PLEASE CLICK ON THE FOLLOWING LINK TO WATCH THE LECTURE ONLINE:-

https://www.youtube.com/watch?v=OpYs4BF9NnU&list=PLuBRb5B7fa_eyzMA0u7jajzWugcmiRi5s&index=8

Radiographic Evaluation of Musculoskeletal Tumors

Mohammad Al-sarayreh

Staging Studies

- Plain Radiograph
- MRI
- CT scan
- Chest CT
- Bone Scan

Plain Radiographs

- **Evaluate:**
  - Rate of tumor growth
  - Tumor interaction with surrounding non-neoplastic tissue
  - Internal composition of tumor

MRI

- Visualize entire bone and adjacent joint
- Best test for intraosseous extent and soft tissue extent
- Identify skip metastases
- Tumor proximity to neurovascular structures
- Occasionally helpful in diagnosis of bone or soft tissue tumors (experienced radiologist)

TABLE 1. *MRI signal intensities of various tissues*

Tissue	Image	
	T1-weighted	T2-weighted
Hematoma	High	High
Fat, fatty marrow	High	Intermediate
Muscle, nerves, hyaline cartilage	Intermediate	Intermediate
Cortical bone, tendons, ligaments, fibrocartilage, scar tissue, air	Low	Low
Hyaline cartilage	Intermediate	Intermediate
Red (hematopoietic) marrow	Low	Intermediate
Fluid	Intermediate	High
Tumors (generally)	Intermediate-to-low	High
Lipoma	High	Intermediate
Hemangioma	Intermediate (slightly higher than muscle)	High

CT

- Good for evaluating cortical details and destruction
- Subtle cortical erosions (endosteal;periosteal) not detectable on plain x-ray or MRI
- Subtle calcifications / ossification (Visible tumor matrix mineralization)

Pain Radiographs

- The next three slides demonstrates how plain radiographs should be utilized to evaluate a bone tumor
- There are specific characteristics that should be identified on plain radiographs that aid in the differential diagnosis of a bone tumor

Plain Radiographs

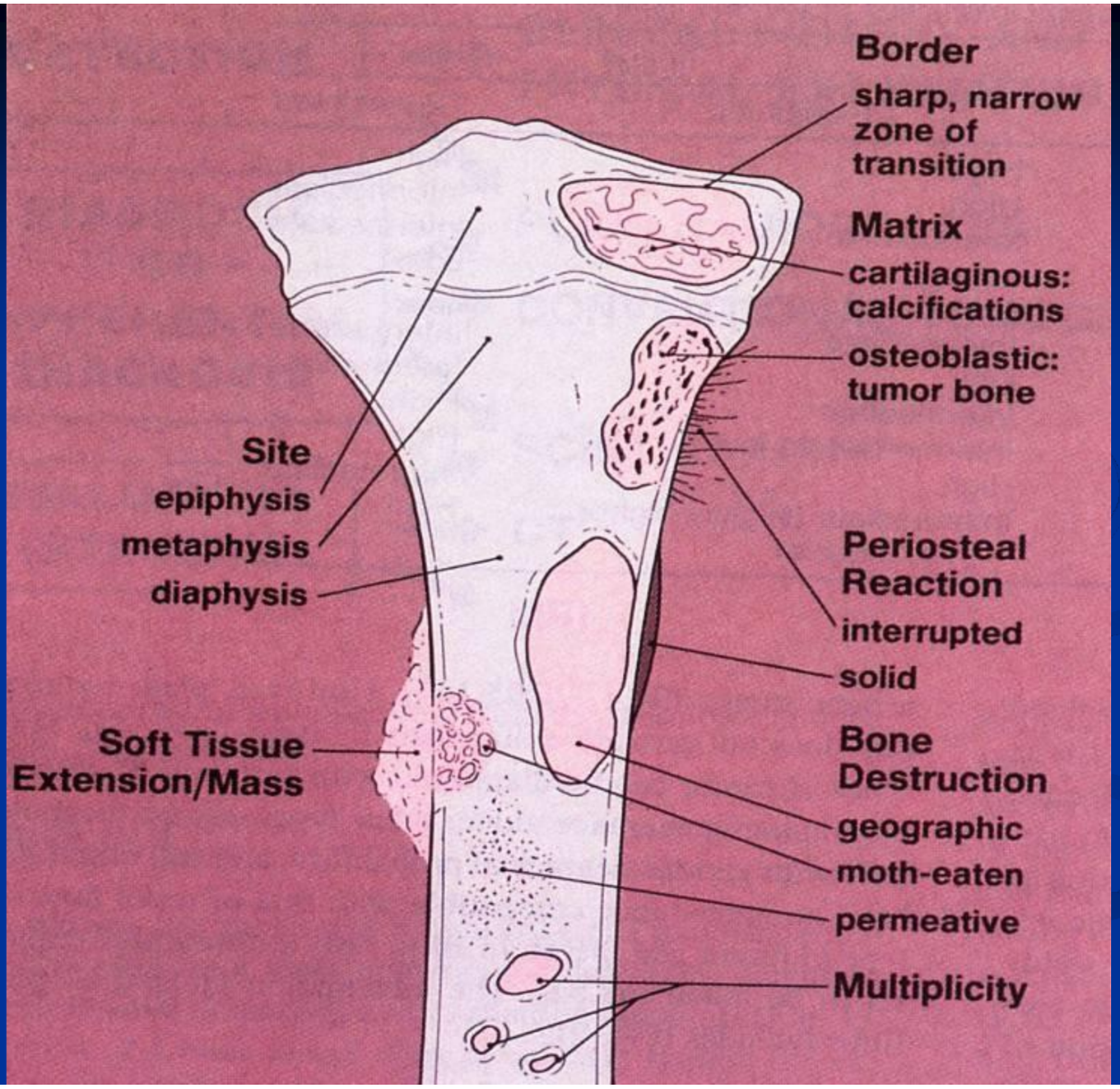
- Bone involved
- Is involved bone normal?
- What part of the bone?
- Open or closed growth plate
- Epicenter of lesion (cortex or medullary canal)
- Tumor contour and zone of transition between tumor and host bone

Plain Radiographs

- Mineralized matrix?
- Cortical destruction?
- Periosteal reaction? What type
- Involvement of joint space?
- Tumor multifocal?
- Is tumor of uniform appearanceor does it have several different components?

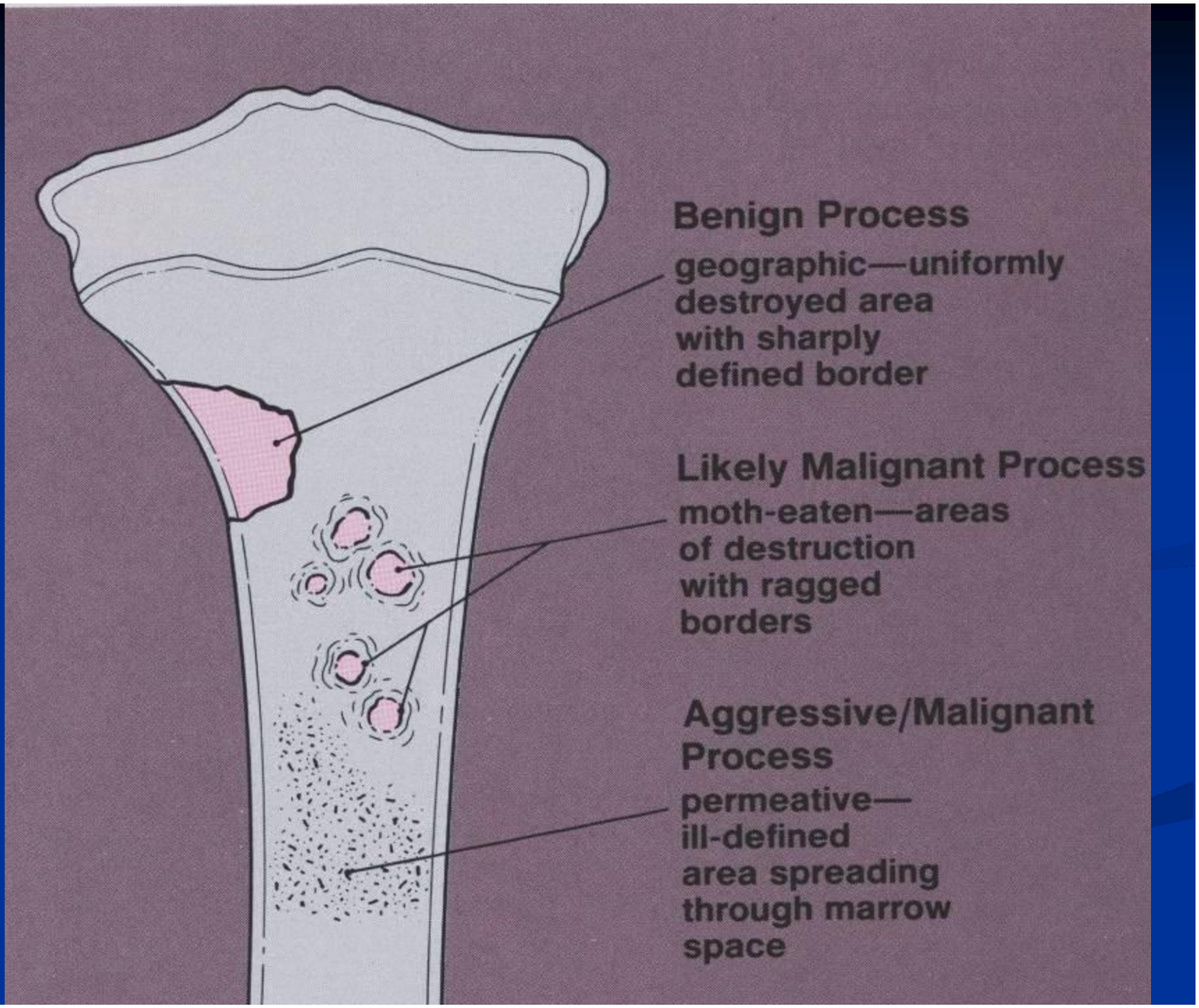
Radiographic Evaluation

- Bone Involved and Position in the Bone
- Pattern of Bone Destruction
  - Geographic, Permeative, Moth Eaten
- Margin of the Lesion
- Presence of Visible Tumor Matrix (Calcification/Ossification)
- Internal Trabeculations
- Cortical Erosion, Penetration, Cortical Expansion
- Periosteal Response
  - Continuous or Interupted


Border
sharp, narrow zone of transition
Matrix
cartilaginous: calcifications
osteoblastic: tumor bone
Site
epiphysis
metaphysis
diaphysis
Periosteal Reaction
interrupted
solid
Soft Tissue Extension/Mass
Bone Destruction
geographic
moth-eaten
permeative
Multiplicity

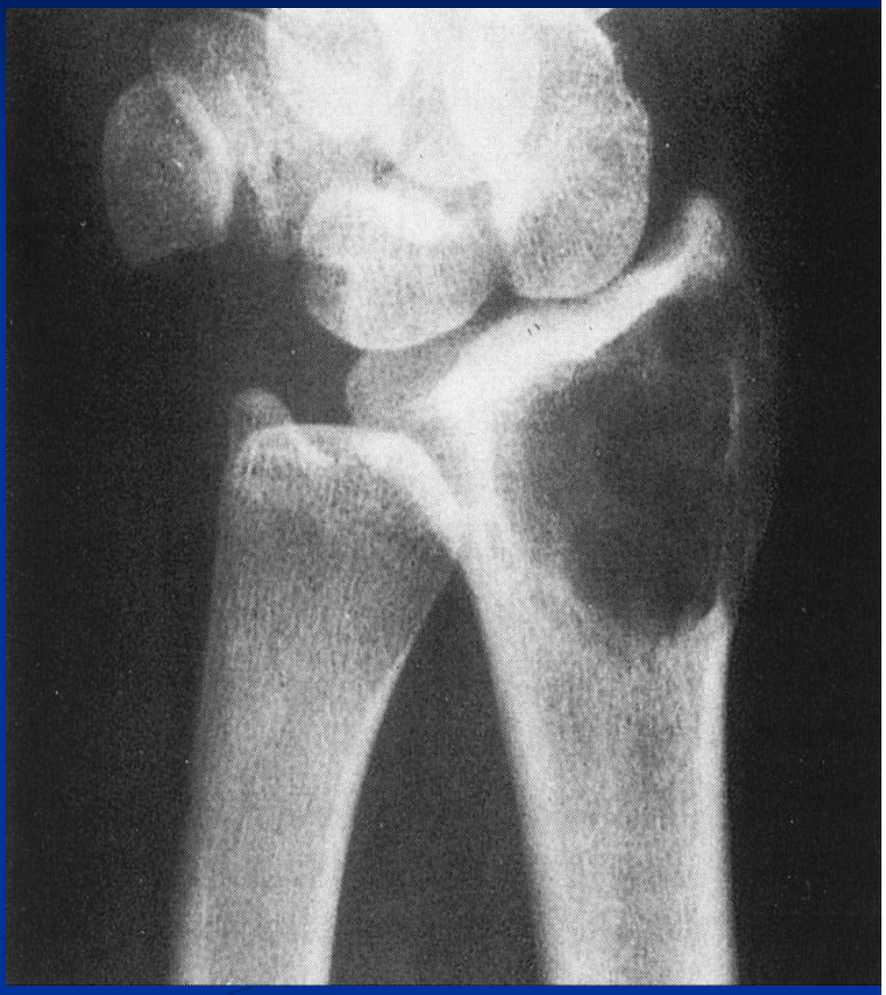
Patterns of Bone Destruction

- Geographic
- Motheaten
- Permeative


Benign Process
geographic—uniformly destroyed area with sharply defined border
Likely Malignant Process
moth-eaten—areas of destruction with ragged borders
Aggressive/Malignant Process
permeative—ill-defined area spreading through marrow space

Geographic Bone Destruction

- Least Aggressive Pattern
- Slow Growing Lesion- Usually Benign
- Clearly Demarcated Lesion
  - Clearly Delineated Borders of Lesion
- Narrow Zone of Transition between Tumor and Normal Bone
- May have Sclerotic Margin
- Thicker Sclerotic Margin is Less Aggressive
- No Surrounding Sclerosis means more Aggressive/Faster Growing

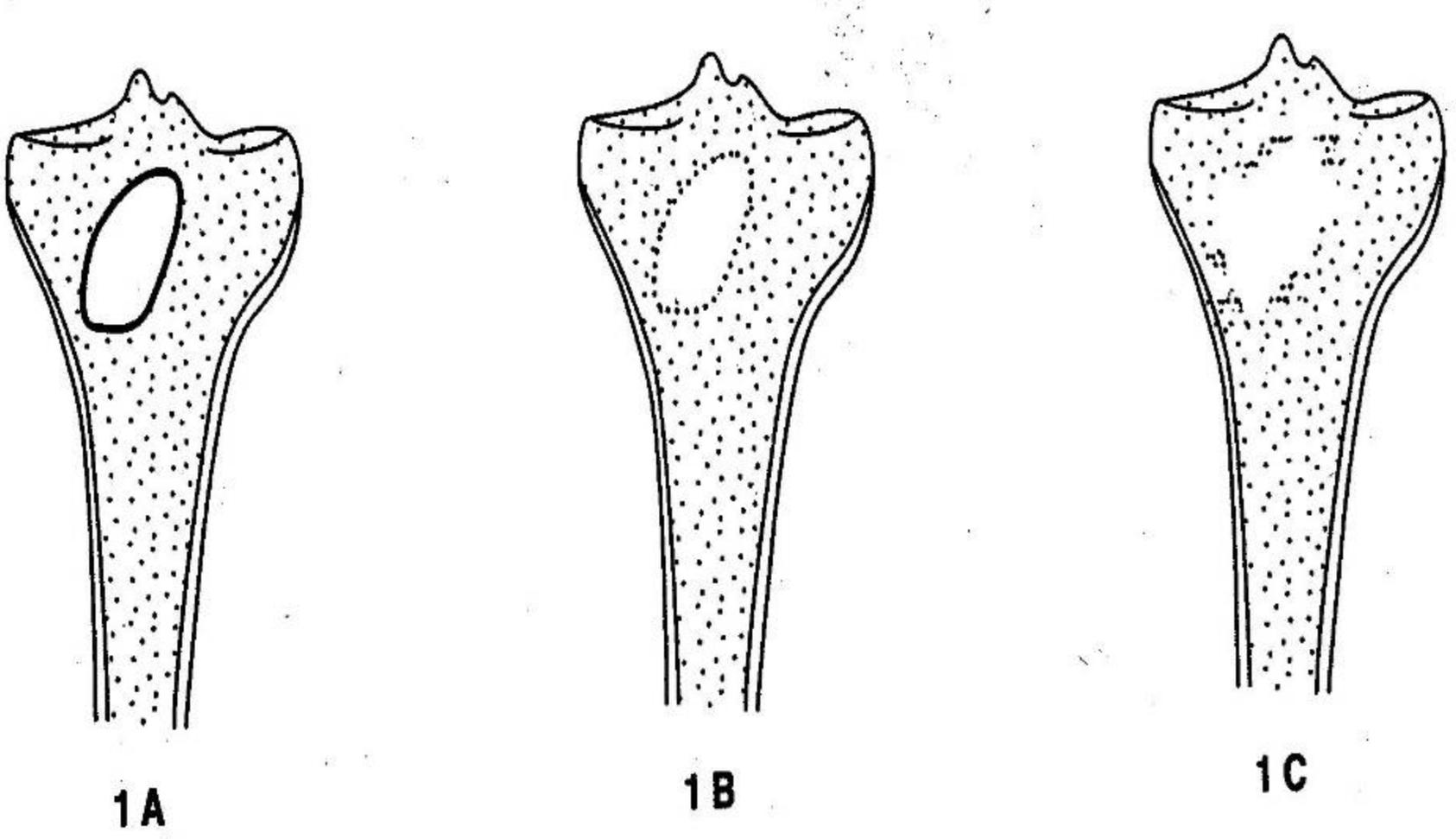


Geographic Bone Destruction

Giant Cell Tumor

Geographic Bone Destruction

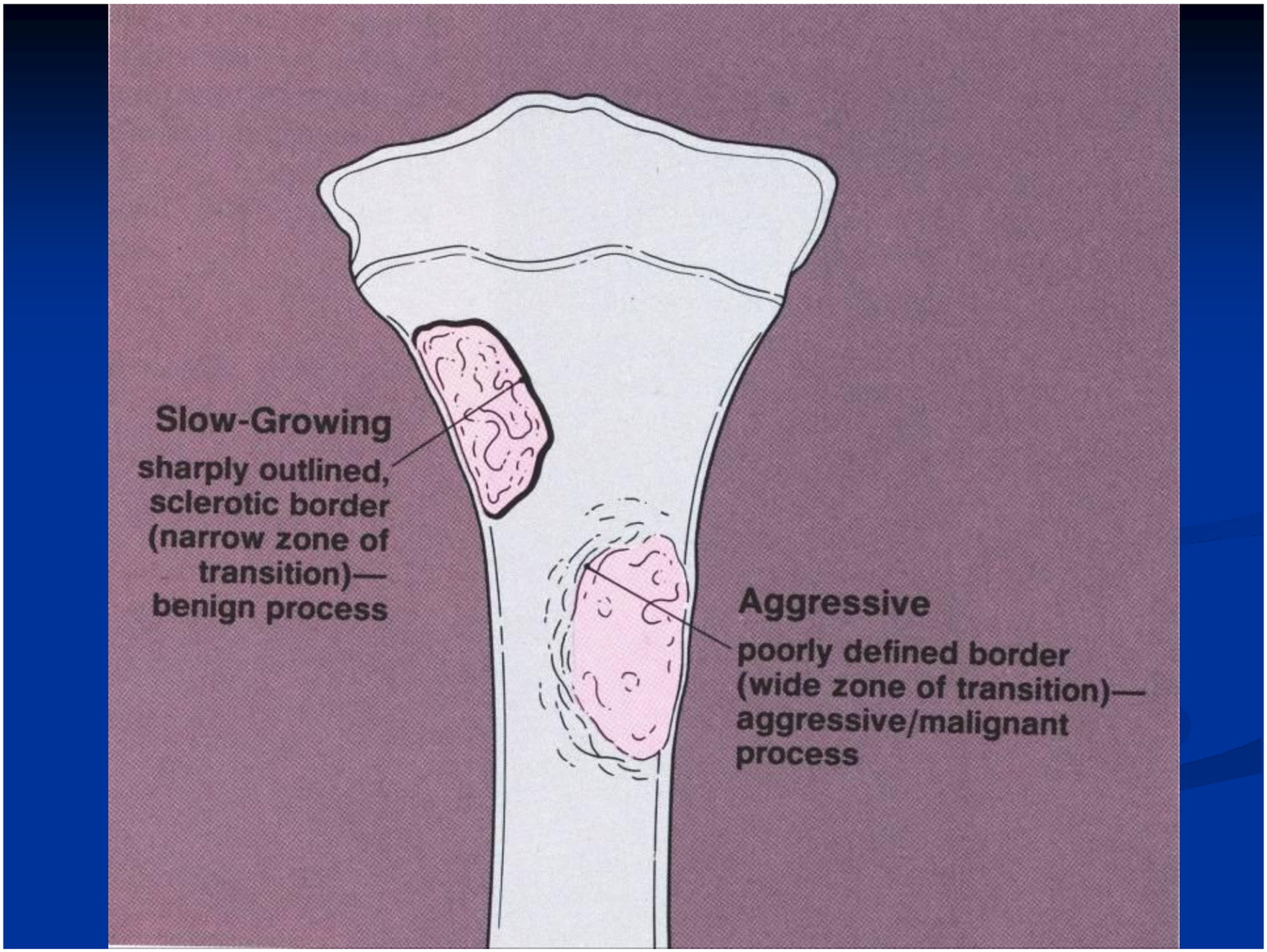
- Types of Margins Around Lesion
  - IA (Thick Complete Sclerotic Margin)
    - Indolent Lesion
  - IB (Thin and Incomplete)
    - Active Lesion
  - IC (No Sclerotic Margin)
    - Aggressive Lesion



1A

1B

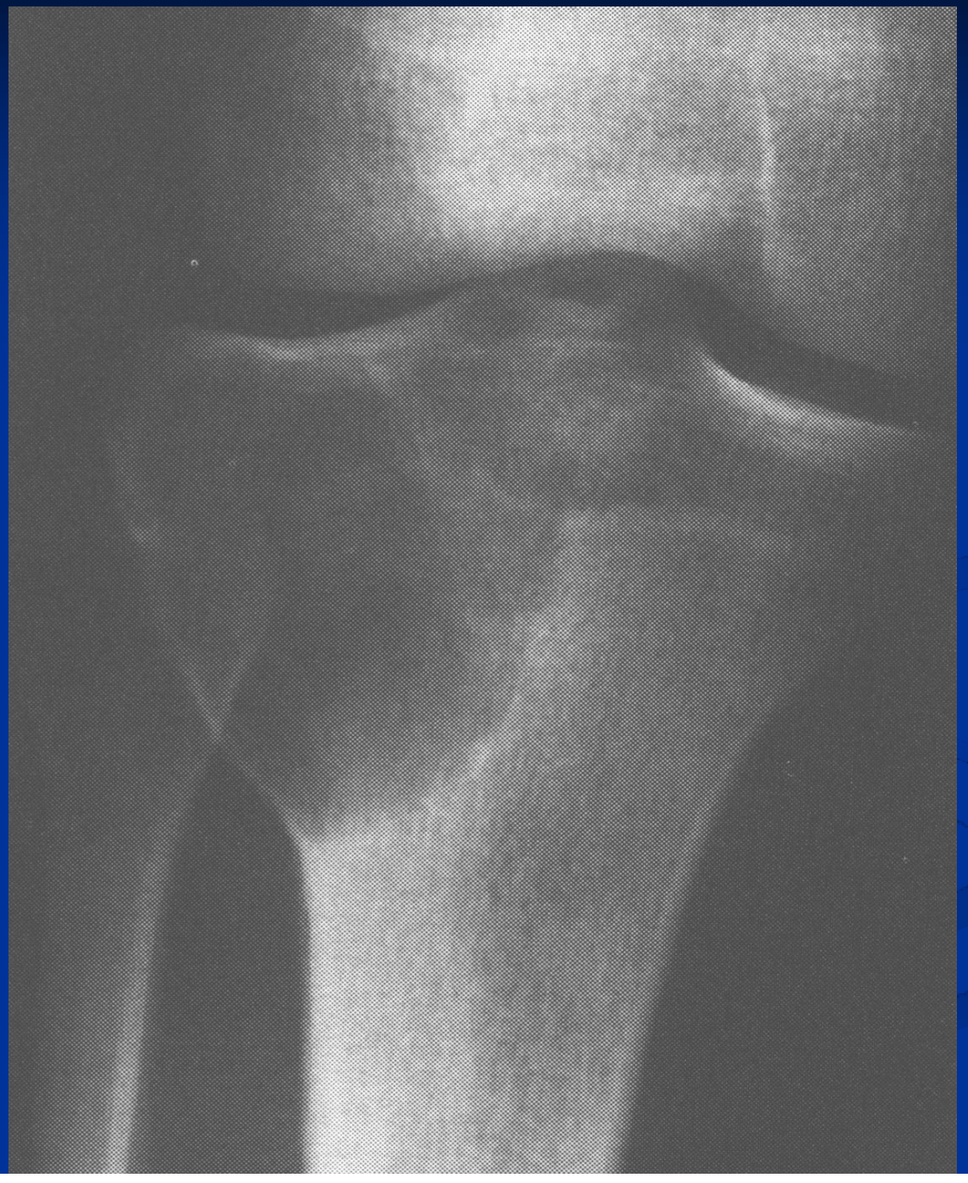
1C


Slow-Growing
sharply outlined, sclerotic border (narrow zone of transition)— benign process
Aggressive
poorly defined border (wide zone of transition)— aggressive/malignant process

