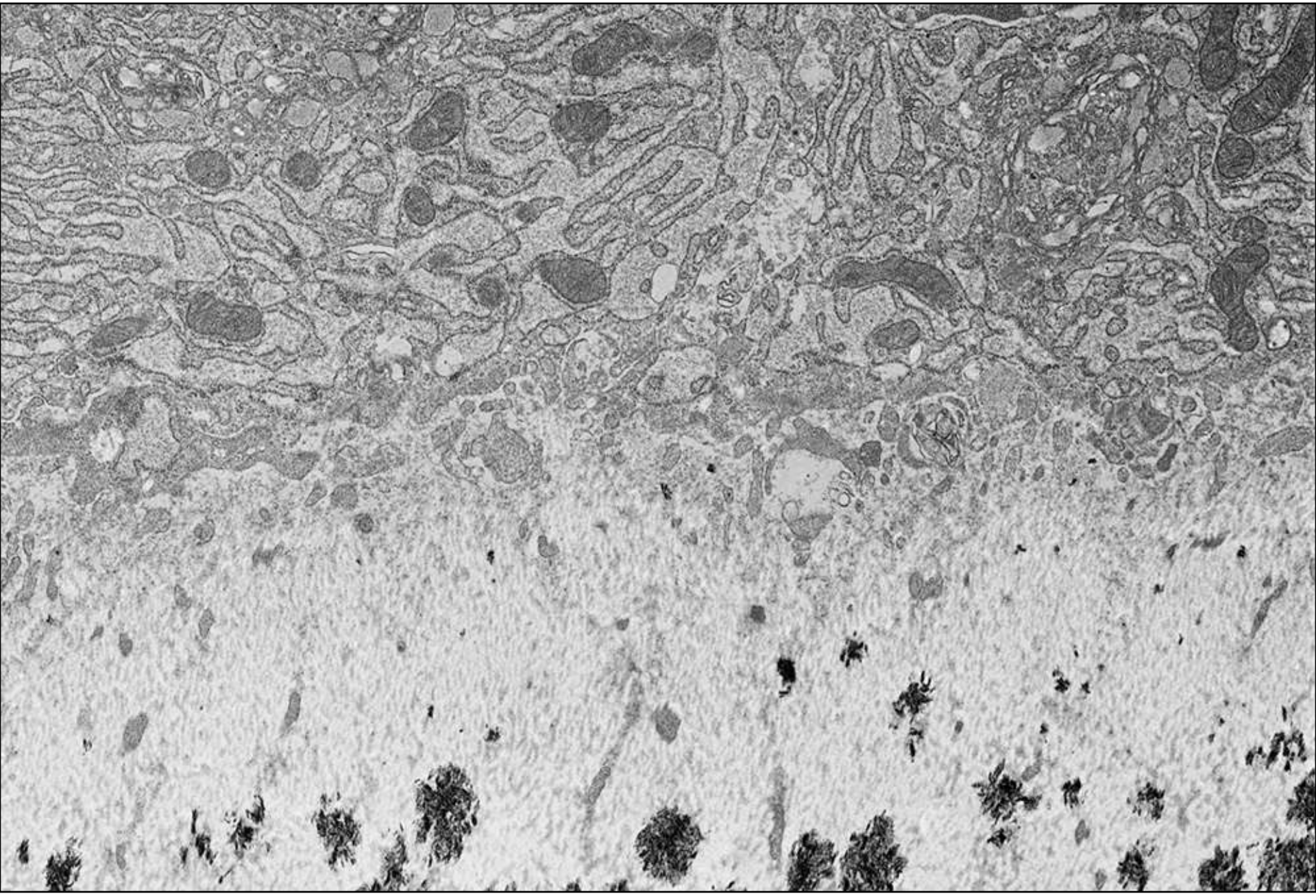


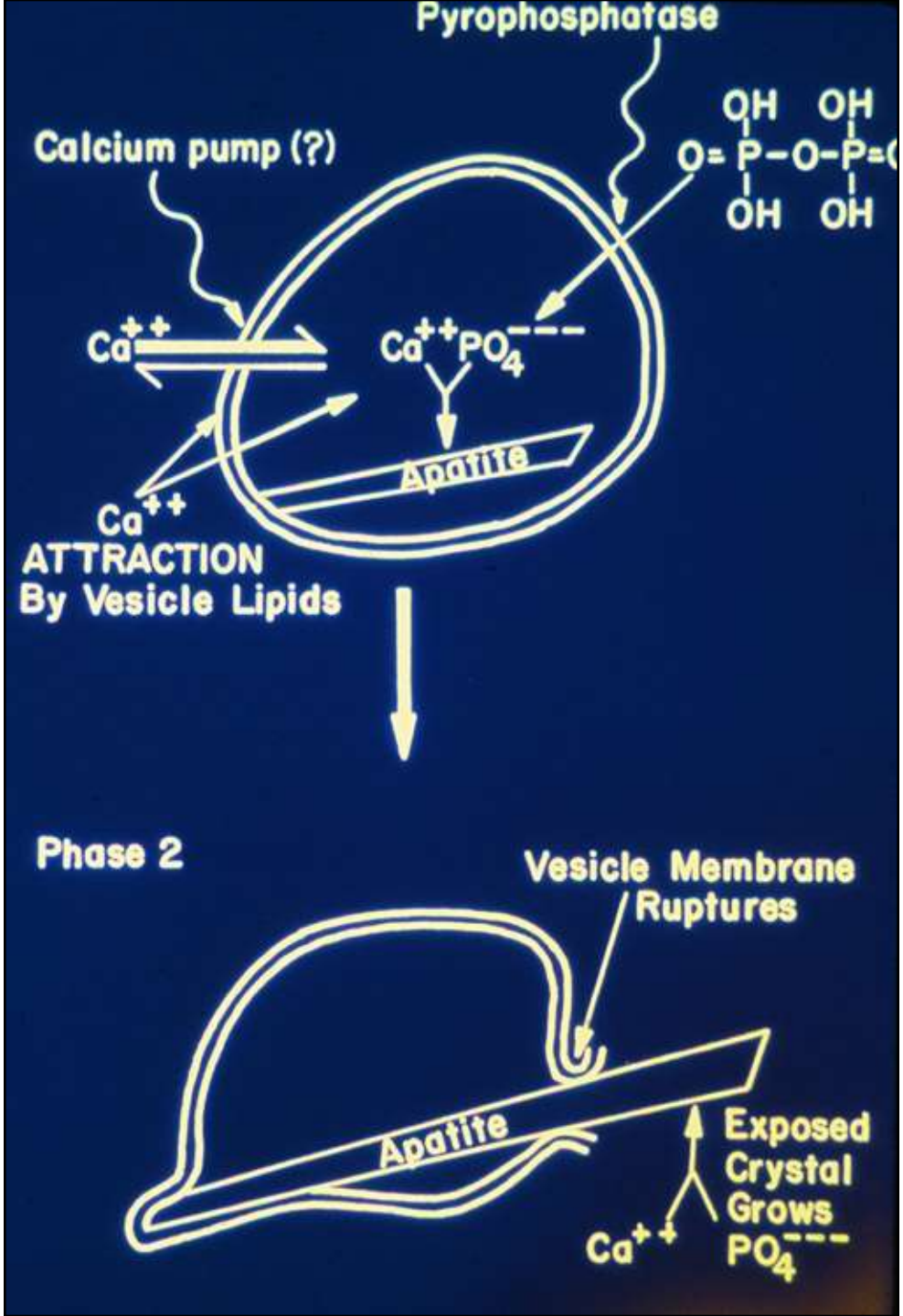
Noncollagenous proteins of bone matrix

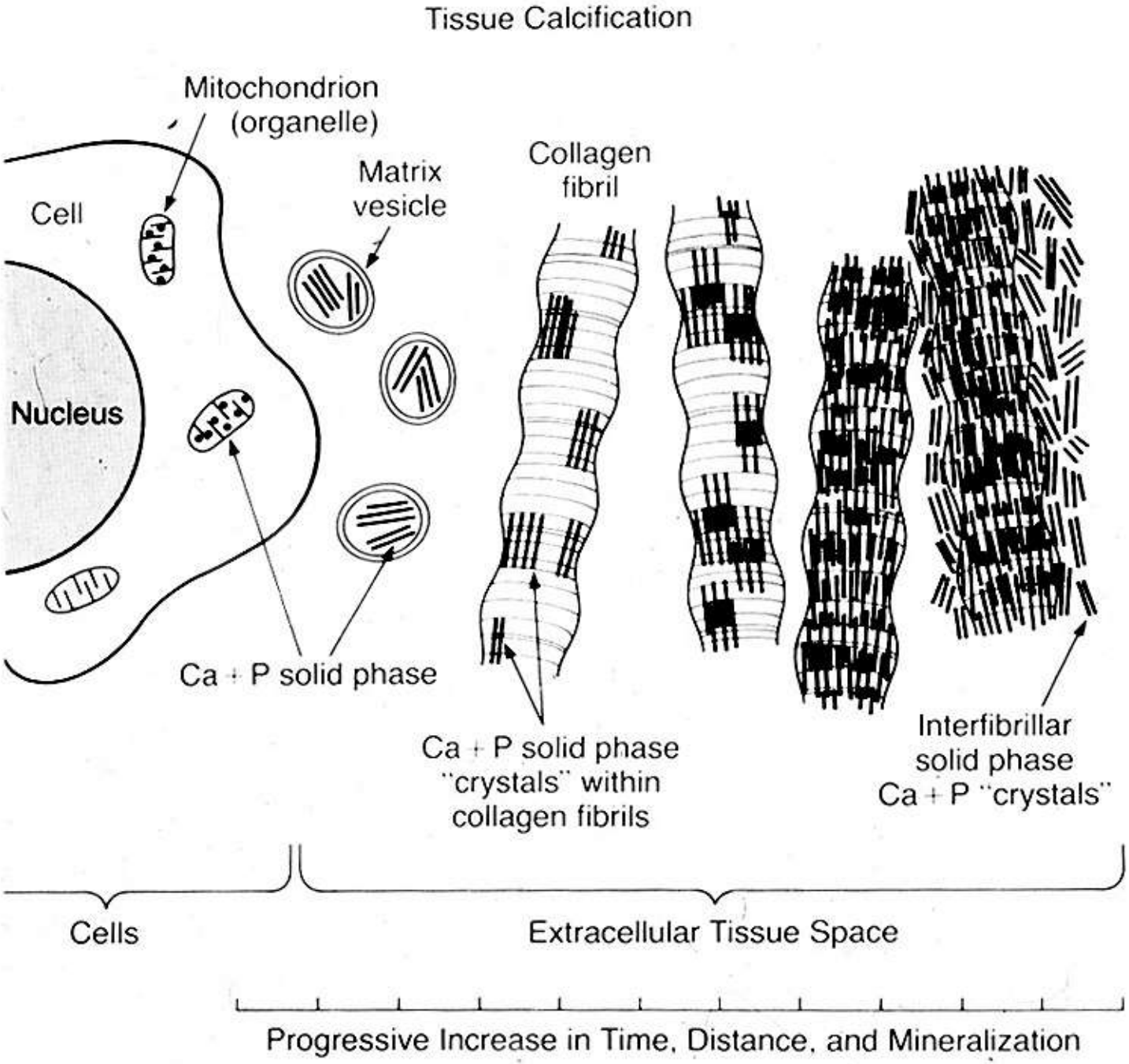
- Deposited by osteoblasts
- Growth factors (TFG; PDGF; BMP)
- Glues (osteonectin; sialoprotein)
- Mineralization (sialoprotein)
- Indicators of bone formation (osteocalcin • ? function)

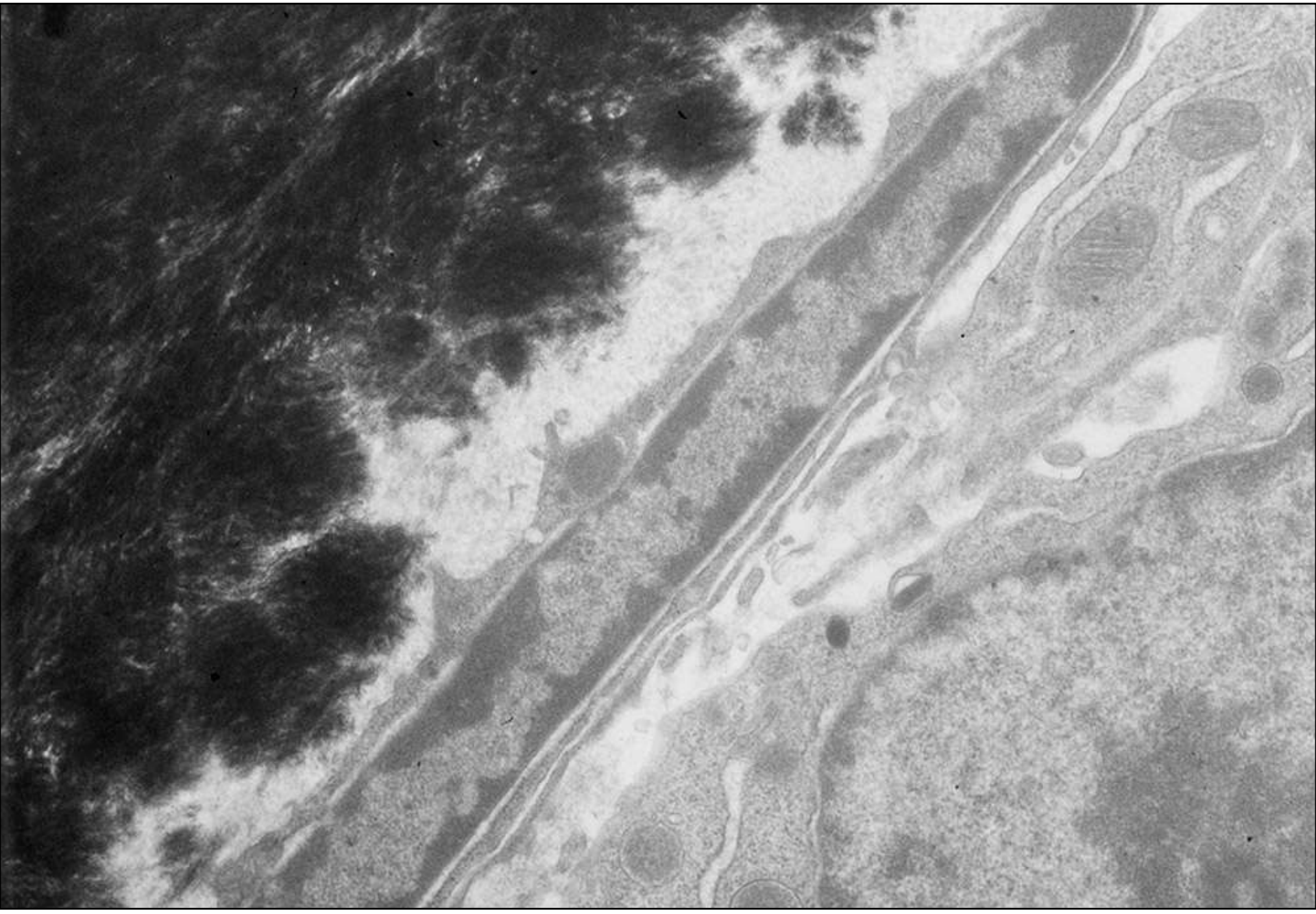
Inorganic Bone Matrix
Hydroxypapatite

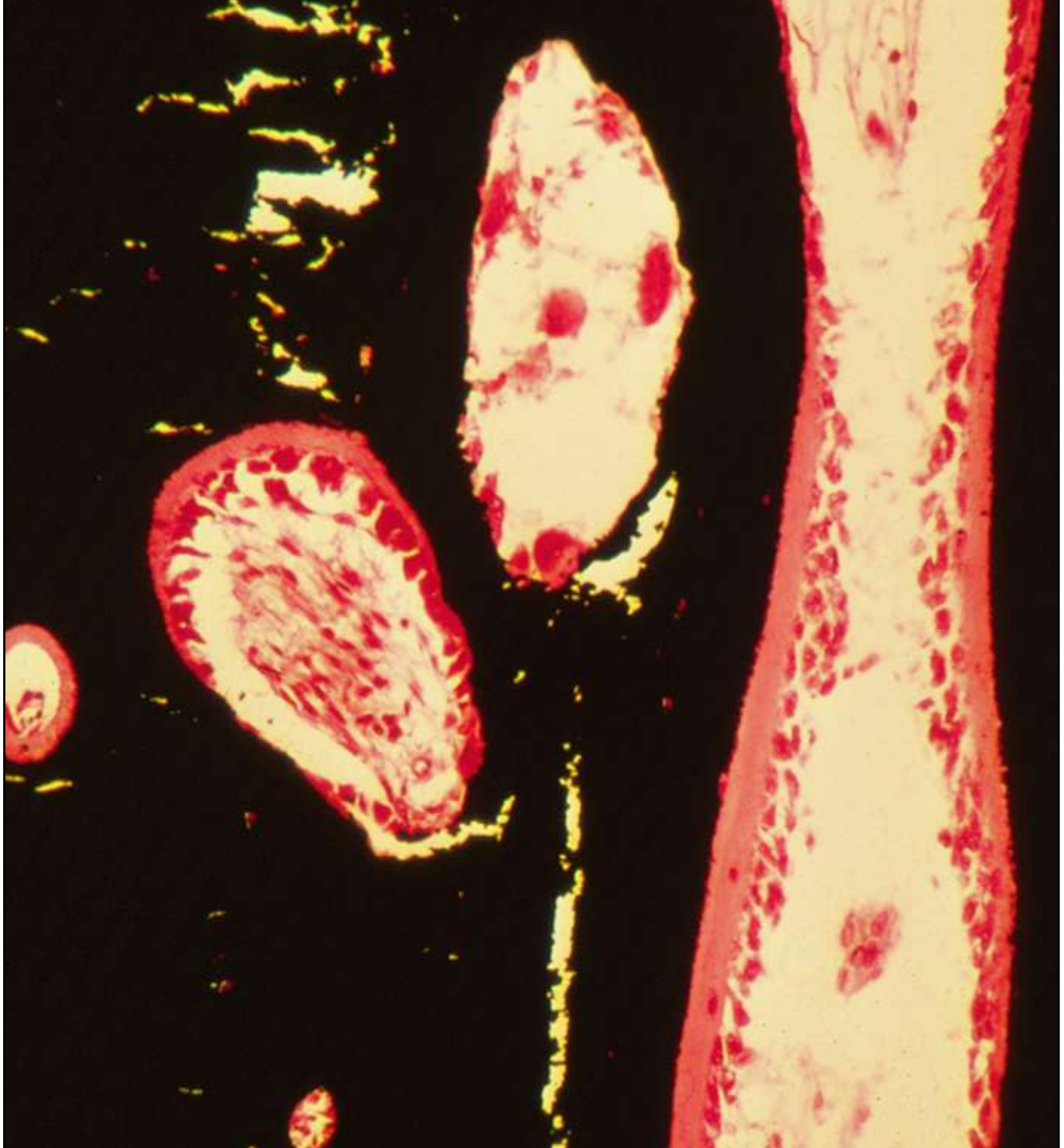
Mineralization of osteoid



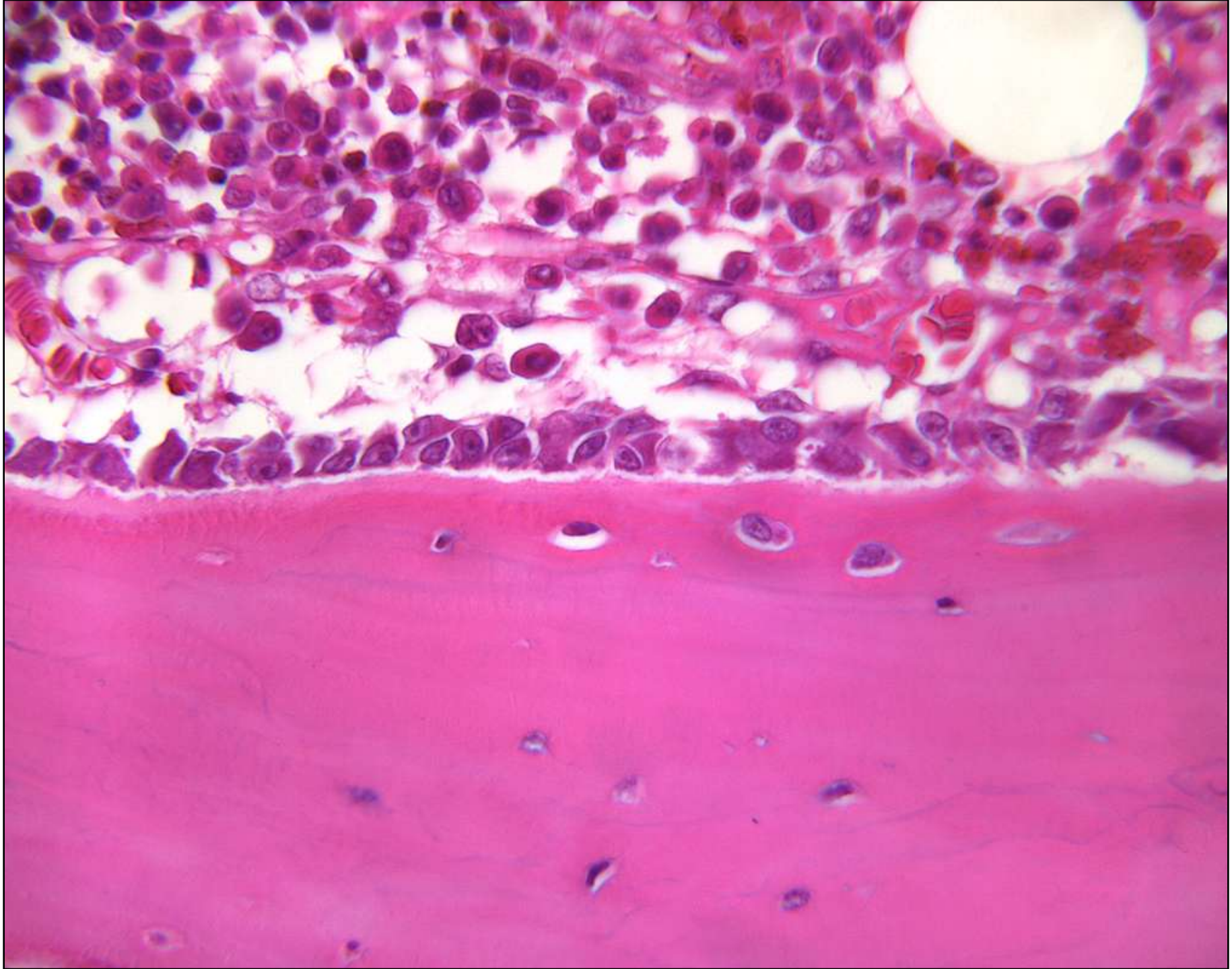

Pyrophosphatase
OH OH
O= P–O–P=(
OH OH
Calcium pump (?)
Ca++
Ca++PO4---
Apatite
Ca++
ATTRACTION
By Vesicle Lipids
Phase 2
Vesicle Membrane
Ruptures
Apatite
Exposed
Crystal
Grows
Ca++
PO4---

