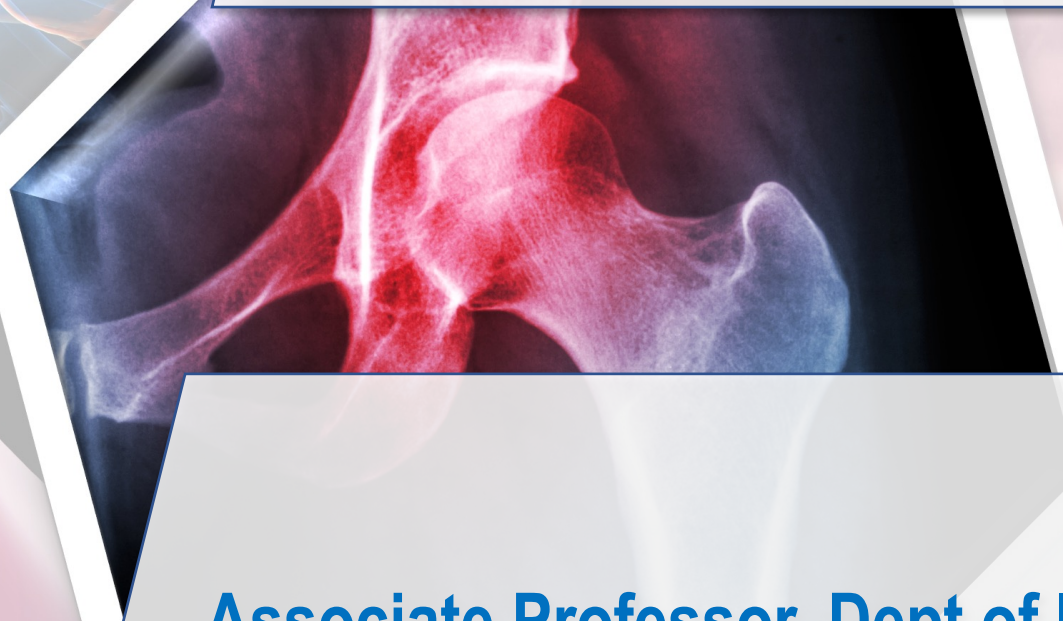
IMPERIAL

Introduction to the Musculoskeletal System



2026

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Honorary Consultant in Rheumatology,
Topic Lead for MSK

Session overview

TEACHING

- What is the musculoskeletal (MSK) system?
- Functions
- Components
- How these can be affected by disease or injury
- The healthcare professionals who look after patients with MSK problems

PRACTICAL INFO

- How the MSK sessions run
- Exams (end of session)

Practical information: learning events

- **6 lectures**

  recorded on Panopto AND slides on Insendi

- **2 interactive tutorials**:

"*Musculosketetal emergency presentations*" & "*Introduction to rheumatology (part 2 of 2)*"

-Based on clinical case scenarios

-Opportunity to practice *applying* knowledge from lectures and develop critical thinking abilities in a clinical scenario

-**Not recorded** on Panopto. Case slides on Insendi but these will not capture all the discussion that arises between you and your tutor(s).

- The course has a 'spiral' curriculum: further MSK module in year 2.

What is the musculoskeletal system?

MSK system = the anatomical structures that allow locomotion (movement)

The importance of a functioning MSK system

What is the musculoskeletal system?

MSK system = the anatomical structures that allow locomotion (movement)

Squat
Stand
Walk
Run
Jump
Throw
Twist
Reach
Carry
Kick
Grab
….
Breathe!

MSK system has evolved to allow us to:

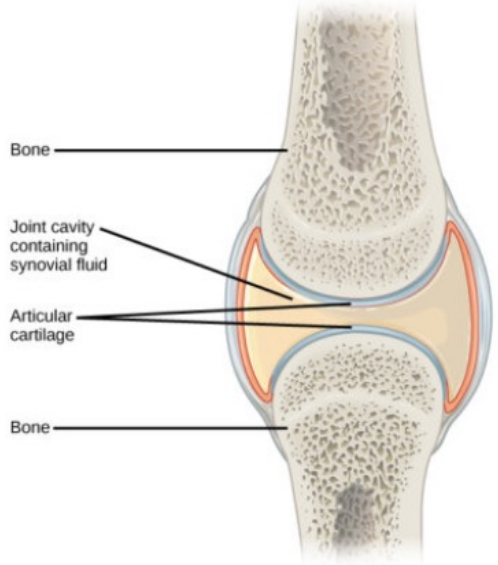
- Escape from predators or threats
- Find food or shelter
- Look after children
- Use tools or weapons

- But evolution has not optimized our MSK system for this:

- Resulting rise in MSK problems in the population

Components of the MSK system

- **Bones**
- **Joints** = where 2 bone meets
- **Muscles**
- **Tendons** = cords of strong fibrous connective tissue attaching *muscle to bone*
- **Ligaments** = sheets of fibrous connective tissue which *connect two bones*



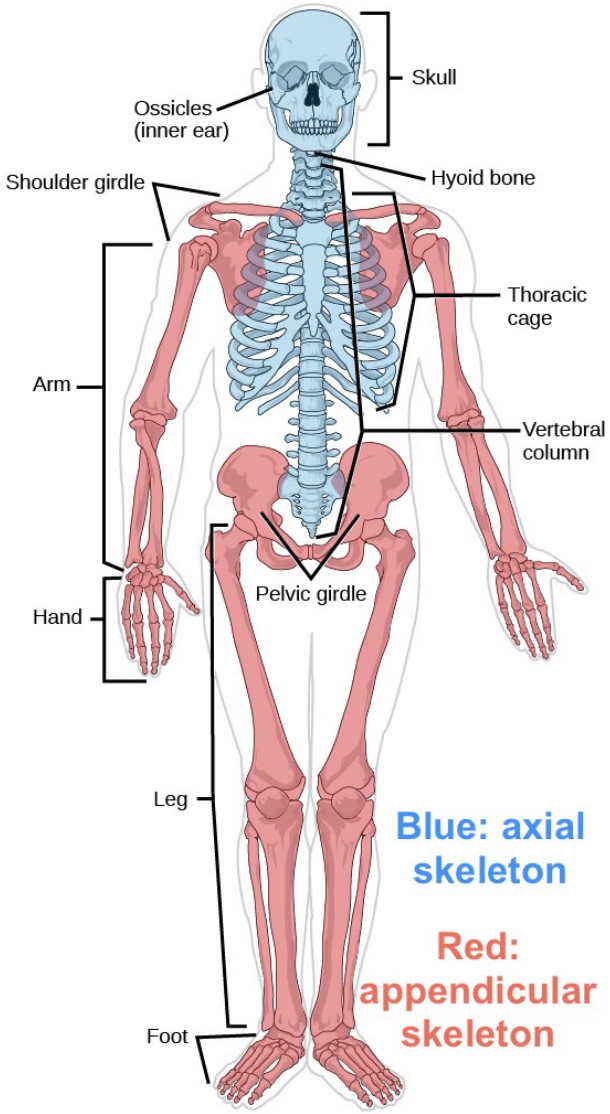
Bones

The human skeleton:

- 206 Bones (+ sesamoids)
- 270 in children

Appendicular vs. Axial skeleton

- Appendicular = pectoral and pelvic girdle, limbs
- Axial = cranium, vertebral column, rib cage



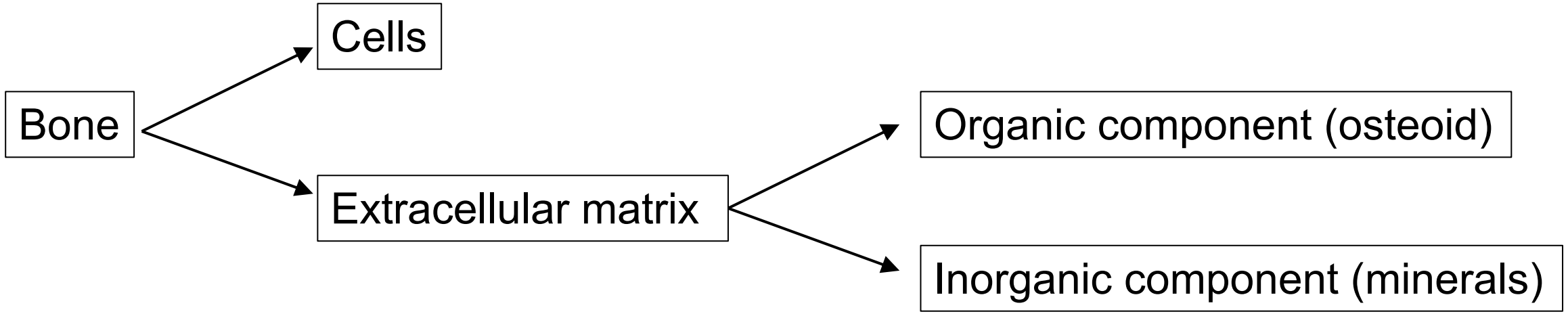
Functions of the skeleton

vs

1. Rigidity/support
2. Movement
3. Protection for internal organs (e.g. skull, rib cage)
4. Mineral storage/homeostasis (e.g. regulation of calcium and phosphate)
5. Bone marrow produces blood cells

Bone - composition

- Bone is NOT inert
- Alive and undergoing continual change in response to external stresses
- Composed of:



Covered in detail in **Injury and Healing part 1**

Bone cells

‘Osteon’ Greek – Bone
‘Osteo-’ prefix for bone

Osteogenic cell
-Bone ‘stem cell’
-Derived from mesenchymal stem cell

Osteoblast
-‘Bone forming’
-Secretes ‘osteoid’
-Catalyse mineralisation of osteoid

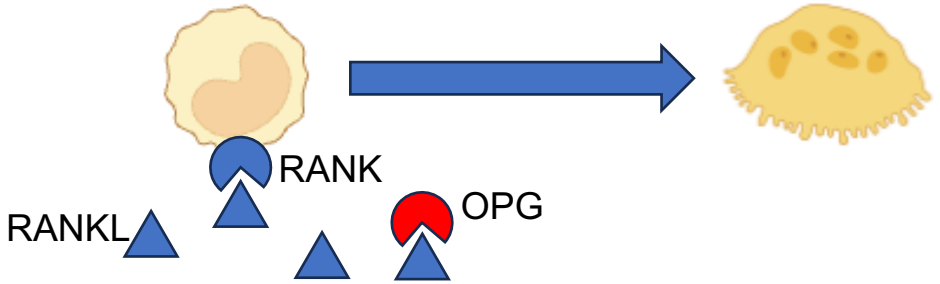
Osteocyte
-‘Mature’ bone cell
-Formed when an osteoblast becomes imbedded in its secretions
-Sense mechanical strain to direct osteoclast and osteoblast activity

Osteoclast
-'Bone breaking’
-Derived from haematopoetic precursors (monocyte/macrophage lineage) which fuse to form multinucleated giant cells
-Dissolve and resorb bone by phagocytosis

****The RANKL-RANK pathway is a key controller of osteoclast activity****

Binding of RANKL to RANK receptor:
-triggers differentiation into osteoclasts
-activates osteoclasts to produce bone-digesting enzymes
-enhances osteoclast survival

OPG (osteoprotegerin) is a decoy receptor which binds RANKL and prevents it binding to RANK

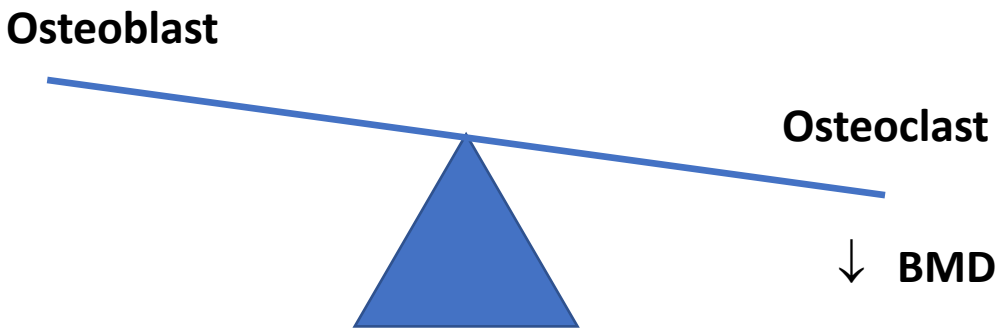


Therapeutic relevance

Balance of osteoblast vs osteoclast activity -> bone mineral density (BMD)

Osteoporosis = low BMD

Risk factor for low-impact fractures (e.g. wrist, hip, lumbar spine)



Can treat osteoporosis (*reduce* fracture risk) with drugs that:

Increase osteoblastic activity:	**Inhibit osteoclastic activity:**
Teriparatide (recombinant PTH)	Bisphosphinates (e.g. alendronate)
Romosozumab – monoclonal antibody vs sclerostin	Denosumab (monoclonal antibody that inhibits **RANKL**)