IA

IA-Non Ossifying Fibroma

IB—Giant Cell Tumor



IC

IB/IC

Motheaten Bone Destruction

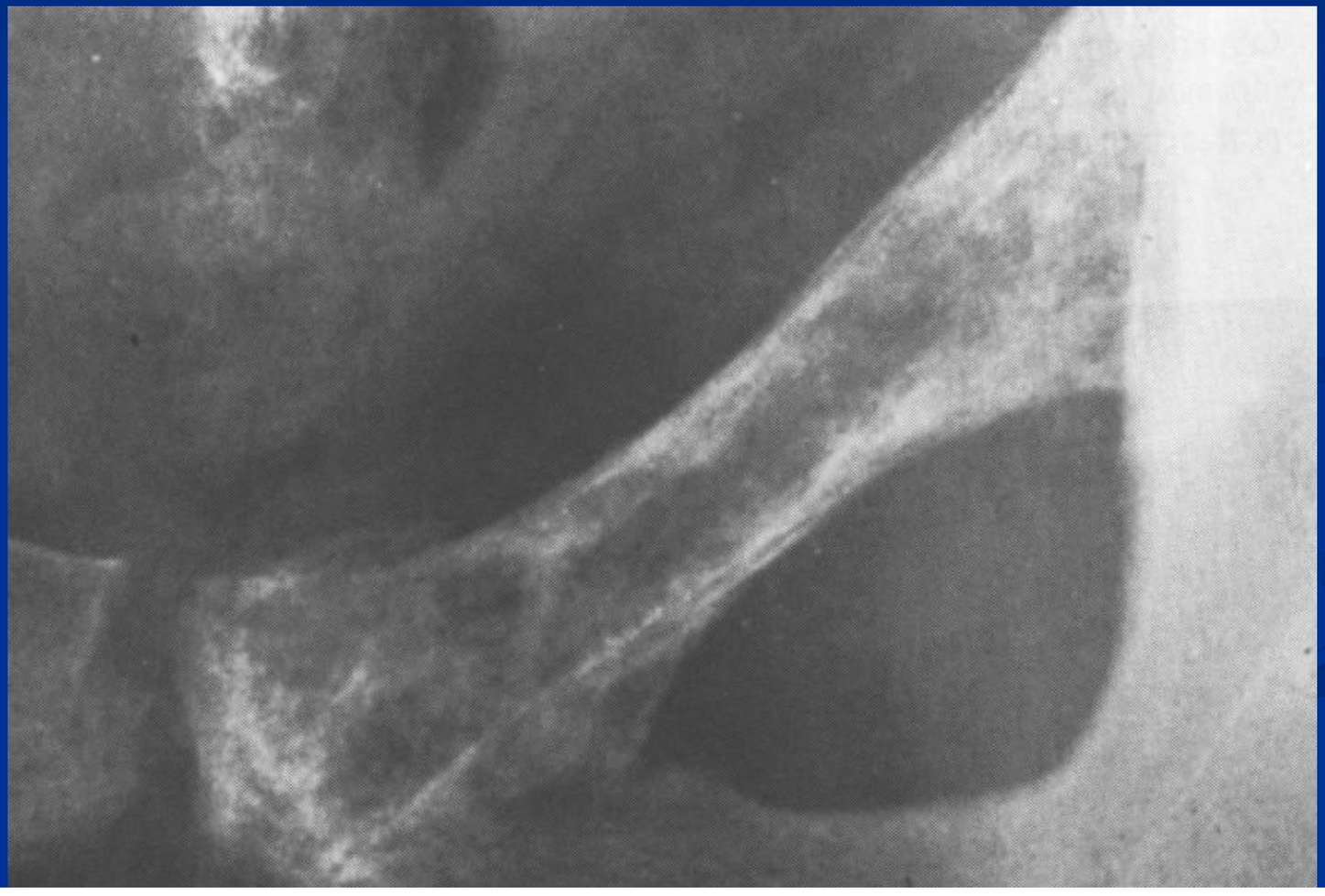
- More Aggressive Bone Destruction
- Less Well Defined Margins
- Larger Zone of Transition From Normal to Abnormal (Tumor)
- Multiple Punched Out Holes in the Bone
- Malignant Bone Tumors, Osteomyelitis, Eosinophilic Granuloma

Motheaten Bone Destruction

Permeative Bone Destruction

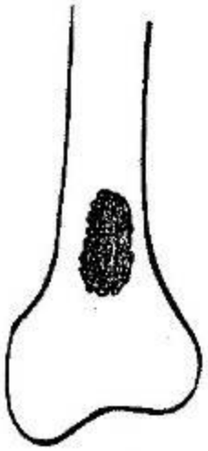
- Aggressive Lesion
- Rapid Growth Potential
- Poorly Demarcated and May Merge Imperceptibly with Uninvolved Bone
- Can Not Delineate Where Tumor Begins and Ends
- Tumor Not Clearly Demarcated From Normal Bone
- Malignant Bone Tumors (Ewings sarcoma;Osteosarcoma),

Permeative Bone Destruction
Lymphoma

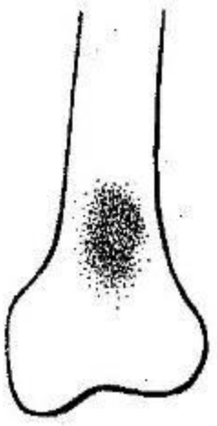


Visible Tumor Matrix

- Calcification
  - Stippled, Flocculent, Rings and Arcs
- Ossification
  - Solid, Cloud-Like, Ivory-Like
- Must Differentiate Mineralization from Calcification Due to Dead or Necrotic Tissue, Fracture Callus (Pathologic Fracture), Sclerotic Response of Non-Neoplastic Bone to Adjacent Tumor Deposit

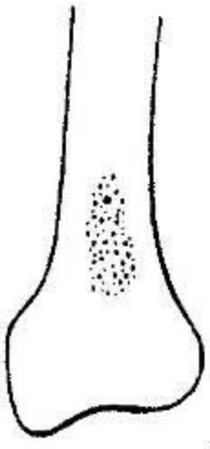


Solid



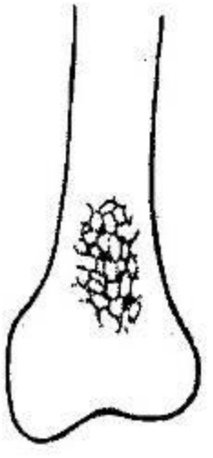
Cloud-Like

Ivory-Like



Stippled

Flocculent



Rings and Arcs

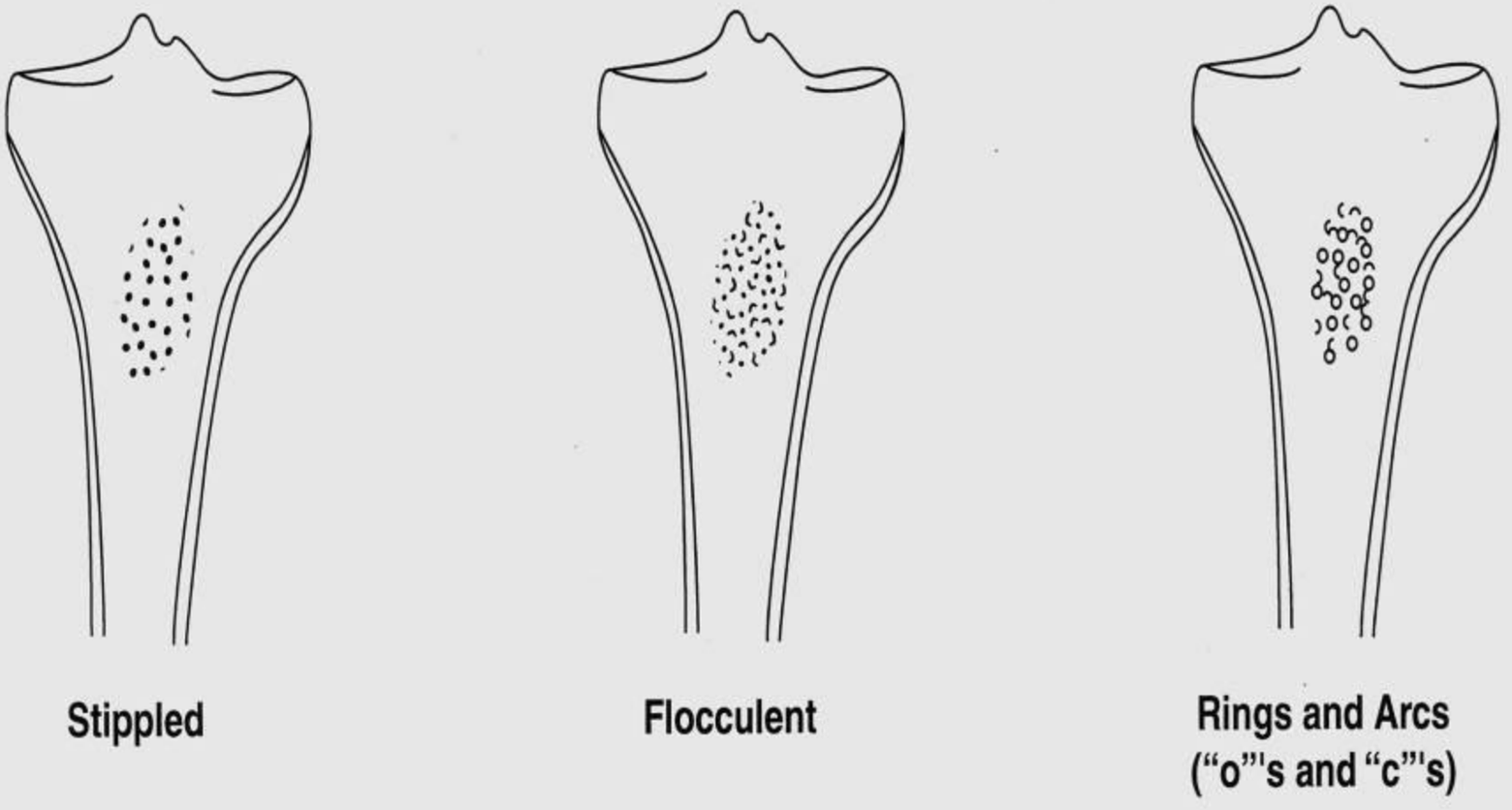
Visible Tumor Matrix

- **Calcification**
  - **Rings, Arcs, Flocculent, Fleck-like**
  - **Cartilage Tumors**
    - **Enchondroma**
    - **Chondrosarcoma**
    - **Chondroblastoma**
    - **Chondromyxofibroma**

Visible Tumor Matrix

- Cartilage grows in a lobular manner or in a ball like manner
- Calcification occurs around the periphery of these lobules
- If the calcification occurs completely around the periphery (circumference) it forms a circle or a **Ring** of calcification that is detectable on the Xray
- If the calcification occurs only partially around the lobule, it forms only part of a circle or an **Arc** that is detectable on the Xray