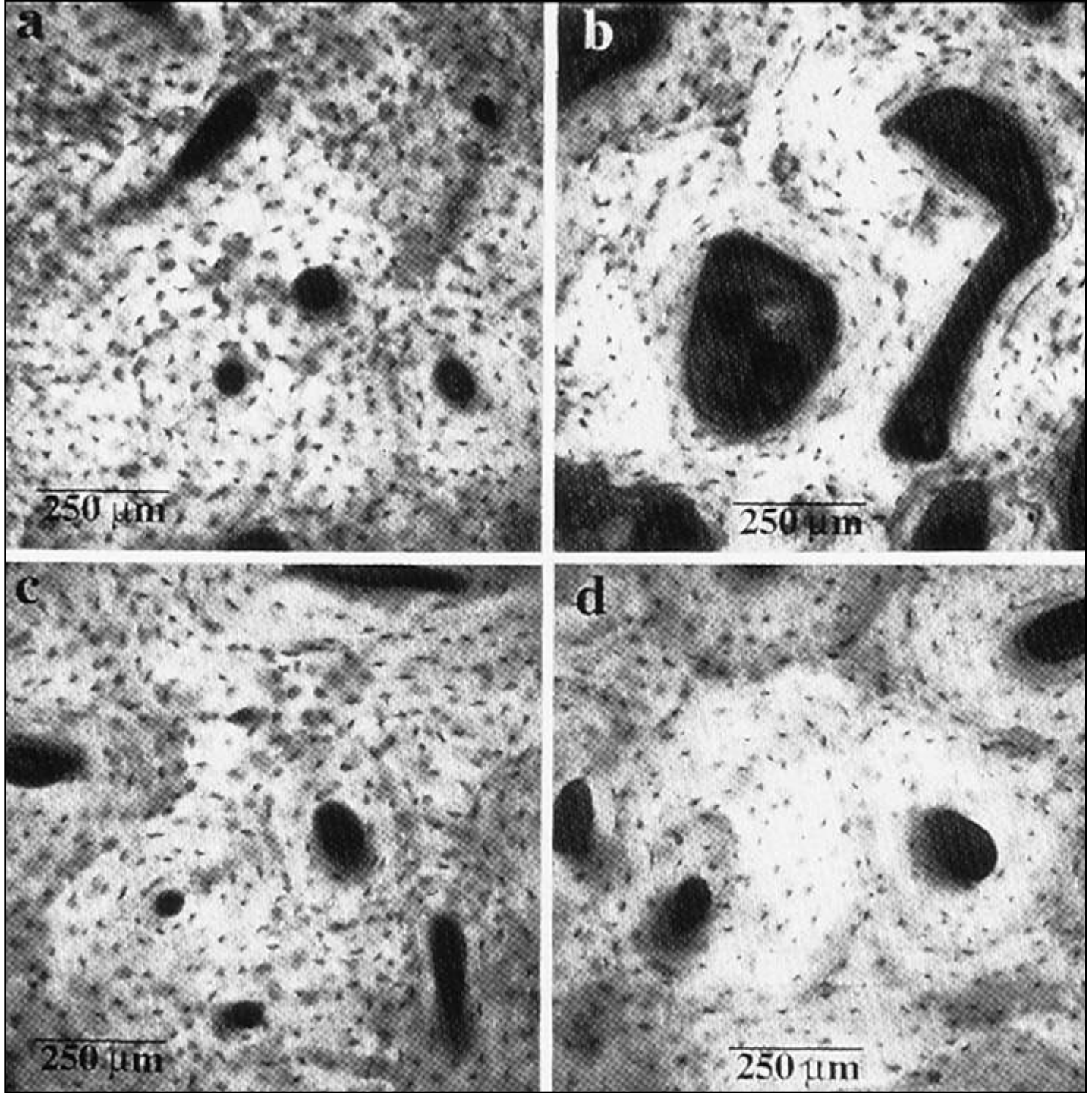

Tissue Calcification
Mitochondrion
(organelle)
Cell
Matrix
vesicle
Collagen
fibril
Nucleus
Ca + P solid phase
Ca + P solid phase
"crystals" within
collagen fibrils
Interfibrillar
solid phase
Ca + P "crystals"
Cells
Extracellular Tissue Space
Progressive Increase in Time, Distance, and Mineralization