Sclerostin:
-made by osteocytes
-inhibits osteoblasts
-Genetic mutations in sclerostin gene (*SOST*) -> bone overgrowth

Measuring bone mineral density

Dual Energy X-ray Absorptiometry (DEXA) scan

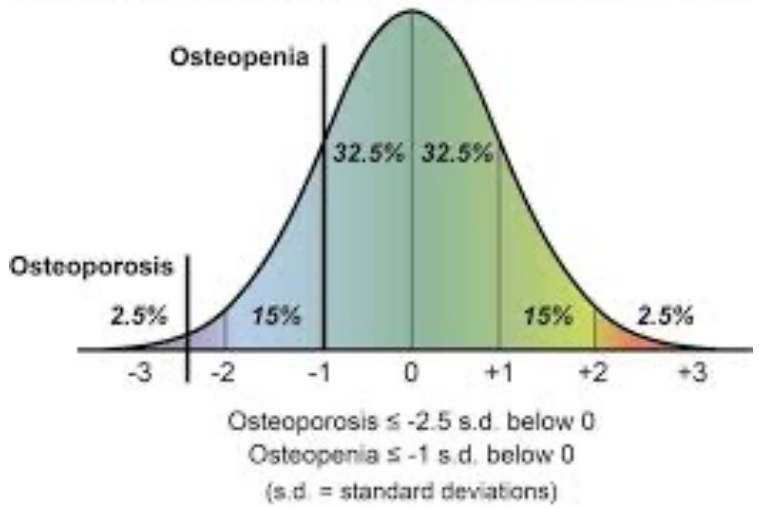
Usually measured at 2 sites: hip and lumbar (L) spine

BMD reported using two metrics comparing to reference populations:

- **T score**: standard deviations from the mean for *healthy young adult* of the same sex
- **Z score**: standard deviations from the mean for *age-matched adult* of the same sex

T score	Interpretation
>-1	“normal”
<-1 and > -2.5	osteopenia
<-2.5	osteoporosis

BMD is approximately normally distributed



Bones and hormones

Bone is the body's primary store of calcium

Blood levels of calcium tightly regulated:

hypercalcaemia
hypocalcaemia
} dangerous

2 key hormones that affect bone and regulate calcium metabolism:

Vitamin D

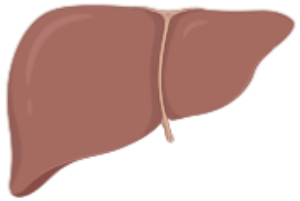
Parathyroid hormone (PTH)

Vitamin D metabolism and physiological actions

Vitamin D2 (*ergocalciferol*)
Sources:
Diet (plants)
e.g. UV-exposed mushrooms, fortified cereals

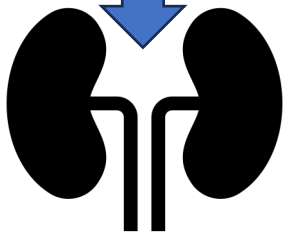
Vitamin D3 (*cholecalciferol*)
Sources:
1) **Sunlight (UVB)**
7-dehydrocholesterol → vitamin D3
2) **Diet** (animal sources e.g. fatty fish, egg yolks, liver)

Hydroxylated in liver



25-hydroxy (OH) vitamin D

Second hydroxyl group added in kidney



1,25-dihydroxyvitamin D (*calcitriol*)
Bioactive form

↑ Ca^{2+} gut absorption
↓ renal Ca^{2+} excretion into urine
↑ bone mineralization
↑ osteoblast activity

Vitamin D insufficiency/deficiency

Serum 25(OH) vitamin D level (nmol/L)	Interpretation	Action
>50	adequate	none
25-50	insufficient	Vitamin D3* supplementation (e.g. 800 iU/day)
<25	deficient	High-dose vitamin D3* (e.g. 5000-10,000 iU/day)

*D3 (cholecalciferol) is preferred :
-Longer $t_{1/2}$
-More effective at ↑ing 25(OH)-D levels
*Give ergocalciferol if vegan

Vit D deficiency → inadequate bone mineralization & accumulation of unmineralized matrix (osteoid)

In adults: **osteomalacia**

In children: **rickets** (deformed bones)

Causes/risk factors:

-Lack of sun exposure
(e.g. frail housebound, cultural/religious dress, more pigmented skin living in temperate latitudes)

-Poor diet or malabsorption

-Rare genetic causes of vitamin D resistance

-(Liver and renal disease): inadequate hydroxylation

menti.com *How would you treat in end-stage kidney disease?*

Caruso et al N Engl J Med 2013;369: e11

Parathyroid hormone (PTH)

Parathyroid glands: 4 glands posterior to thyroid

Produce PTH which:

- stimulates osteoclasts → bone resorption → releases Ca^{2+} & phosphate (PO_4) into blood
- ↑ renal resorption of Ca^{2+}, ↓ urine Ca^{2+} excretion
- ↓ renal resorption of PO_4, ↑ urine PO_4 excretion
- ↑ renal production of active 1,25(OH) vit D (and thus indirectly ↑ Ca^{2+} intestinal absorption)

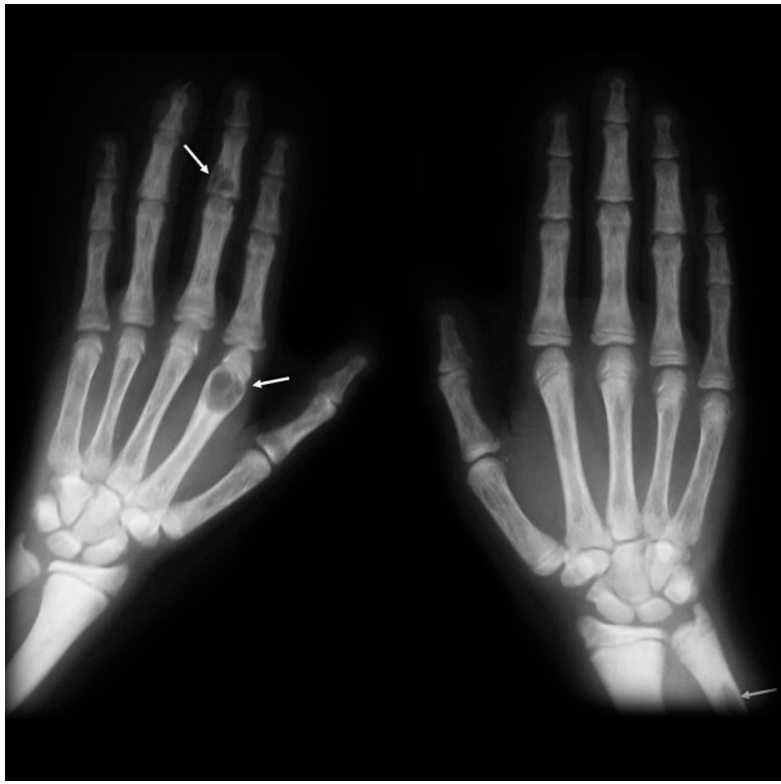
Net effect on serum levels: ↑ Ca^{2+}, ↓ PO_4