Cartilage Matrix

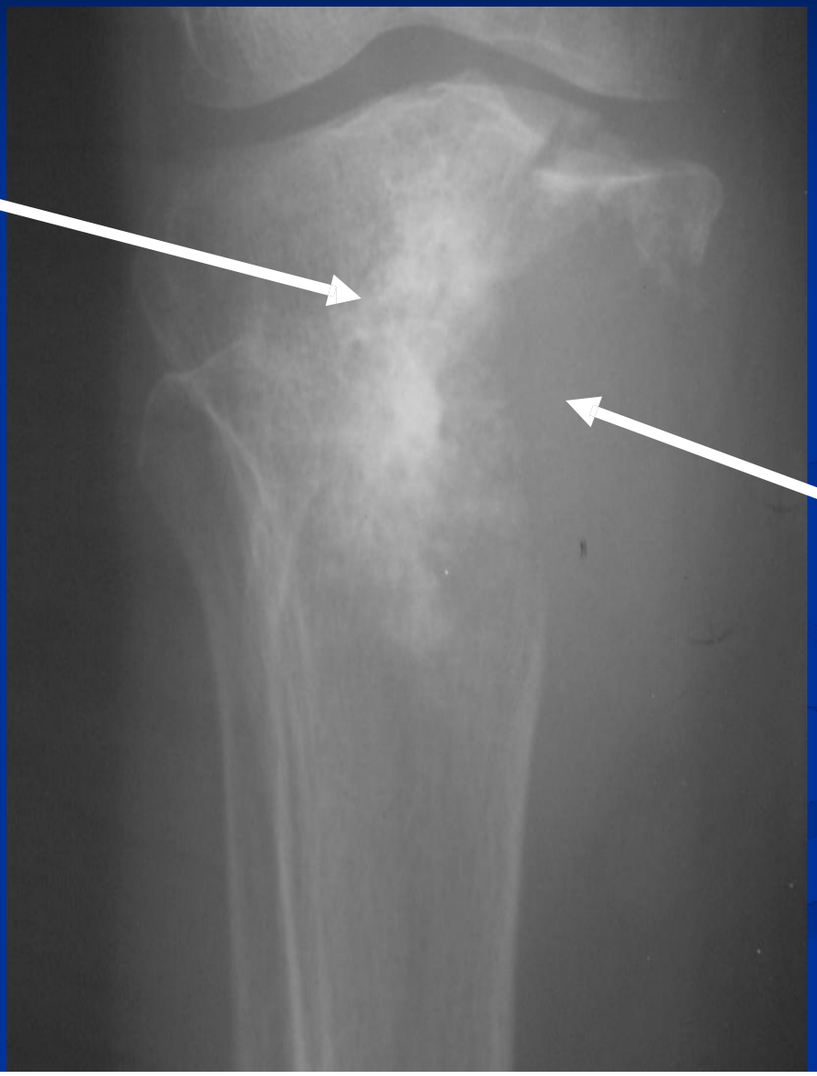


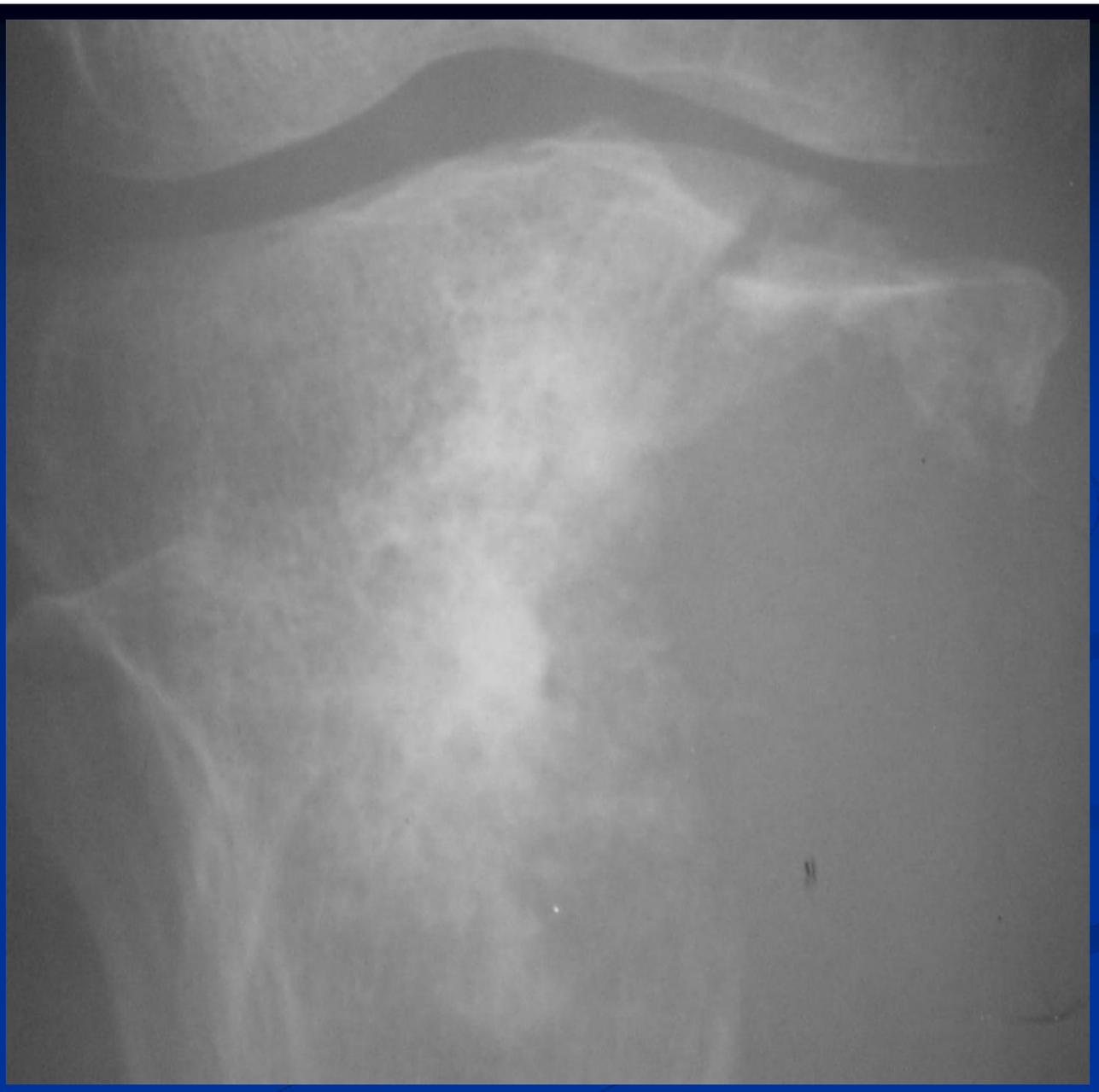
Enchondroma or Low Grade Chondrosarcoma

Intraosseous Lipoma

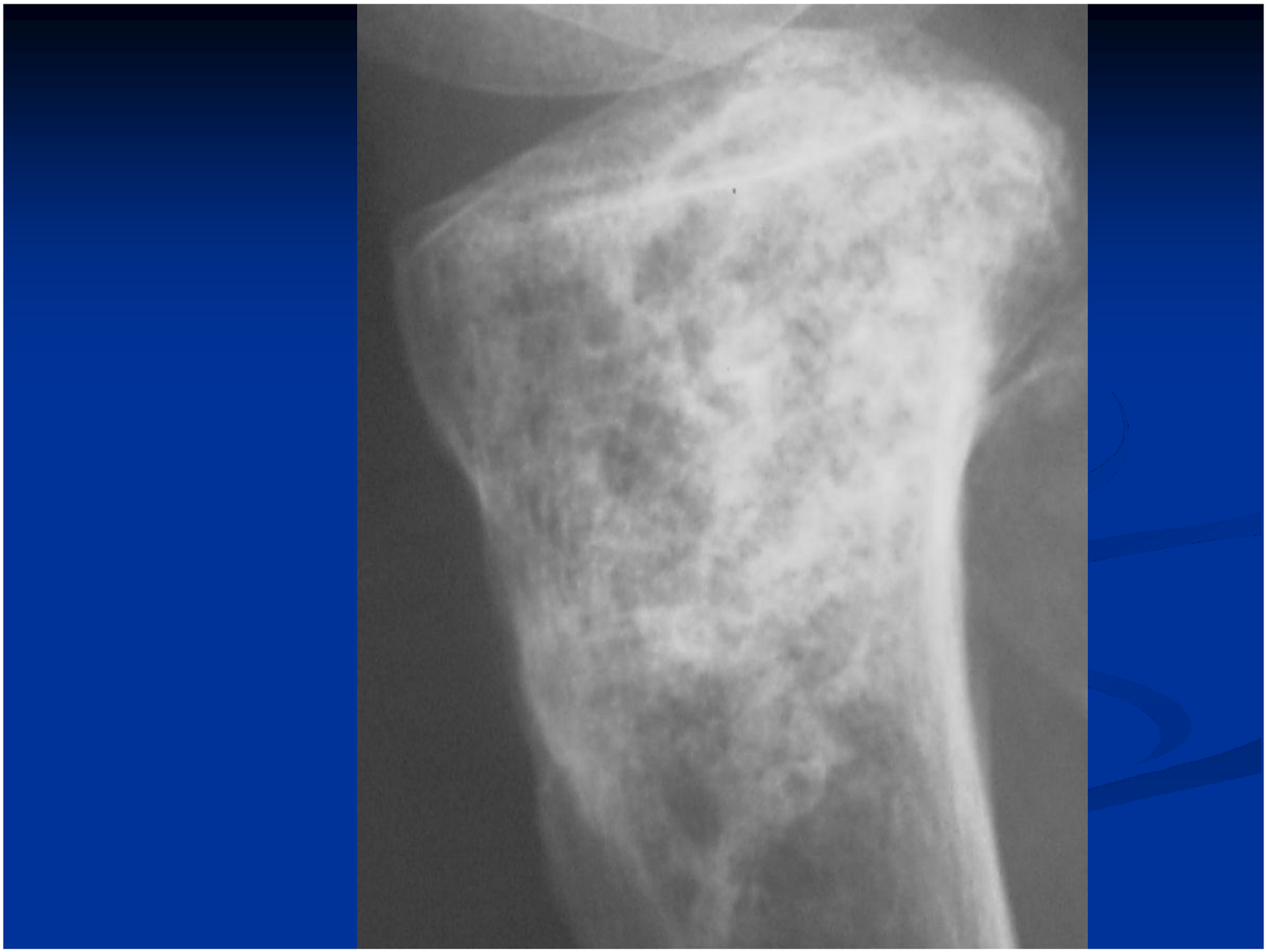

52:14 PM/40.67 P79

Dedifferentiated Chondrosarcoma



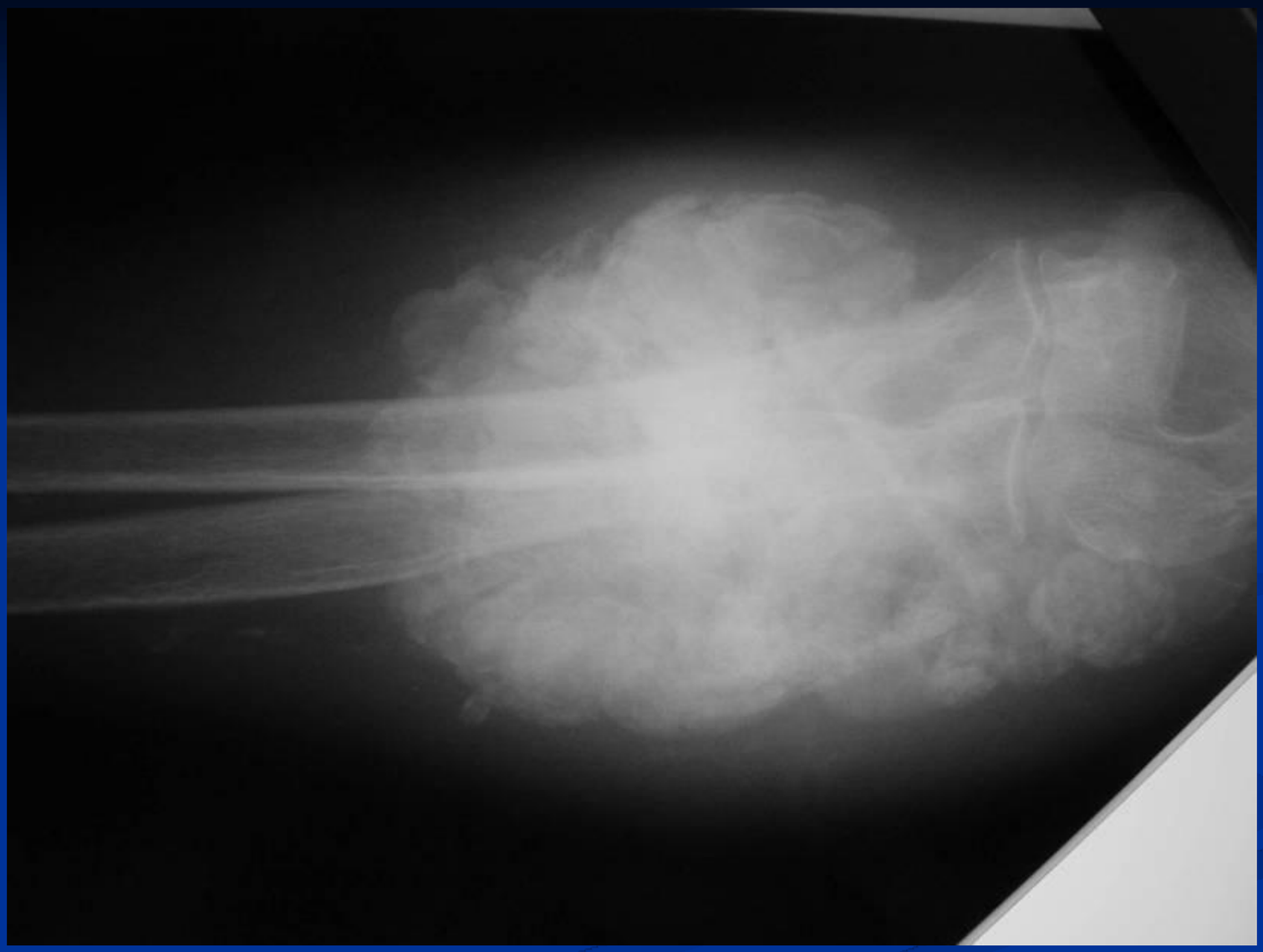


Rings and Arcs

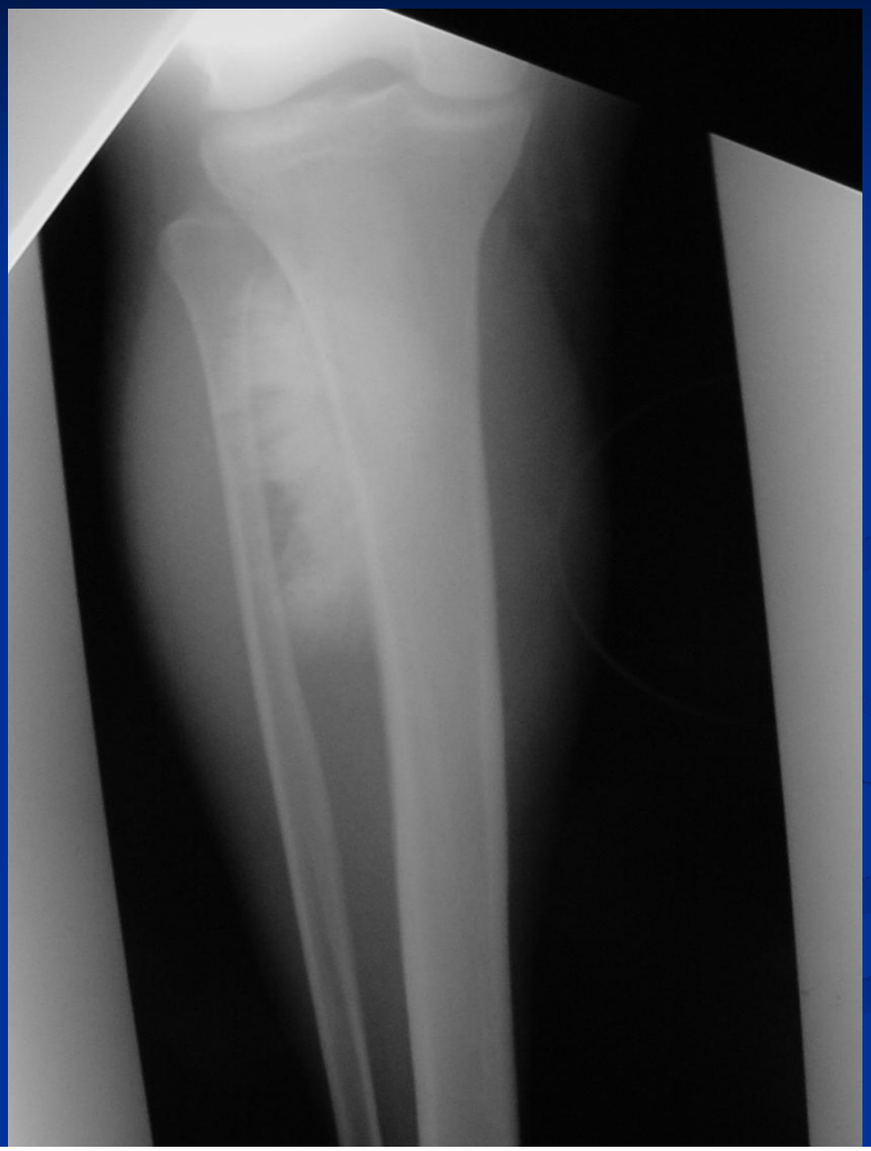


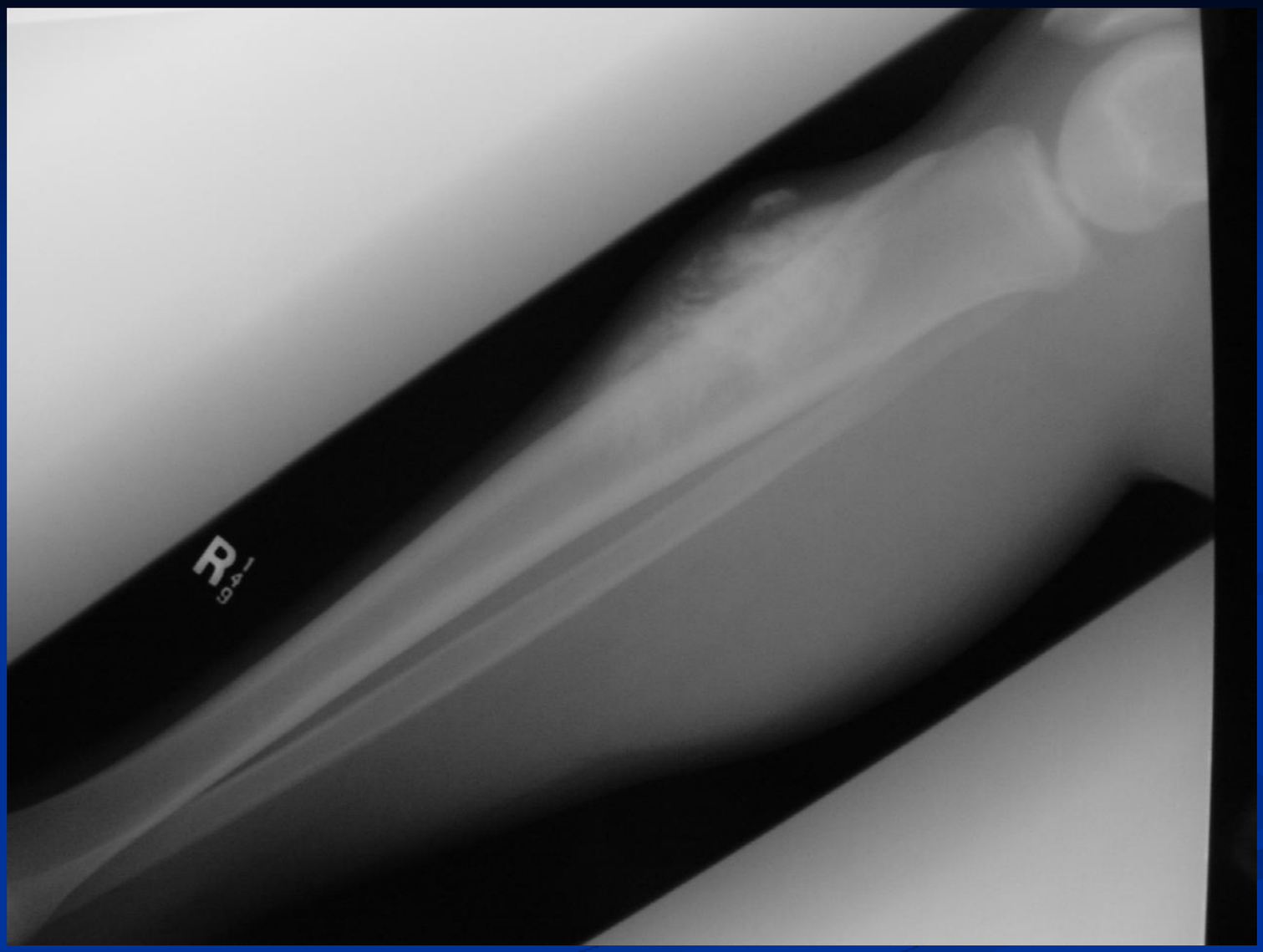
Visible Tumor Matrix

- **Ossification**
  - Cloudlike, Fluffy, Marble-like
    - Osteosarcoma
    - Parosteal Osteosarcoma
    - Osteoblastoma
    - Osteoma



Periosteal Osteosarcoma

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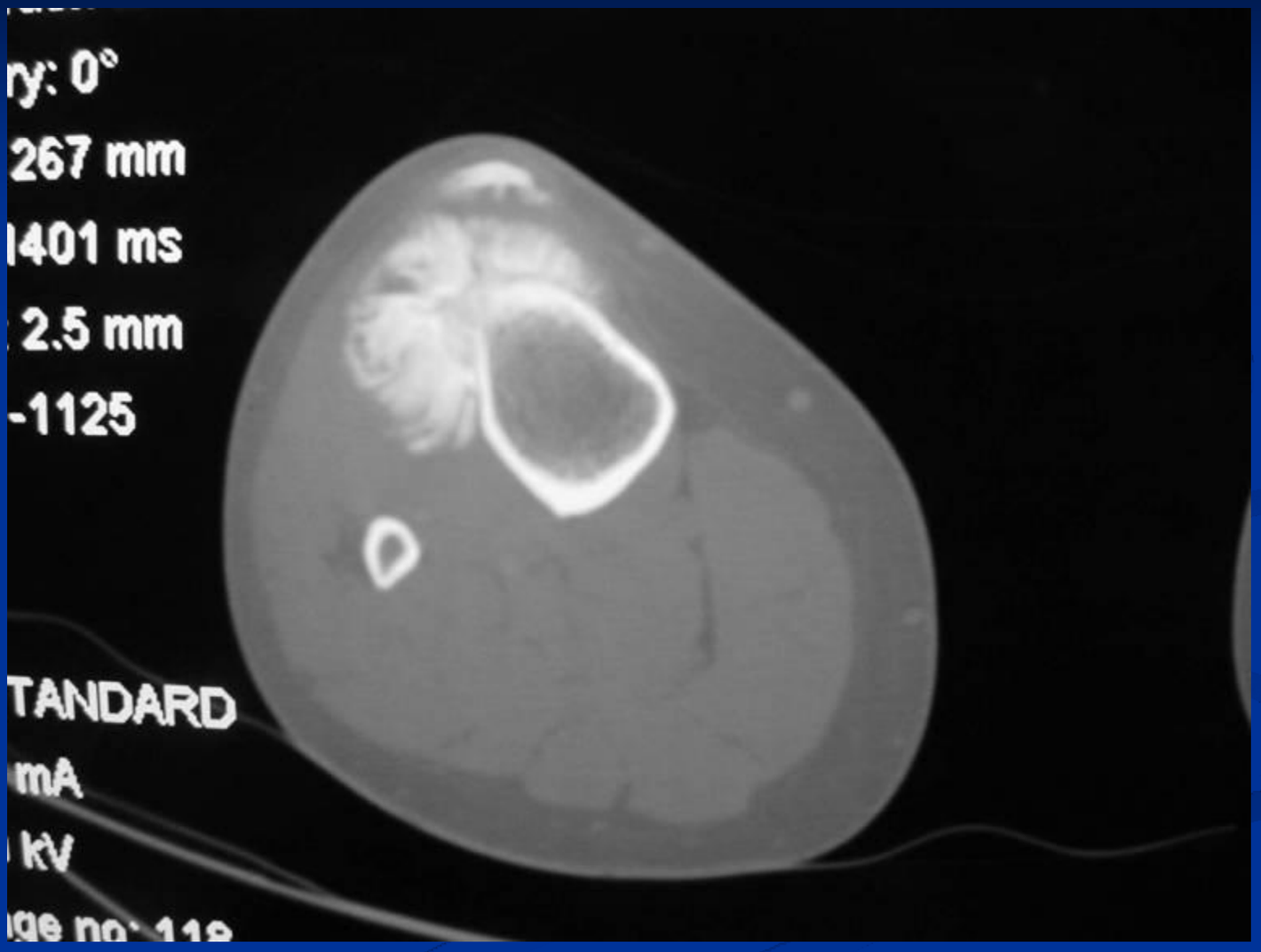
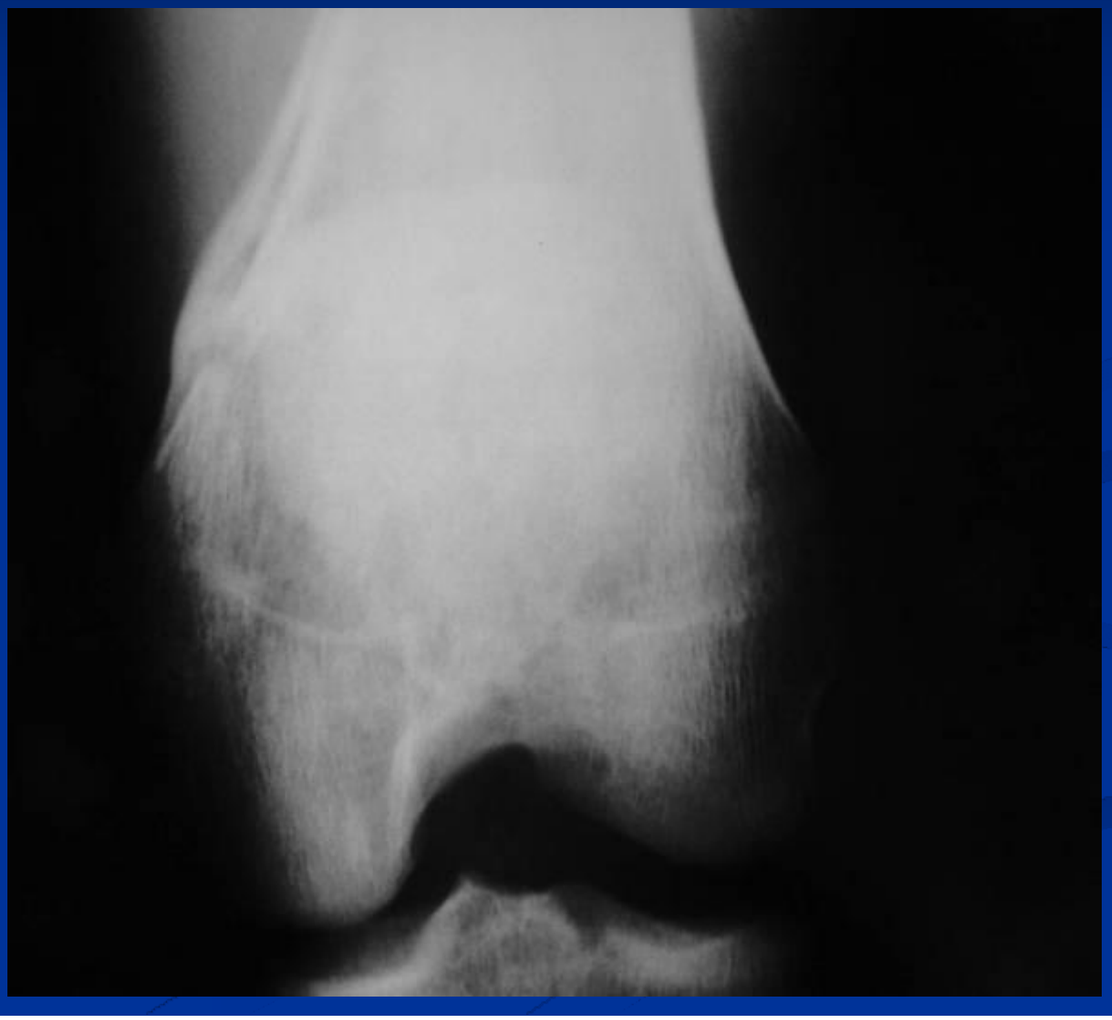
Periosteal Osteosarcoma CT Scan



Conventional Intramedullary Osteosarcoma



Conventional Intramedullary Osteosarcoma

Marble-Like Ossification Osteosarcoma

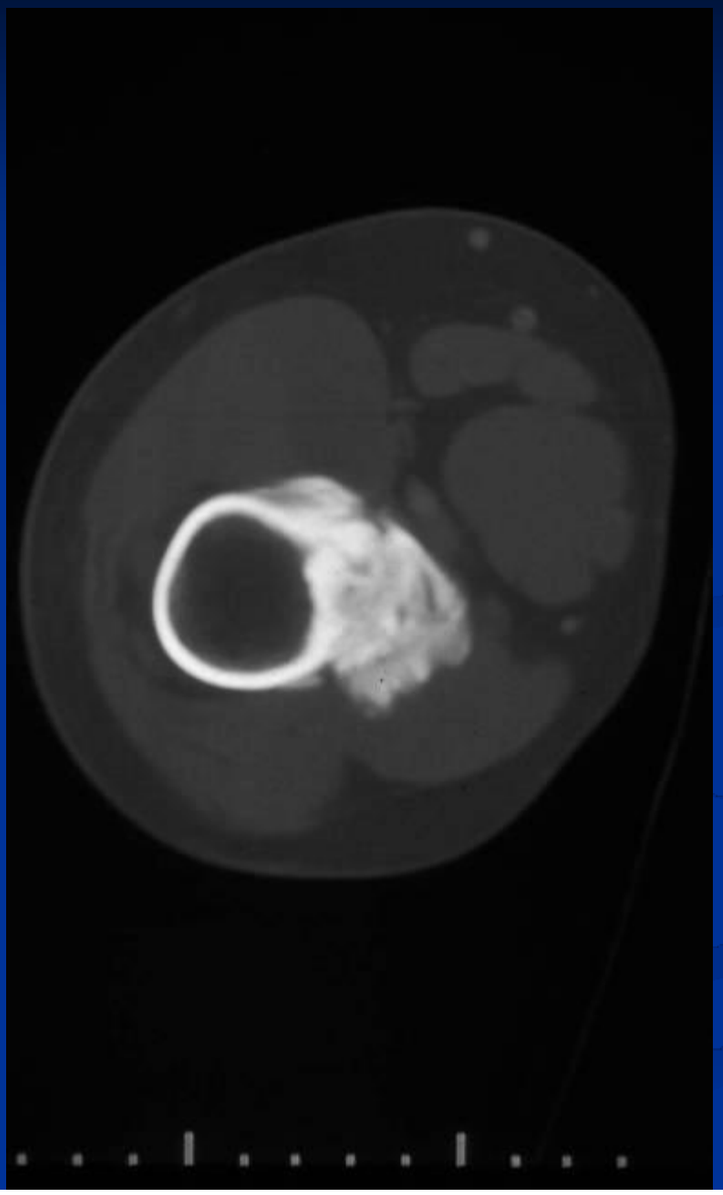
Parosteal Osteosarcoma

Parosteal Osteosarcoma

Parosteal Osteosarcoma CT Scan

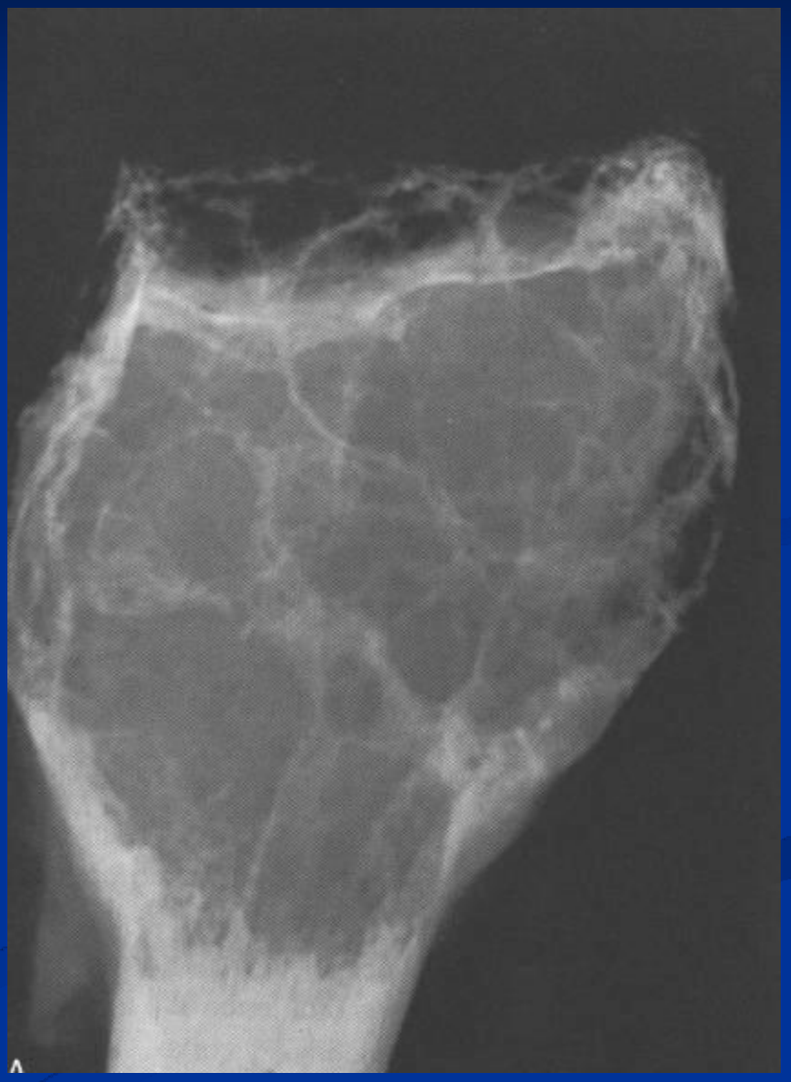
Parosteal Osteosarcoma

Parosteal Osteosarcoma CT Scan



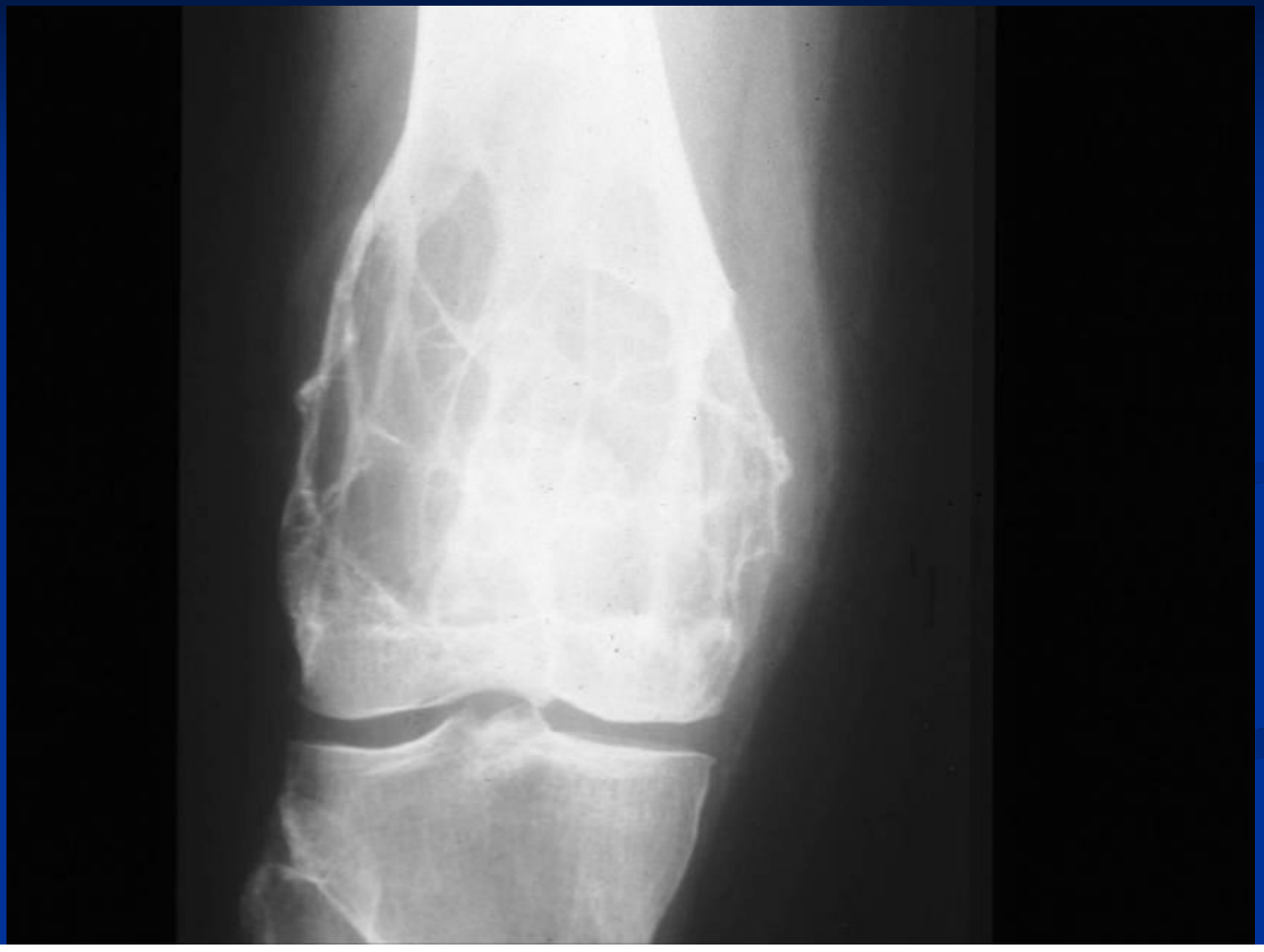
Internal Trabeculations

- Residual Trabeculae or New Bone Formation Due to Adjacent Tumor
- **Differential Diagnosis:**
- ~~**Giant Cell Tumor**~~
- **Chondromyxofibroma**
- **Desmoplastic Fibroma**
- **Nonossifying Fibroma**
- **Aneurysmal Bone Cyst**
- **Hemangioma**