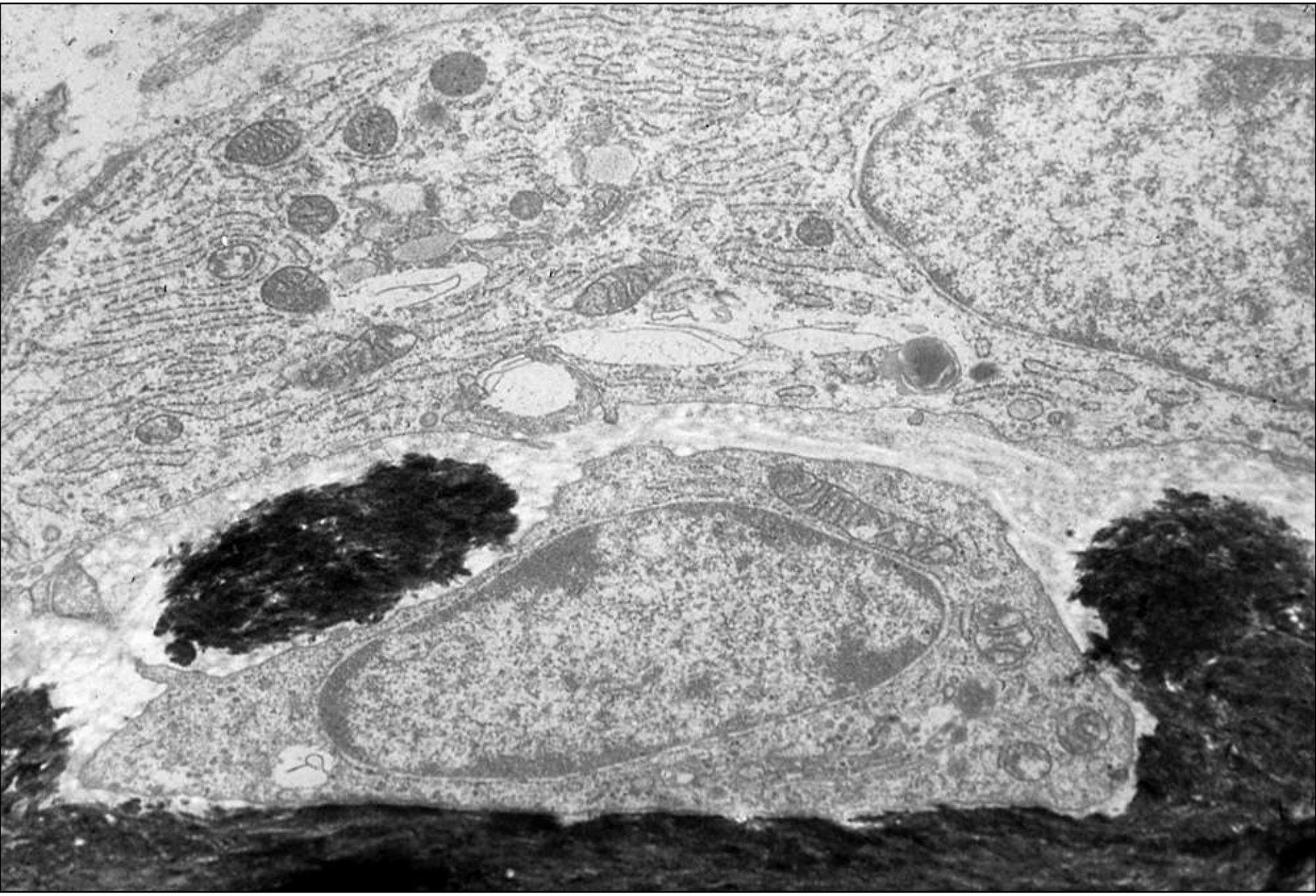


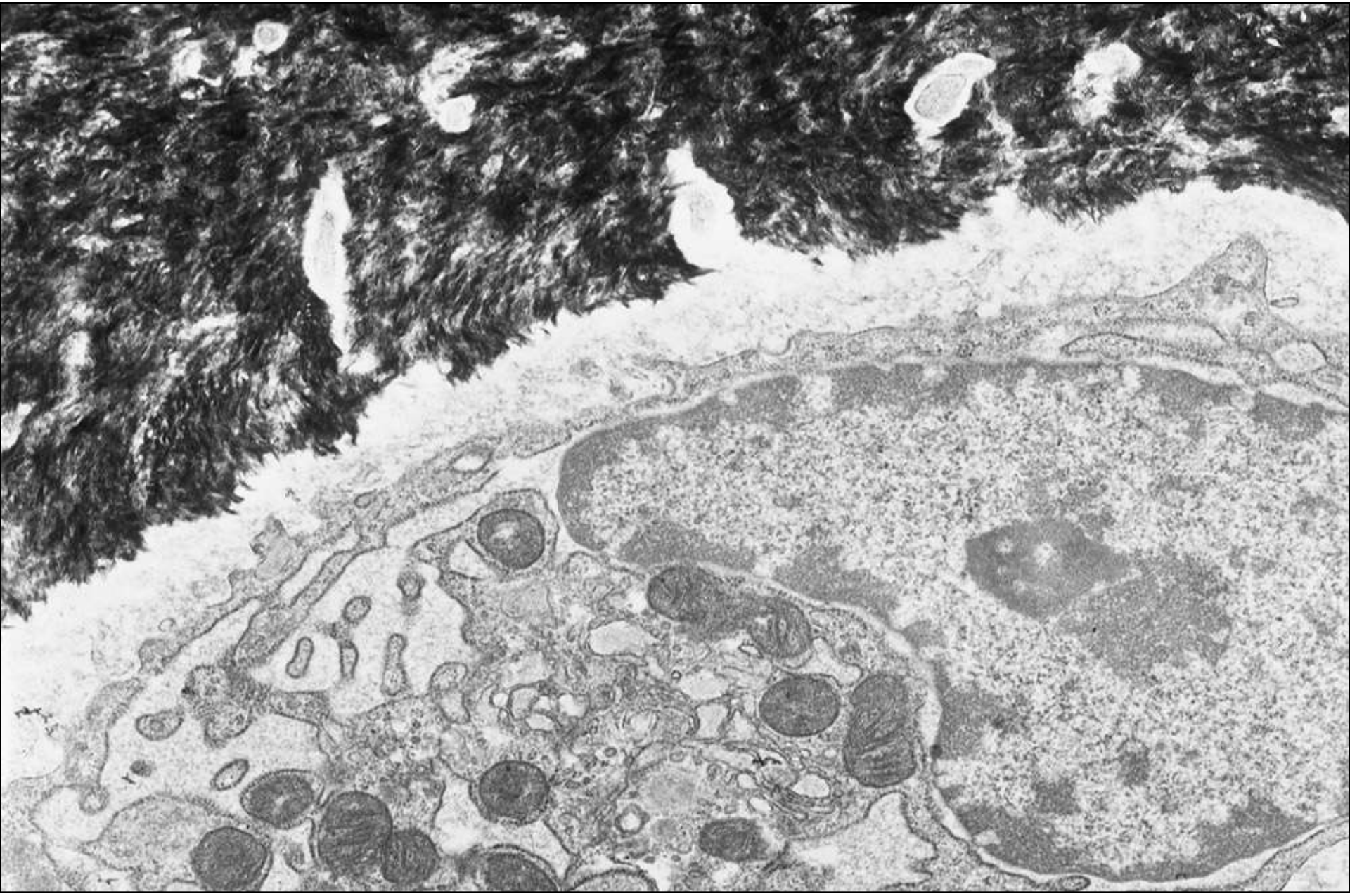


Osteocytes

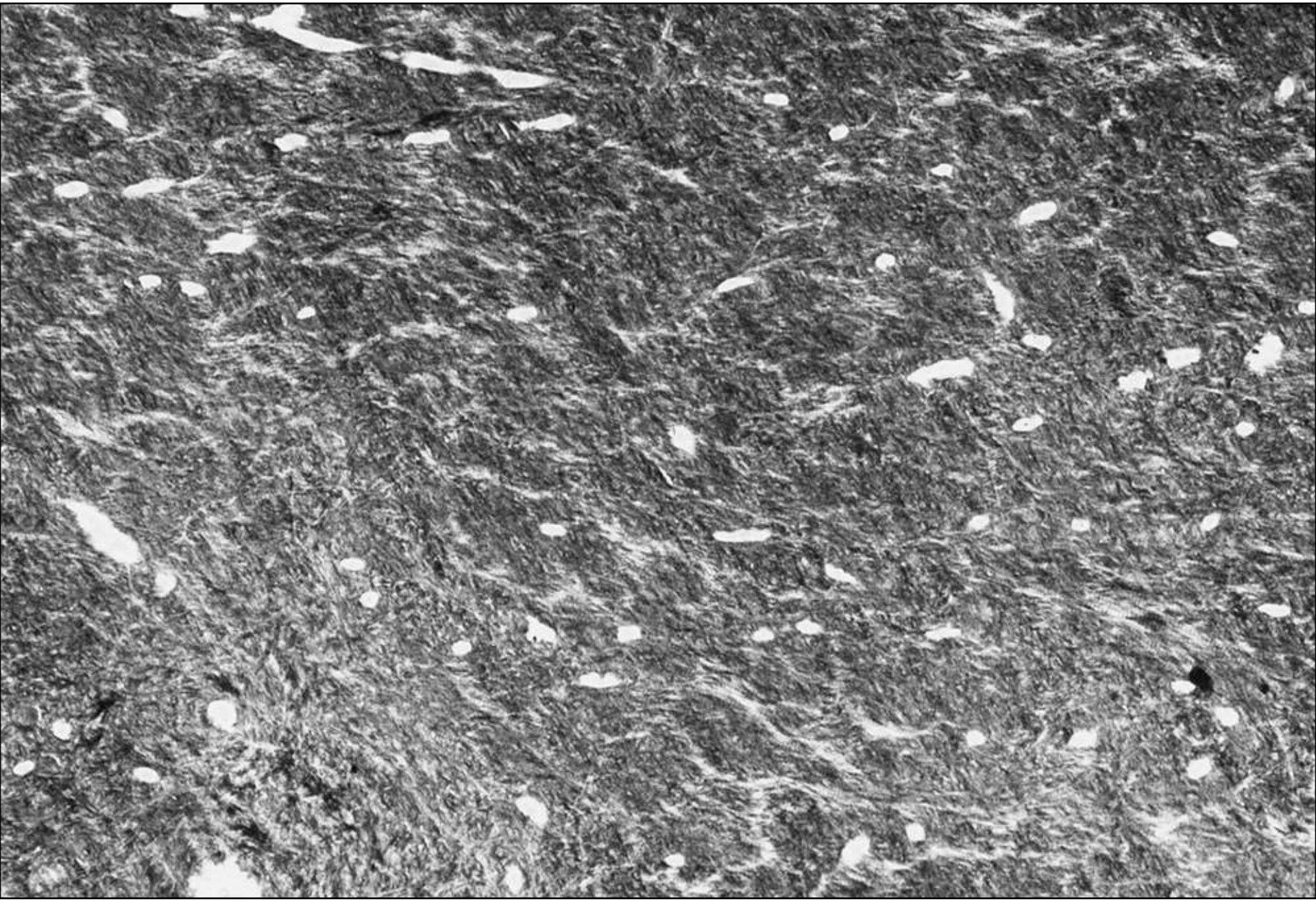


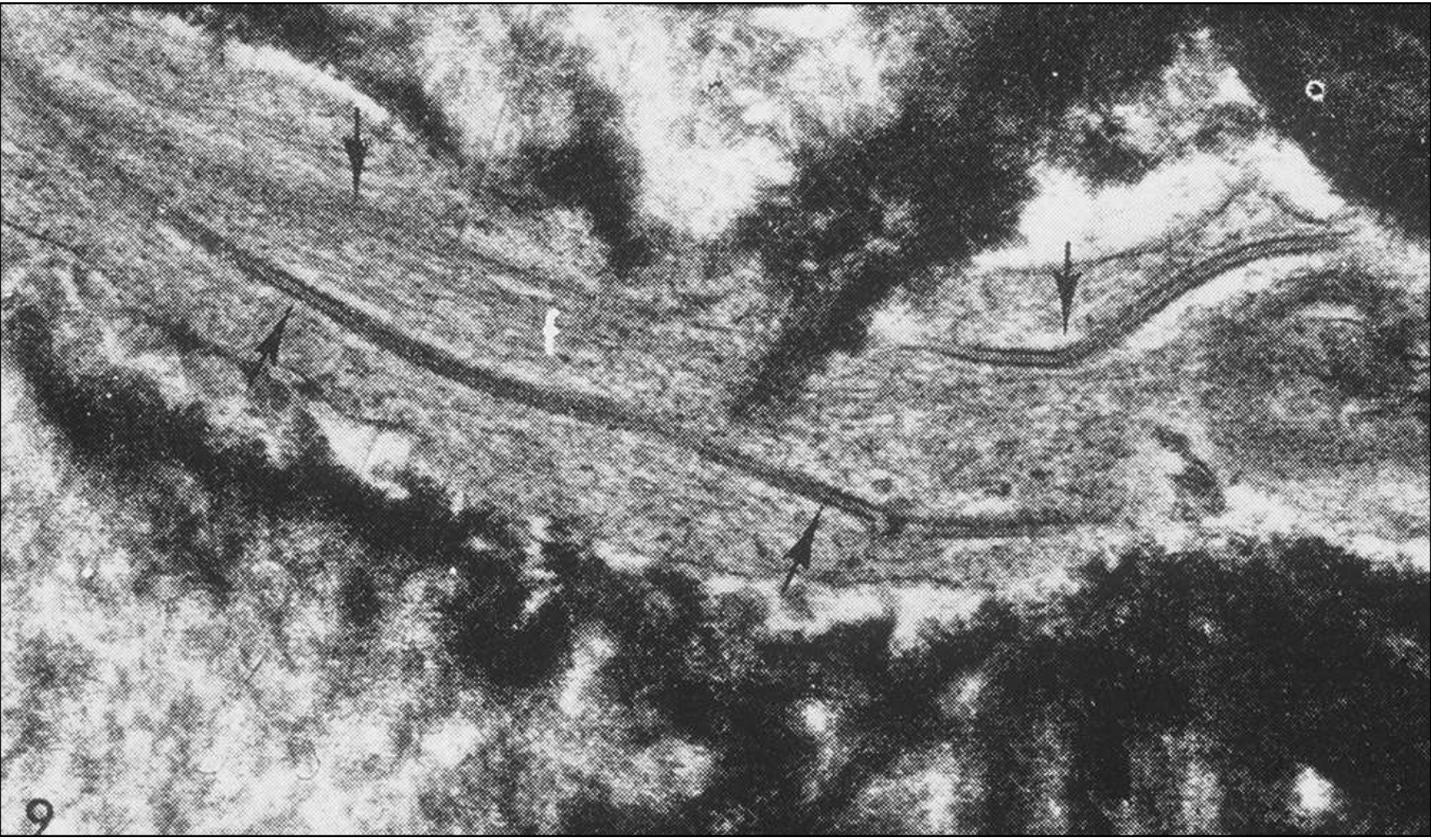

a
250 μm
b
250 μm
c
250 μm
d
250 μm



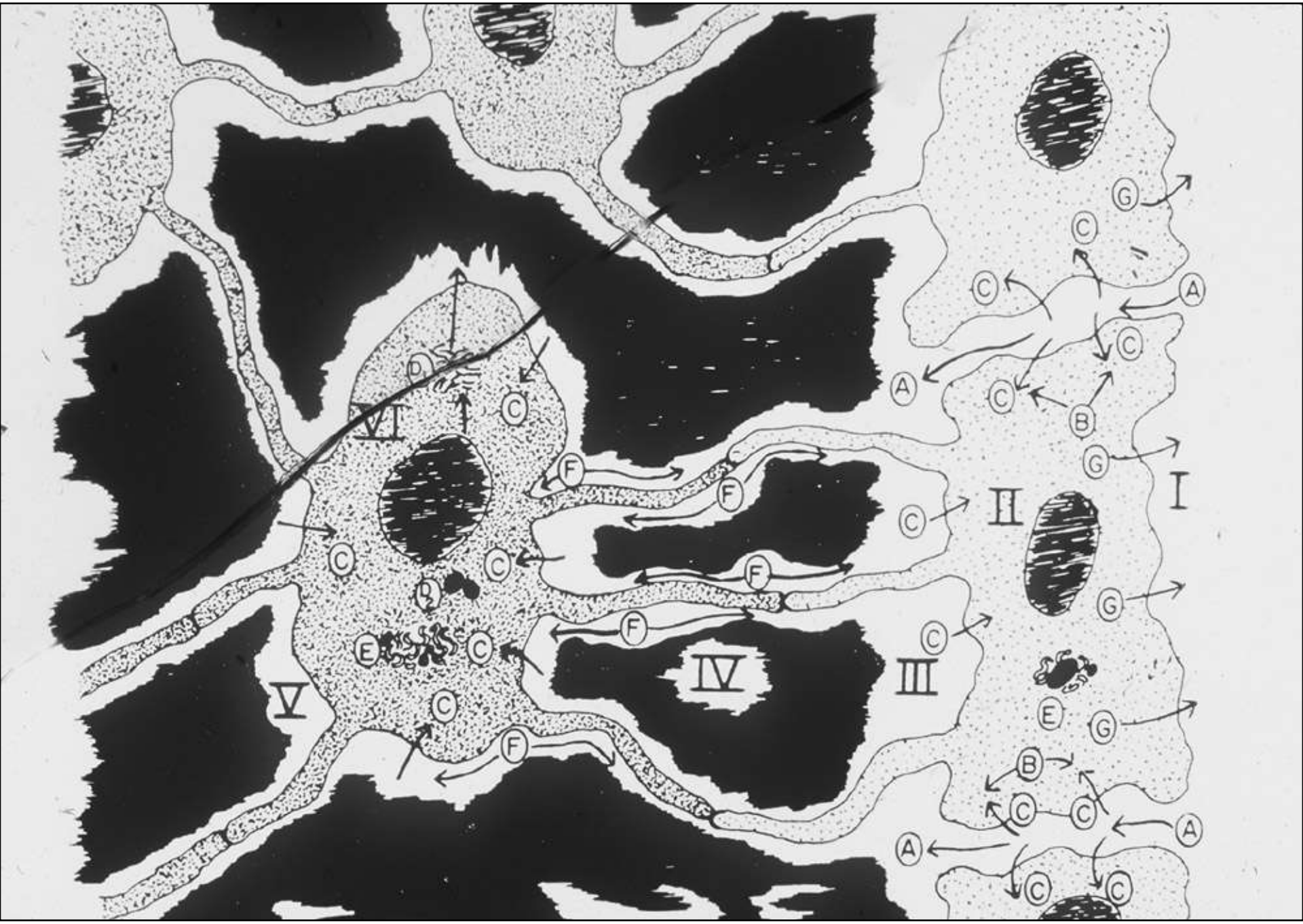


EM of canaliculi

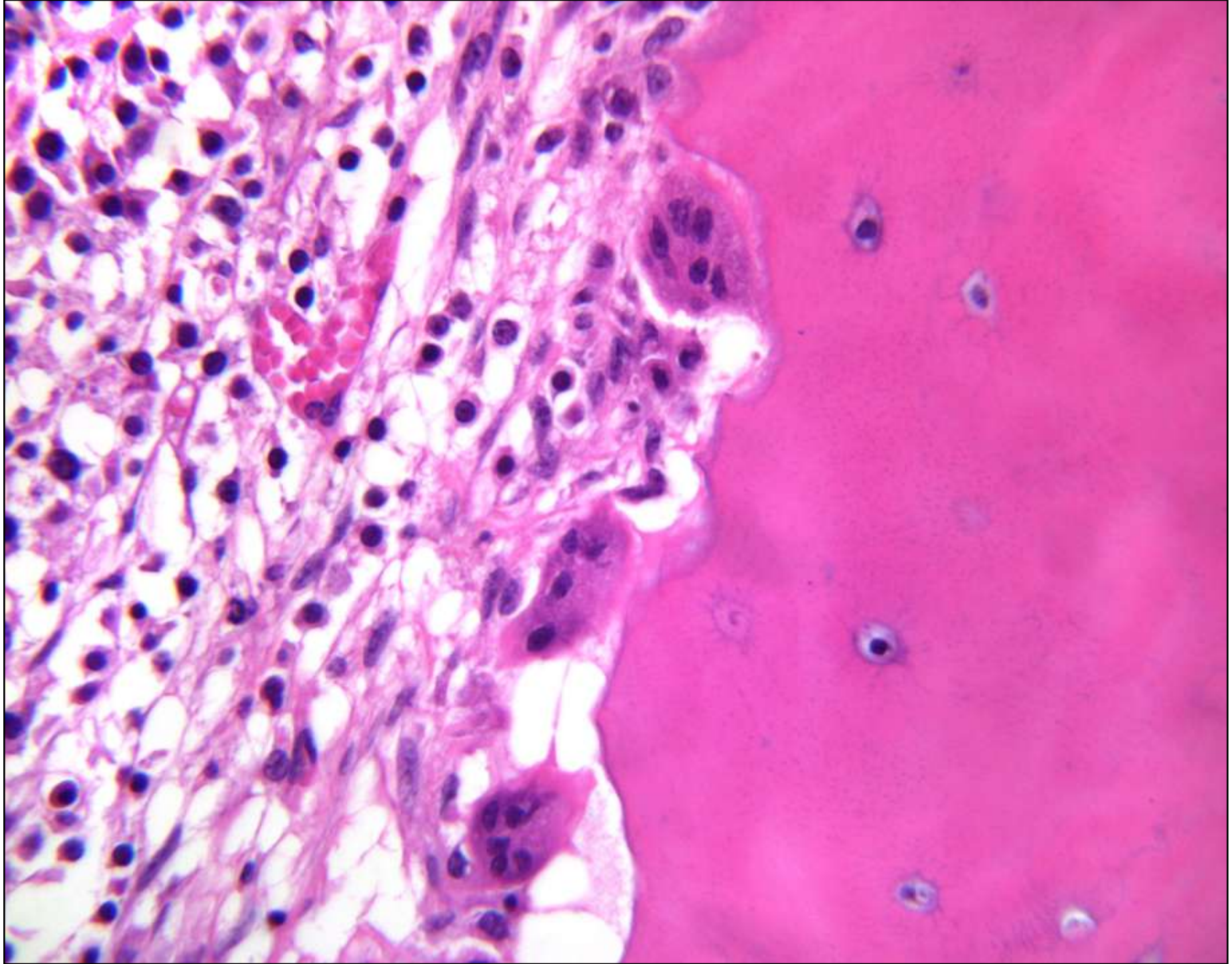


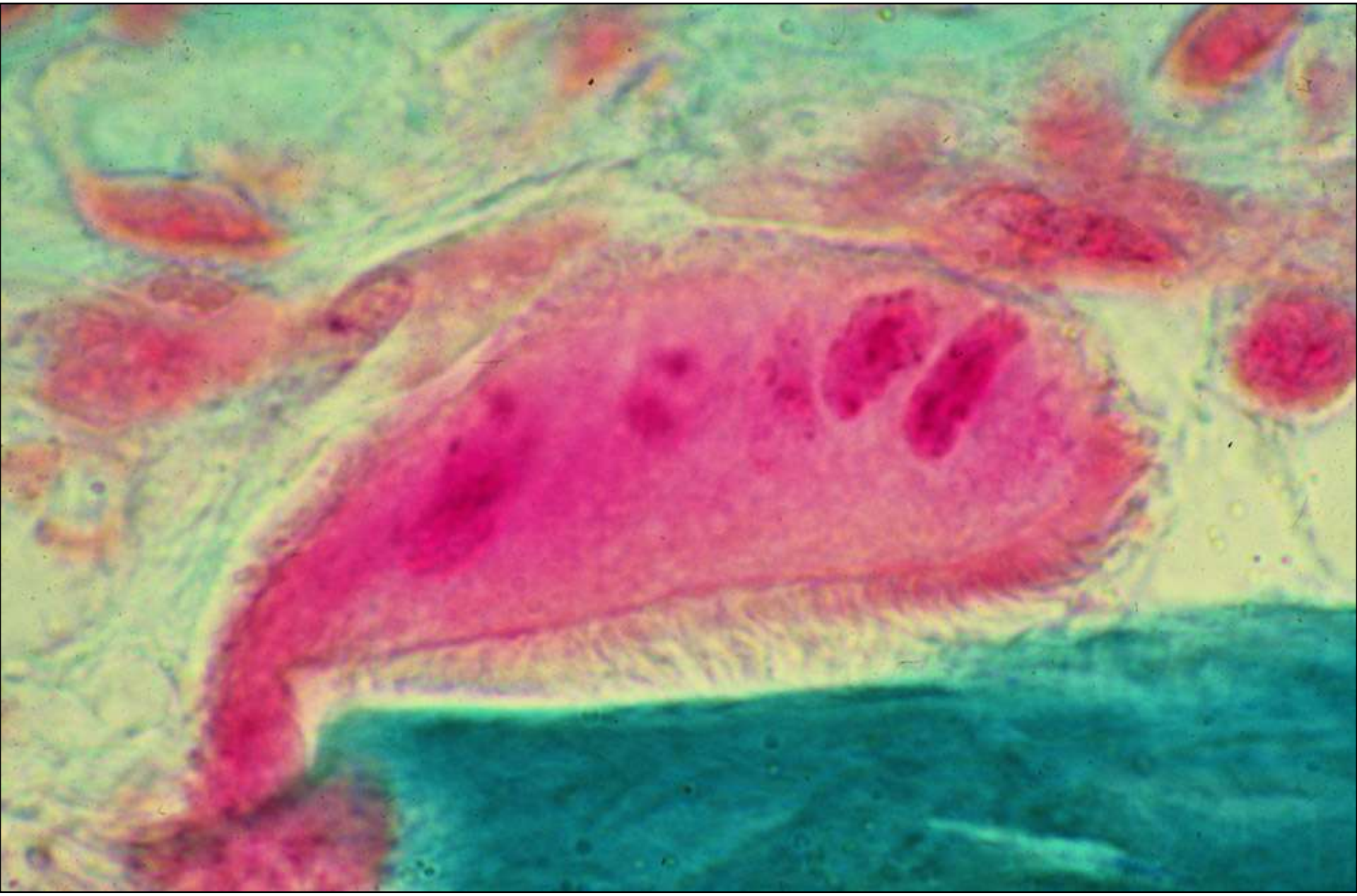


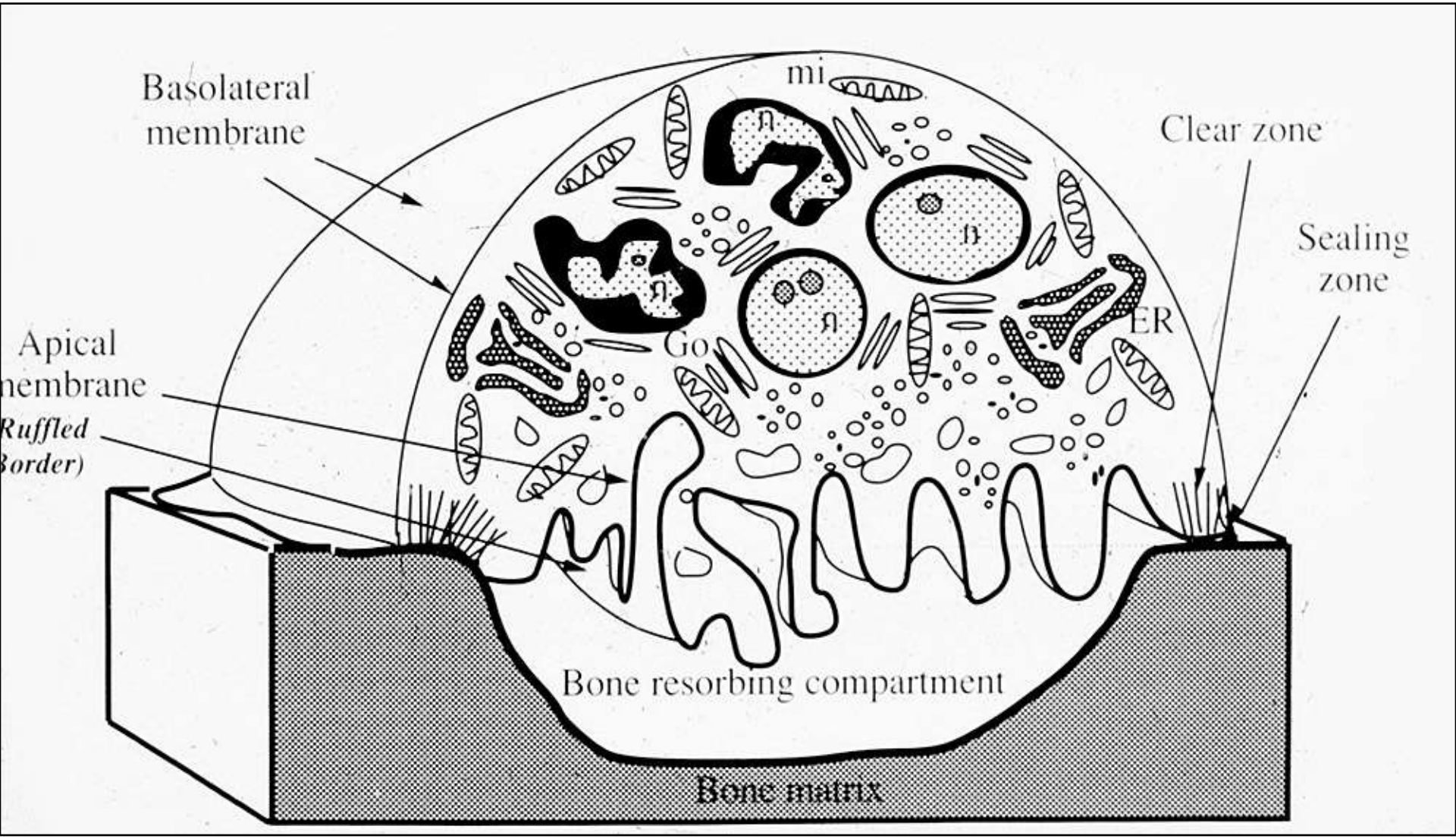
9

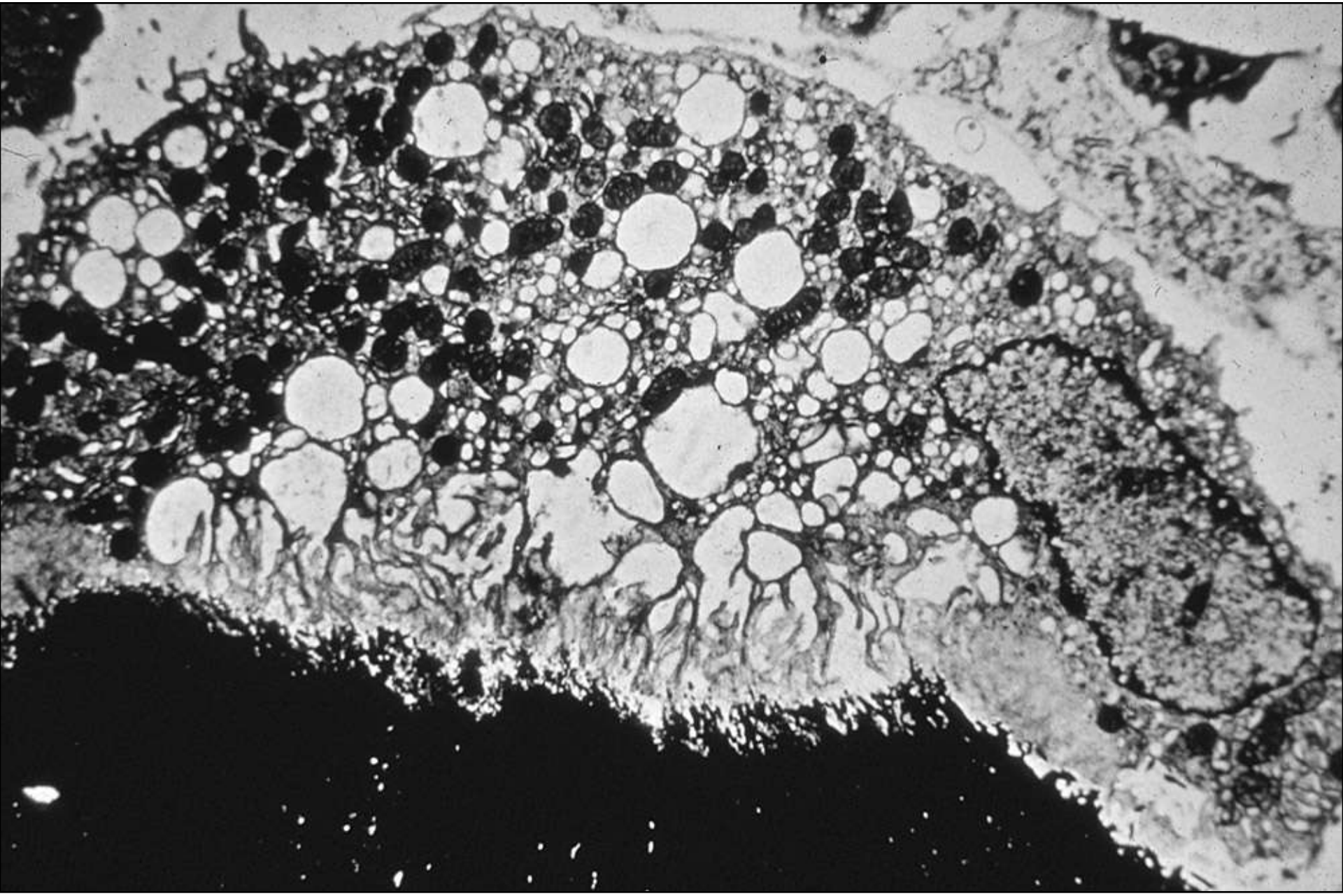

I
II
III
IV
V
VI
A
B
C
D
E
F
G

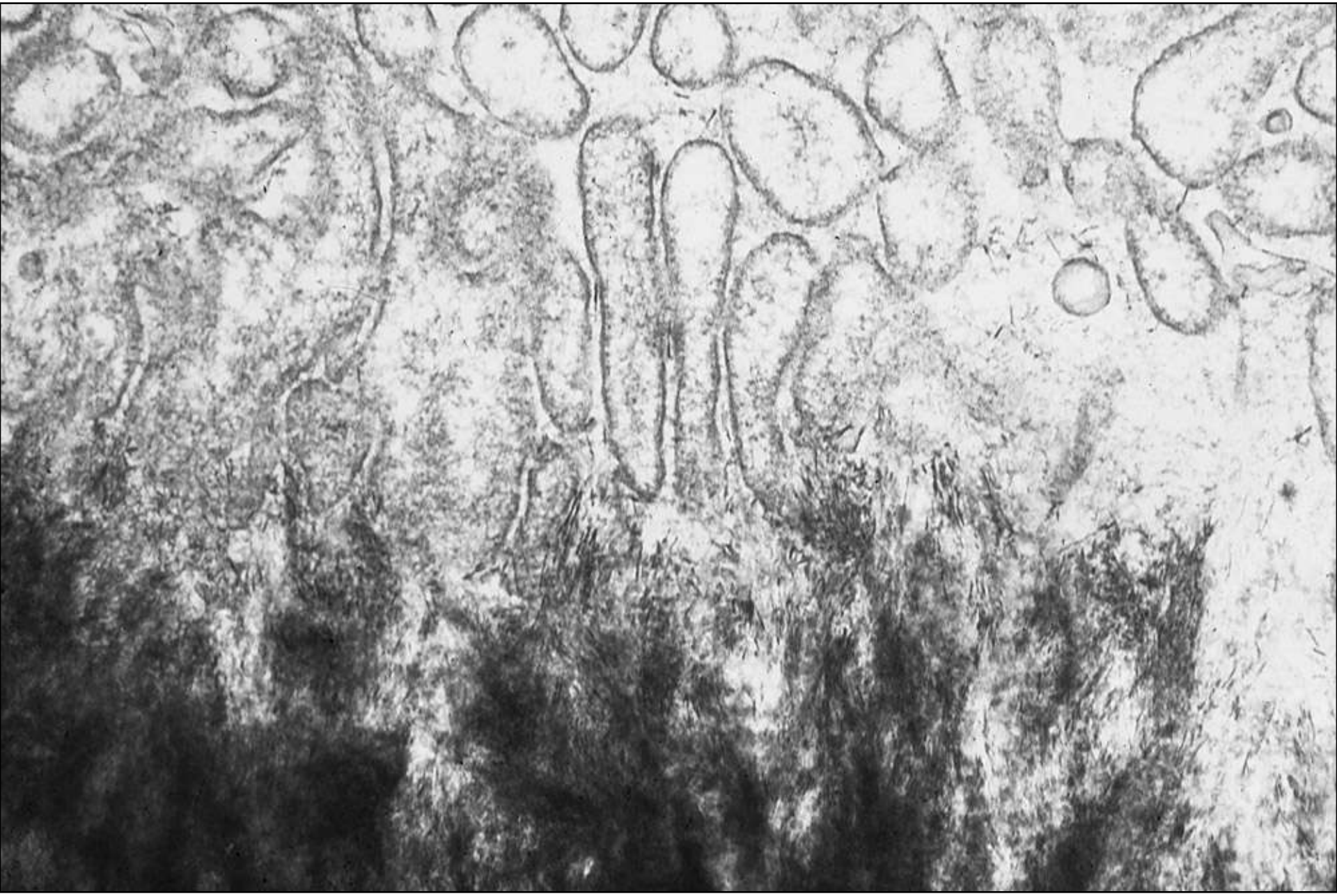
Osteoclasts

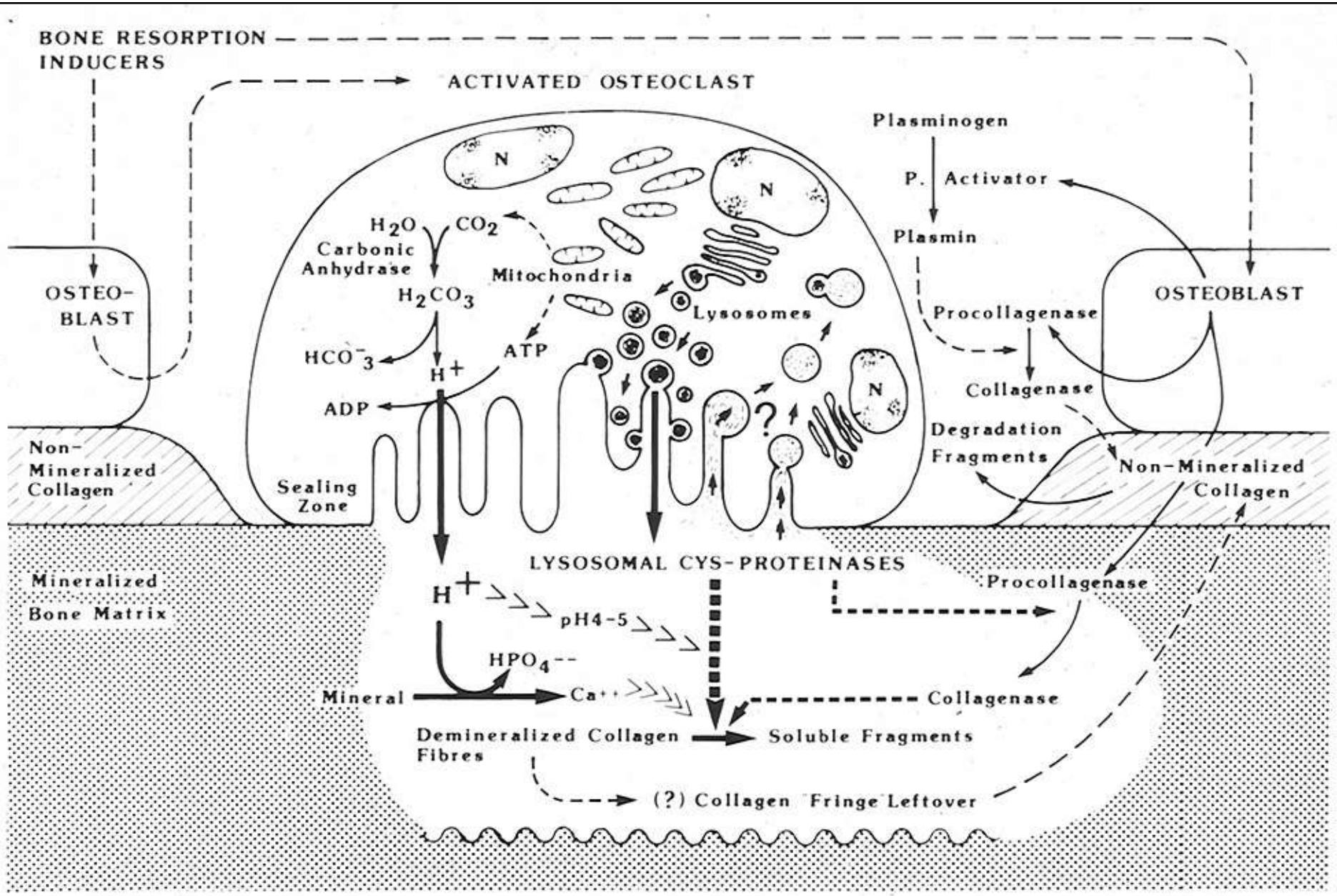


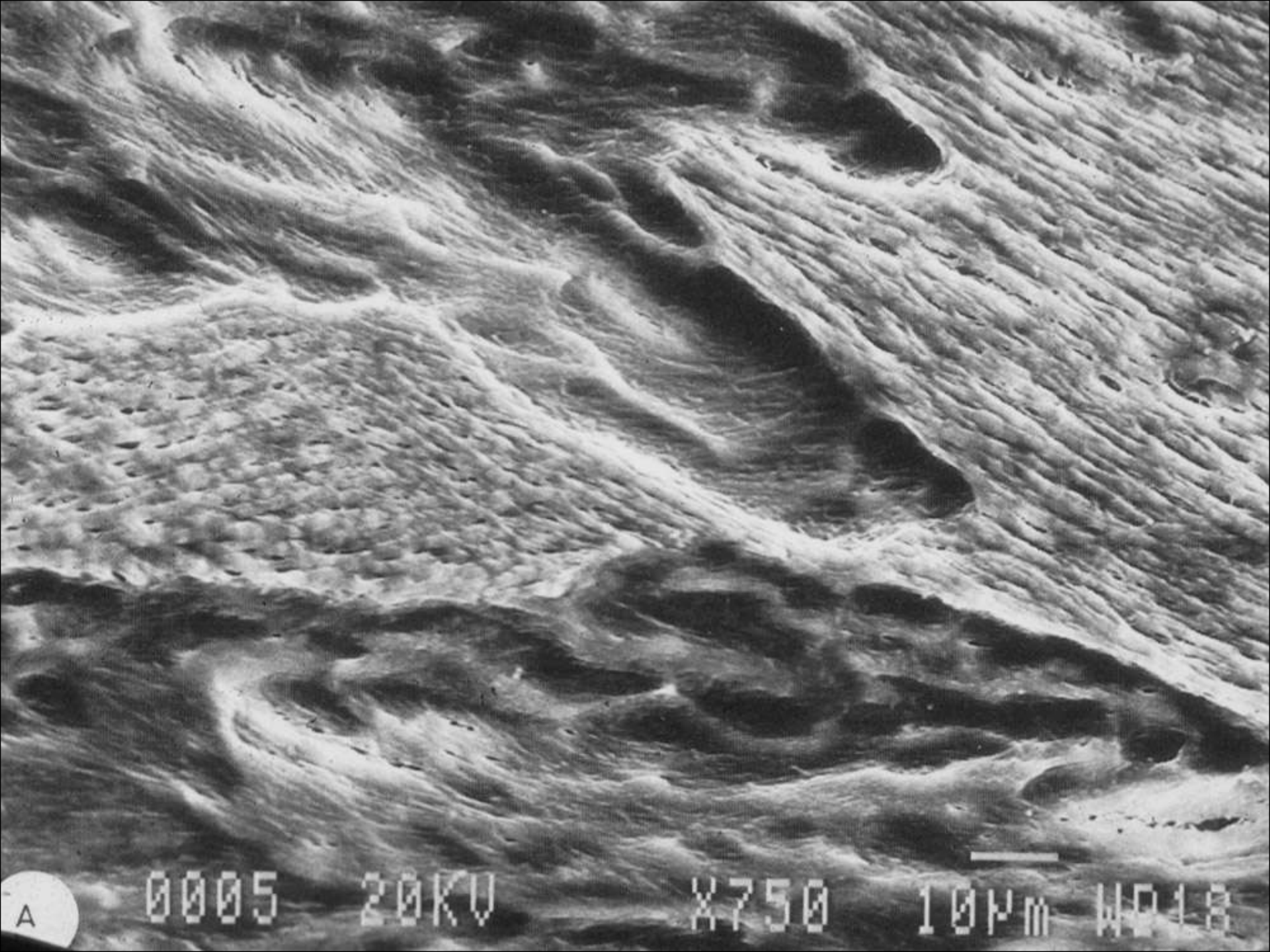



Basolateral membrane
mi
Clear zone
Sealing zone
Apical membrane
(Ruffled Border)
Go
ER
Bone resorbing compartment
Bone matrix

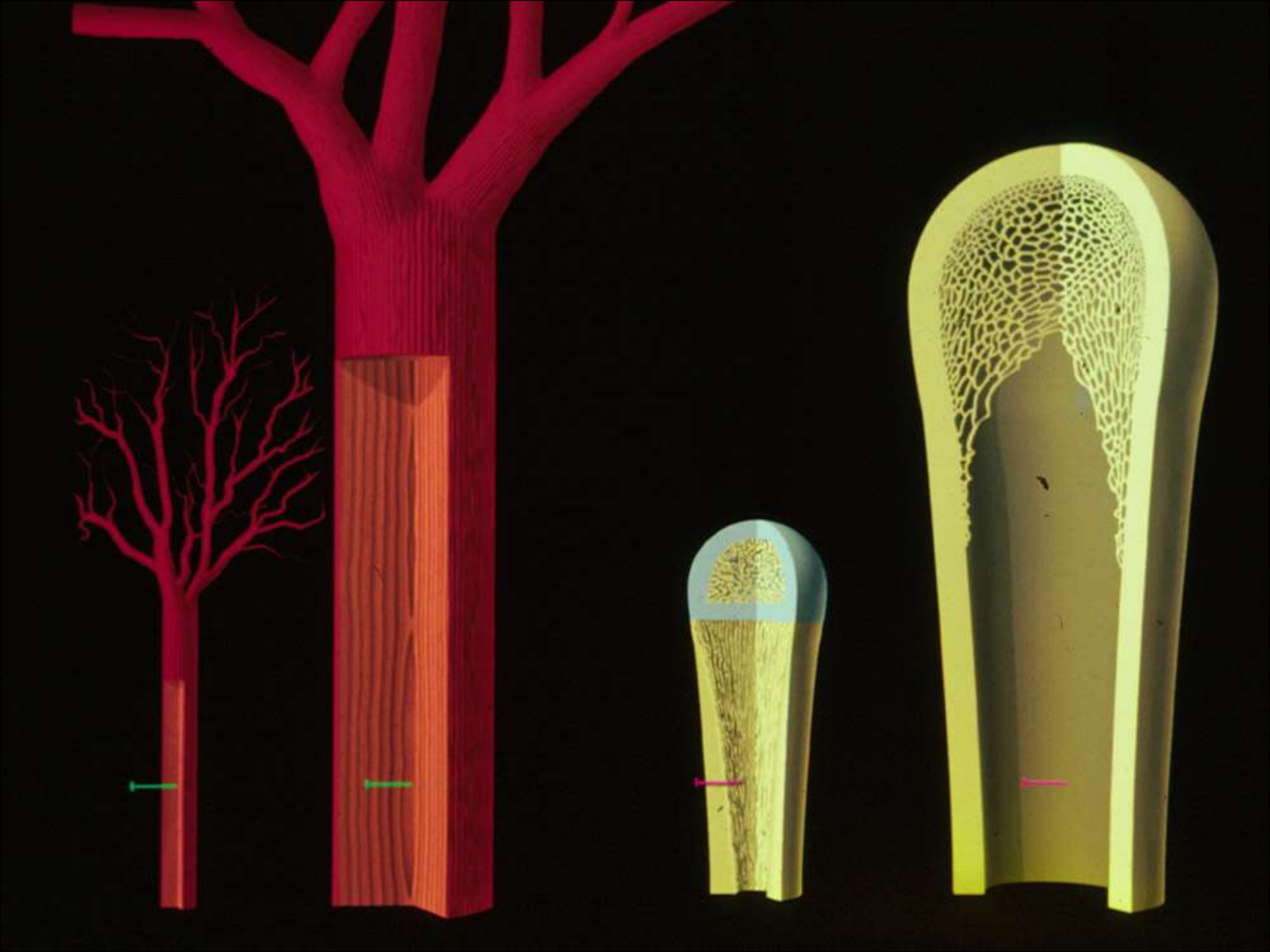


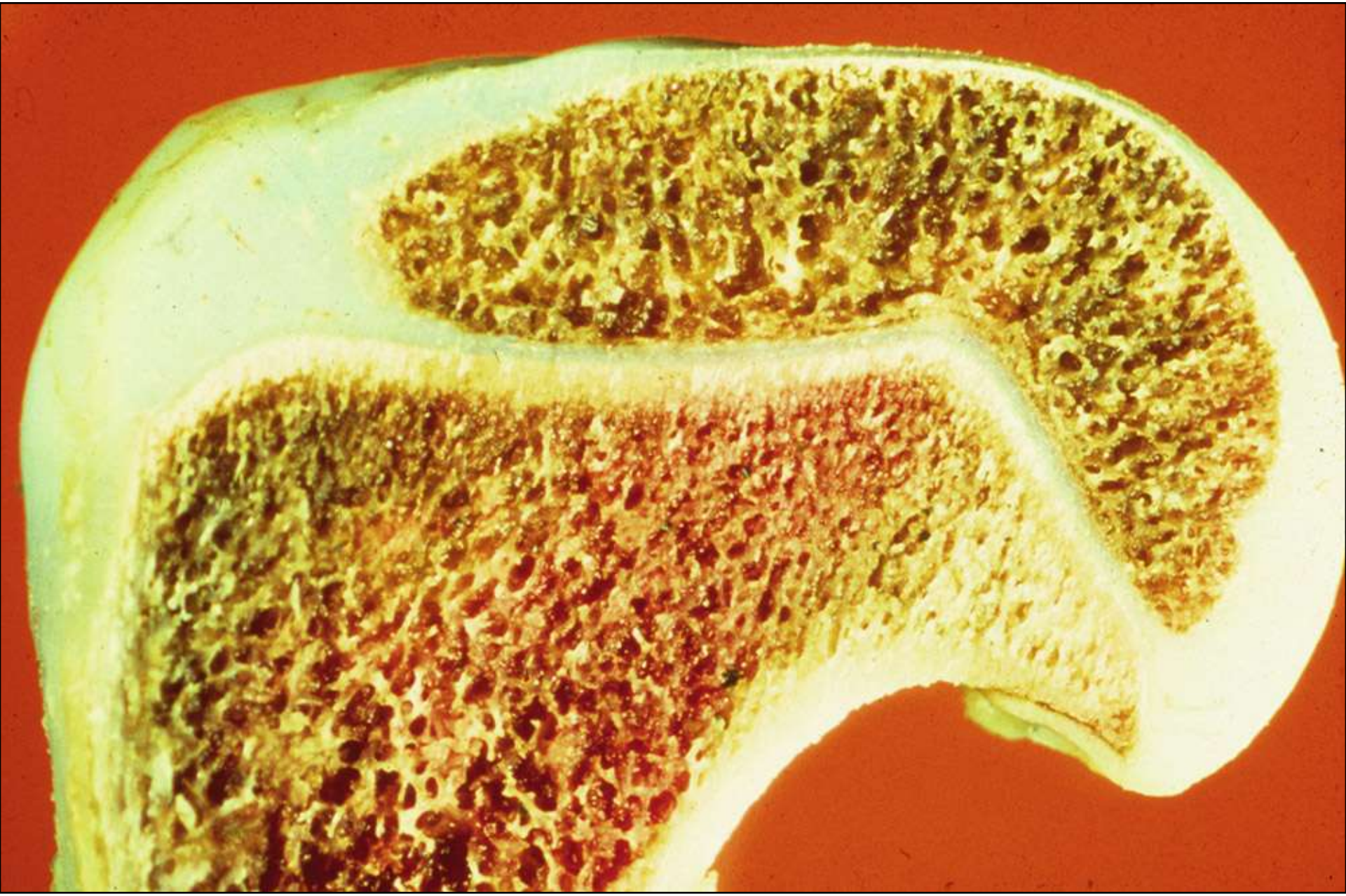