Clinical significance:

Hyperparathyroidism (↑ PTH)

Hypoparathyroidism (↓ PTH)

Hyperparathyroidism



Primary
-often asymptomatic with incidental finding of mildly ↑ Ca^{2+}
-may have symptoms of hypercalcicaemia:
"**bones**, **stones**, psychic **moans**, abdominal **groans**"
-osteoporosis/fragility fracture
-bone resorption: brown 'tumours', pepperpot skull
Tests: ↑ Ca, ↑ PTH (or inappropriately normal)
Cause: usually solitary adenoma of PT gland

Secondary
appropriate response to ↓ Ca^{2+} (e.g. resulting from low vit D)
Tests: ↓ Ca, appropriately ↑ PTH

Tertiary
After prolonged period of secondary hyperparathyroidism, glands become hyperplastic and autonomously produce excess PTH with loss of normal feedback loops. Seen in ESKD.
Tests: ↑ Ca, *inappropriately* ↑ ↑ PTH

Malignant hyperparathyroidism*
Secretion of parathyroid-related protein (PTrP) by a tumour (often lung squamous cell carcimona).
Mimics effects of PTH.
Tests: ↑ Ca, ↓ PTH (assay does not detect PTrP)

*won't be tested in MSK 1a exam qu.s

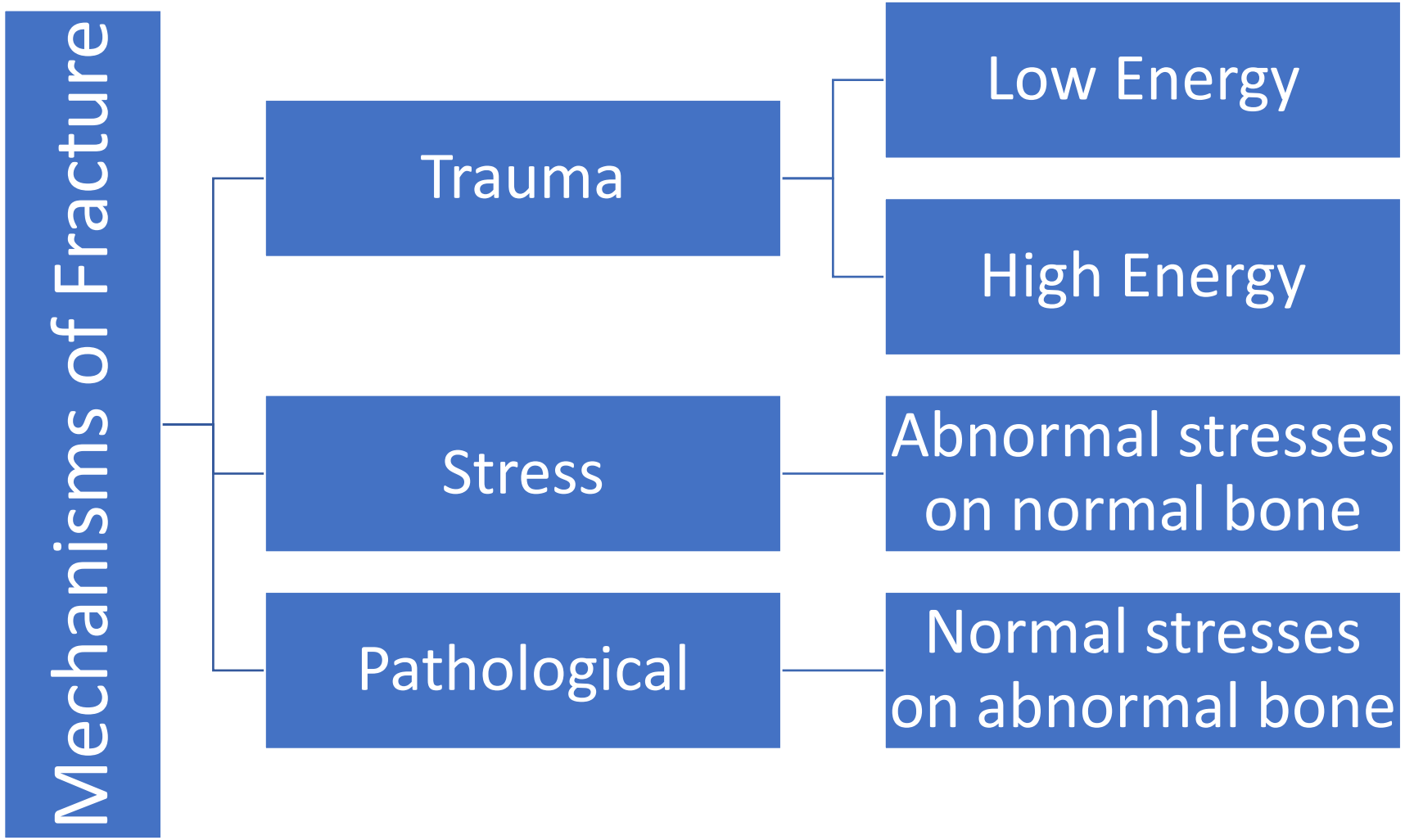
Bones – injury and disease

Orthopaedic surgeons are usually the specialty dealing with bone problems

Emergency vs Elective (planned) work

Vast majority of emergency orthopaedic work is managing **acute traumatic fractures** (Sometimes the speciality is referred to as "*Trauma* and Orthopaedics")

Mechanisms of Bone Fracture



Covered in detail in ***Injury and Healing part 1***

Traumatic fractures: some common scenarios

- **Falls**

-from standing
-from slight elevation (e.g. playground accident)
-from a height (e.g. fall from scaffolding)

- **Road traffic accident (RTA)**

i) MUCH worse for pedestrian or cyclist than car occupants
ii) NB $E = ½ mv^2$
Double speed -> **4x** the energy