Giant Cell Tumor

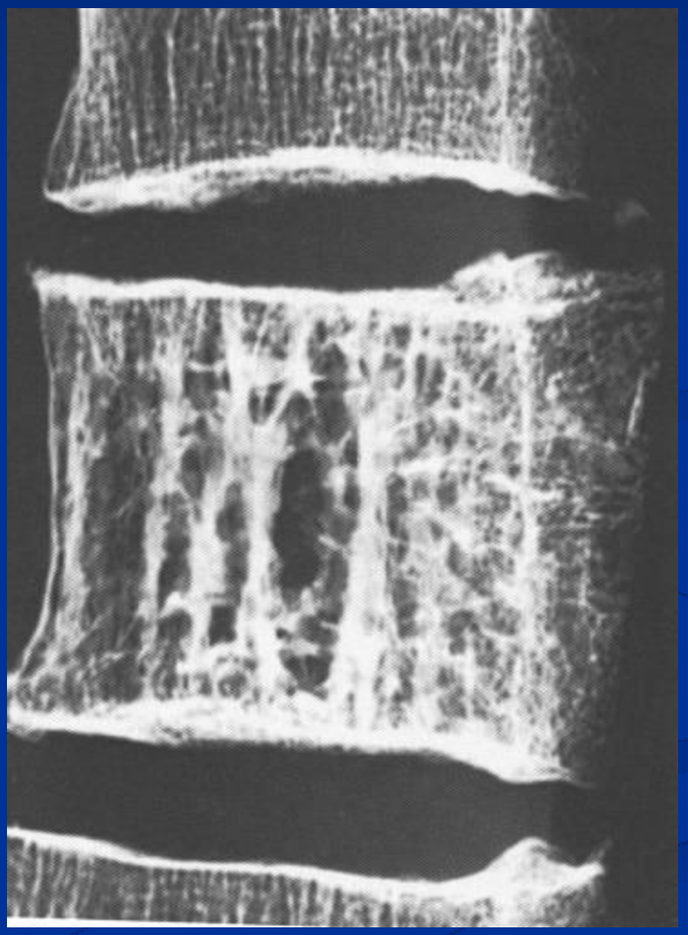
Desmoplastic Fibroma



Chondromyxofibroma

Nonossifying Fibroma

Hemangioma



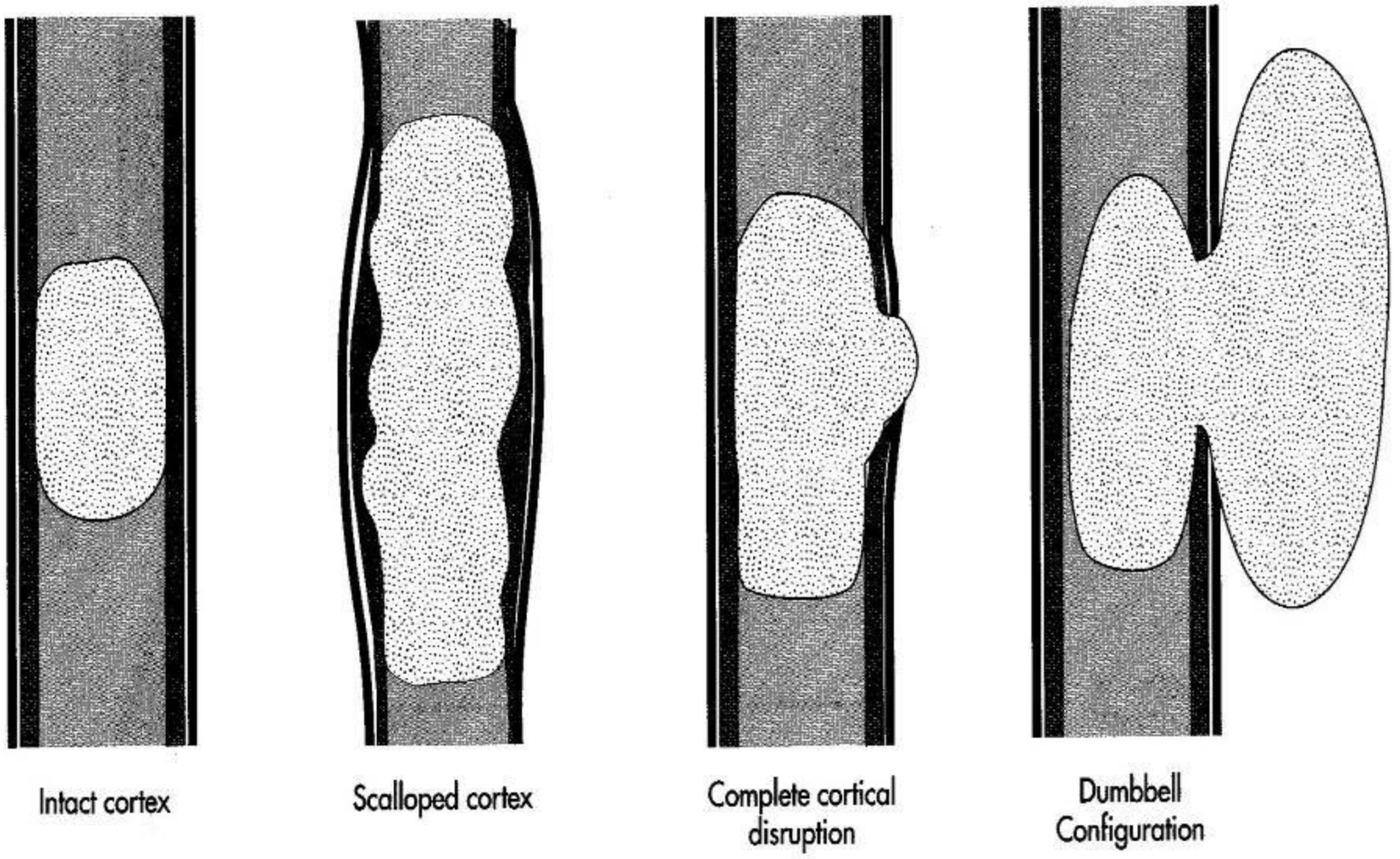
ABC

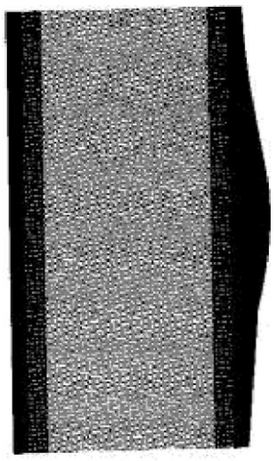
Cortical Erosion, Expansion, Penetration

- Bone Cortex Can Be an Effective Barrier To Tumor Growth of Certain Tumors
- Certain Tumors Penetrate the Cortex Partially or Completely (Benign and Malignant)
- Progressive Endosteal Erosion that is Accompanied by a Periosteal Reaction Leads to an ExpandedBony Contour (Like an ABC)
- Aggressive lesion that Penetrates the entire Cortex or Penetrates Haversian Canals will Elevate the Periosteum and Lead to a Periosteal Reaction

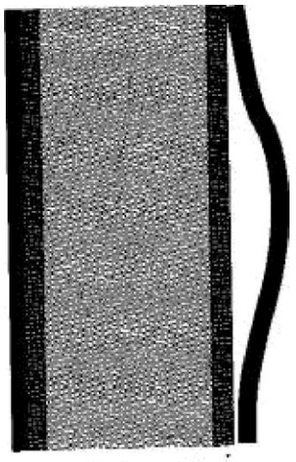
Cortical Erosion, Expansion, Penetration

- It is important to understand that both benign and malignant tumors can penetrate the cortical bone and form a soft tissue mass. The fact that there is a soft tissue mass does not automatically confer that the tumor is malignant. Certain benign tumors can also form a soft tissue mass. The periosteum usually remains intact around a benign soft tissue mass. This may only be detectable on a CT scan demonstrating an “Egg-Shell” rim of calcification around the periphery of the mass. The periosteum is usually destroyed by malignant tumors and does not remain intact around the soft tissue component of a malignant tumor.

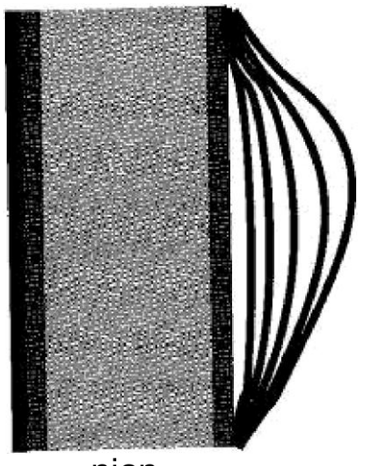

Intact cortex
Scalloped cortex
Complete cortical disruption
Dumbbell Configuration



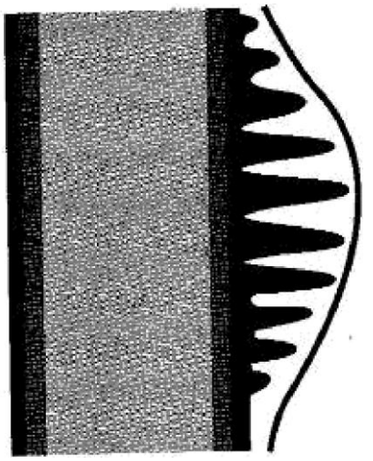
Solid

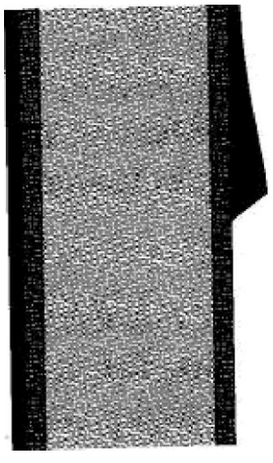


Single lamellar

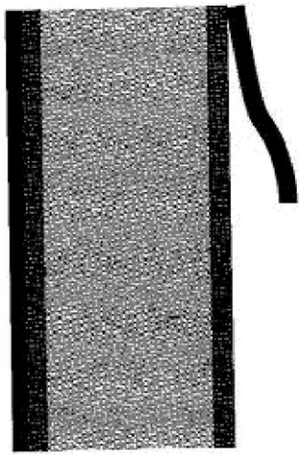


O nion-
skin





uttress



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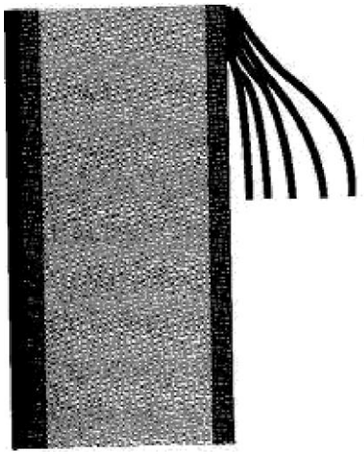
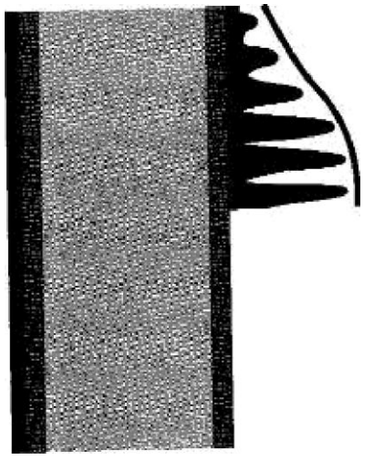
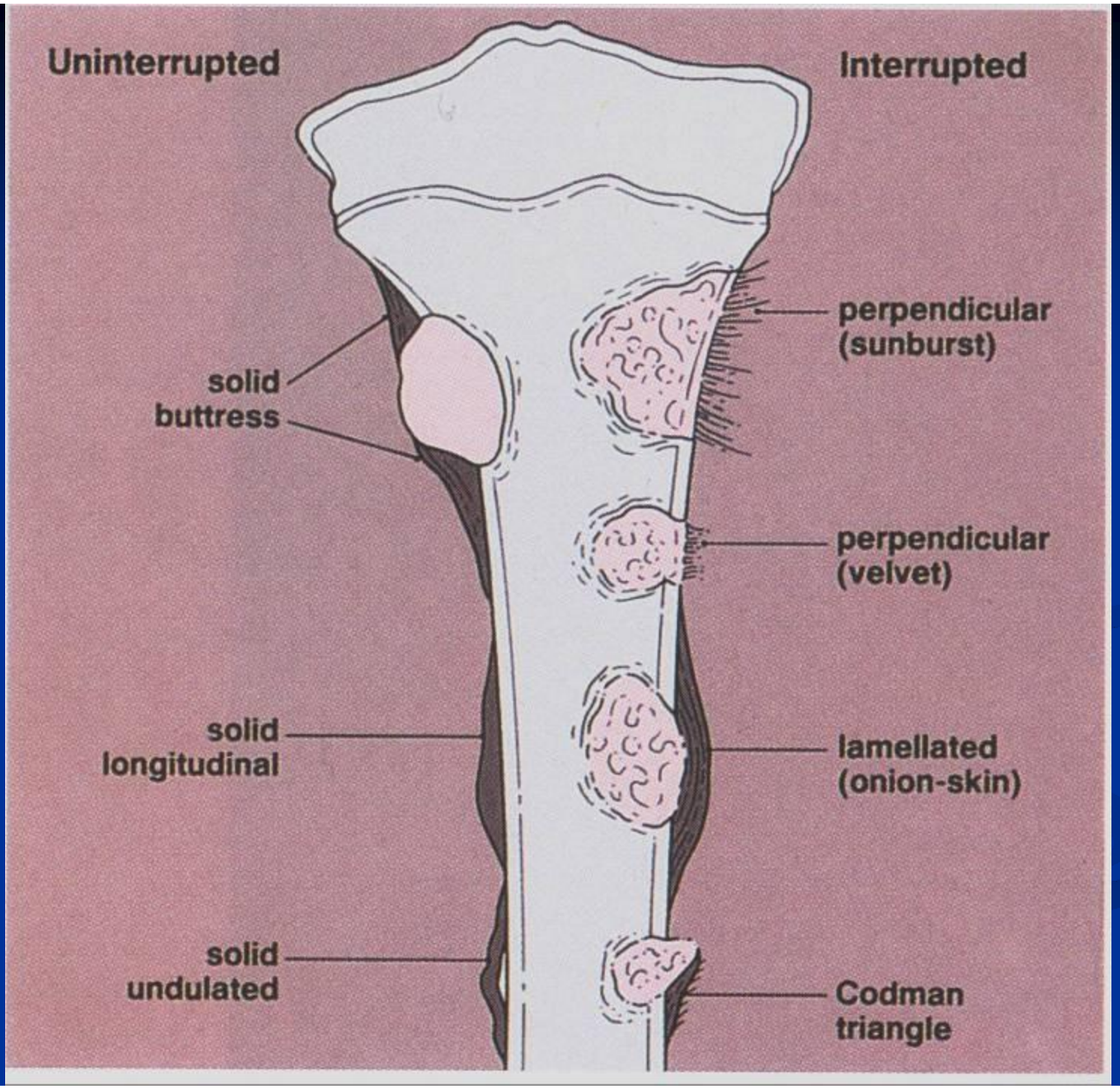
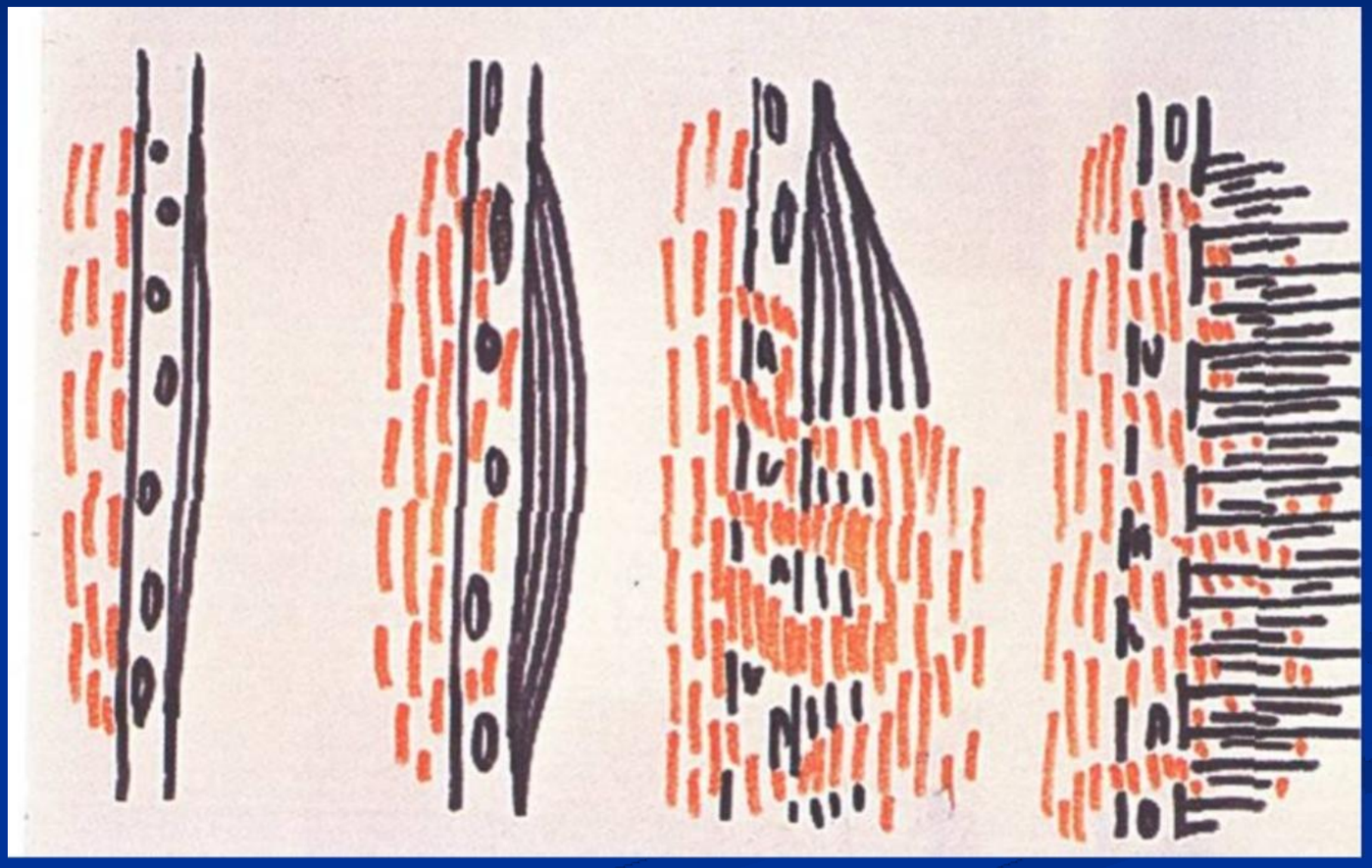


Lamel




Uninterrupted
Interrupted
perpendicular
(sunburst)
solid
buttress
perpendicular
(velvet)
solid
longitudinal
lamellated
(onion-skin)
solid
undulated
Codman
triangle

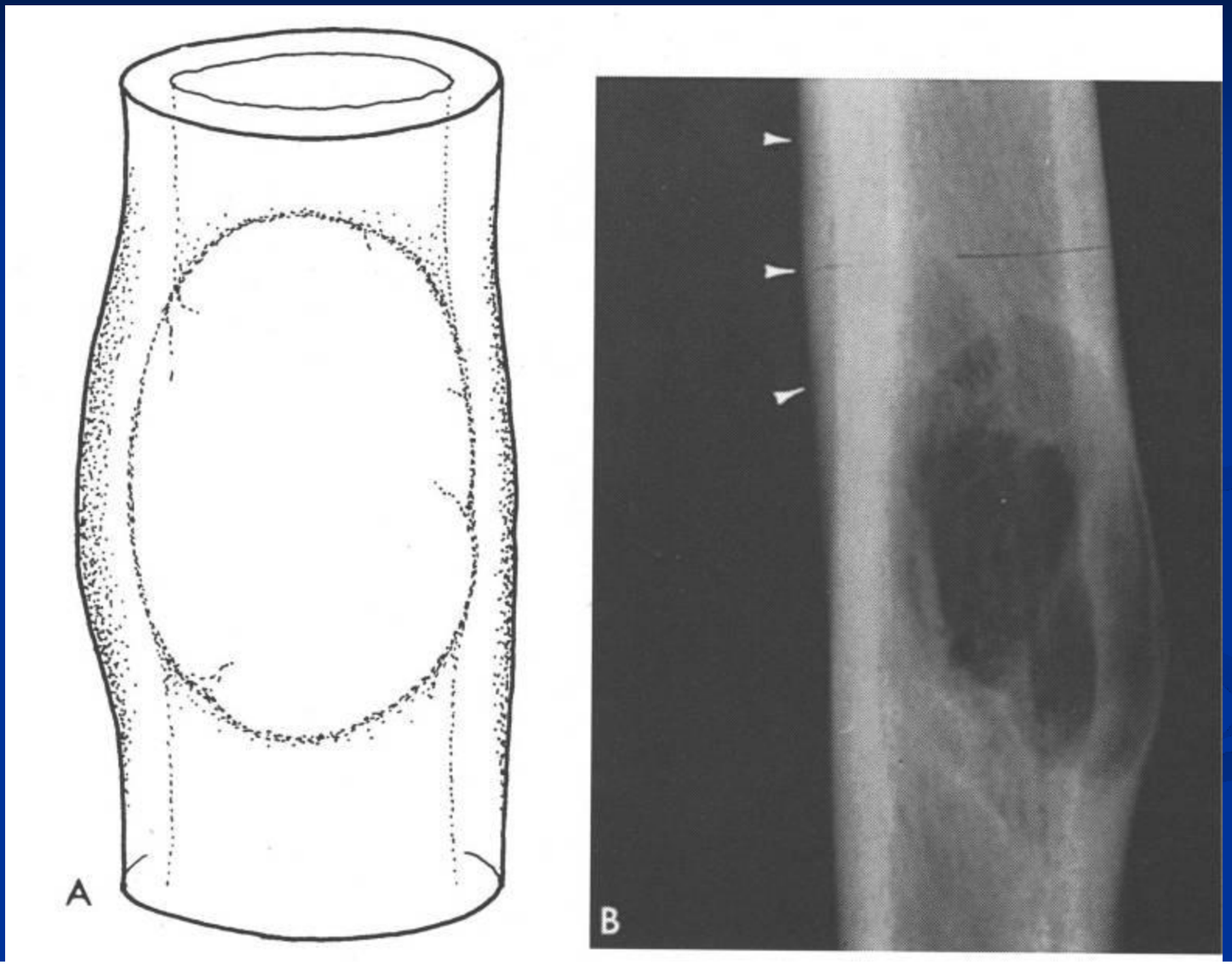
Periosteal Reactions as Related to Tumor Growth



Periosteal Response

- **Benign: Buttressing Pattern; Single Lamellar; Cortical Thickening; Bony Expansion**
  - Endosteal Erosion Leads to Periosteal Proliferation
  - Can Be Same or Diminished Thickness Compared to Normal Cortex
  - Buttressing: Interface Between Normal and Expanded Cortex is Filled In with Bone