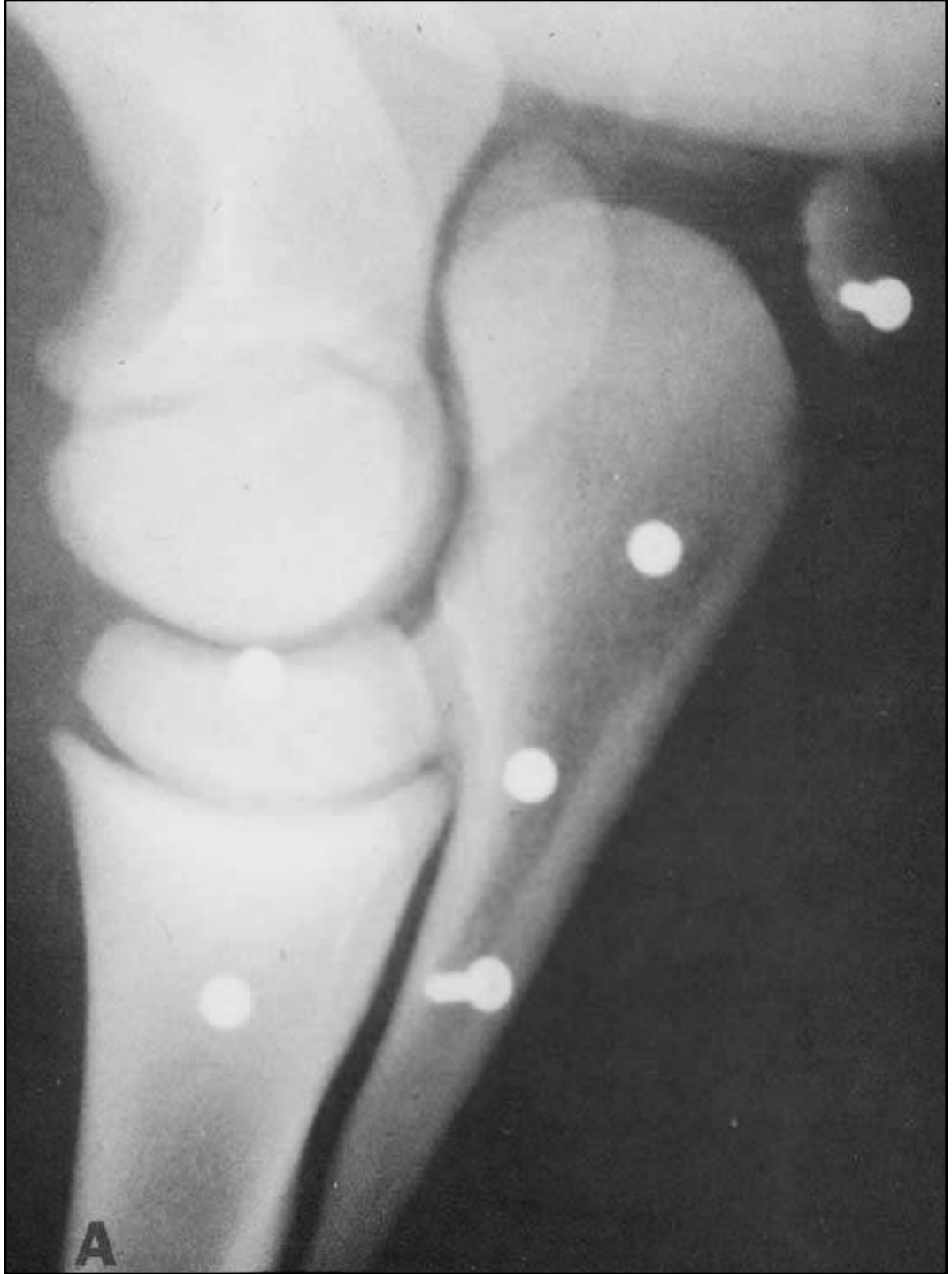

BONE RESORPTION INDUCERS
ACTIVATED OSTEOCLAST
Plasminogen
P. Activator
Plasmin
OSTEO-BLAST
OSTEOBLAST
N
H_2O
CO_2
Carbonic Anhydrase
H_2CO_3
Mitochondria
Lysosomes
Procollagenase
Collagenase
HCO^-_3
H^+
ATP
ADP
Degradation Fragments
Non-Mineralized Collagen
Sealing Zone
LYSOSOMAL CYS-PROTEINASES
Mineralized Bone Matrix
pH4-5
HPO_4^{--}
Mineral
Ca^{++}
Demineralized Collagen Fibres
Soluble Fragments
(?) Collagen Fringe Leftover


0005 20KV X750 10µm WD18
A

Endochondral Bone Growth






A

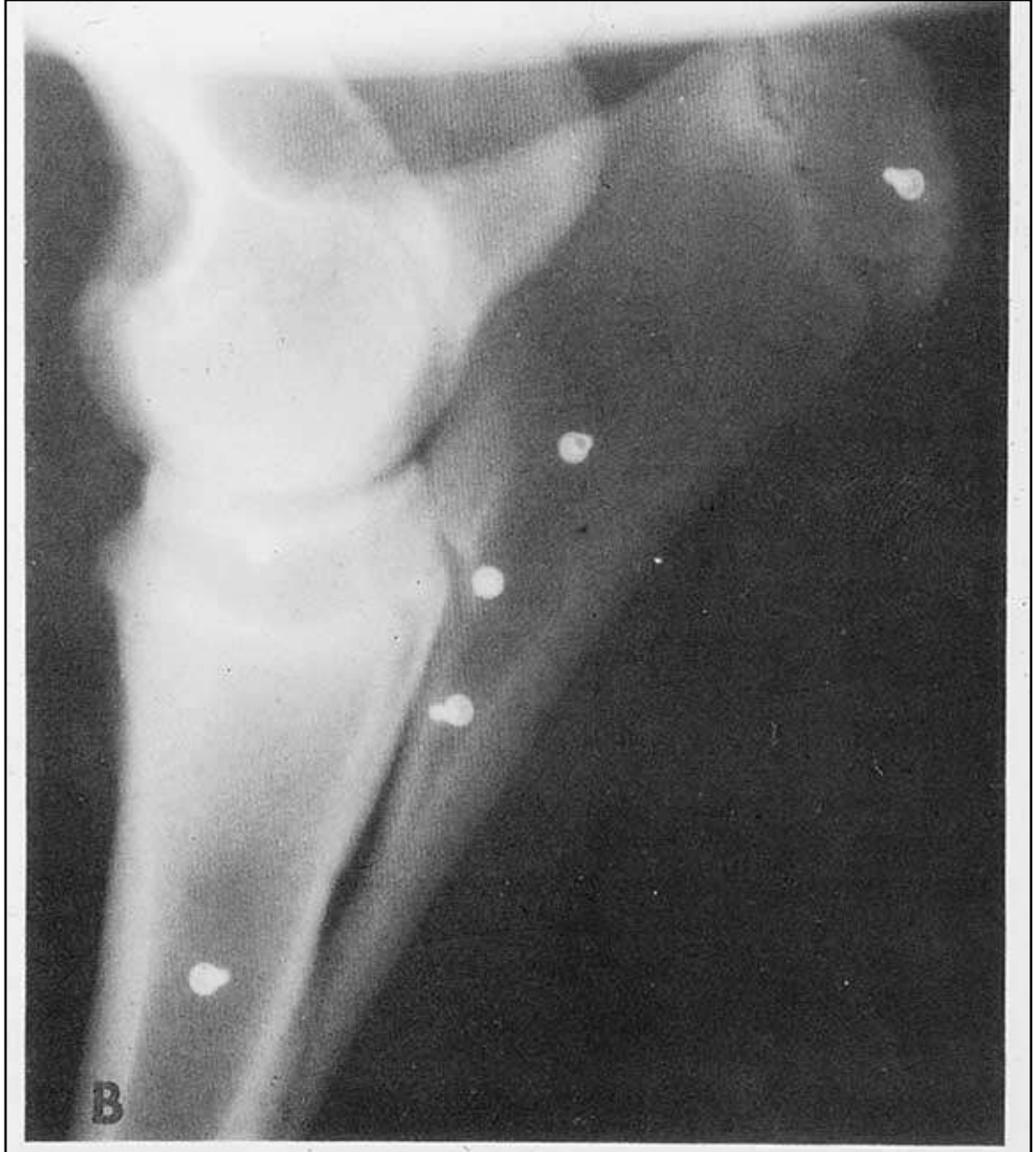


Figure 5—Lateral radiographic views of a foal immediately after surgical placement of markers (A) and 72 weeks later (B). Notice that the location of marker 3 (*see* Figure 1 legend) in relation to the radial epiphysis did not change.