- **Assault**

- **Sports**

- **Crush injury** (e.g. heavy machinery)

Non-traumatic diseases affecting bone

Cancer:
- bone metastases
- myeloma*
- primary* (rare)

Osteoporosis:
- post-menopause
- advanced age
- glucocorticoid induced

Endocrine/metabolic diseases:
- Hyperparathyroidism
- Osteomalacia (Vitamin D deficiency)

Paget's disease:
- localized area(s) of increased bone turnover due to increased osteoblast and osteoclast activity
- bony enlargement, fracture risk, deafness (nerve compression)

Genetic diseases
- osteogenesis imperfecta
- sickle cell anaemia* -> osteonecrosis

*Detailed knowledge **not** required for 1a MSK exams

Joints

- Where two bones meet
- Joints can be classified on the basis of **structure** or **function**

Medical significance:

- Diseases of joints = "**arthritis**"
- Joint diseases can have a profound impact on quality of life and function
- Affect ability to perform activities of daily living (ADLs)
- Limit ability to work or do leisure activities
- Secondary effects on cardiovascular and metabolic systems

Joint classification

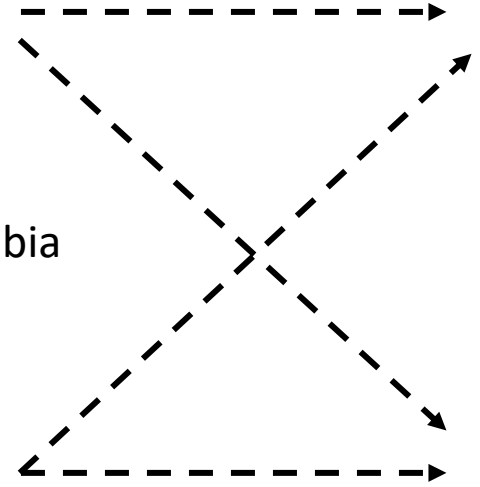
Joints can be classified on the basis of **structure** or **function**

Structural classification:

Fibrous Joints
No space between the bones
Examples:
-sutures in the skull
-syndesmosis (sheet of connective tissue) in tibia and fibula joint (ankle)

Cartilaginous Joints
Joints in which the bones are connected by cartilage
E.g. joints between spinal vertebrae

Synovial Joints
-have a space between the adjoining bones (synovial cavity)
-This space is filled with synovial fluid.



Functional classification:

Synarthroses
Generally allow no movement

Amphiarthroses
Allow very limited movement

Diarthroses
Allow for free movement of the joint

Synovial Joints: functional types

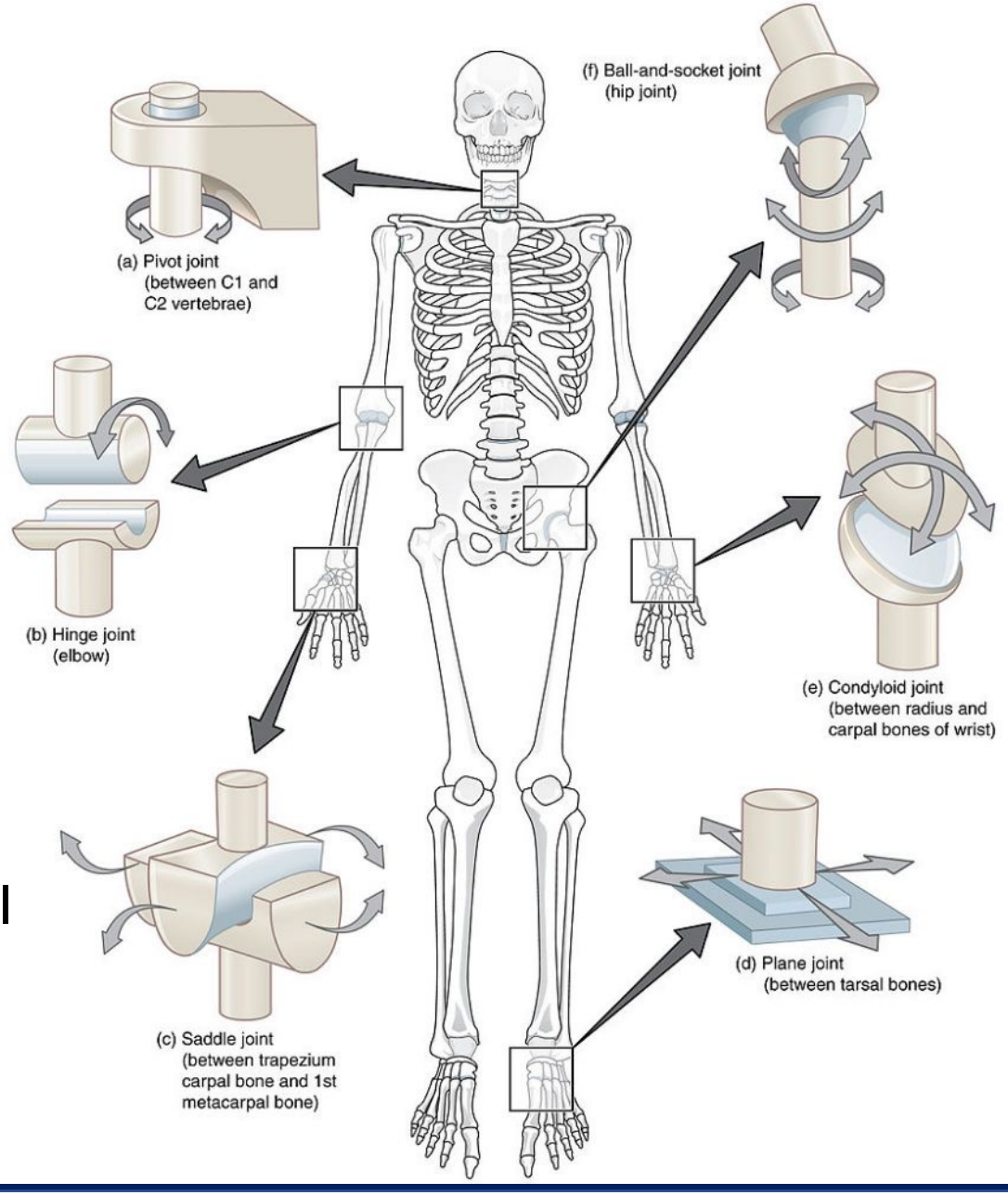
- Hinge (e.g. knee)

  Monoplanar
- Ball and socket (e.g. shoulder, hip)