Buttressing

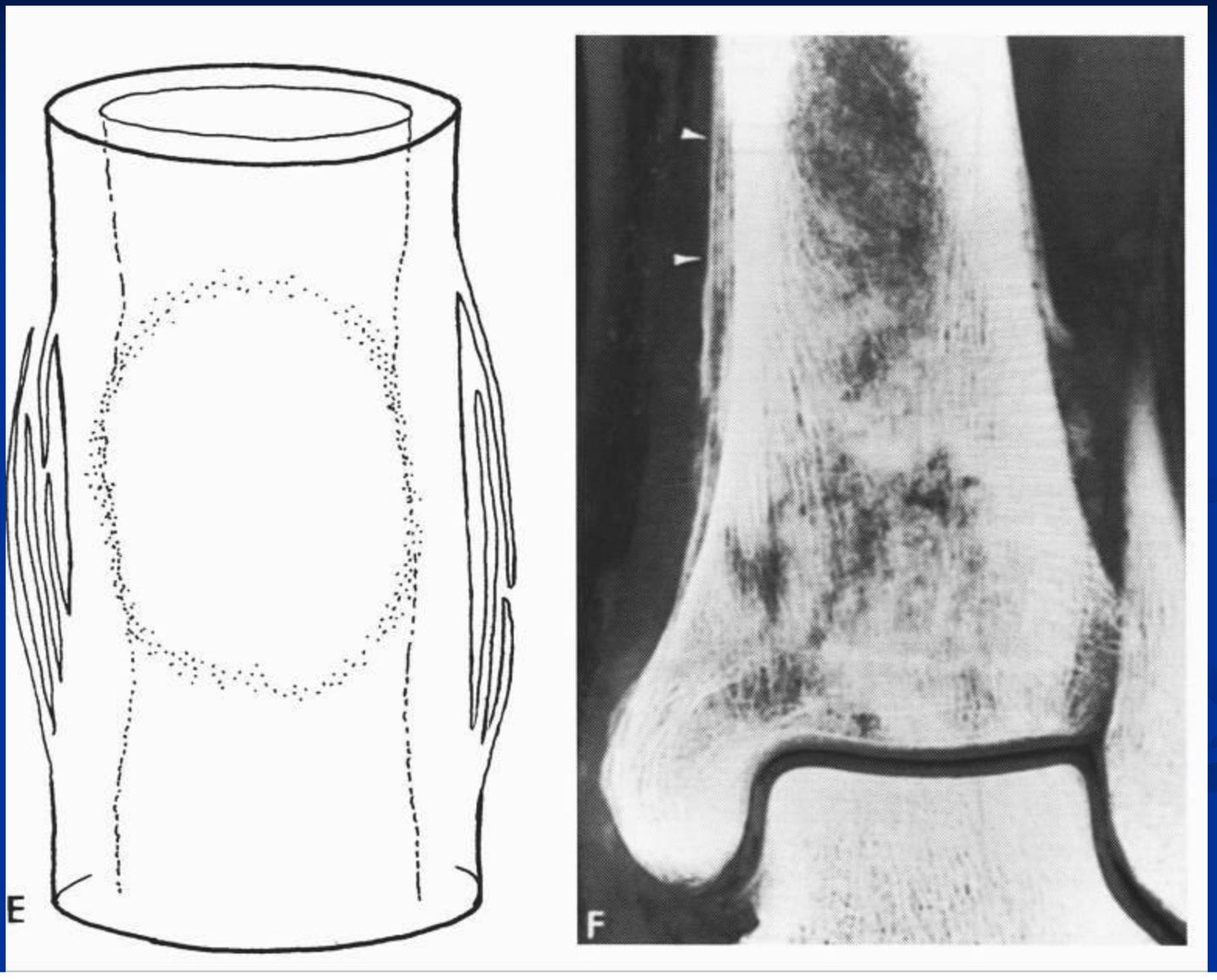


Buttressing

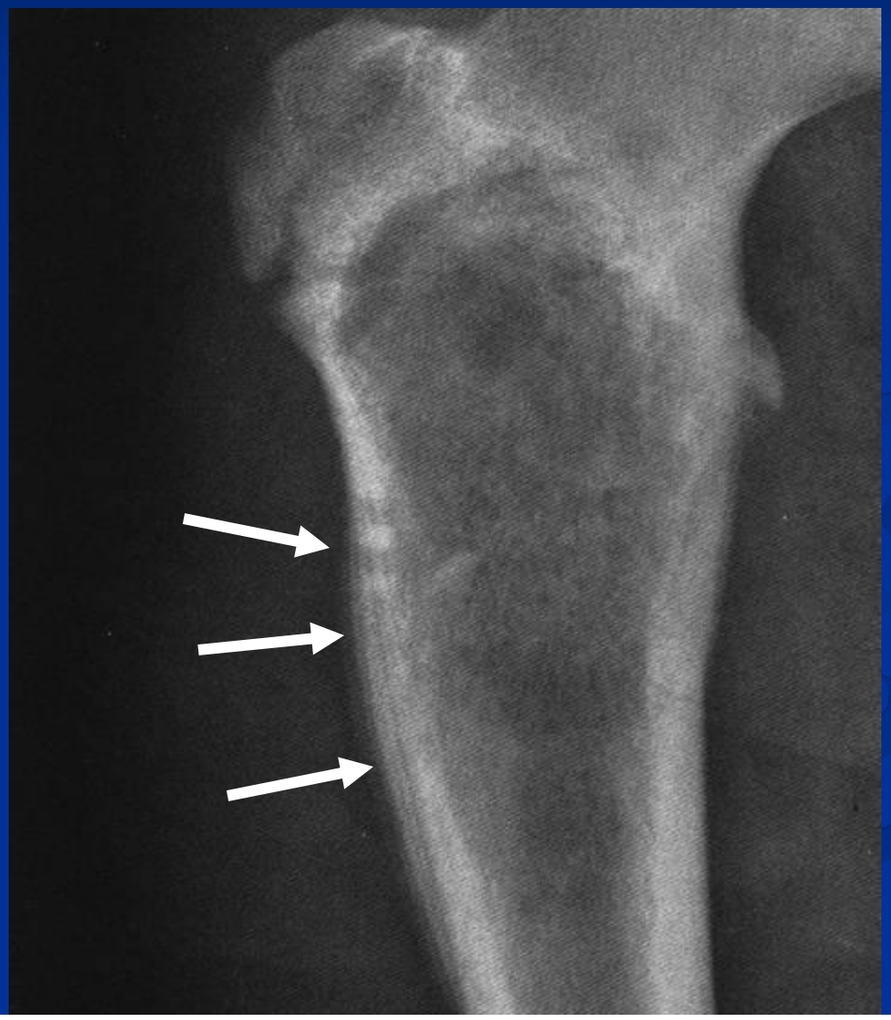
Periosteal Response

- **Malignant Tumors**: Rapid Tumor Growth May Lead to Single or Multiple Concentric Layers
- **Types of Malignant Periosteal Reactions:**
  - Onion Skin: Multiple Concentric layers
  - Codman's Triangle: Occurs at the Periphery of a Lesion or Infective Focus
  - Sun Burst: Delicate Rays that Extend Away from the Bone (Angled with Bone)
  - Hair On End: Rays are Perpendicular to Bone