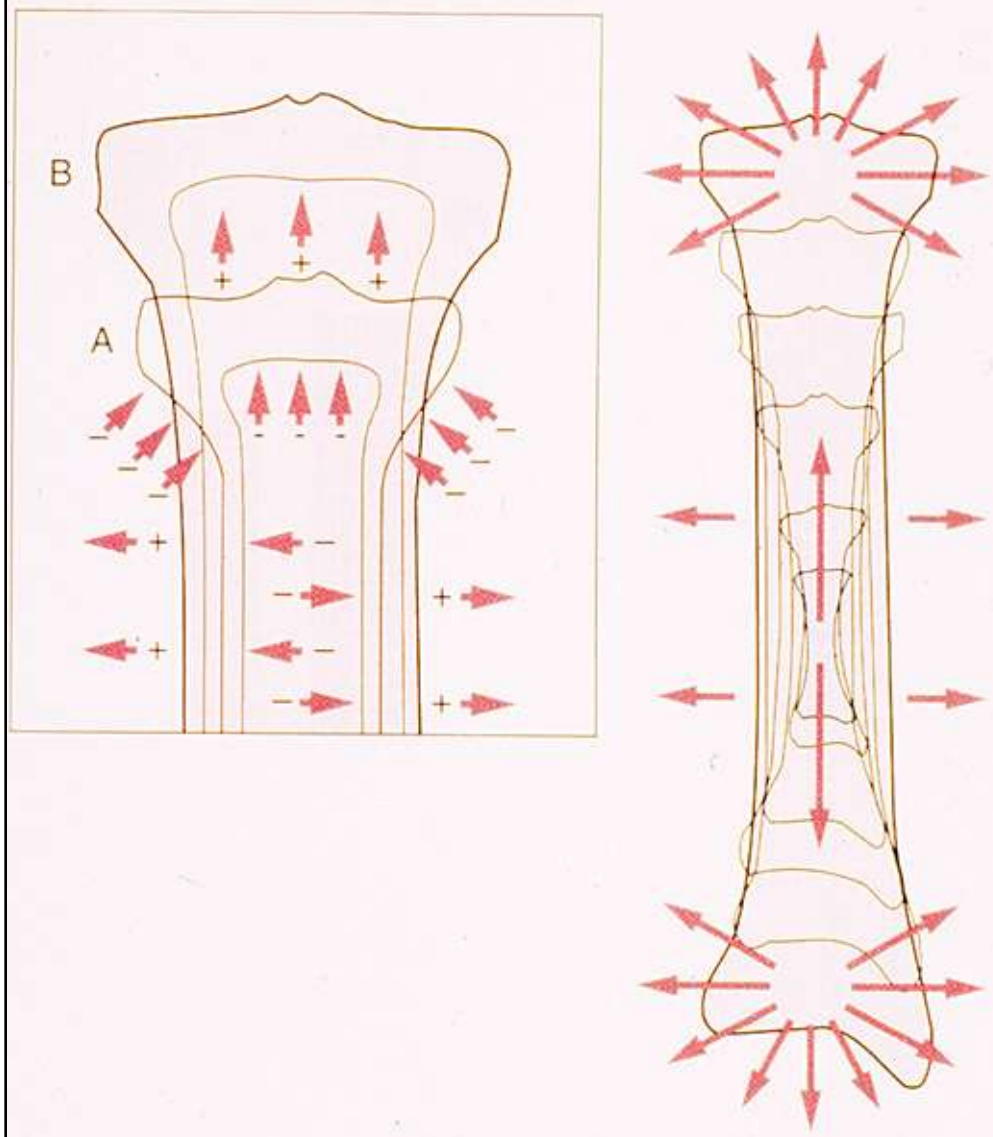
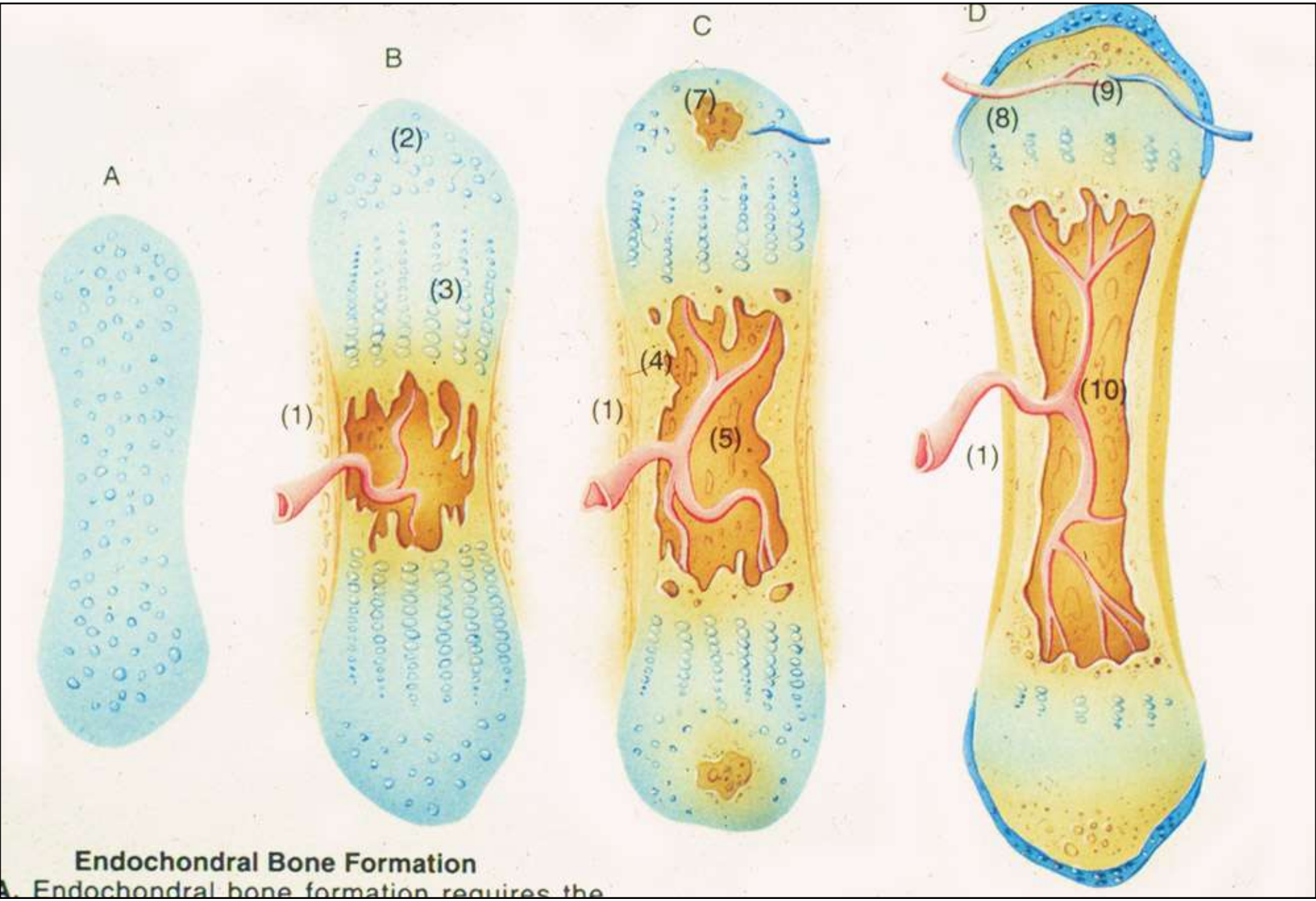
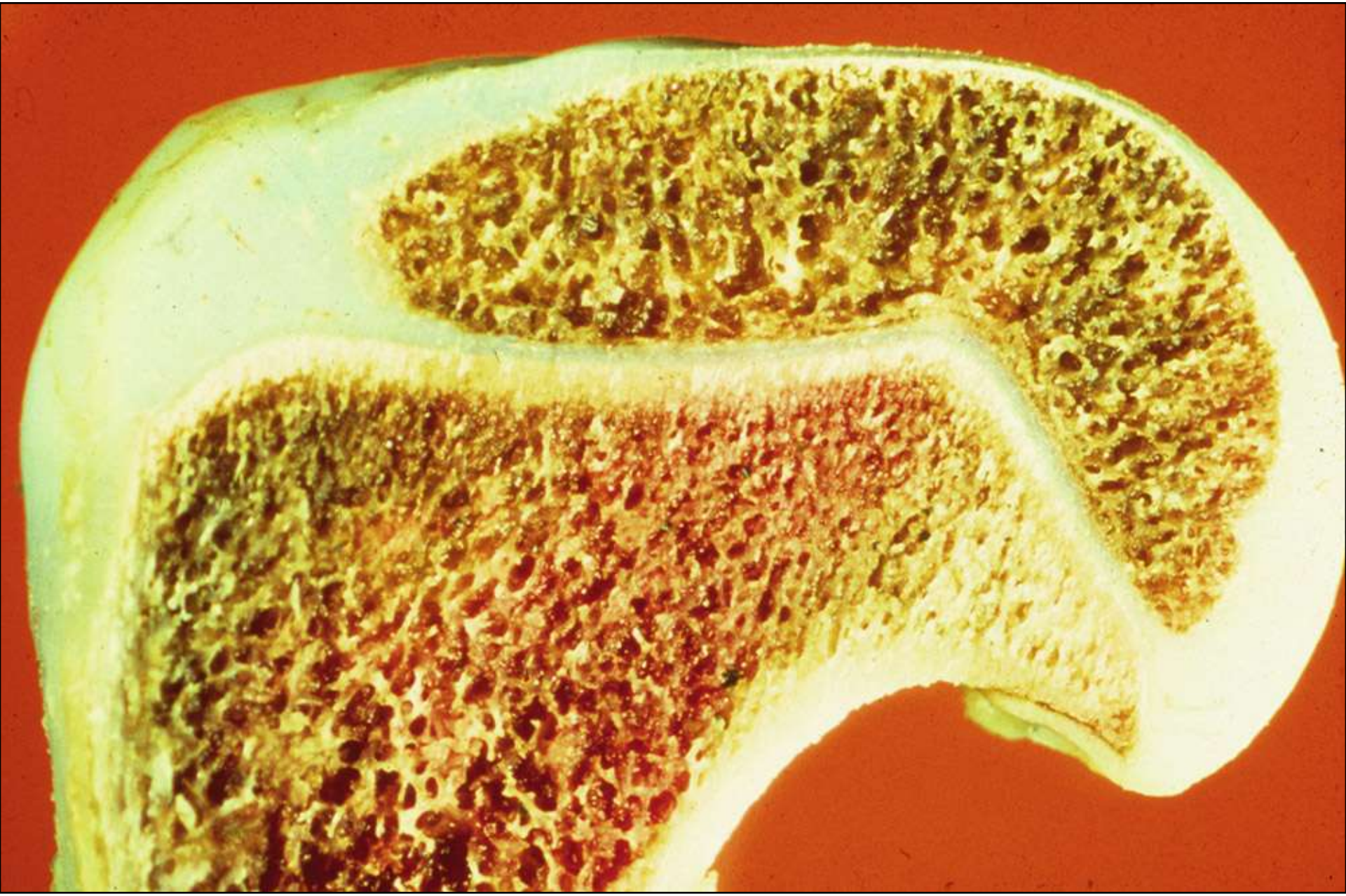


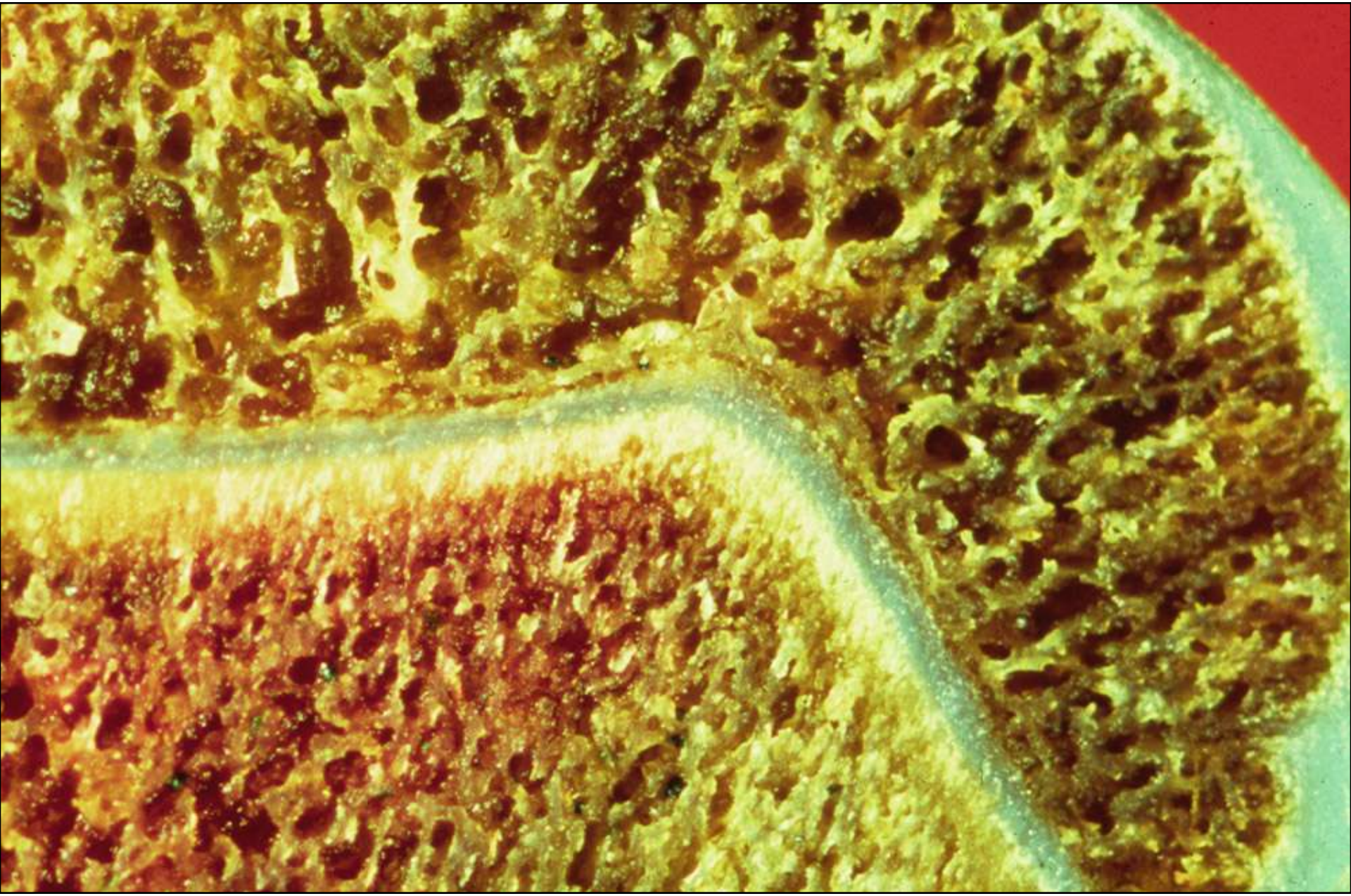
FIG. 25. Bone growth. By cellular resorption or formation, bone is either resorbed or formed, yielding the eventual recognizable length, width, and structure of bone.

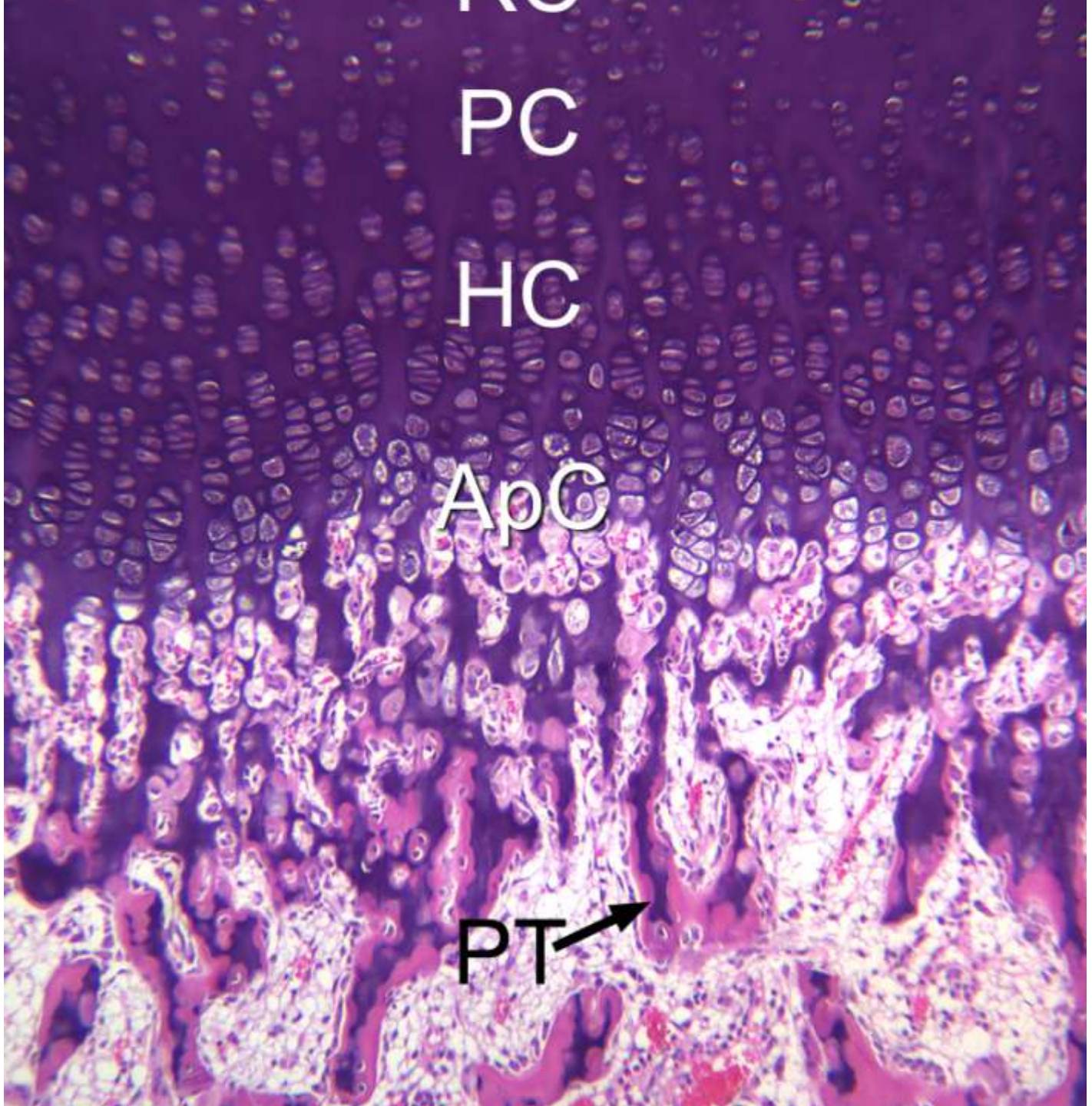


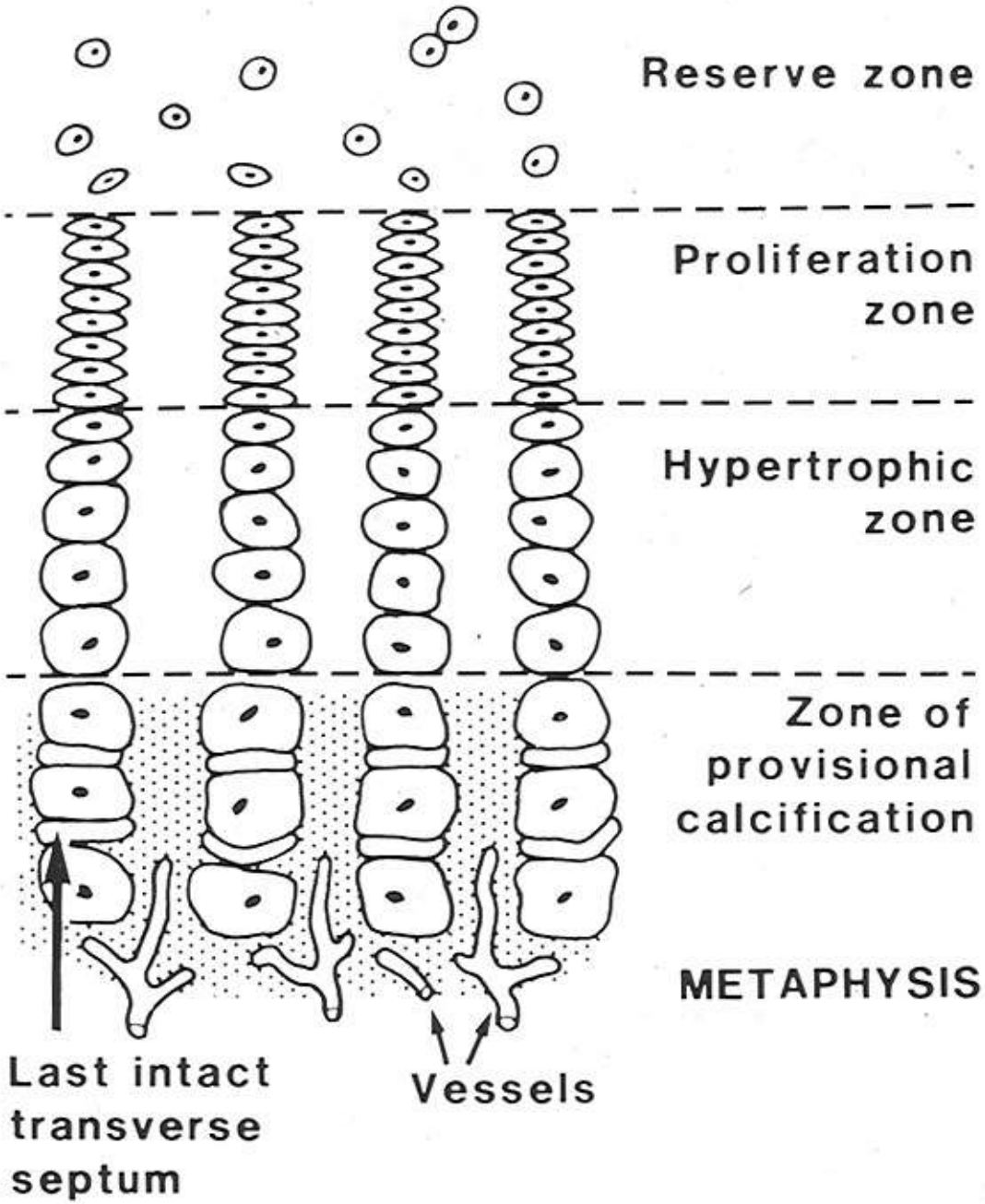
Endochondral Bone Formation

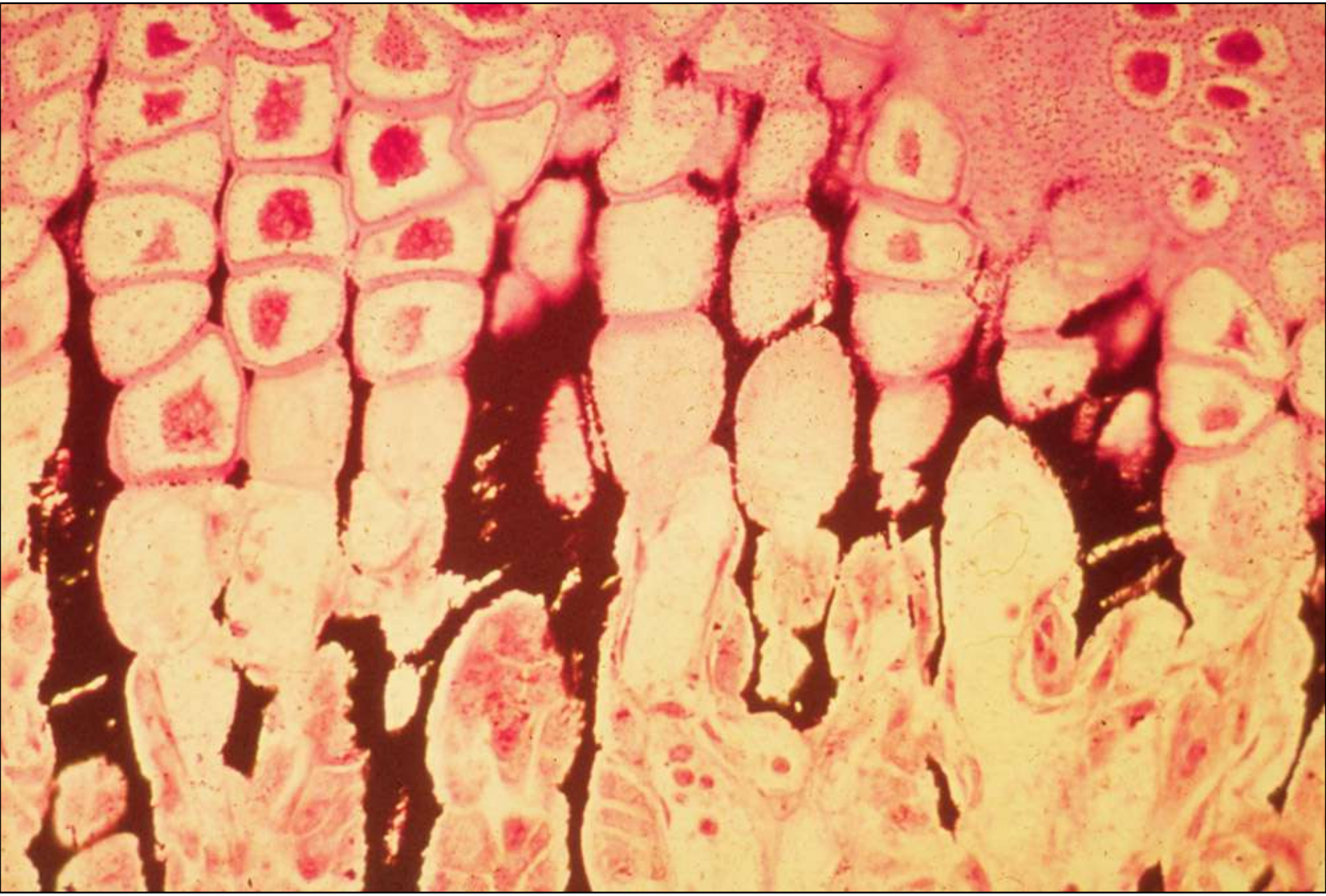
A. Endochondral bone formation requires the