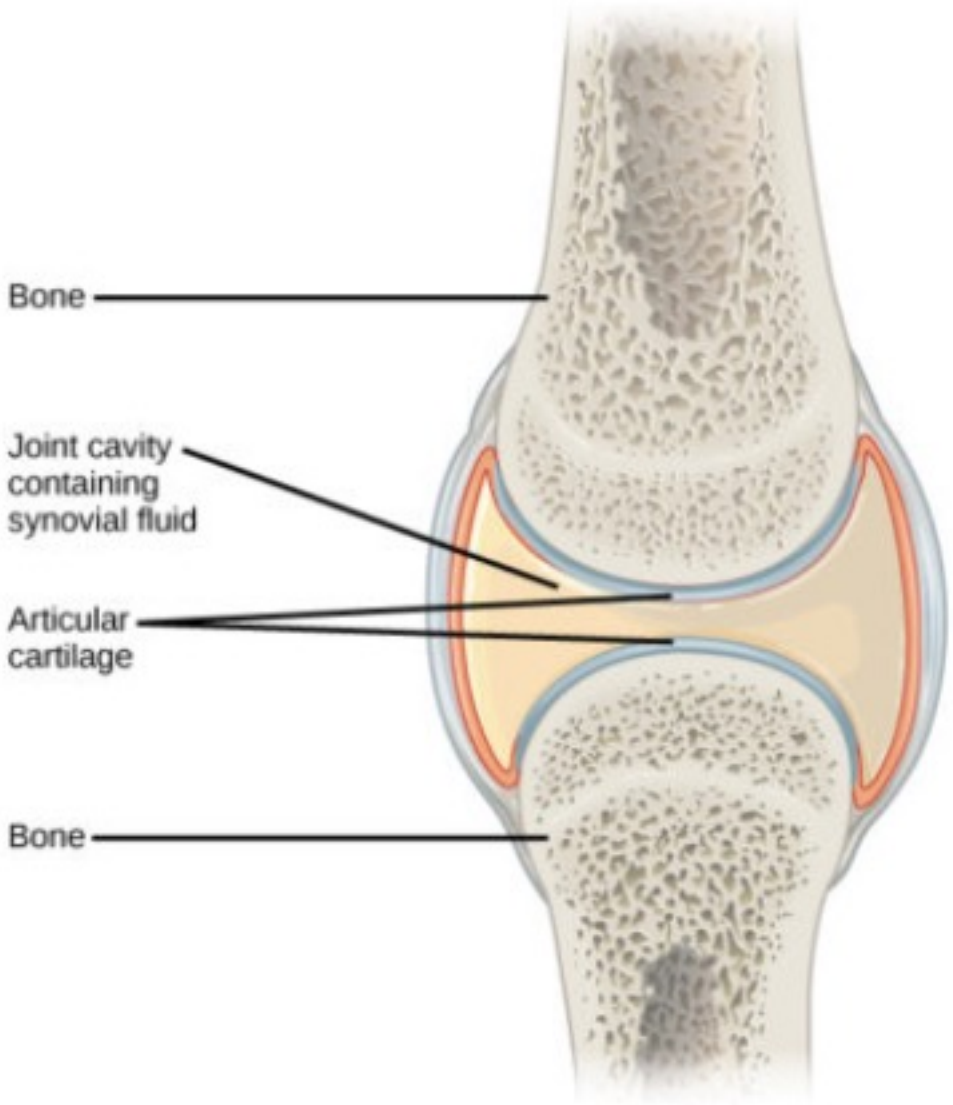
  Multiplanar
- Pivot joint (e.g. cervical spine)

  allow limited rotating movements
- Condyloid (aka Ellipsoidal joints) (e.g. wrist)

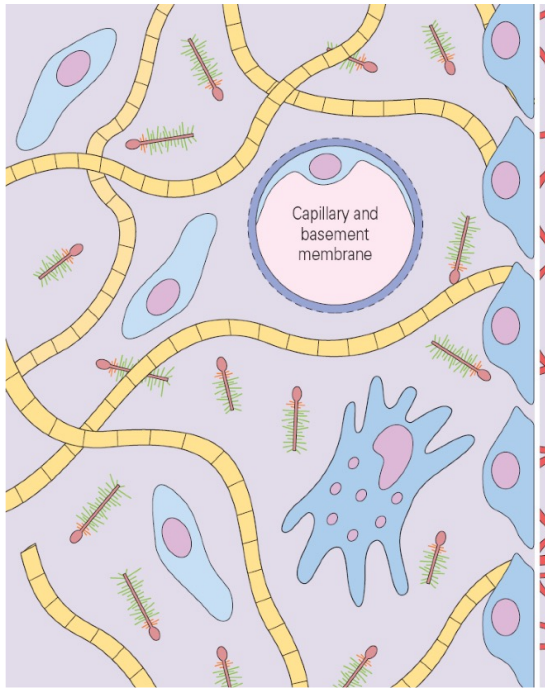
  allow all types of movement except pivotal movements.



Components of a synovial joint

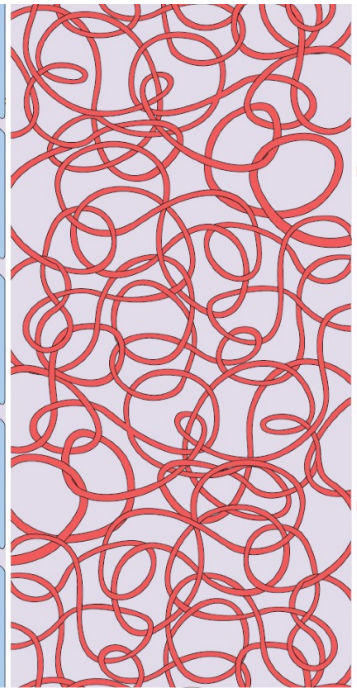


Synovium



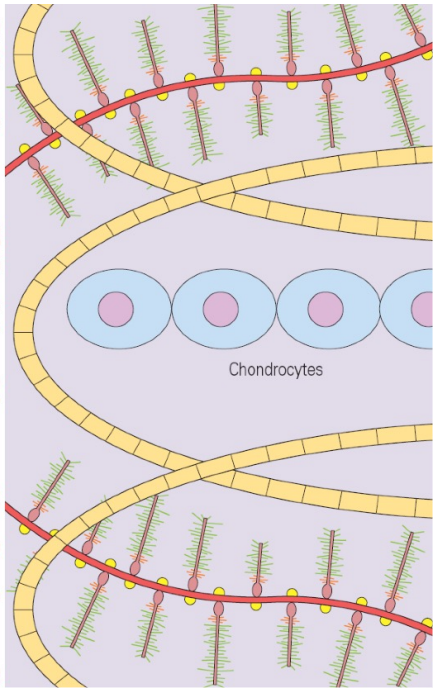
- 1-3 cell deep lining containing macrophage-like phagocytic cells (type A synoviocyte) and fibroblast-like cells that produce hyaluronic acid (type B synoviocyte)
- Type I collagen