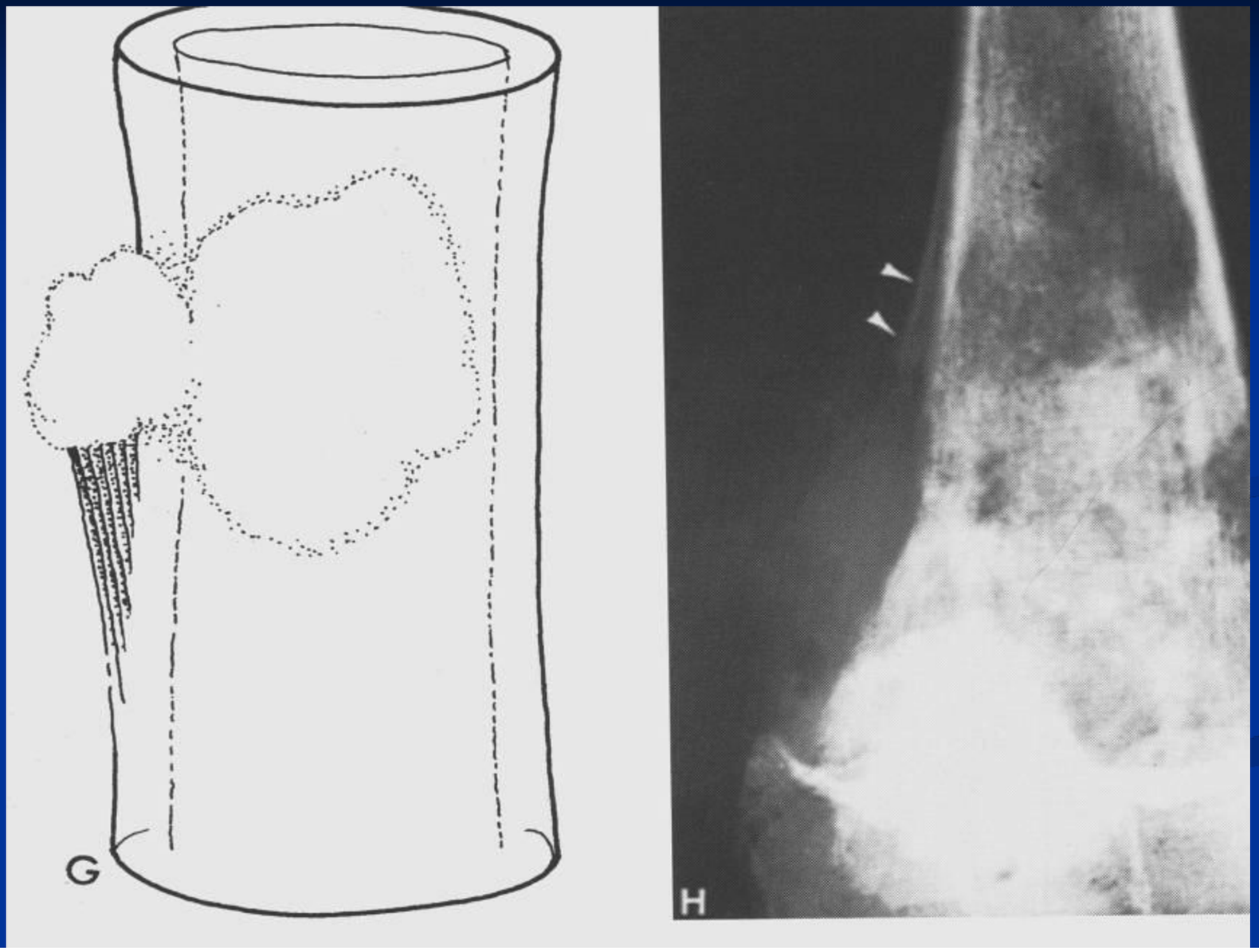
Onion Skin Appearance



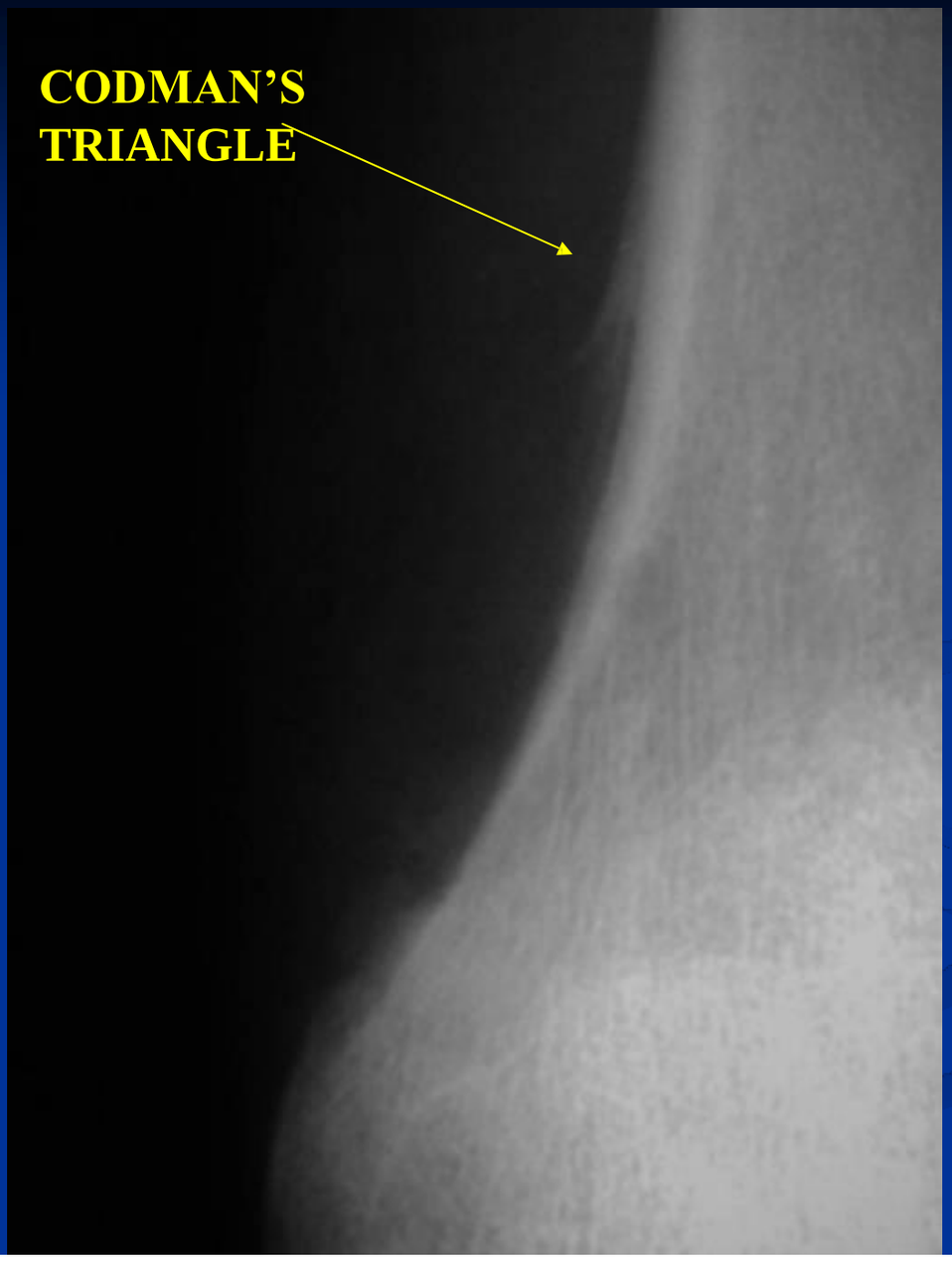
Onion Skin



Codman's Triangle

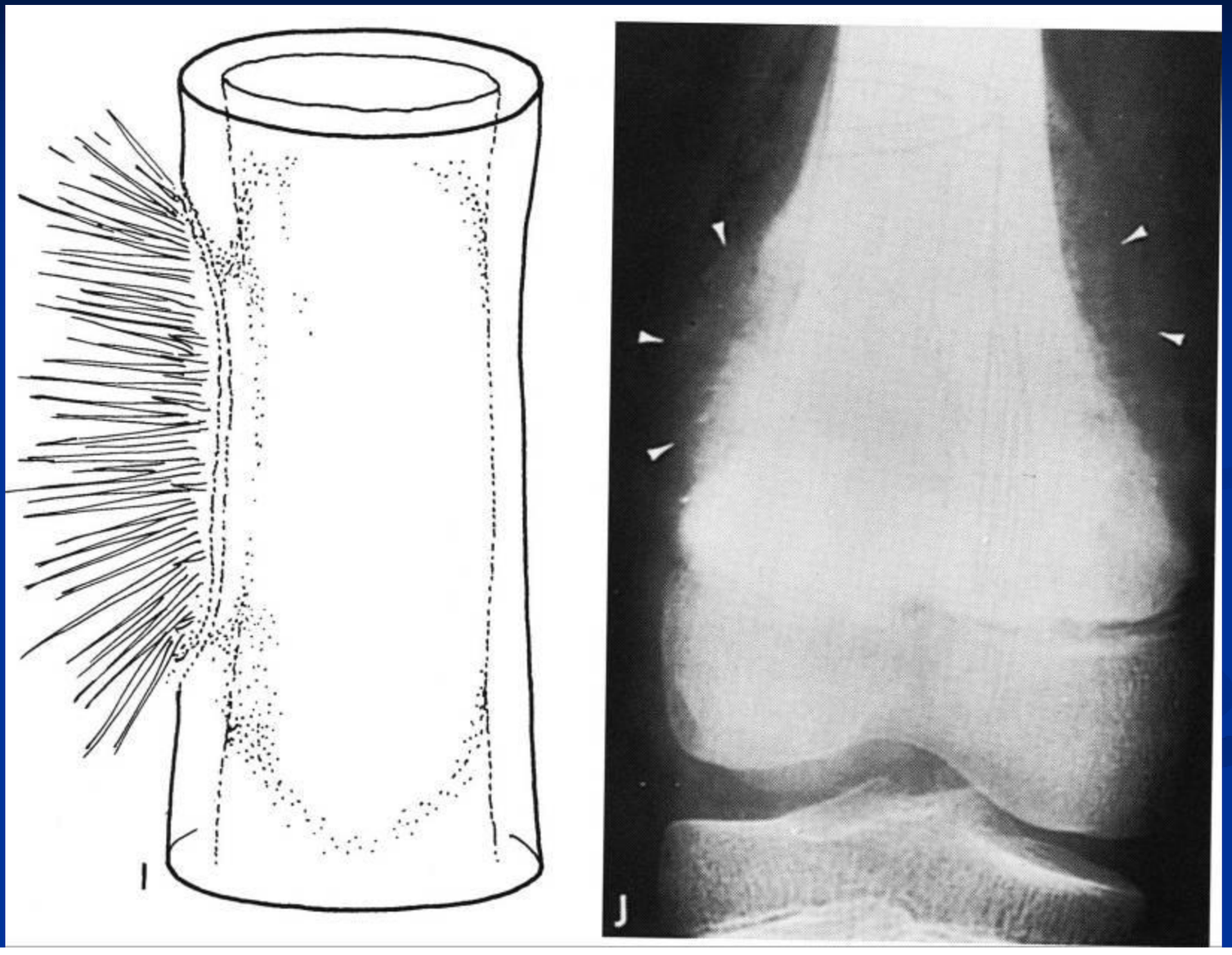


Codman's Triangle


CODMAN'S
TRIANGLE

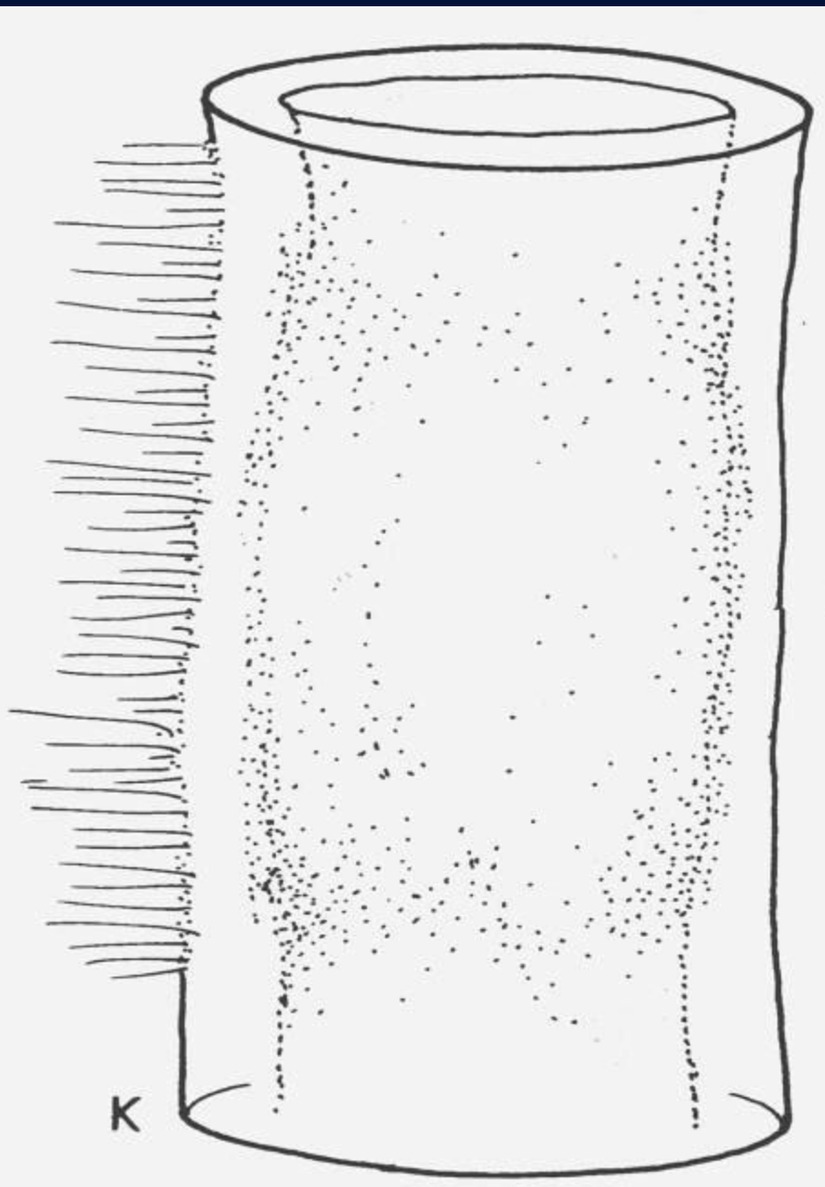
CT Scan of Codman's triangle

Sunburst Pattern

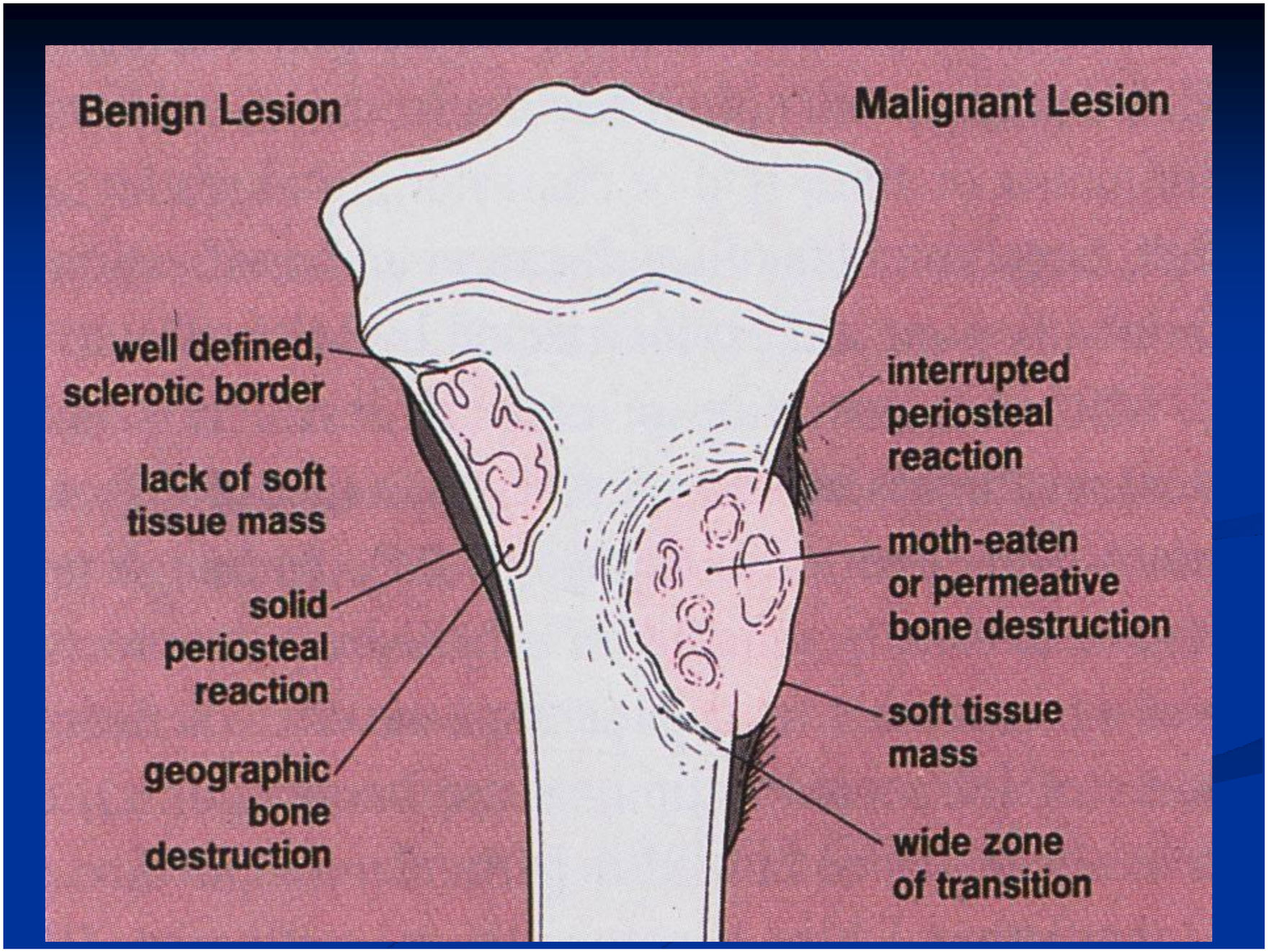


Sunburst Pattern

Hair On End

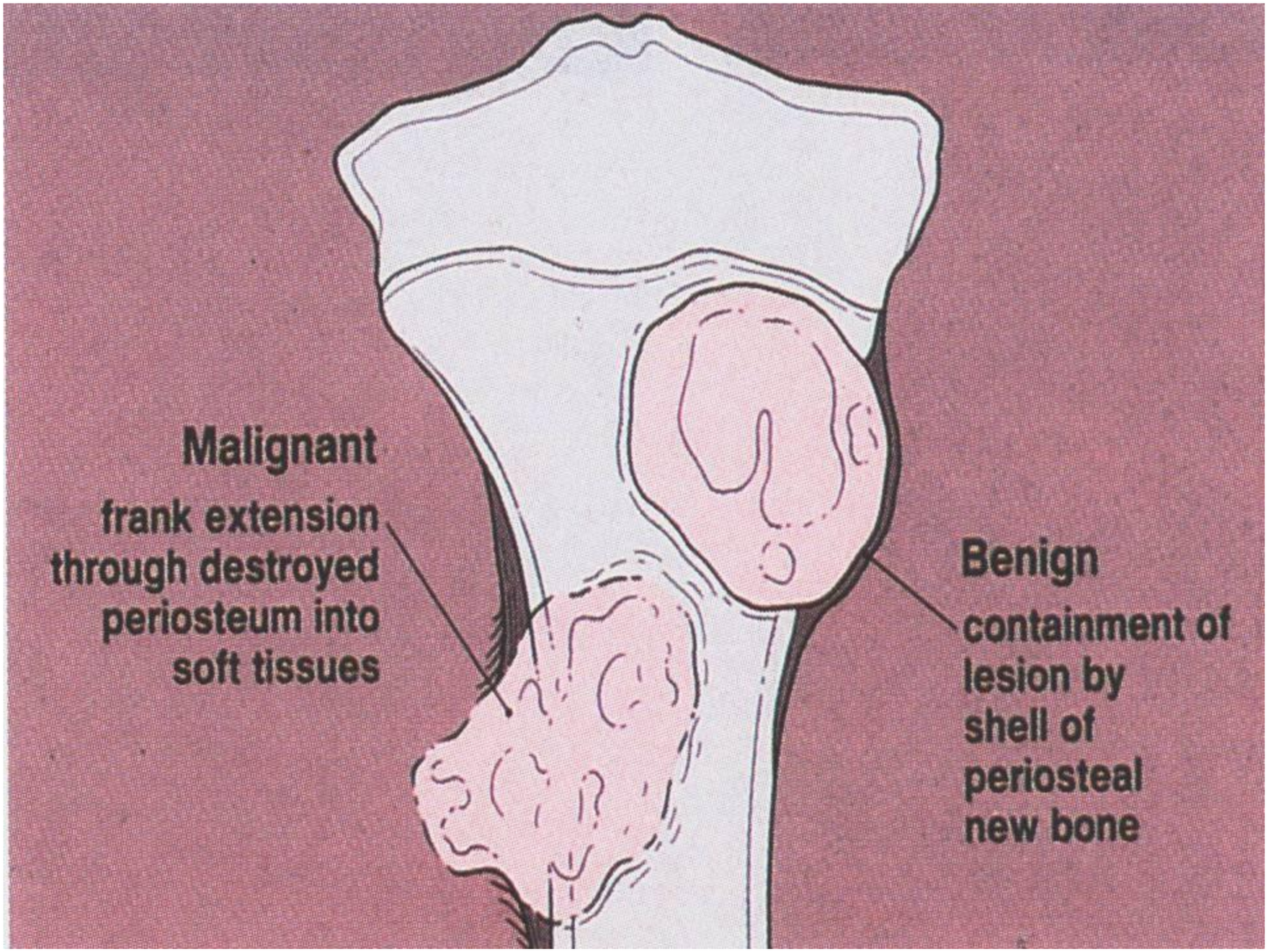


Hair on End Periosteal Reaction

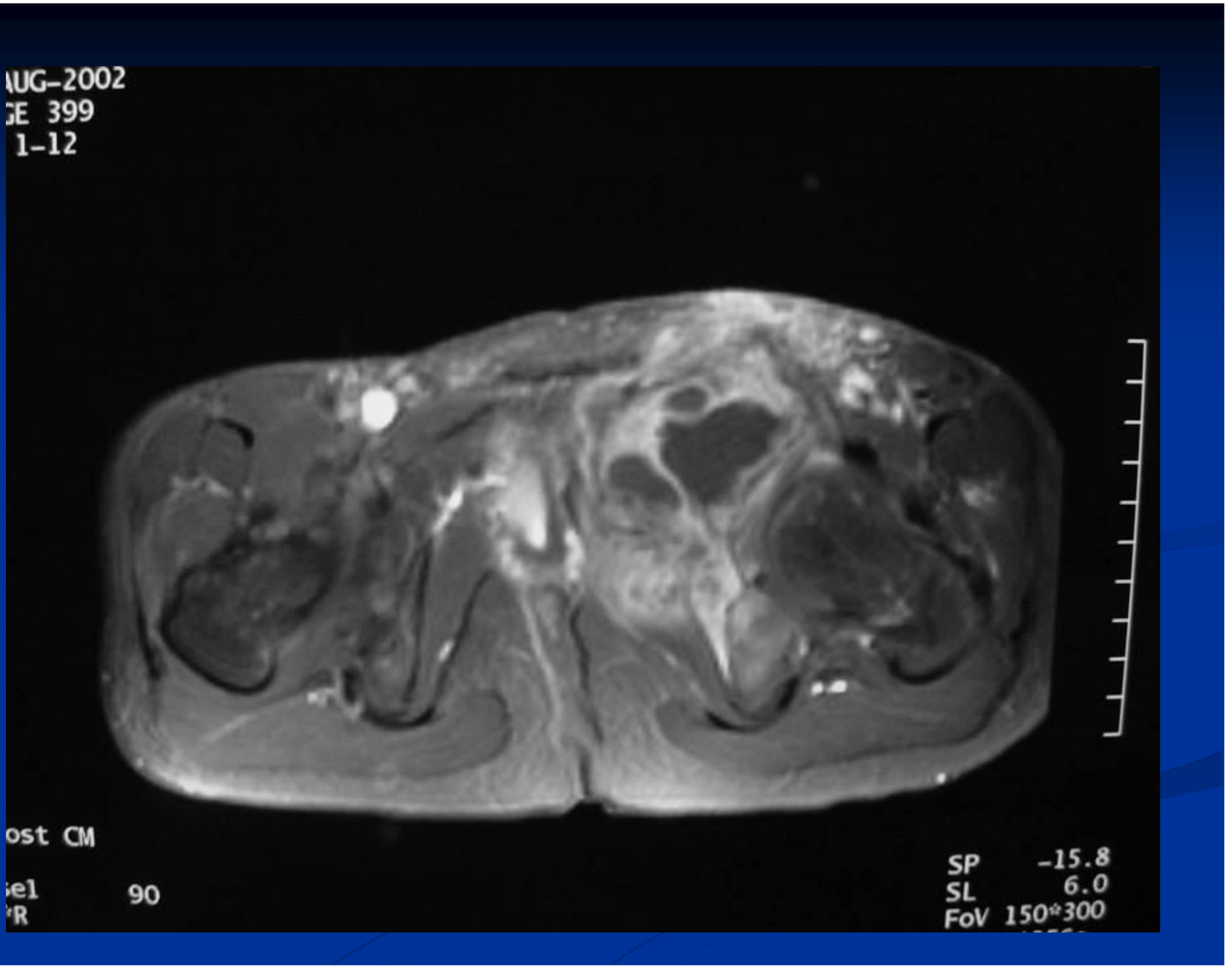

Benign Lesion
Malignant Lesion
well defined, sclerotic border
lack of soft tissue mass
solid periosteal reaction
geographic bone destruction
interrupted periosteal reaction
moth-eaten or permeative bone destruction
soft tissue mass
wide zone of transition

Soft Tissue Mass

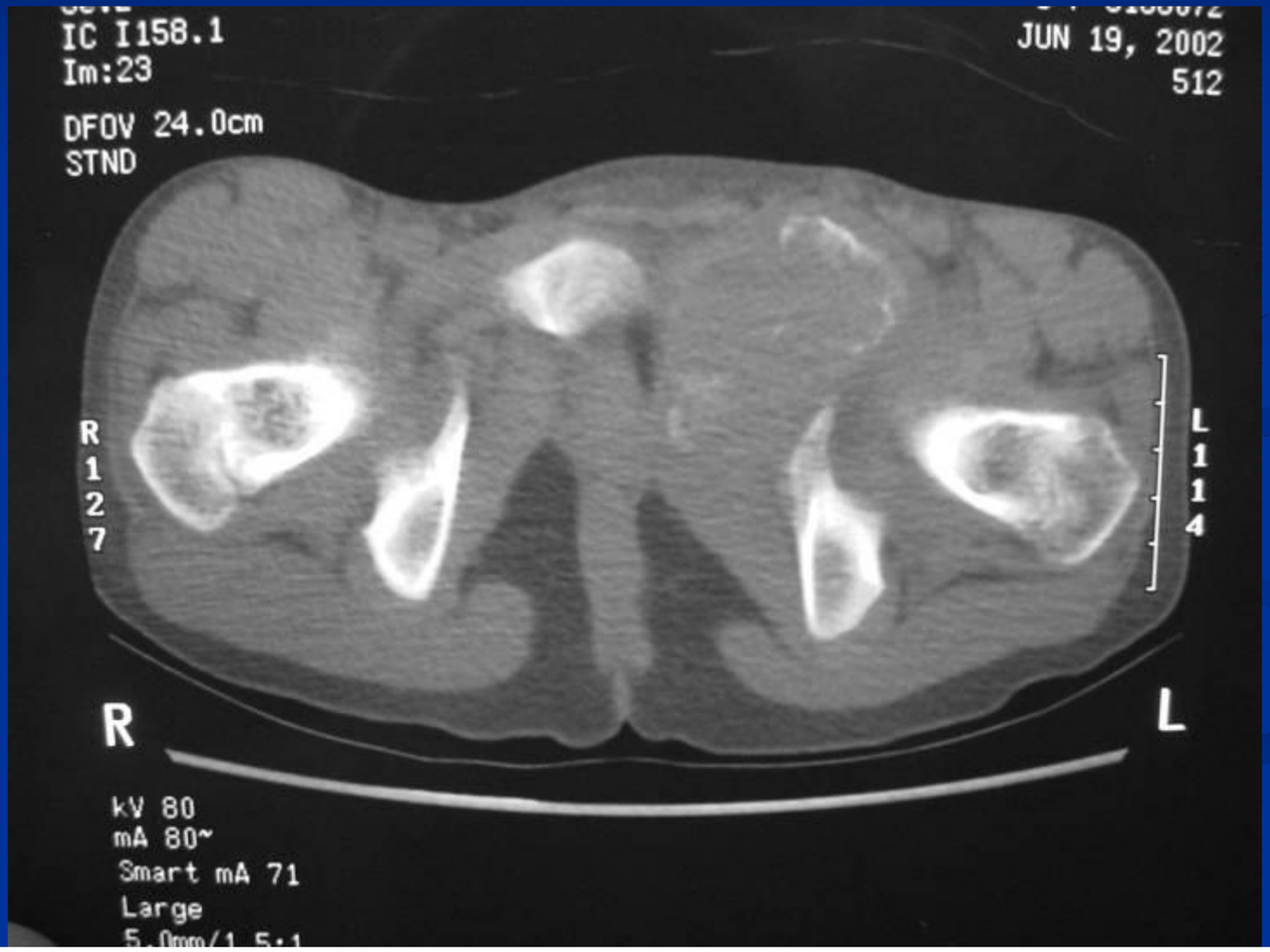
- Primary Malignant Bone Tumors
- Benign Aggressive Bone Tumors
- Mets
- Osteomyelitis


Malignant
frank extension through destroyed periosteum into soft tissues
Benign
containment of lesion by shell of periosteal new bone

Benign Aggressive Tumor

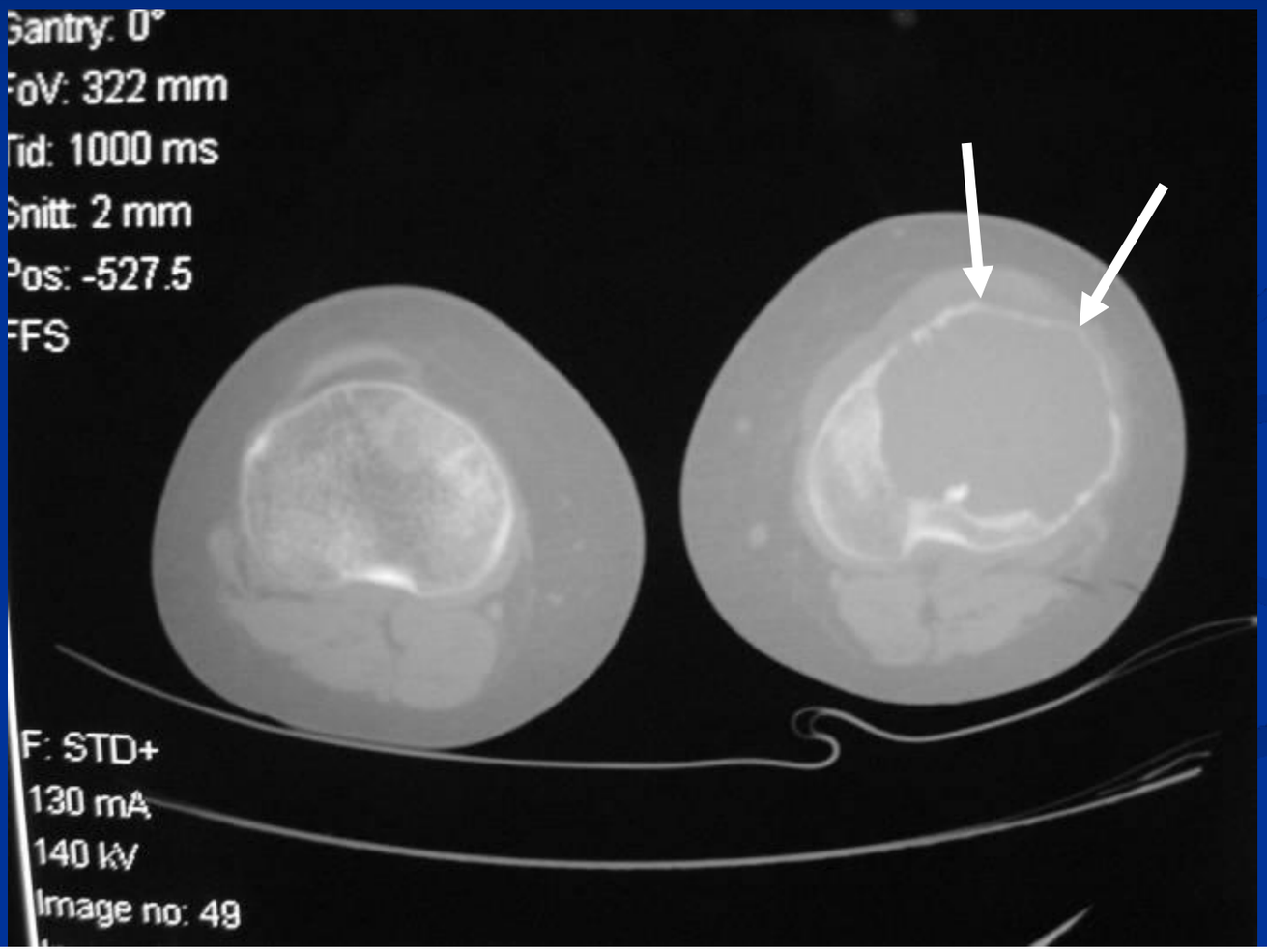

AUG-2002
GE 399
1-12
ost CM
el
R
90
SP -15.8
SL 6.0
FoV 150*300

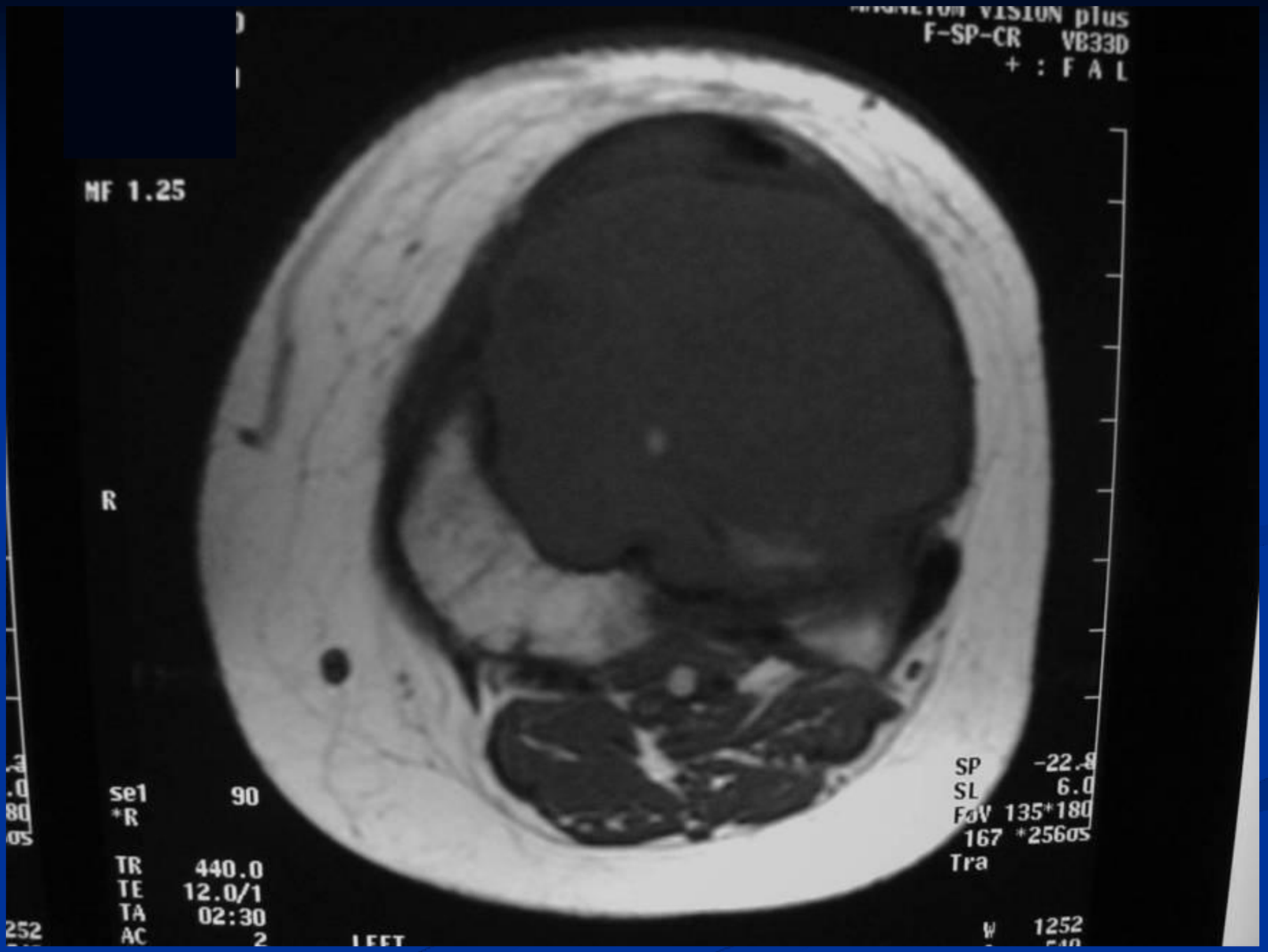
Periosteum Intact Around Periphery of Soft Tissue Mass



Benign Aggressive Giant Cell Tumor

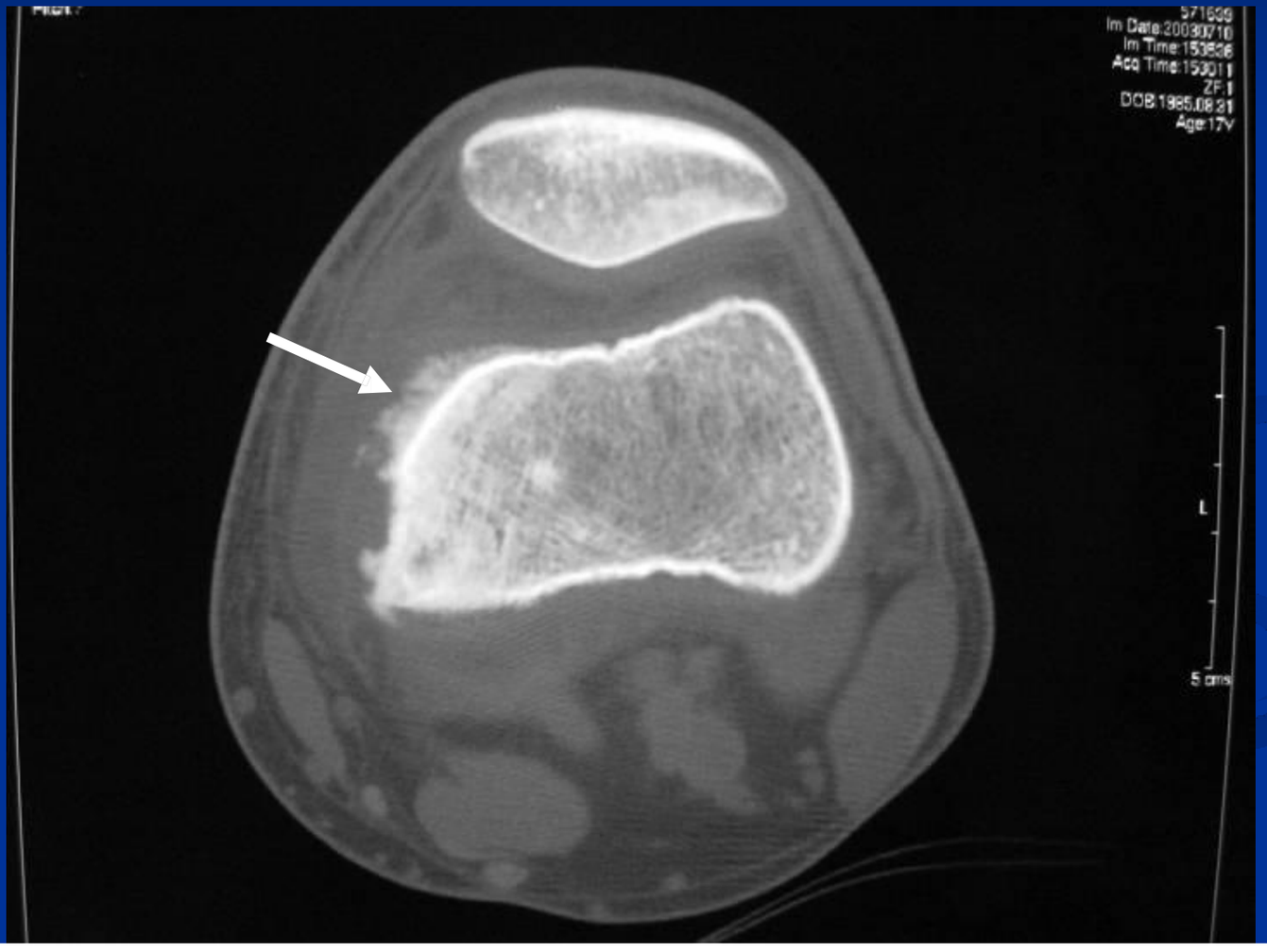
Periosteum Intact Around Periphery



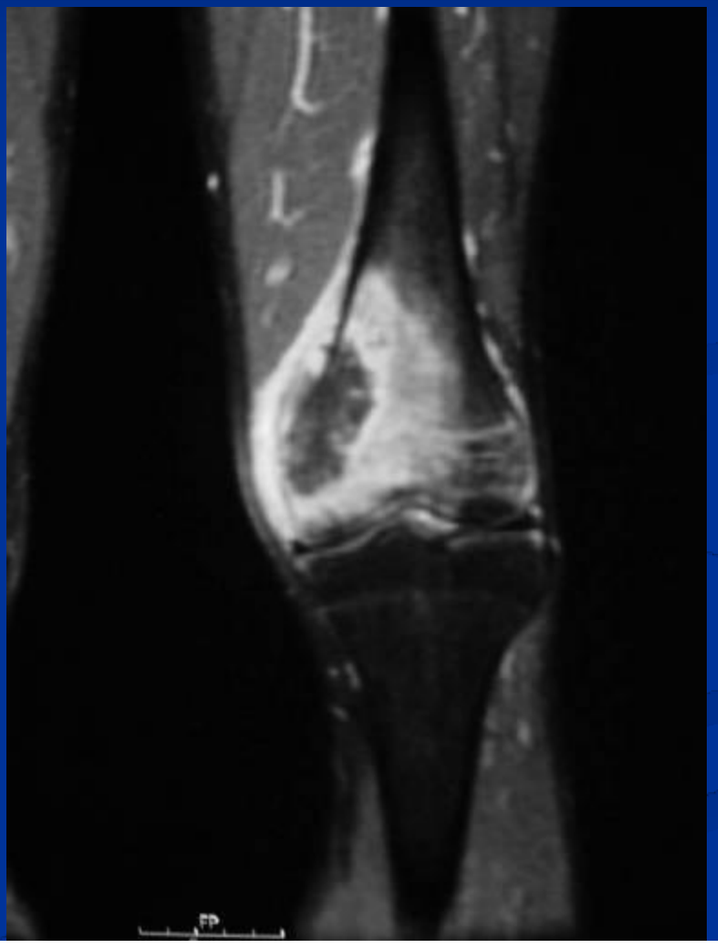

F-SP-CR VB33D
+ : F A L
MF 1.25
R
se1 90
*R
TR 440.0
TE 12.0/1
TA 02:30
AC 2
SP
SL 6.0
FOV 135*180
167 *256
Tra
W 1252

Malignant-- Osteosarcoma

Periosteum Not Intact Around Soft Tissue Mass

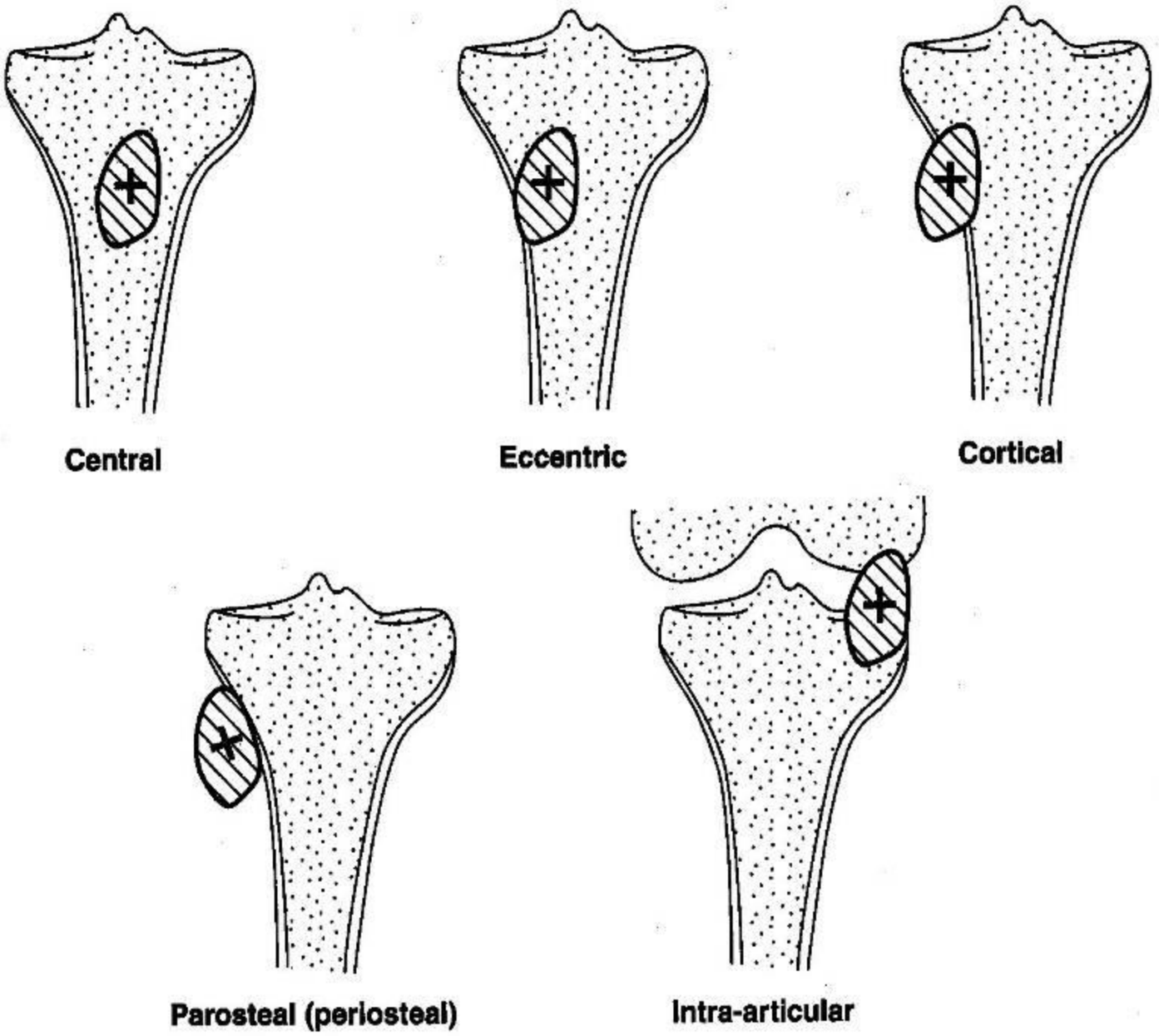


MRI of Osteosarcoma Periosteum Not Intact Around Soft Tissue Mass



Distribution in Bone

- **Position in Transverse Plain**
  - Central
  - Eccentric
  - Cortical
  - Juxtacortical (Periosteal/Parosteal)
  - Soft Tissue Location