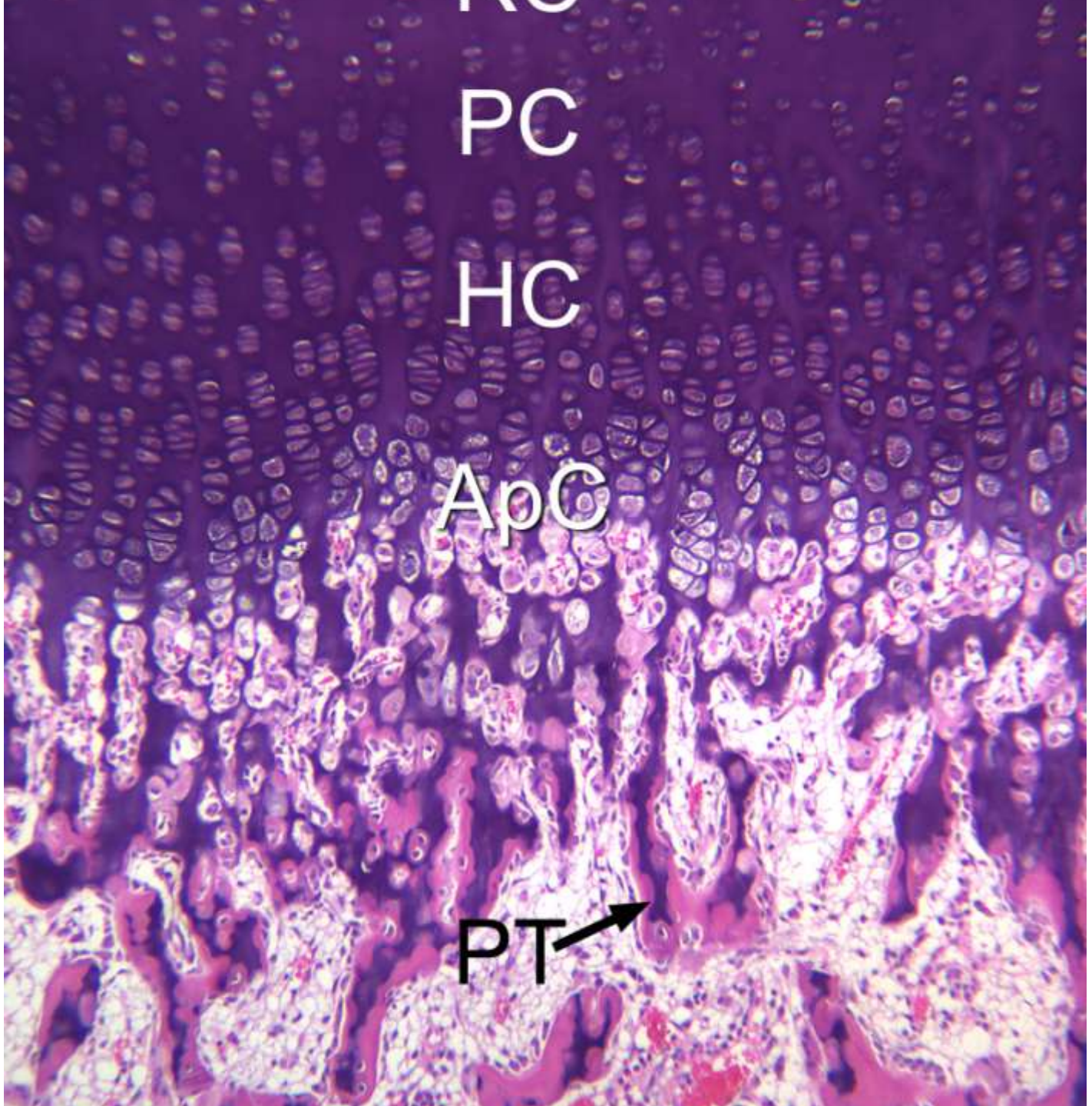


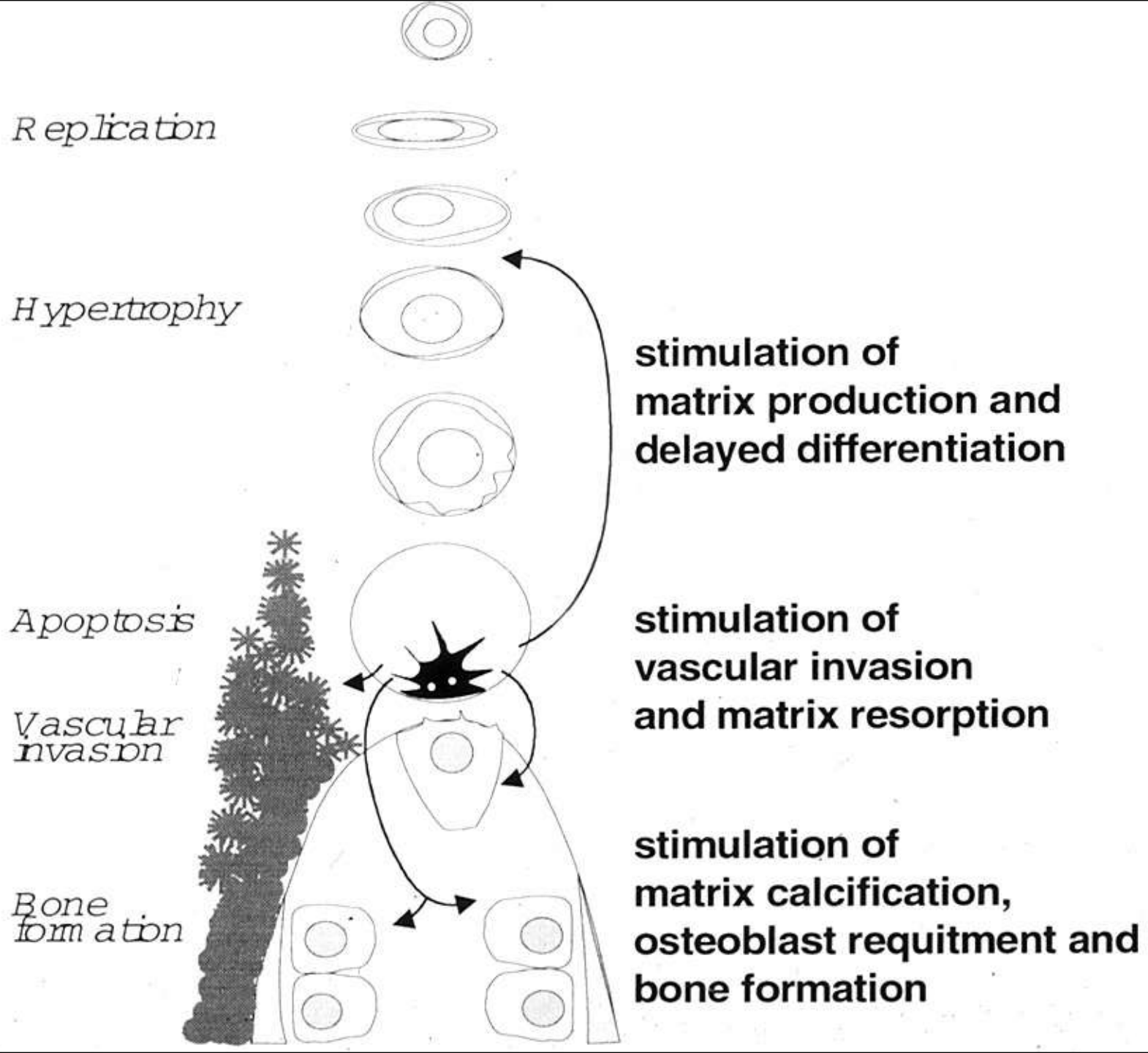


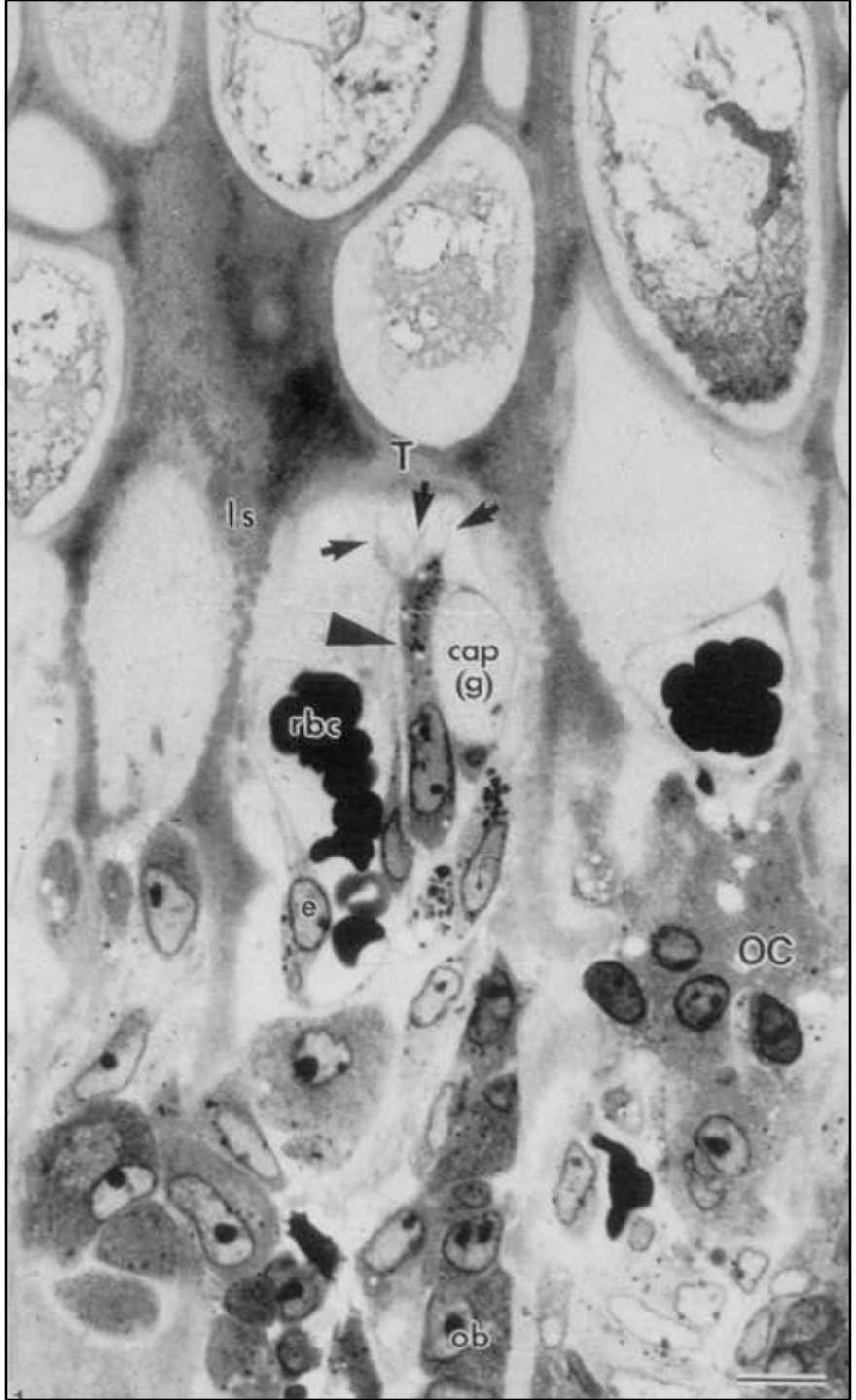

RC
PC
HC
ApC
PT

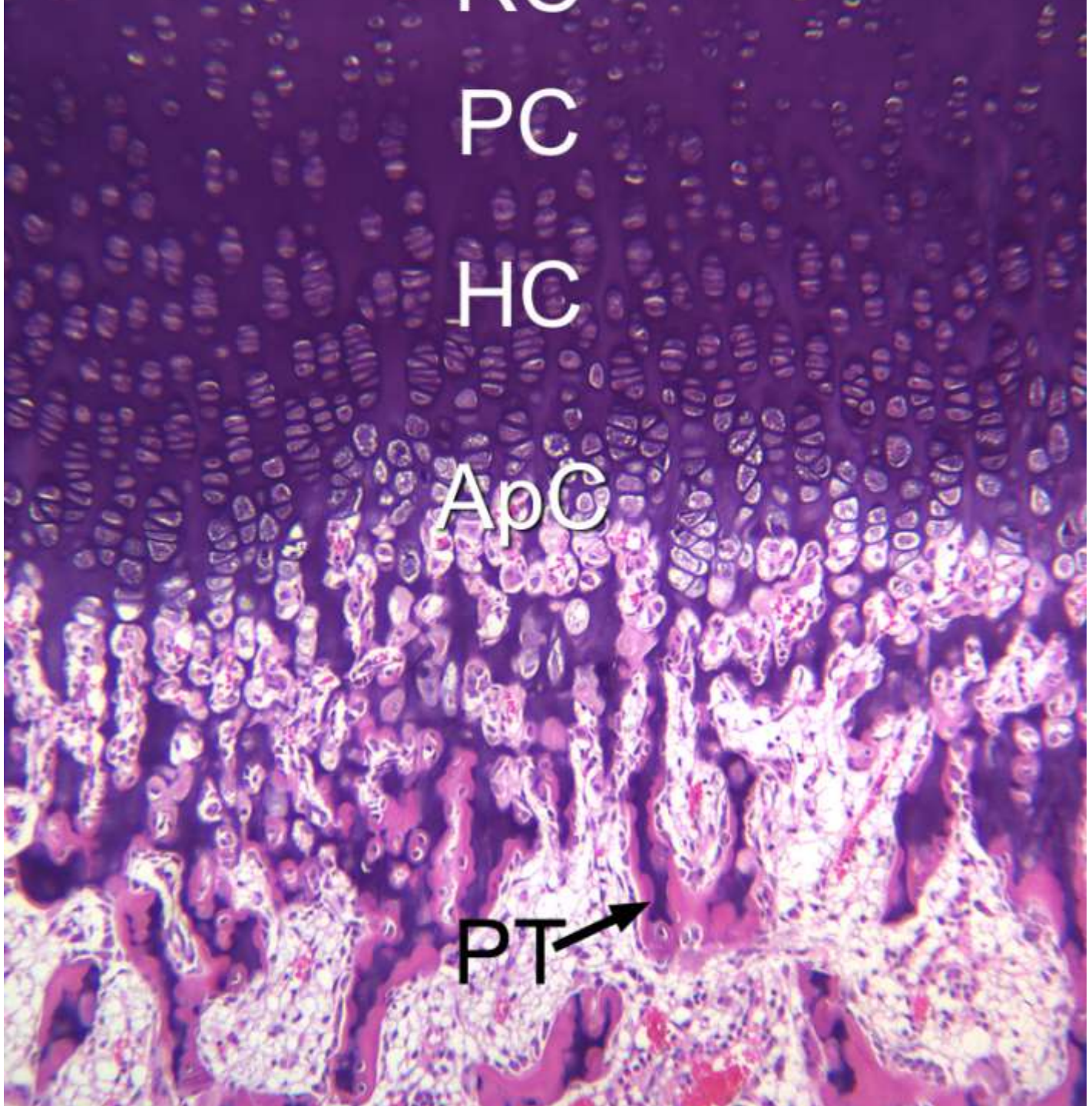

Reserve zone
Proliferation zone
Hypertrophic zone
Zone of provisional calcification
METAPHYSIS
Last intact transverse septum
Vessels