Synovial fluid



Hyaluronic acid-rich viscous fluid

Articular cartilage



Type II collagen

Proteoglycan (aggrecan)

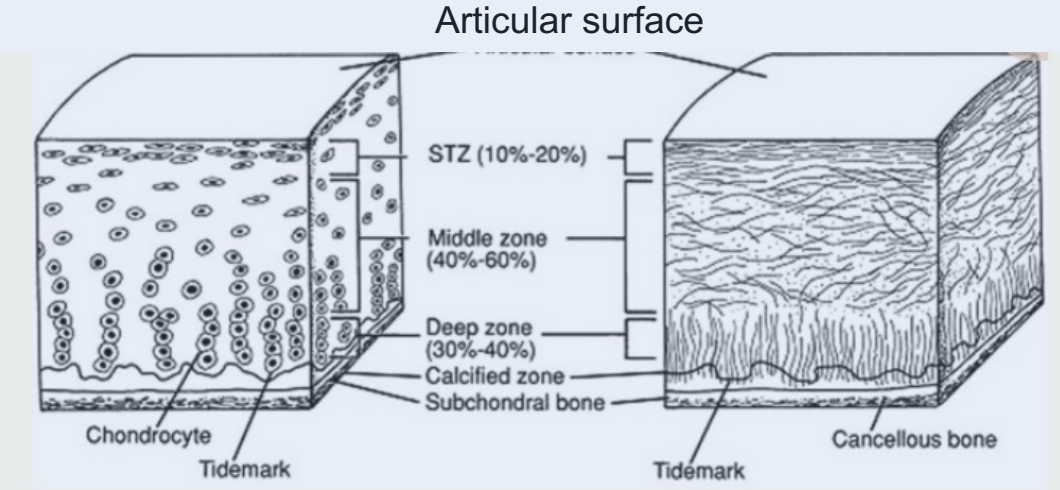
Cartilage

Cartilage provides a smooth lining at a joint to allow the ends of two bones to move with minimal friction

Composed of:
1) specialized cells (chondrocytes)
2) extracellular matrix: water, collagen and proteoglycans (mainly *aggrecan*)

Cartilage is avascular – it has no blood supply

Cartilage structure



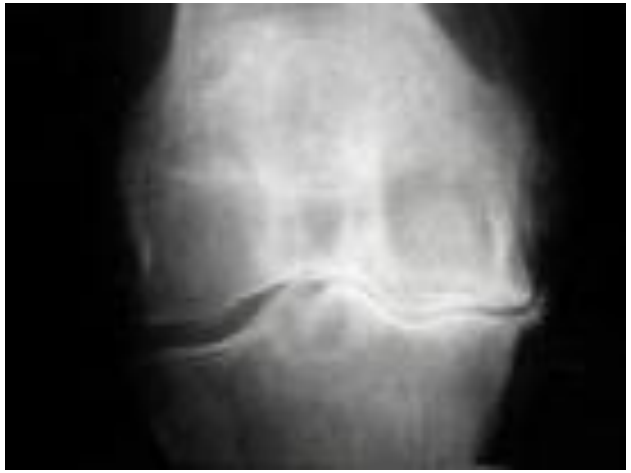
Cellular organisation Collagen fibre architecture

Aggrecan is:
-a proteoglycan that possesses many chondroitin sulfate and keratin sulfate chains
-characterized by its ability to interact with hyaluronan (HA) to form large proteoglycan *aggregates*

Joint diseases - overview

Arthritis = disease of the joints
There are many different types of arthritis
Two broad divisions

Osteoarthritis
"Degenerative" arthritis: loss of cartilage
Generally considered non-inflammatory*
*(this may not be entirely accurate, but inflammation is much less than in the conditions on the left)



Lack of space indicates loss of articular cartilage leading to bone in contact with bone

Covered in ***Cartilage Biology & Osteoarthritis*** lecture

Arthritis associated with inflammation

<u>Autoimmune</u> (e.g. rheumatoid arthritis)
Immune system attacks self

<u>Crystal arthritis</u> (gout and pseudogout)
Crystals trigger inflammation
- Urate -> gout
- Calcium pyrophosphate dihydrate (CPPD) -> pseudogout

<u>Septic arthritis</u>
Bacterial infection in the joint

Covered in ***Introduction to rheumatology 1&2***

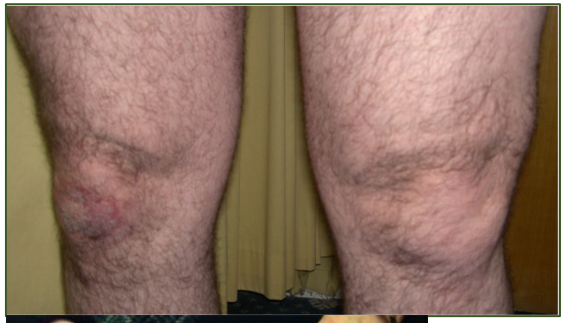
Joint pain – clues in the history

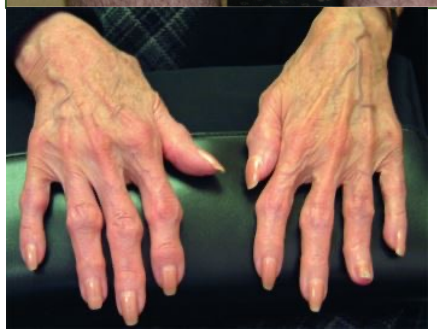
History of injury (recent or old?)