Central
Eccentric
Cortical
Parosteal (periosteal)
Intra-articular

A

Central Axis

- Enchondromas
- Fibrous Dysplasia
- Simple Bone Cysts

UBC

Fibrous Dysplasia

Enchondroma

Eccentric Lesions

- Giant Cell Tumor
- Osteosarcoma
- Chondrosarcoma
- Chondromyxofibroma

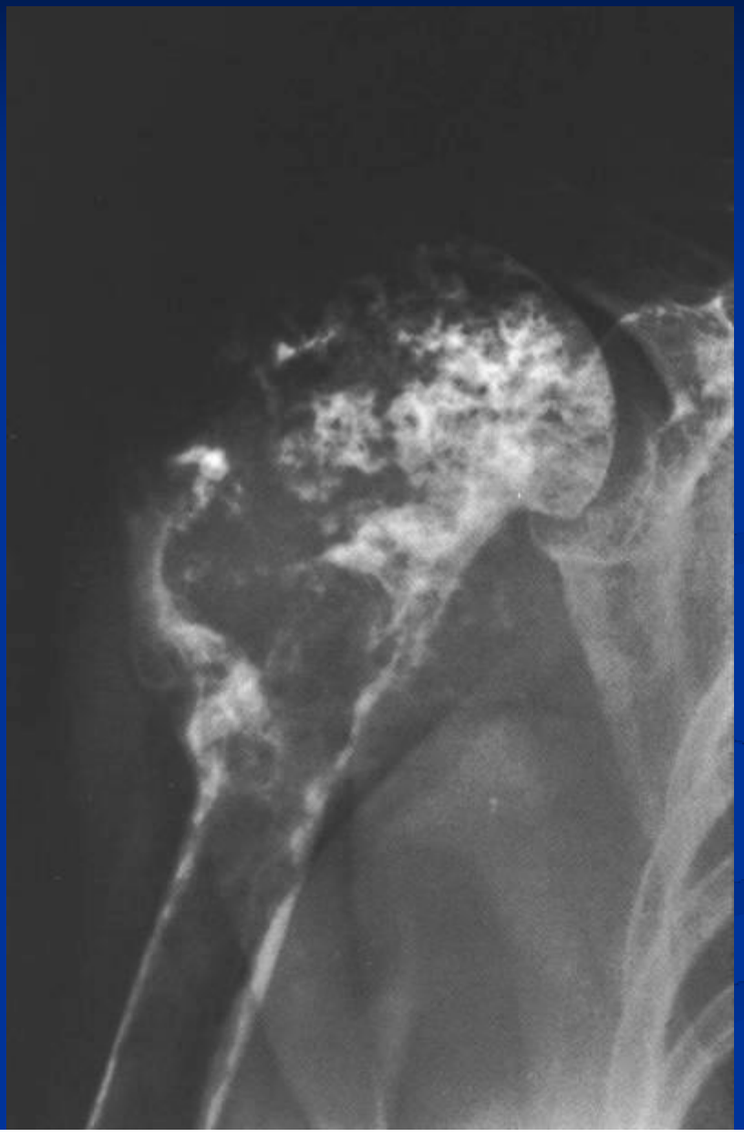
GC

Osteosarcoma

Osteosarcoma

Osteosarcoma

Chondrosarcoma



Chondromyxofibroma

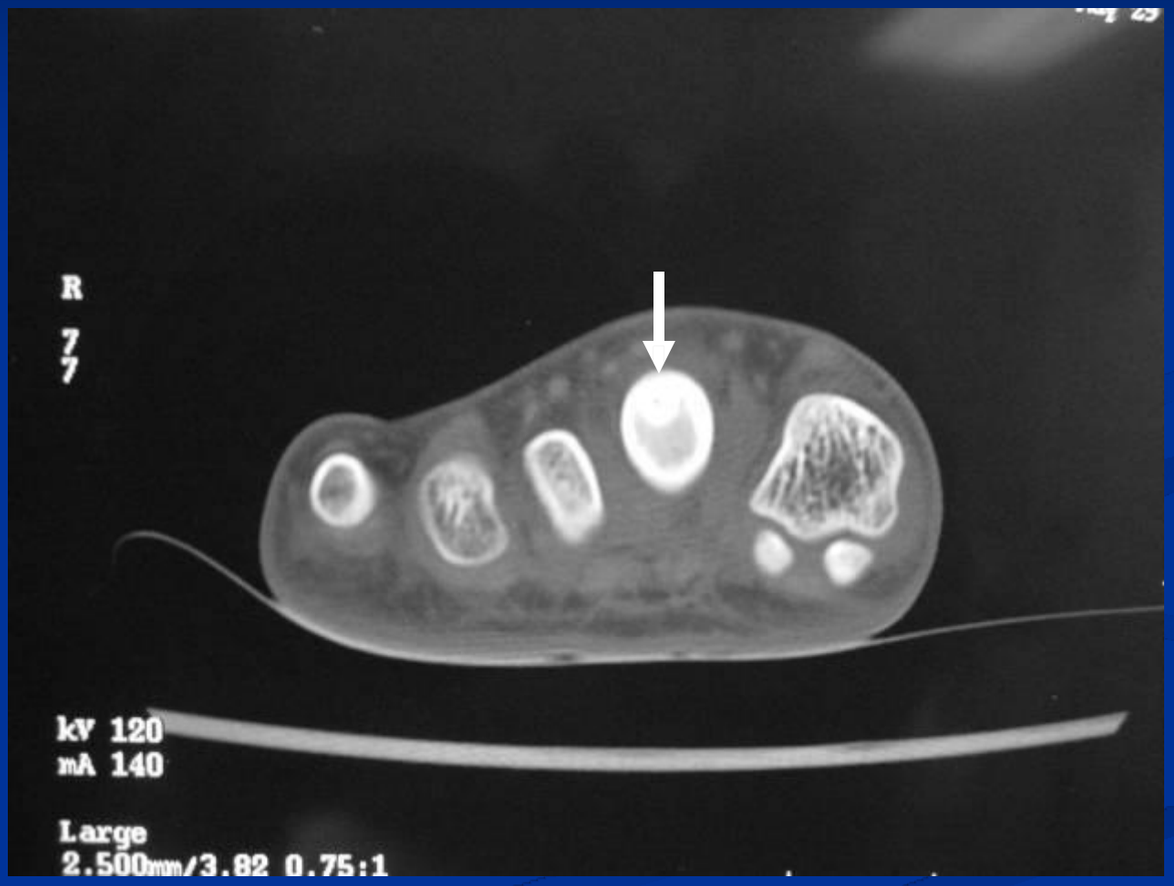
Cortical Lesions

- Nonossifying Fibromas
- Osteoid Osteomas

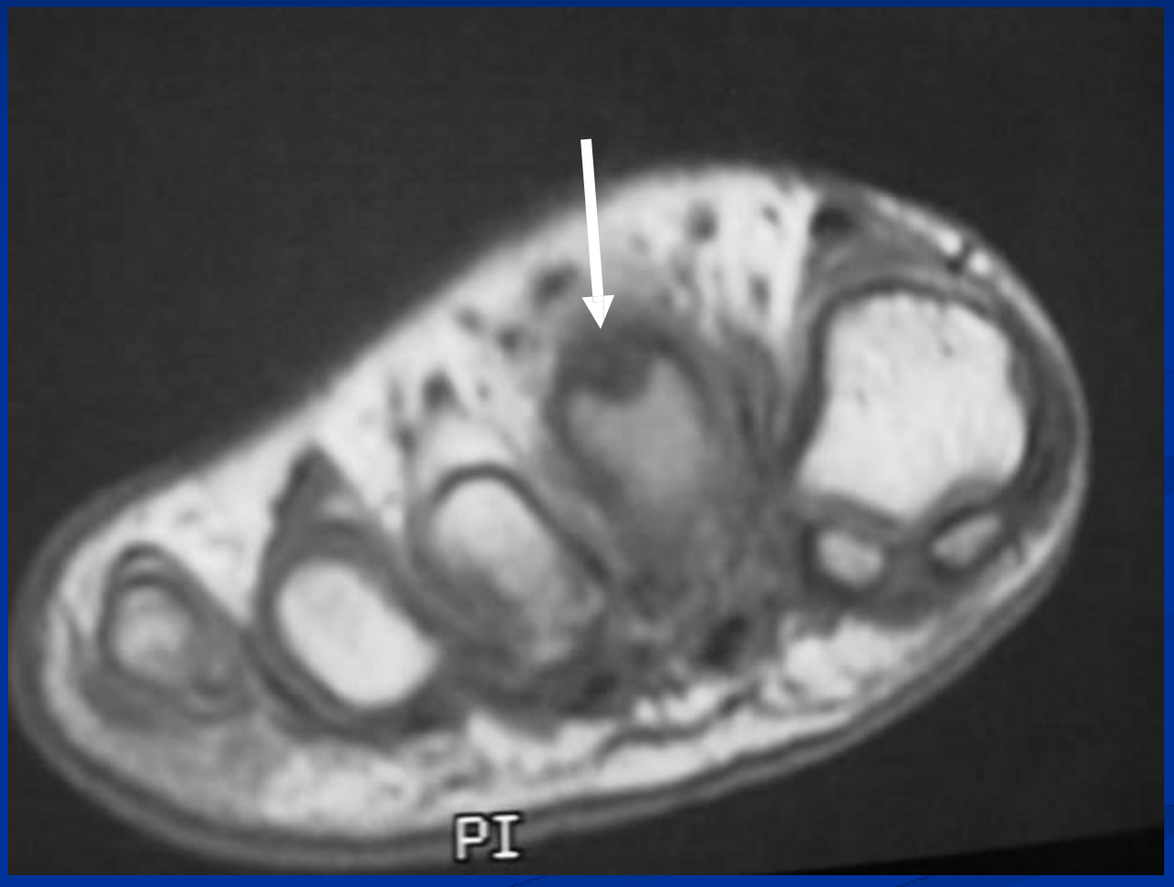
Nonossifying Fibroma

Osteoid Osteoma

Osteoid Osteoma

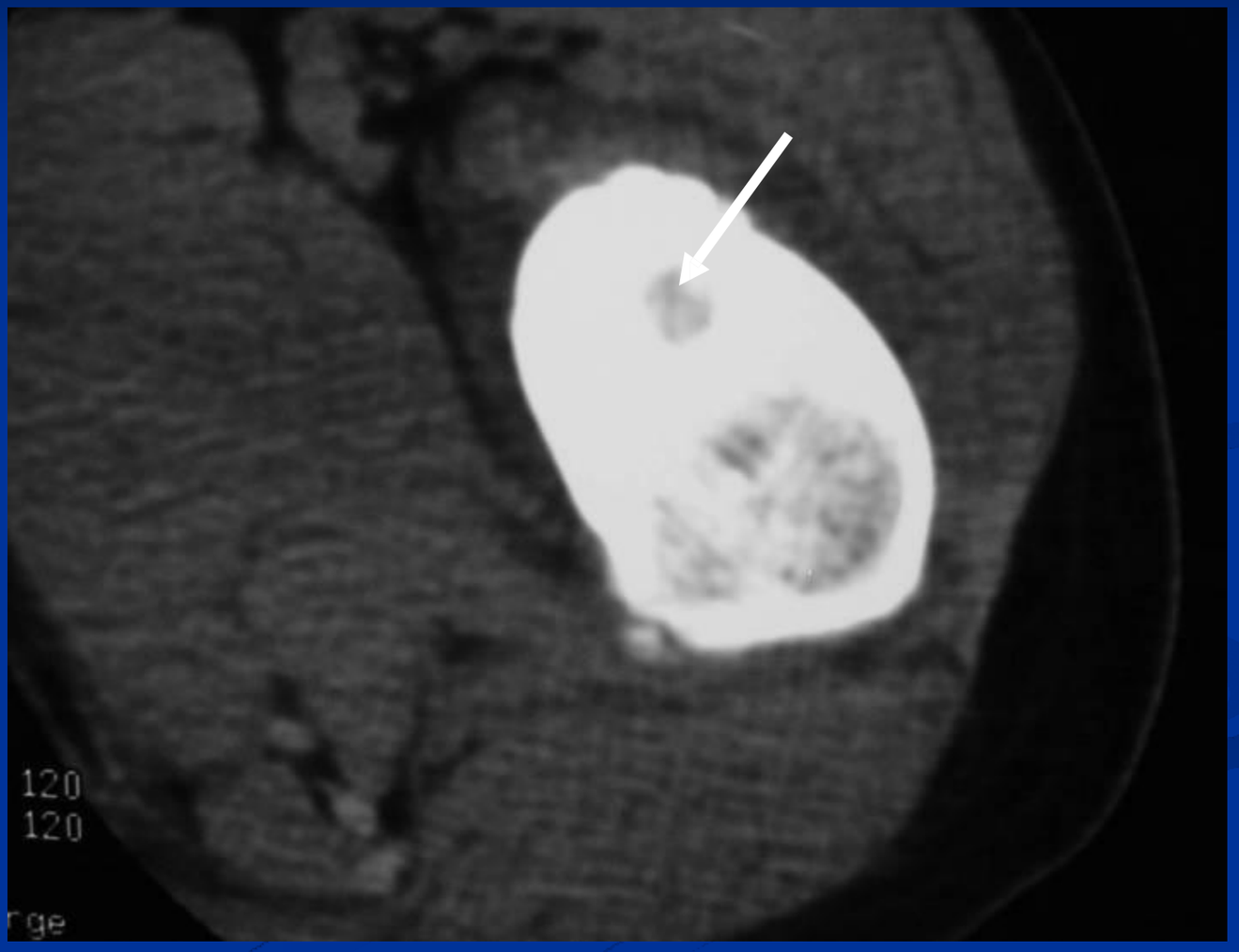


Osteoid Osteoma



Osteoid Osteoma

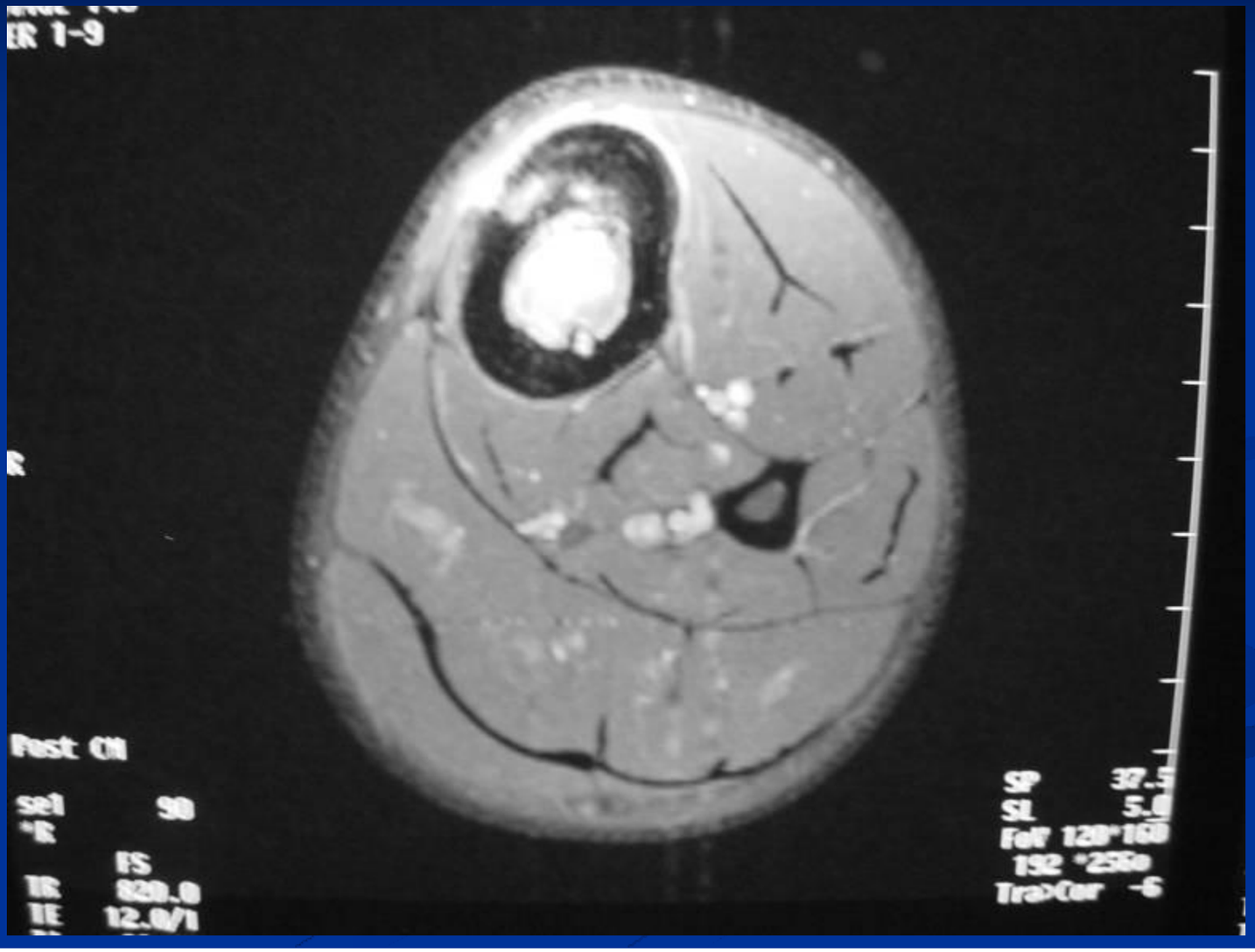
Osteoid Osteoma



Brodie's Abscess

Brodie's Abscess

Brodie's Abscess

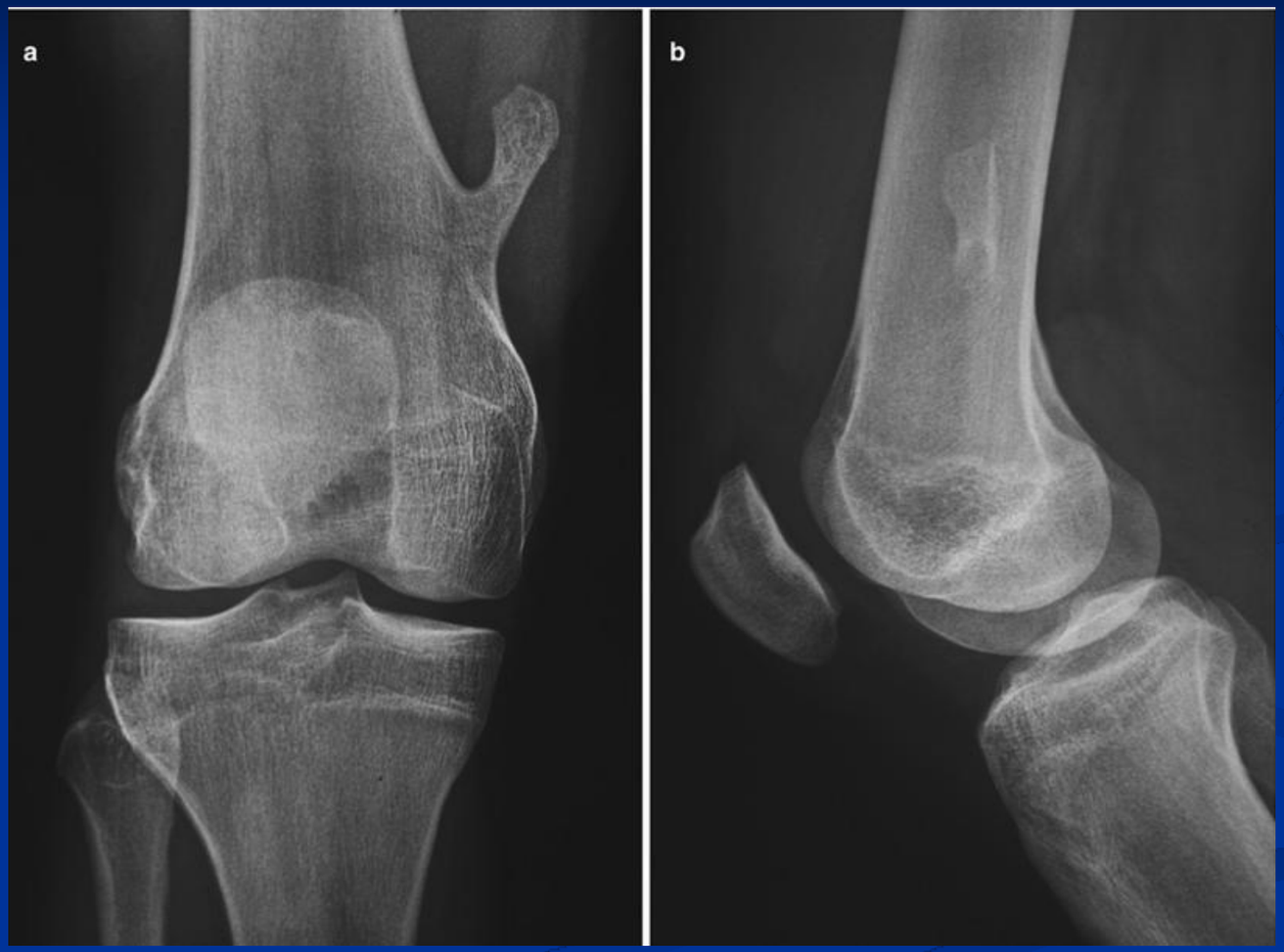


Juxtacortical Lesions

- Juxtacortical Chondroma
- Periosteal Osteosarcoma/Chondrosarcoma
- Parosteal Osteosarcoma