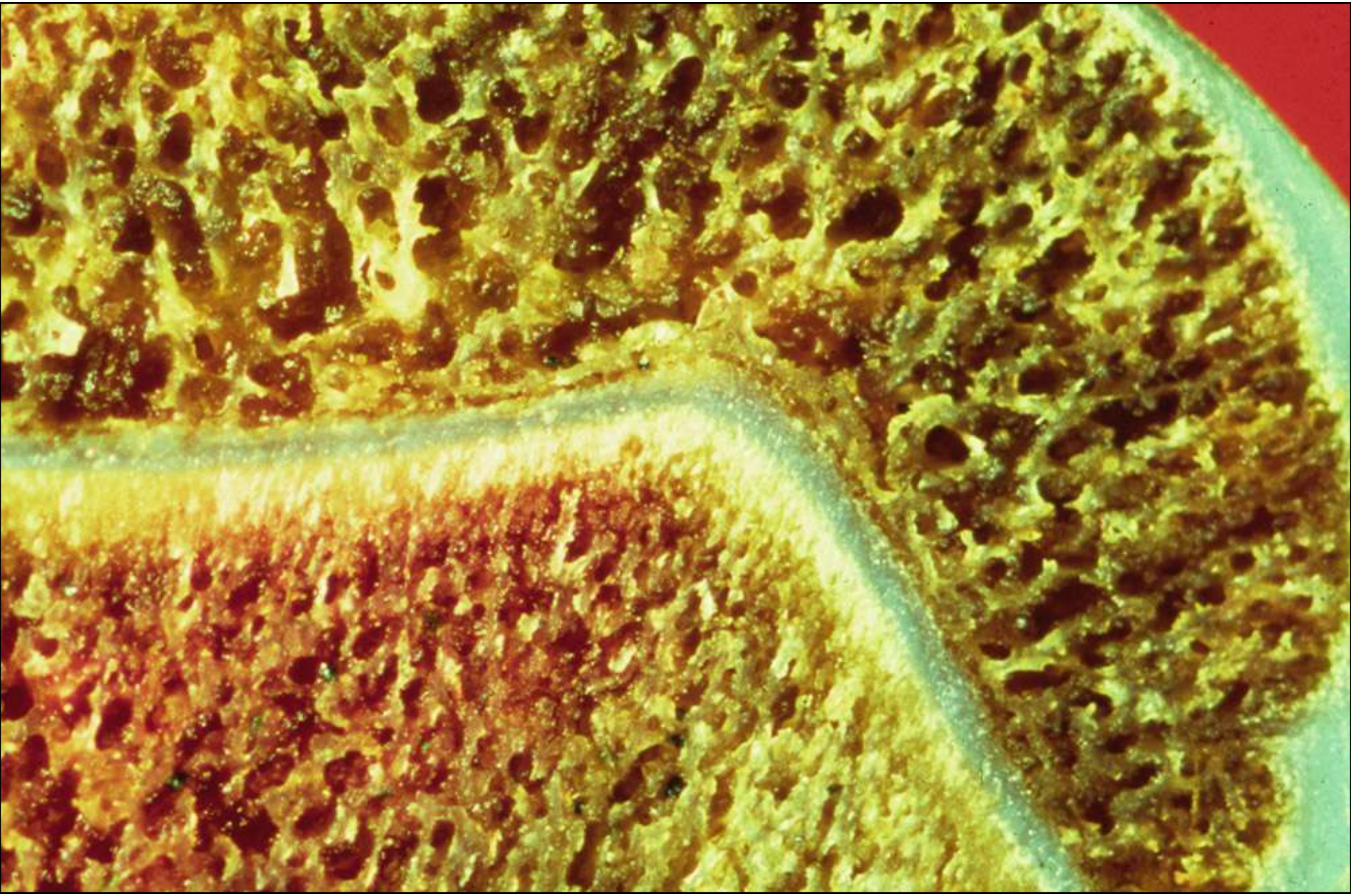


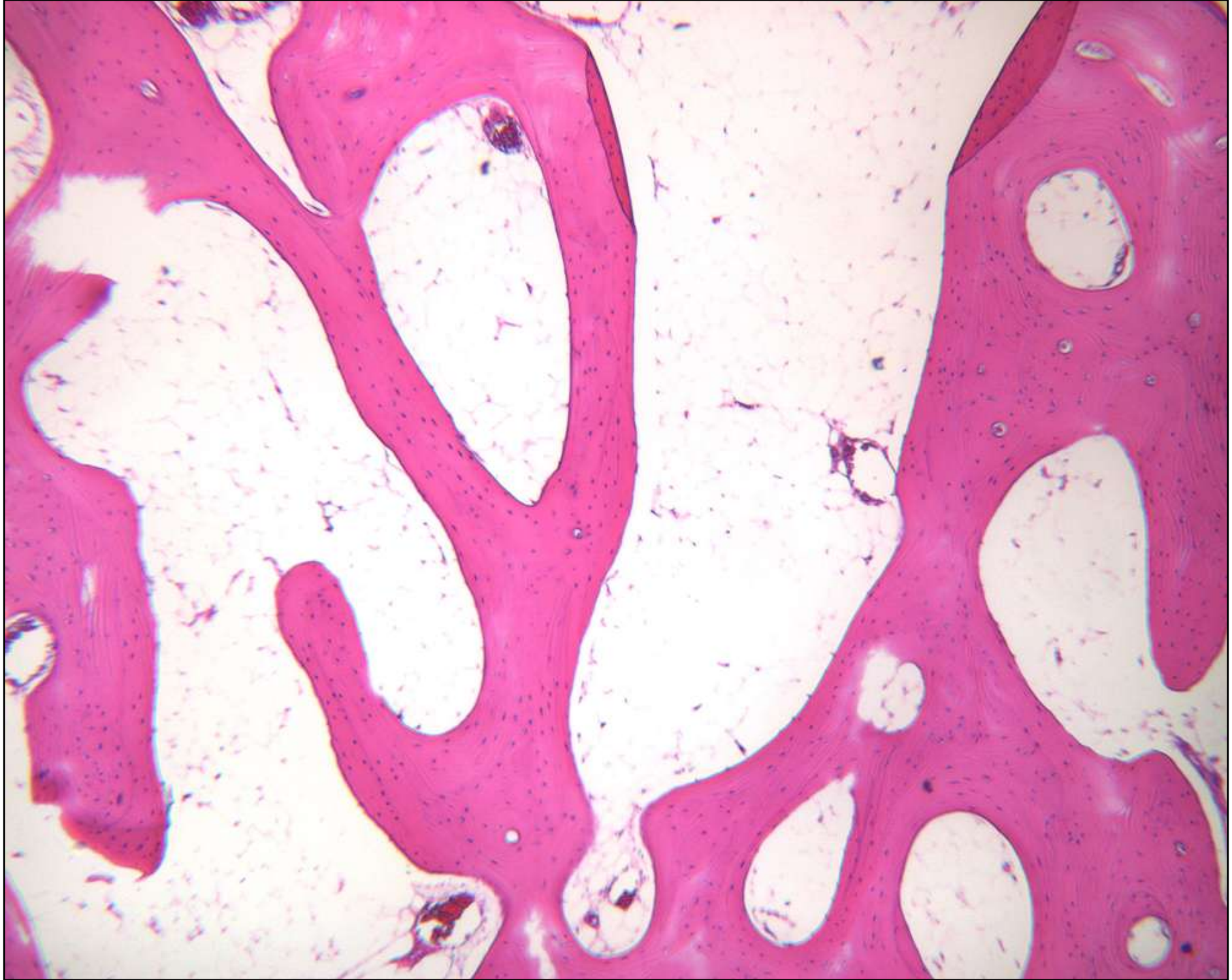

RC
PC
HC
ApC
PT

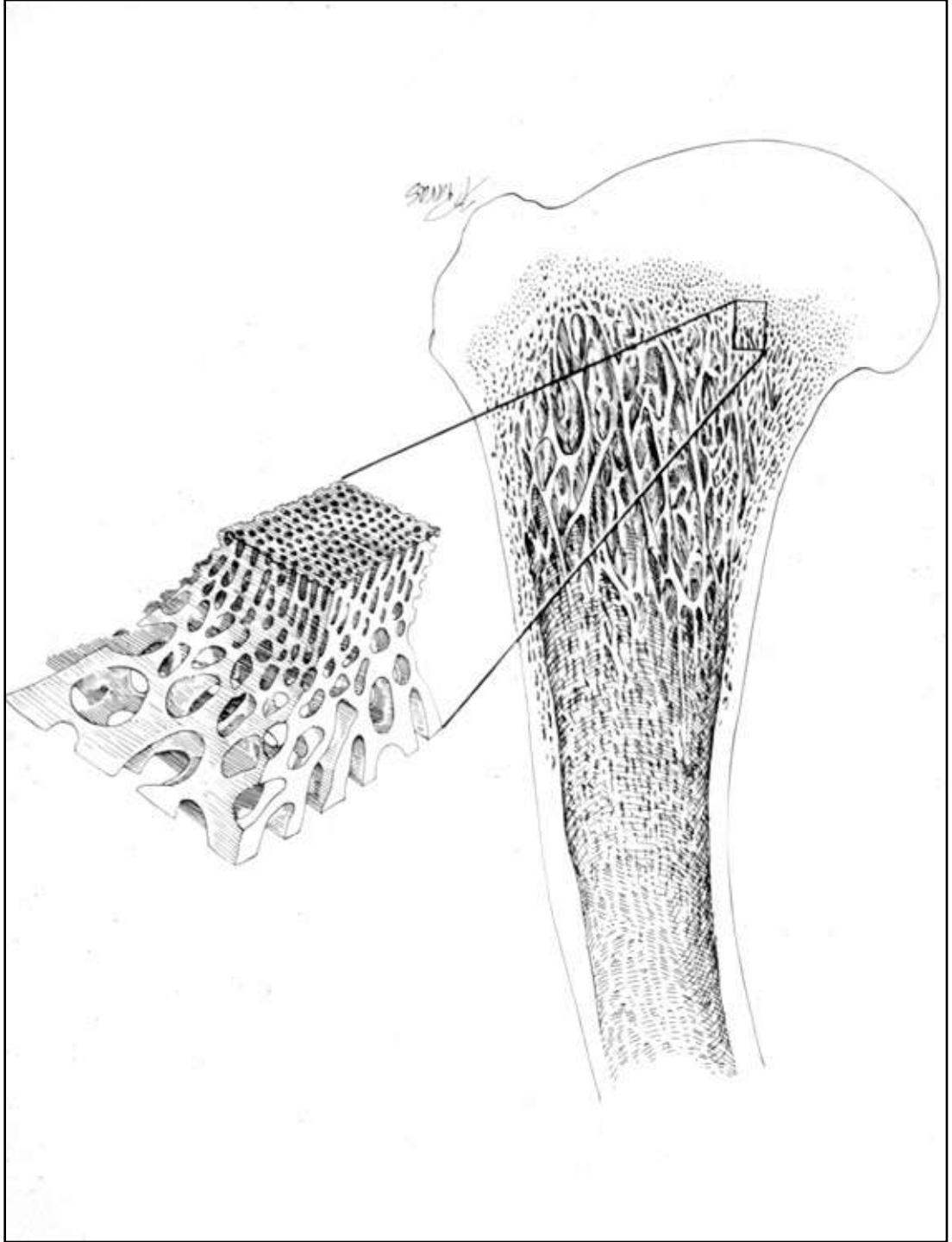

Replication
Hypertrophy
Apoptosis
Vascular invasion
Bone formation
stimulation of matrix production and delayed differentiation
stimulation of vascular invasion and matrix resorption
stimulation of matrix calcification, osteoblast requitment and bone formation