Periosteal Chondroma

Osteochondroma

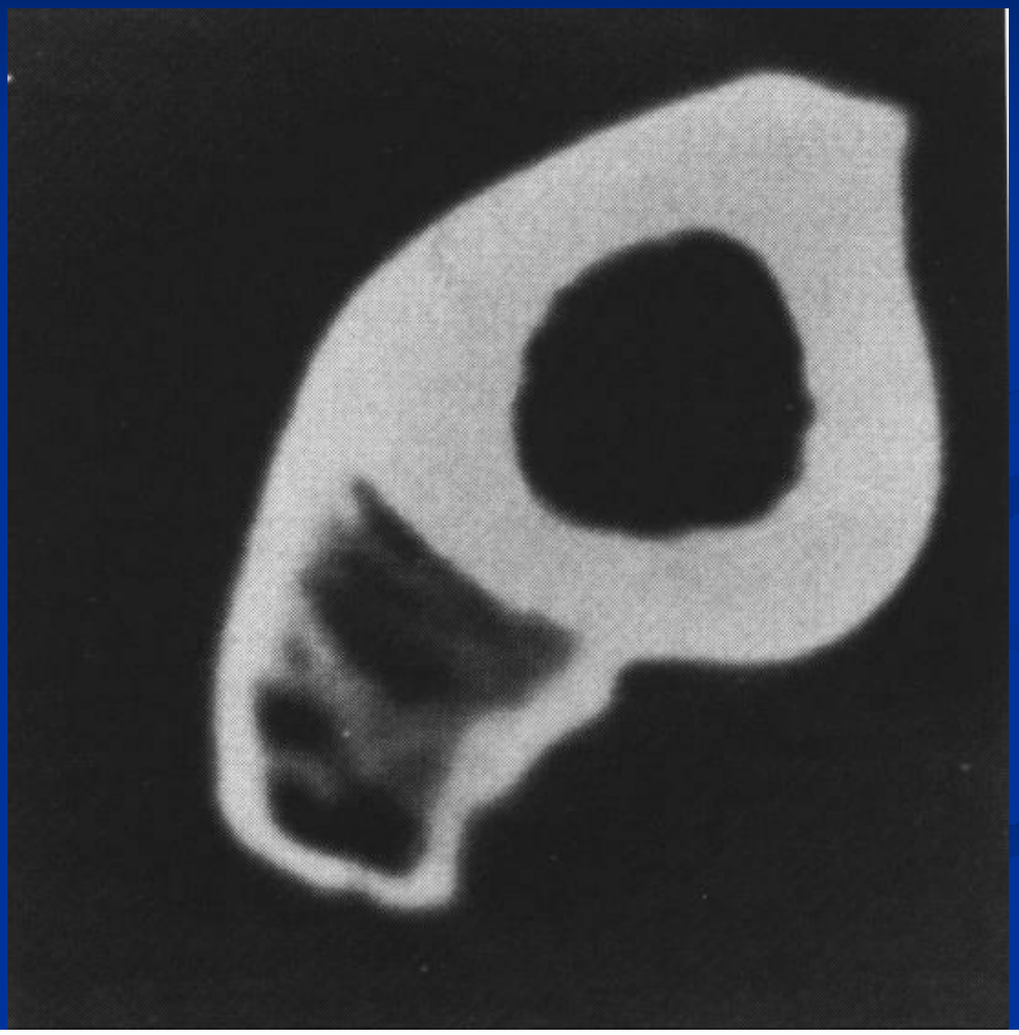


Osteochondroma Cortico-Medullary Continuity

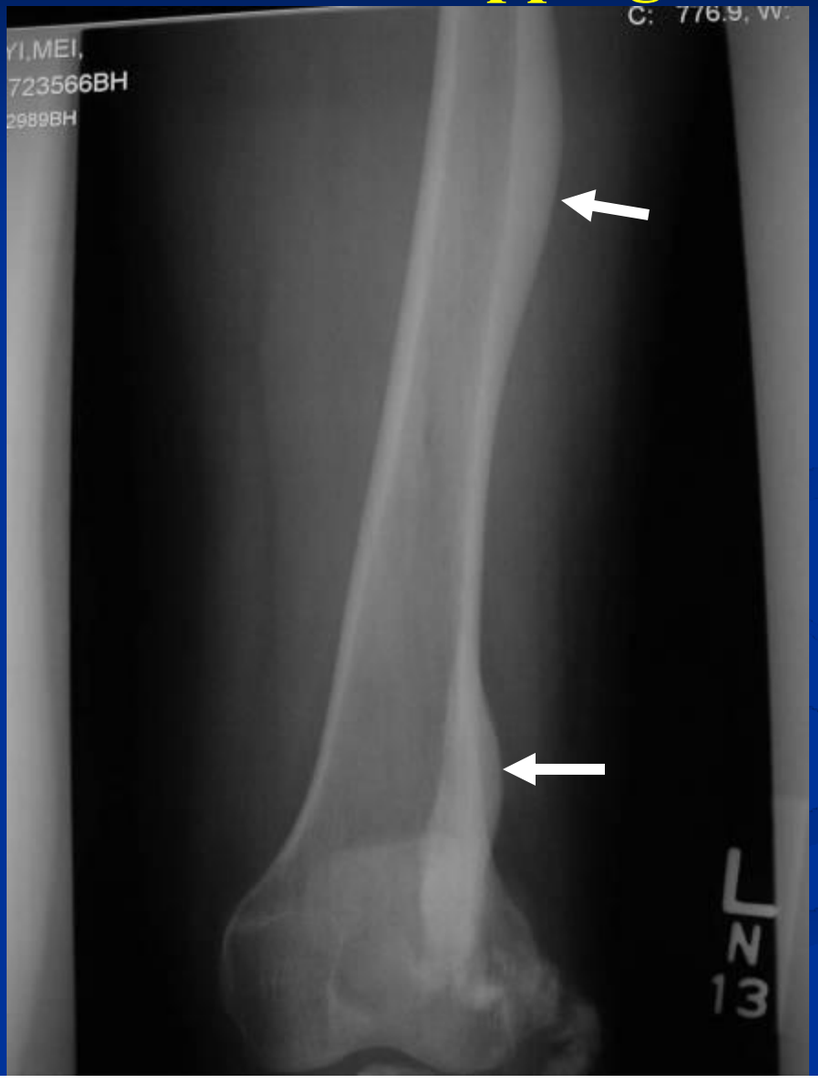
Surface Osteoma

Myositis Ossificans

Myositis Ossificans
Zonal Phenomenon—Central Lucency



Melorrheostosis
“Candle Wax Drippings”



Position of Lesion in Longitudinal Plane

- Epiphysis
- Metaphysis
- Diaphysis

Epiphyseal Lesions

- Adults:
  - Clear Cell Chondrosarcoma
  - Metastasis, Myeloma, Lymphoma
  - Lipoma
  - Intraosseous Ganglion

Epiphyseal Lesions

- Children:
  - Chondroblastoma
  - Osteomyelitis
  - Osteoid Osteoma
  - Enchondroma
  - Eosinophilic Granuloma

Metaphyseal Lesions

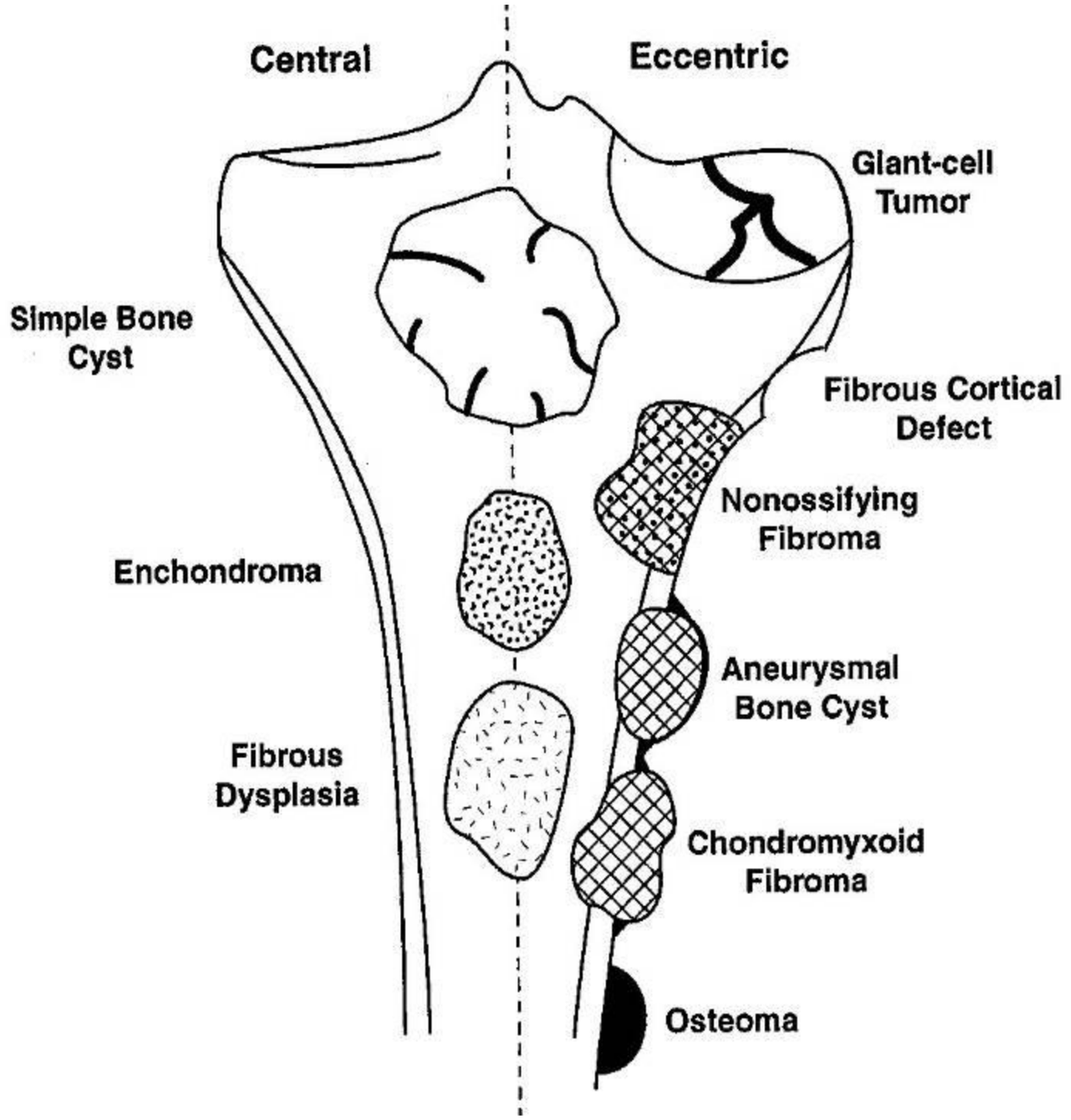
- GCT (extends to epiphysis)
- Nonossifying Fibroma
- Chondromyxoid Fibroma
- Simple Bone Cyst (Unicameral Bone Cyst)
- Osteochondroma
- Brodie's Abscess
- Osteosarcoma
- Chondrosarcoma
- MFH/Fibrosarcoma

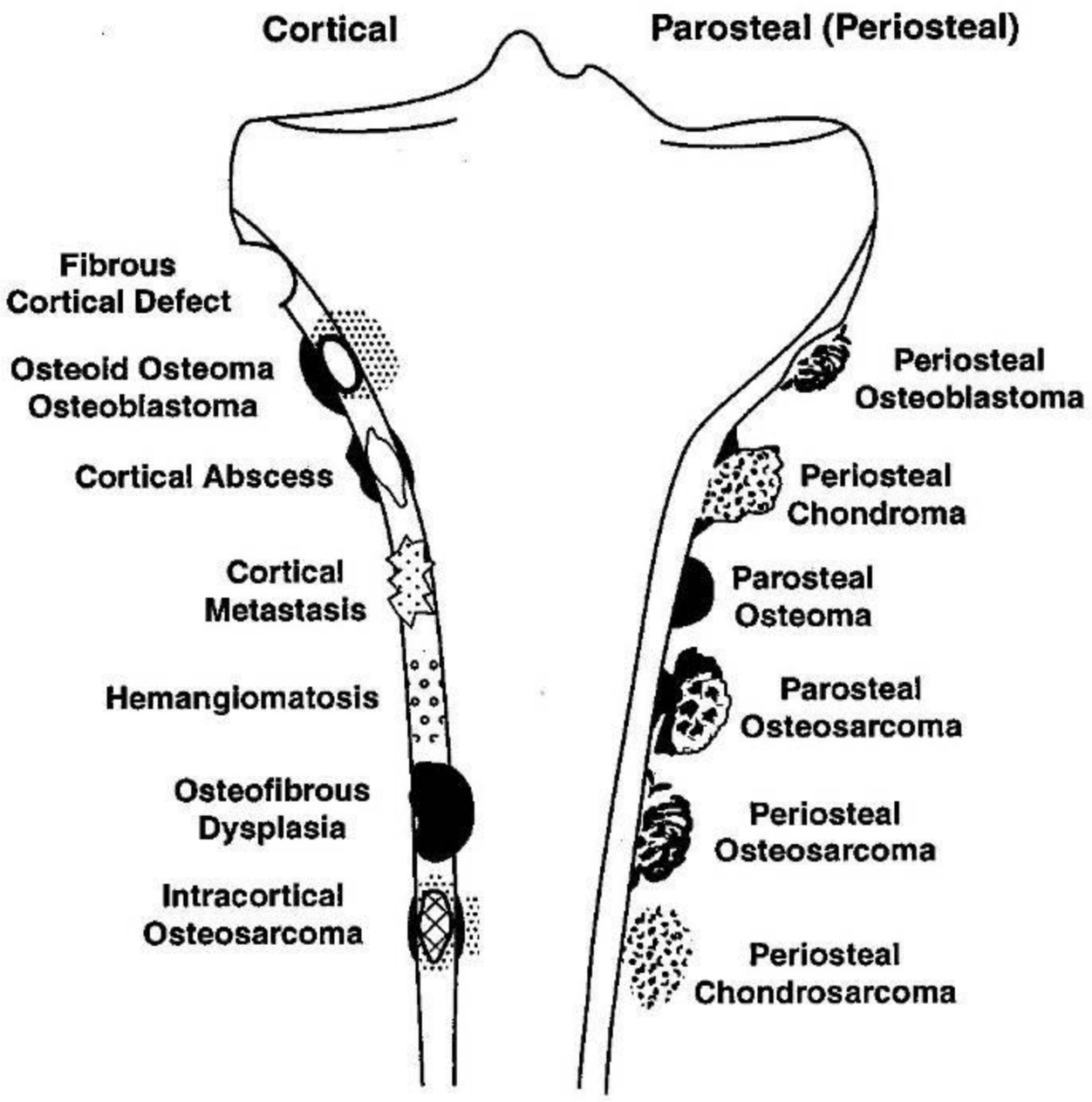
Diaphyseal Lesions

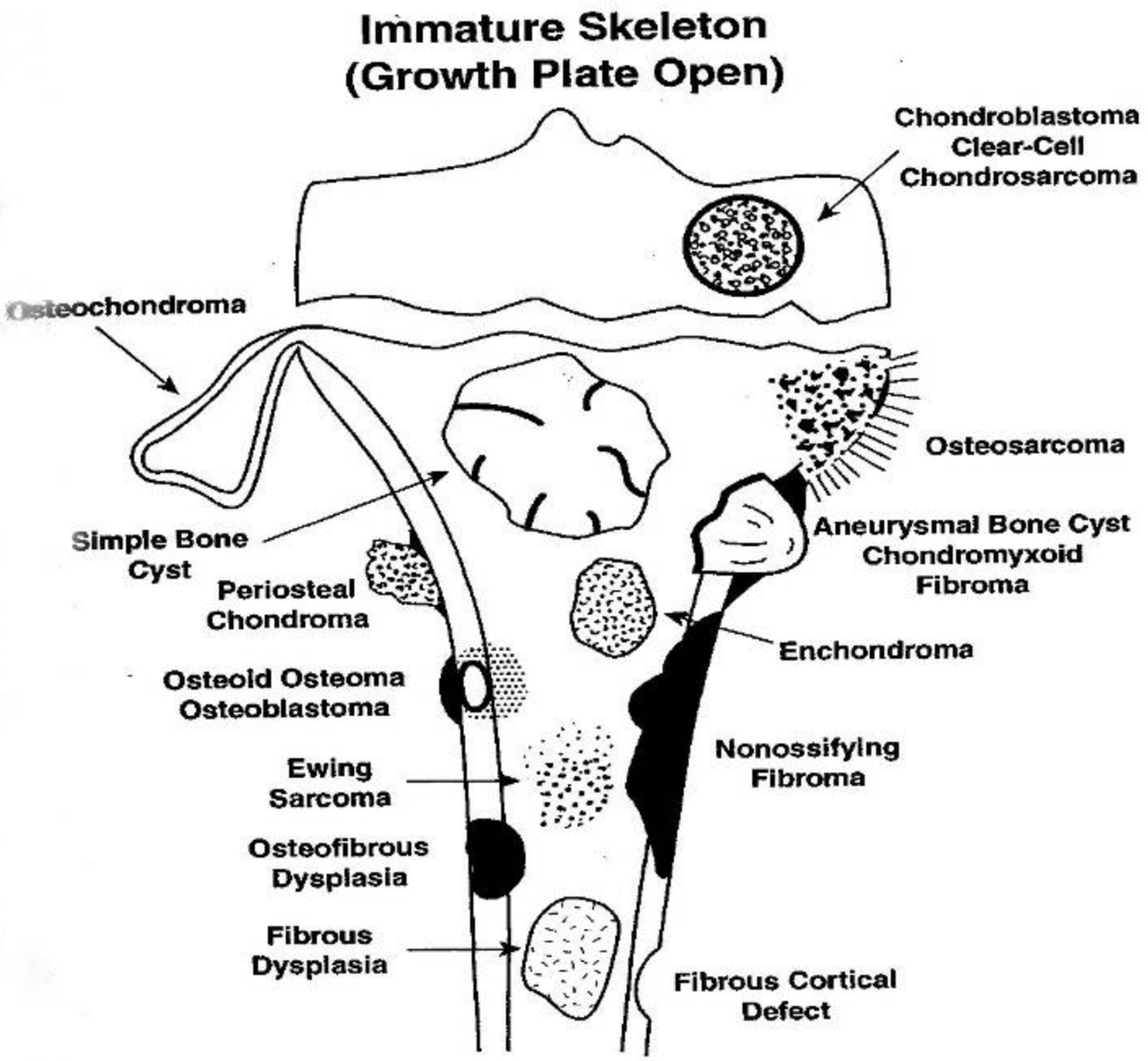
- Ewing's Sarcoma
- Nonossifying fibroma
- Simple Bone Cysts
- Aneurysmal Bone Cysts
- Enchondromas
- Osteoblastomas
- Fibrous Dysplasia
- Adamantinoma
- Osteofibrous

Epiphyseal Equivalent Areas

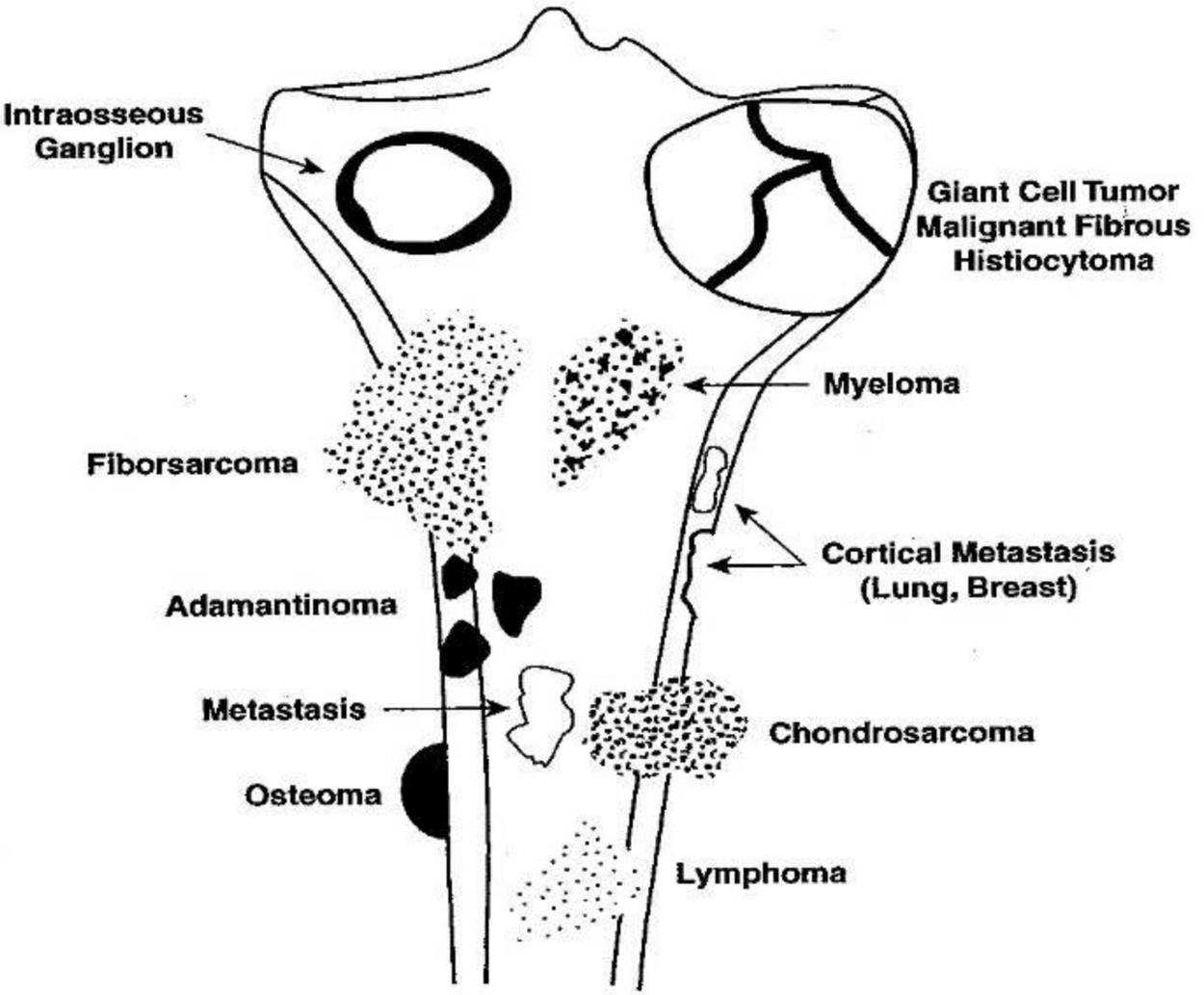
- Subchondral Regions of Acetabulum and Scapula
- Tarsal Bones
- Calcaneus, Talus


Central
Eccentric
Giant-cell Tumor
Simple Bone Cyst
Fibrous Cortical Defect
Nonossifying Fibroma
Enchondroma
Aneurysmal Bone Cyst
Fibrous Dysplasia
Chondromyxoid Fibroma
Osteoma


Cortical
Parosteal (Periosteal)
Fibrous Cortical Defect
Osteoid Osteoma Osteoblastoma
Cortical Abscess
Cortical Metastasis
Hemangiomatosis
Osteofibrous Dysplasia
Intracortical Osteosarcoma
Periosteal Osteoblastoma
Periosteal Chondroma
Parosteal Osteoma
Parosteal Osteosarcoma
Periosteal Osteosarcoma
Periosteal Chondrosarcoma


Immature Skeleton
(Growth Plate Open)
Chondroblastoma
Clear-Cell
Chondrosarcoma
Osteochondroma
Osteosarcoma
Simple Bone
Cyst
Aneurysmal Bone Cyst
Chondromyxoid
Fibroma
Periosteal
Chondroma
Enchondroma
Osteoid Osteoma
Osteoblastoma
Nonossifying
Fibroma
Ewing
Sarcoma
Osteofibrous
Dysplasia
Fibrous
Dysplasia
Fibrous Cortical
Defect

Mature Skeleton
(Growth Plate Closed)



Specific Bones

- Heamatopoietic Marrow—predilection for sites with red marrow; rich sinusoidal vasculature
- Axial and Appendicular Skeleton in Children
- **Axial Skeleton in Adults**
  - Metastatic Disease
  - Myeloma
  - Ewing's Sarcoma
  - Histiocytic Lymphoma

Specific Bones

- **Areas of Rapid Growth**
- Primary Bone Tumors
  - Distal Femur
  - Proximal Tibia
  - Proximal Humerus

Specific Bones

- **Sacrum**
  - Chordoma
  - Myeloma/Plasmacytoma
  - Giant Cell Tumor
  - Mets
  - Simple Cysts
  - Neurogenic Tumors /Schwannoma

Specific Bones

- **Ribs**
  - Mets
  - Fibrous Dysplasia
  - Enchondroma

Specific Bones

- **Metacarpals and Phalanges**
  - Giant Cell Tumor
  - Giant Cell Reparative Granuloma
  - Sarcoidosis
  - ABC
  - Fibrous Dysplasia
  - Enchondroma

Specific Bones

- **Terminal Phalanges**
  - Inclusion Cyst
  - Glomus Tumor
  - Mets (Lung)