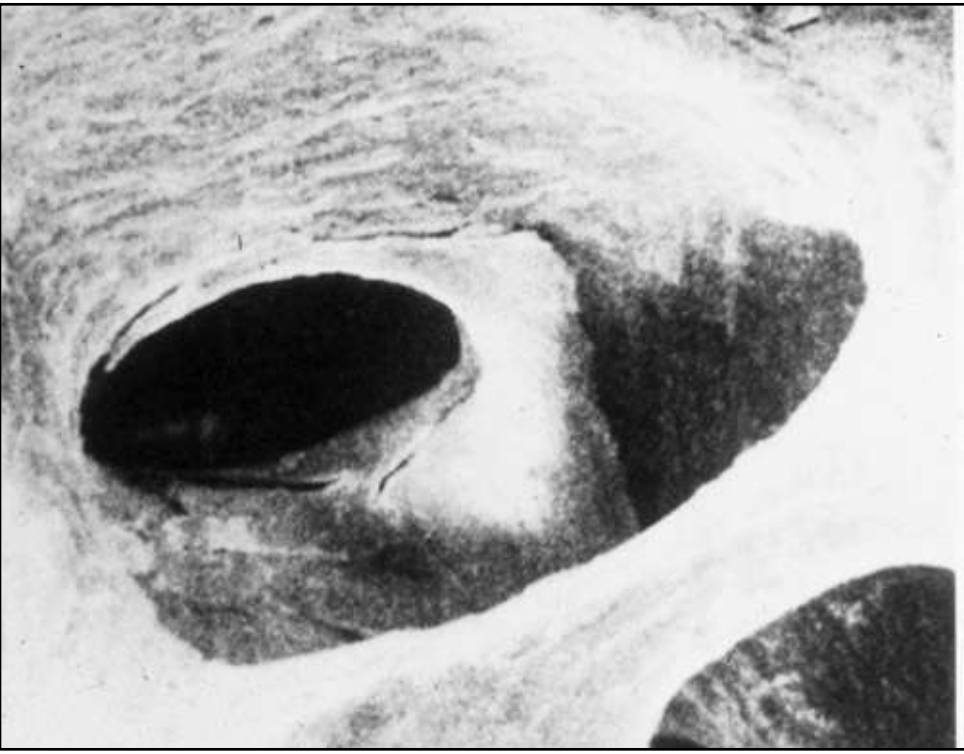

T
ls
cap
(g)
rbc
e
OC
ob

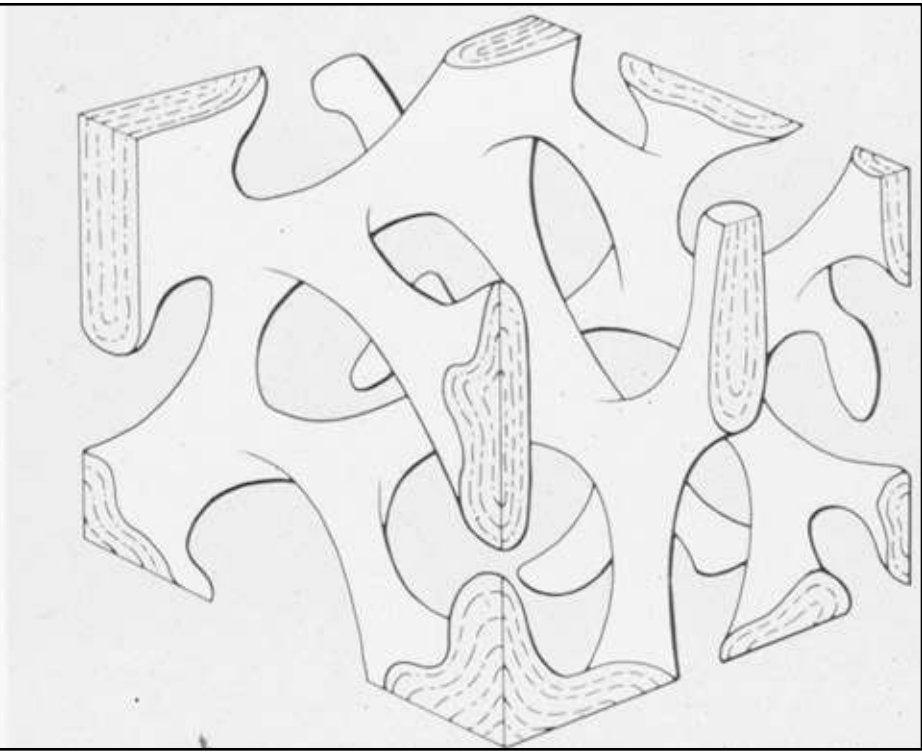

RC
PC
HC
ApC
PT

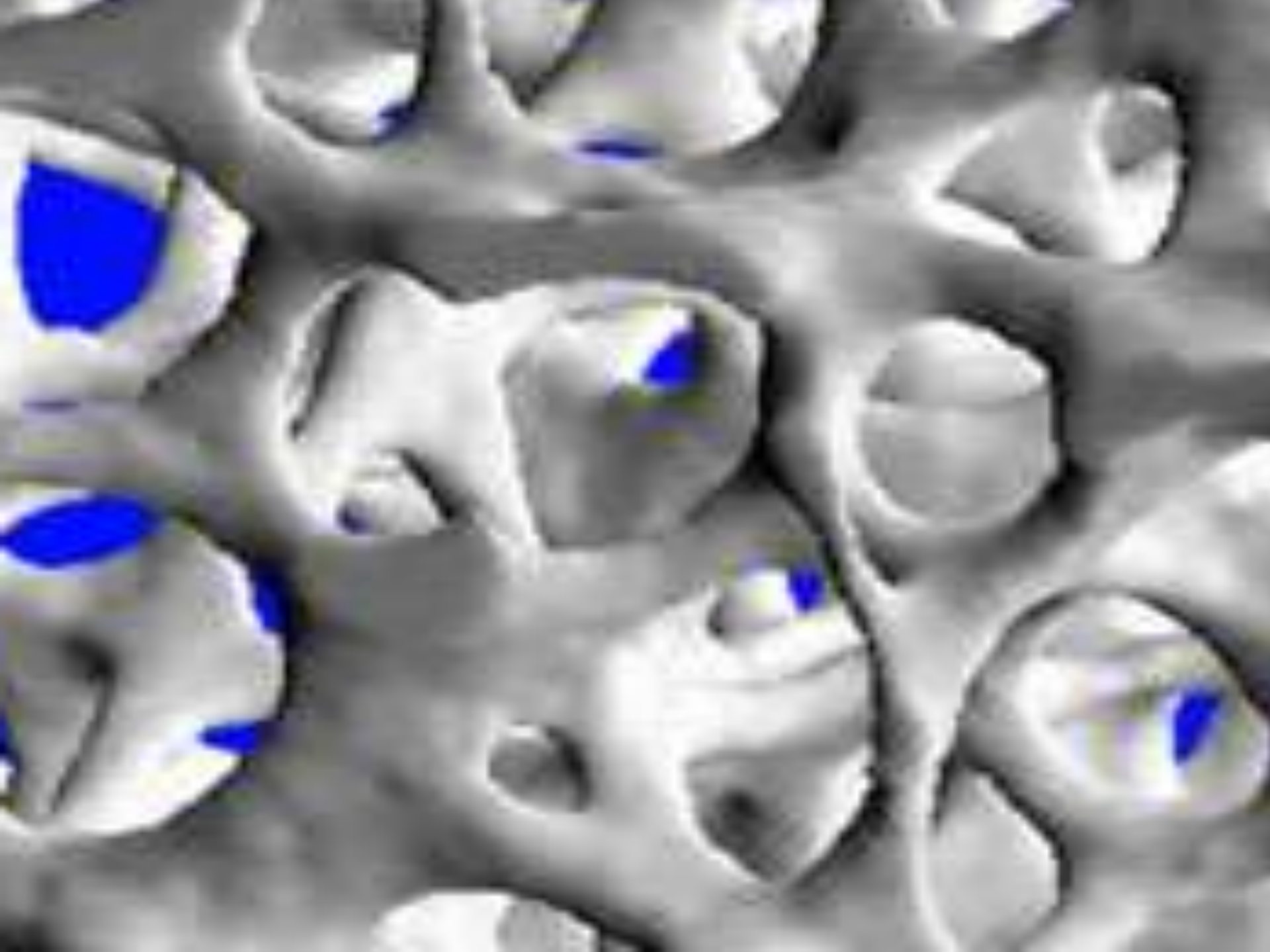




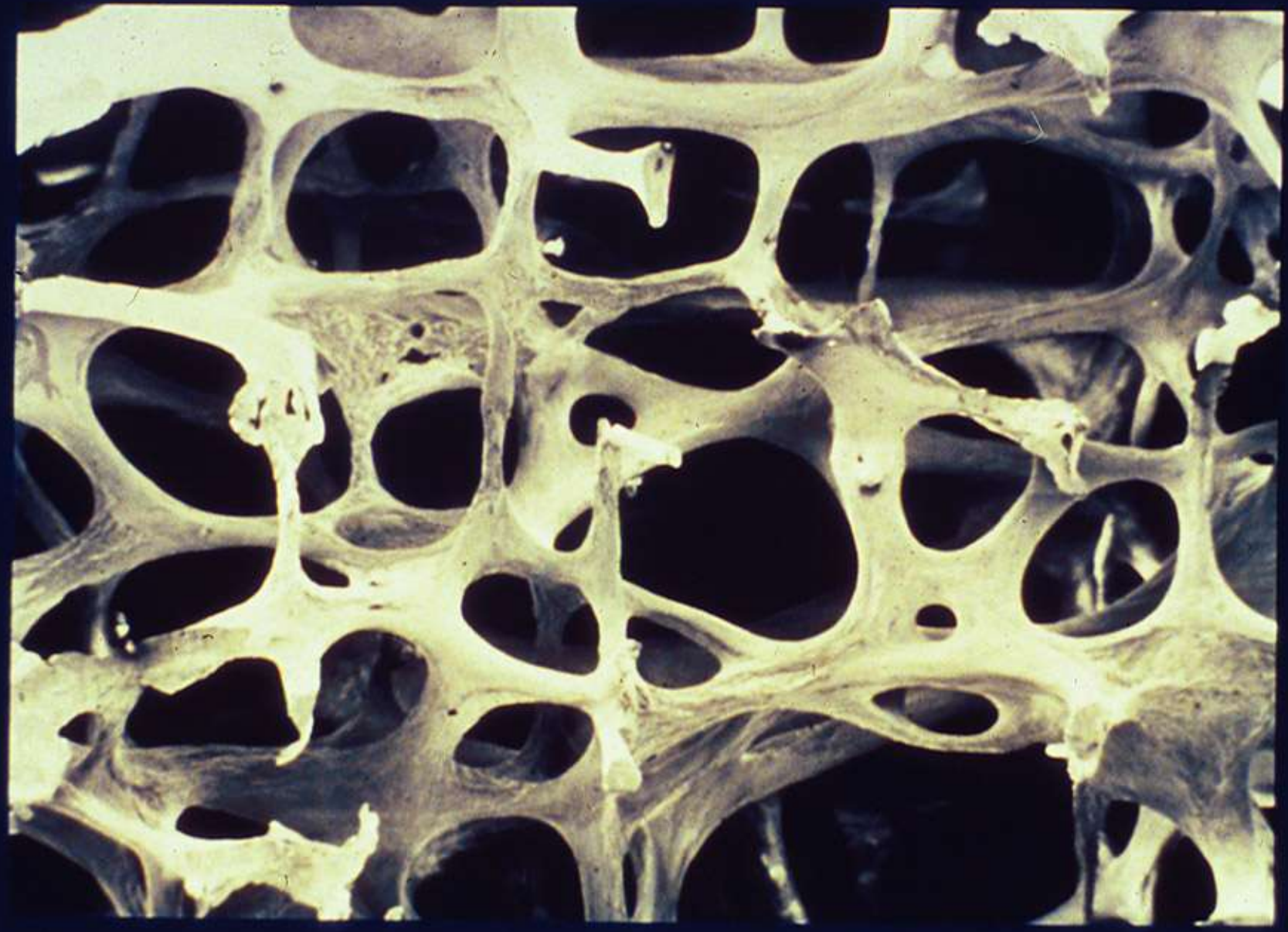




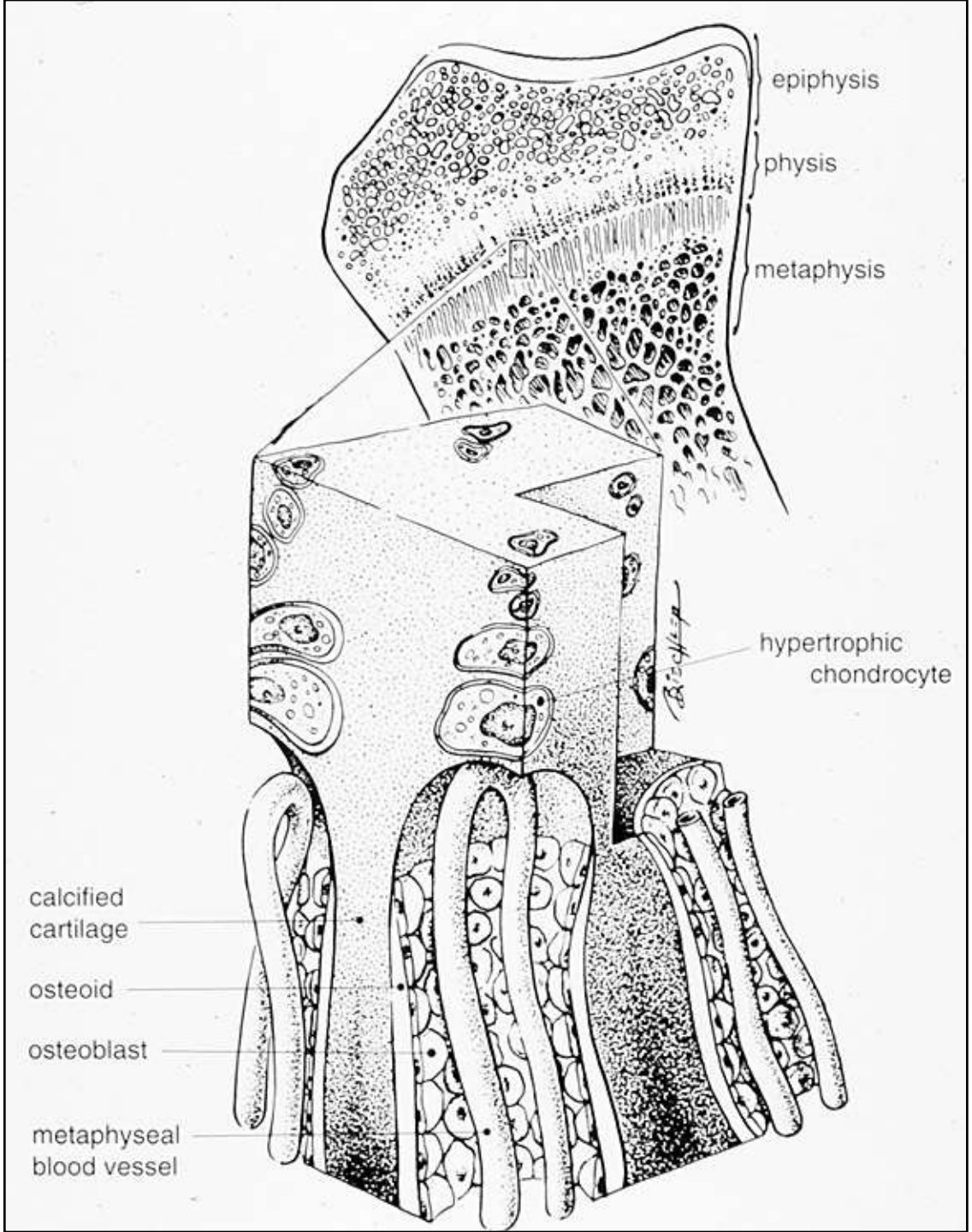


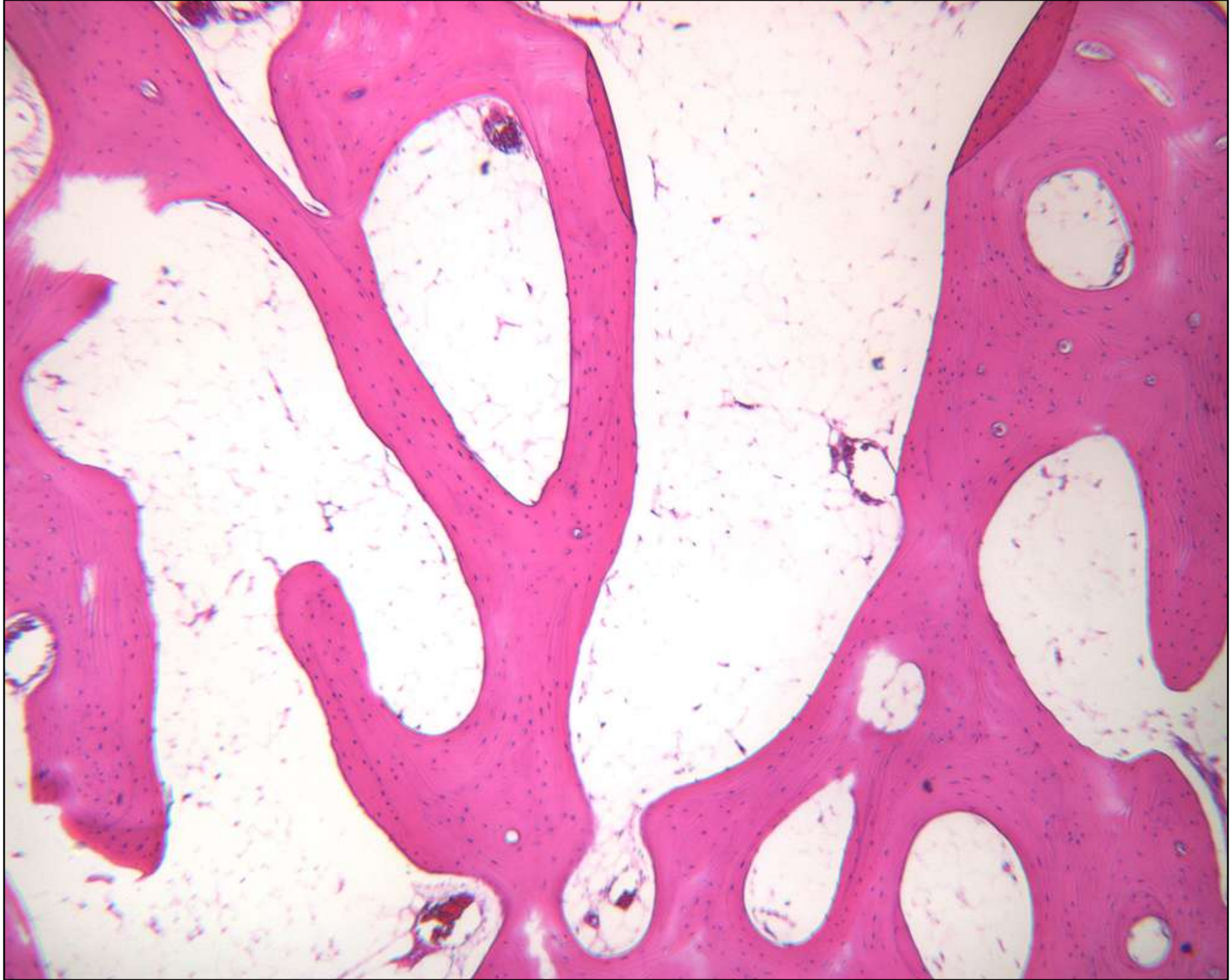


Osteoporotic bone

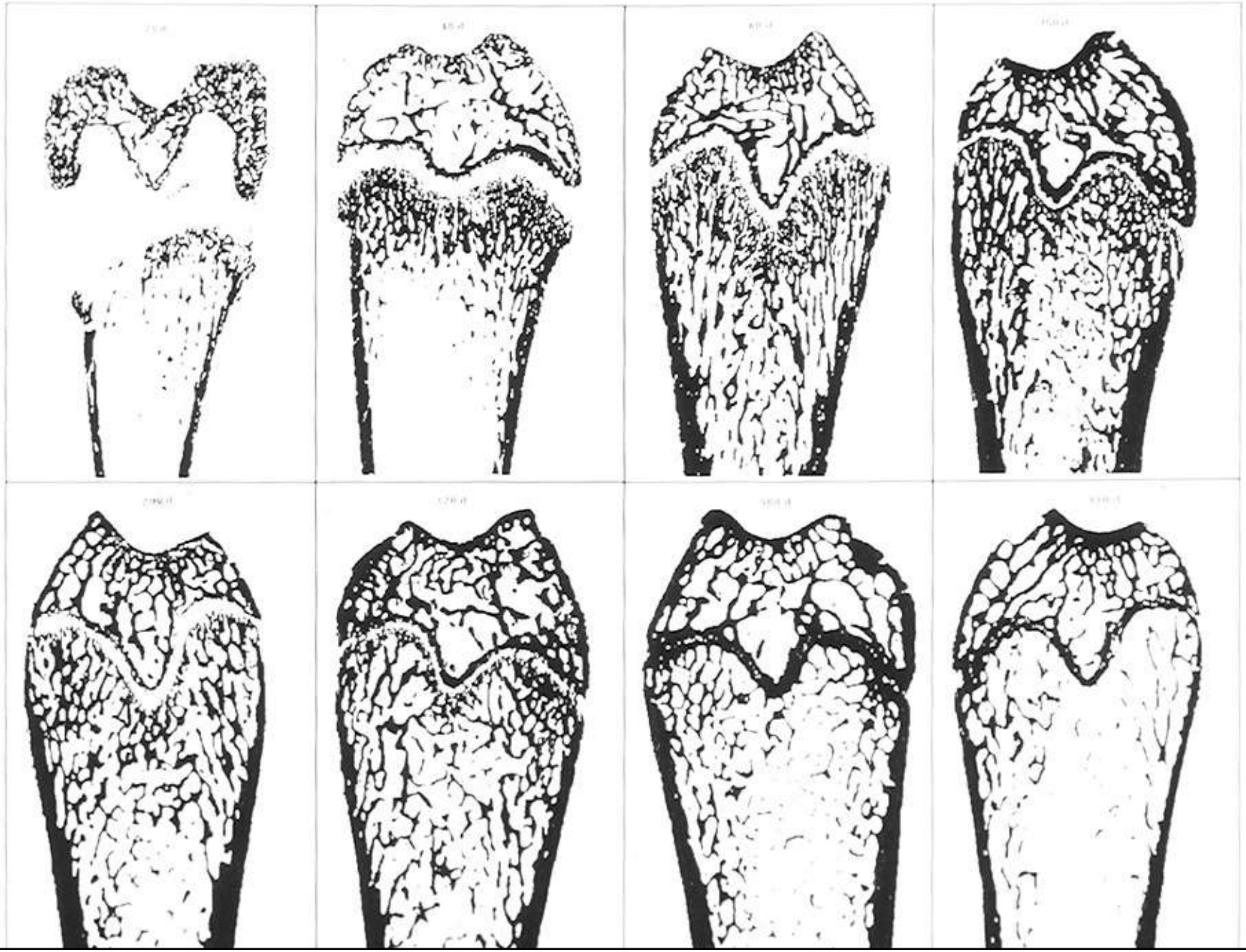


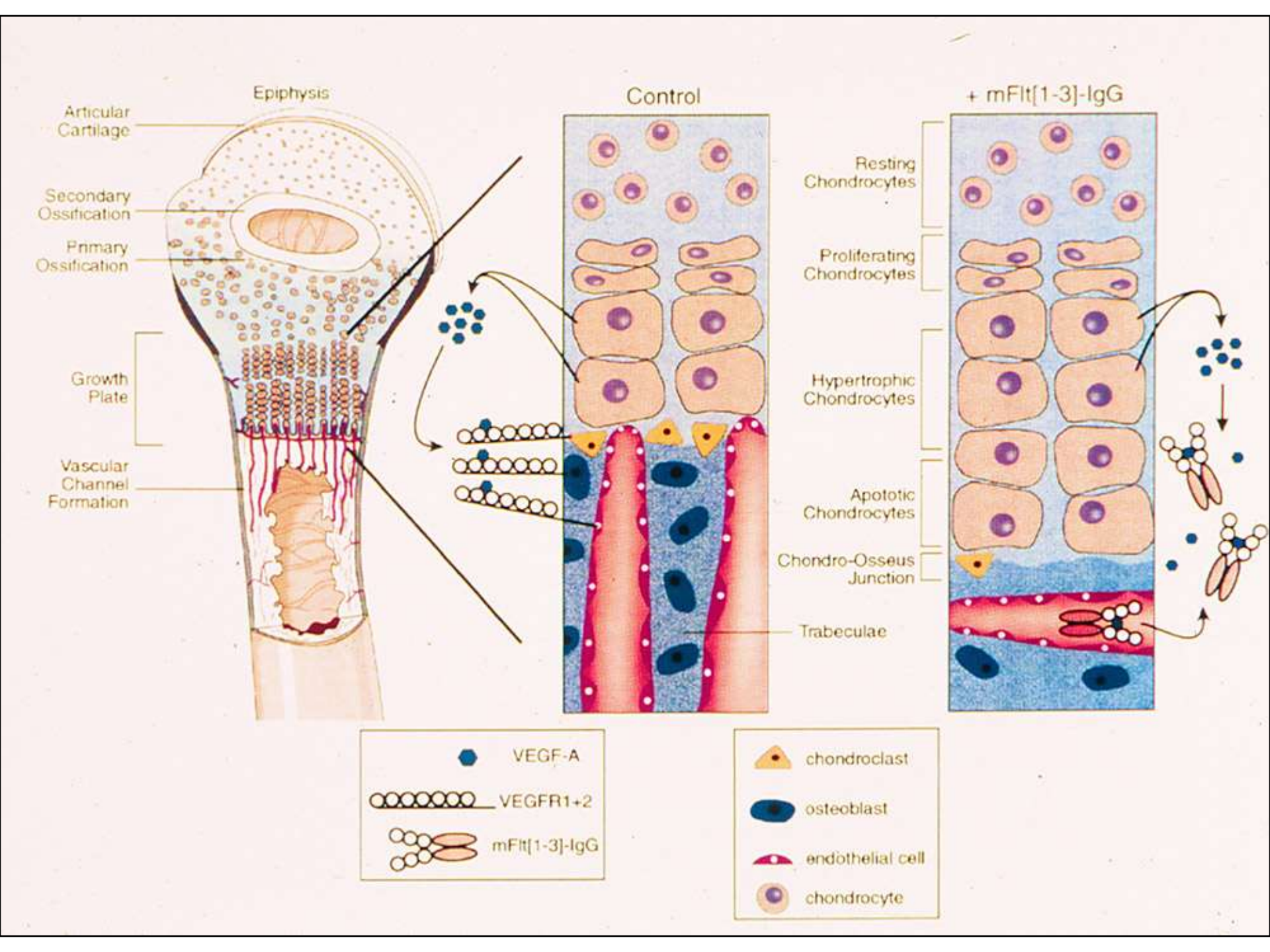
Trabecular bone


epiphysis
physis
metaphysis
hypertrophic chondrocyte
calcified cartilage
osteoid
osteoblast
metaphyseal blood vessel

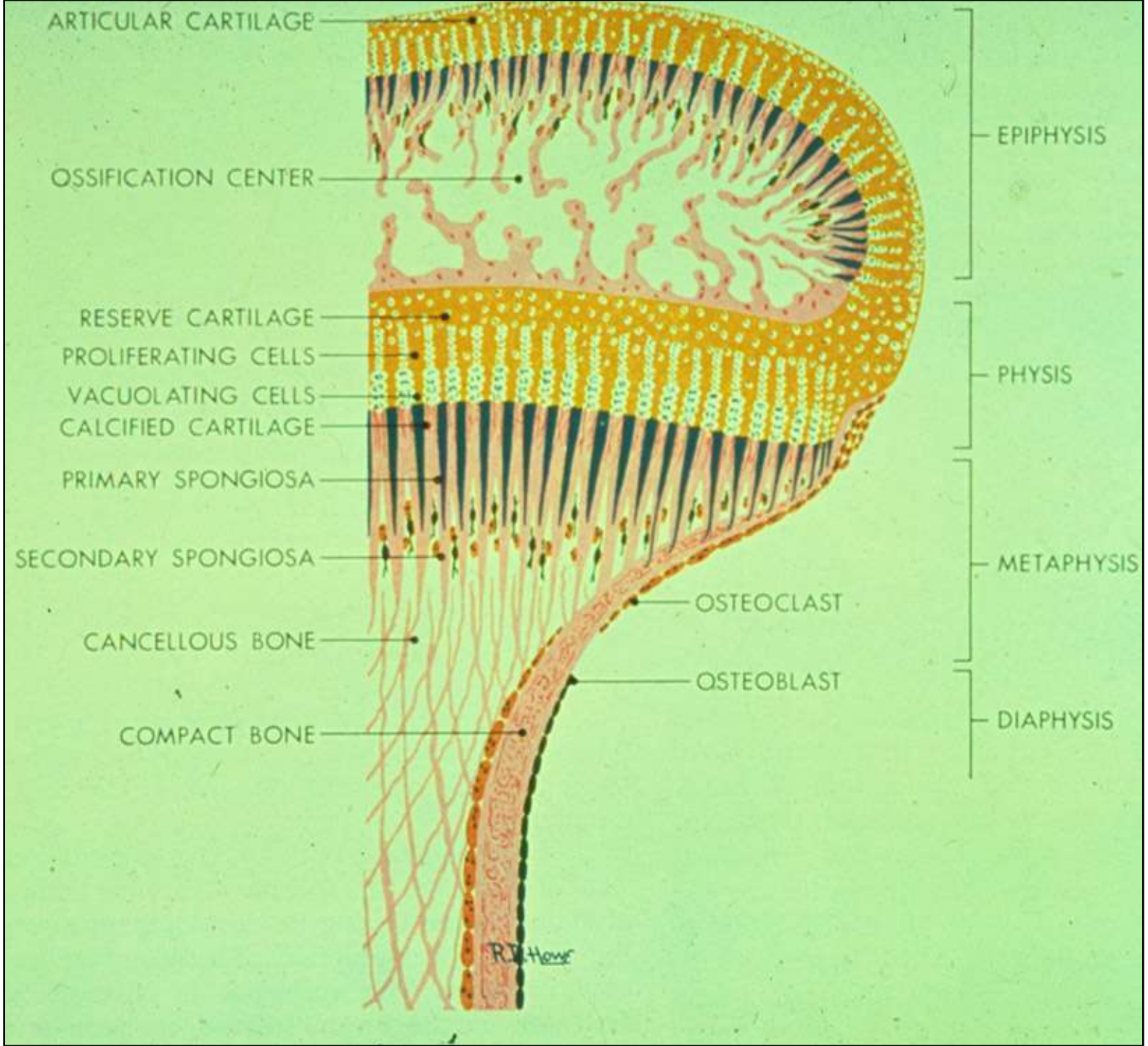


DISTAL FEMORA OF FEMALE RATS




Epiphysis
Articular Cartilage
Secondary Ossification
Primary Ossification
Growth Plate
Vascular Channel Formation
Control
+ mFlt[1-3]-IgG
Resting Chondrocytes
Proliferating Chondrocytes
Hypertrophic Chondrocytes
Apototic Chondrocytes
Chondro-Osseus Junction
Trabeculae
VEGF-A
VEGFR1+2
mFlt[1-3]-IgG
chondroclast
osteoblast
endothelial cell
chondrocyte

Endochondral bone growth in width – membranous bone formation


ARTICULAR CARTILAGE
OSSIFICATION CENTER
RESERVE CARTILAGE
PROLIFERATING CELLS
VACUOLATING CELLS
CALCIFIED CARTILAGE
PRIMARY SPONGIOSA
SECONDARY SPONGIOSA
CANCELLOUS BONE
COMPACT BONE
OSTEOCLAST
OSTEOBLAST
EPIPHYSIS
PHYSIS
METAPHYSIS
DIAPHYSIS
R.J. House

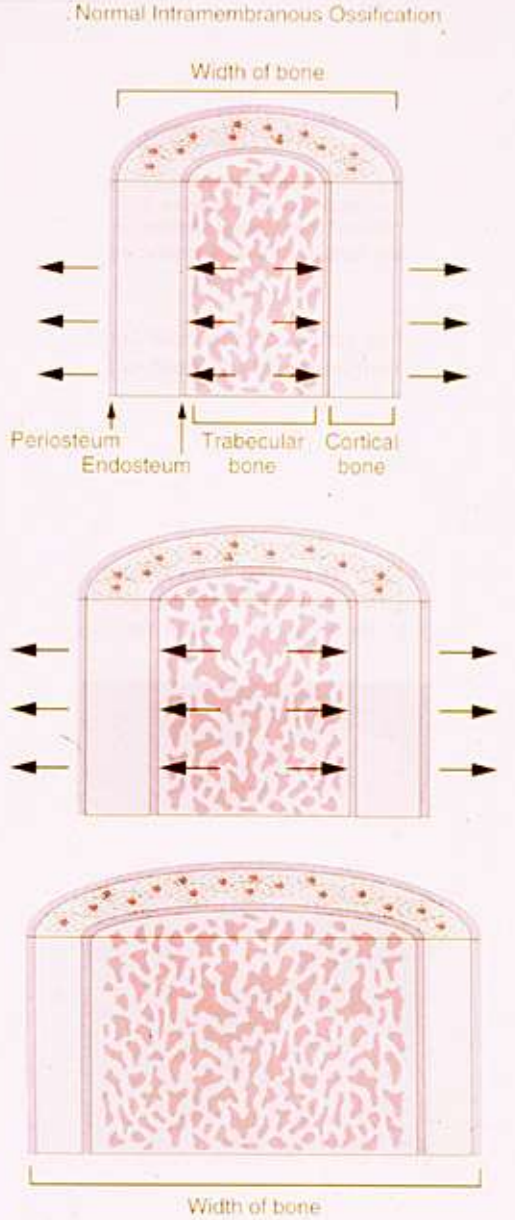
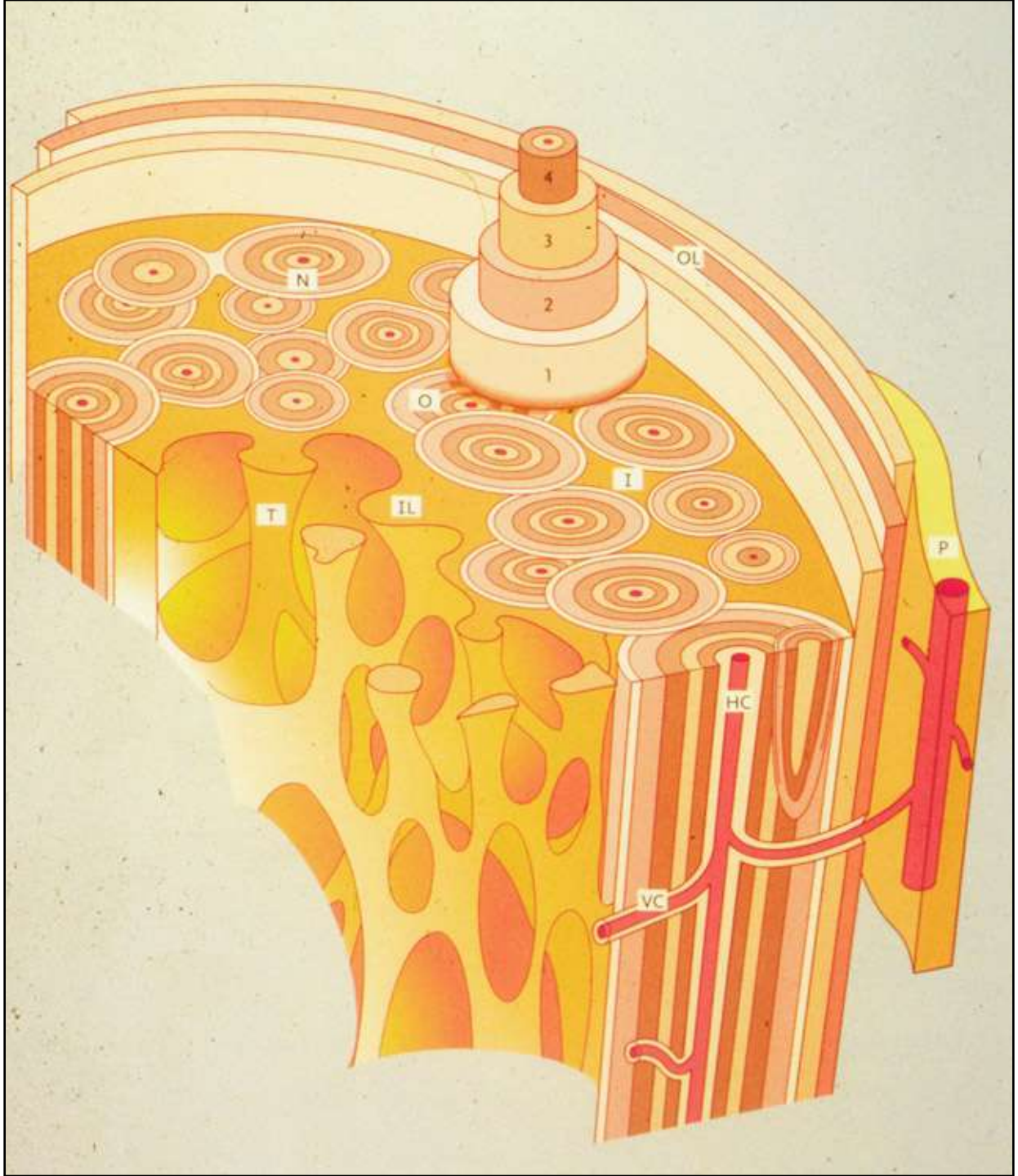


FIG. 29. Membranous ossification (MO) is seen classically at the diaphysis of developing bones where it fuses with the bone development by endochondral ossification. In MO, there is no cartilaginous step. Fibrous tissue develops directly into bone. Periosteal bone formation throughout life is an example of MO and accounts for the long bone widening that occurs with aging.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