Speed of onset:
Osteoarthritis: slow (months -> years)
Autoimmune: subacute (usually weeks -> months)
Septic arthritis: rapid (hours)
Crystal arthritis: rapid (hours)

Effect of movement?
Osteoarthritis worse with movement
Rheumatoid arthritis worse with inactivity

Prolonged morning stiffness suggests inflammatory cause (e.g. rheumatoid arthritis)





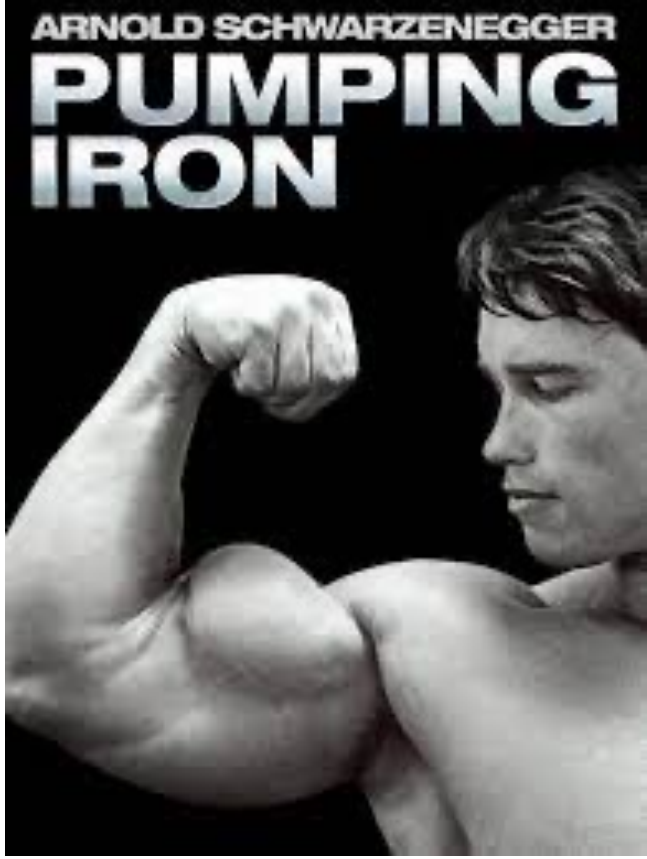
Associated swelling?
Bony vs soft tissue or fluid?

Systemic disturbance
Fever: ? infection
Other organs affected (***extra-articular***): ? systemic disease

Muscle

Force generators of the MSK system:
move bones around a joint

Example: hinge joint
Muscles are paired as **agonists/antagonists**
Biceps contracting (shortening), triceps relaxed –> flexes elbow
Triceps contracting, biceps relaxed –> extends elbow



Respond to load (***hypertrophy***)
Vs ***atrophy*** with disuse (NB joint disease)

Also provide some protection for underlying structures (eg pectorals)

Less vulnerable to injury cf bone, joint, tendons and ligaments

Covered in detail in ***Muscle Microstructure and Contraction***

Ligaments and tendons

Strong soft tissue structures

Both predominantly consist of Type I Collagen

Less blood supply than muscle

Ligaments – connect bone to bone
- Restrict joint motion
- Stability and proprioception

Tendons – connect muscle to bone
- Transmit forces
- Collagen fibrils -> fibres

Tendon pathology

Acute

Force exceeds tensile strength

Tendon tear:
Incomplete vs Complete

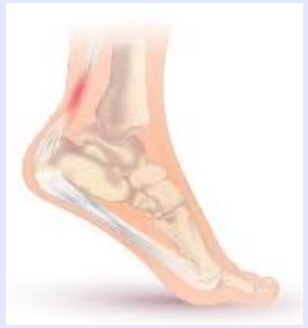
E.g.
Achilles tendon
Rotator cuff

Chronic

Pathological response to poor biomechanics or overuse

Tendinopathy
Disordered collagen fibres
Neovascularisation

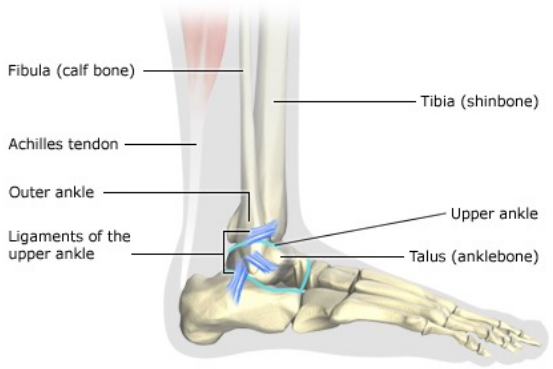
E.g.
-Achilles tendinopathy
-“tennis elbow” aka lateral epicondylitis



Tendinopathy can progress to tear

*More in ***Injury and Healing Part 2***

Ligament injuries



Example 1

Lateral ligament ankle sprain

Common, usually not serious

Mechanism: ankle eversion

Example 2

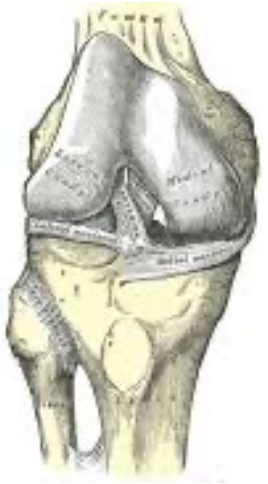
Anterior cruciate ligament of the knee

Less common, usually serious, sports

Mechanism:

-contact: blow to outside of knee

-non-contact: weight transfer with twist on planted leg



*More in ***Injury and Healing Part 2***

Healthcare Professionals dealing with MSK problems

A&E

GP

Rheumatology

- Medical specialty dealing with MSK problems
- Treatments with injections, medications, infusions)
- Emphasis on treatment of autoimmune diseases (immunosuppressive drugs) & osteoporosis

Orthopaedics

- Surgical specialty dealing with MSK problems
- *Acute*: fractures, septic arthritis
- *Chronic*: elective surgery e.g. joint replacement, arthroscopic surgery

Physiotherapy

- Corrective exercises: strengthen, stretch, improve neuromuscular control and movement patterns
- Hands-on manipulation of soft tissues, trigger points

Also: **Podiatry** (feet) & **hand therapists**

Take home messages

- Know the components of the MSK system, their functions and basic structure
- Understand the potential impact of MSK problems on patients' quality of life
- Have a broad overview of the types of MSK problems that can arise
- Know some key history-taking questions in a patient with joint pain and how this can help differentiate possible causes

- **Deeper dives to come in subsequent sessions**

Exams

- *Factual* material is all covered in the slide decks.

- However, some questions involve a clinical scenario and interpretation of symptoms, signs and test results (*knowledge application*). **The interactive tutorials are the best opportunity to develop this skillset**.

- Sometimes I will provide useful background information to give context but not needed for the 1a MSK exam questions. This will be indicated during the talk.

⚠️ ⚠️ Exams: 76 resits last year ⚠️ ⚠️

- Single best answers – best of 5
- Very short answer questions (VSAQ) – 4 words or fewer!
- Short answer questions (SAQs): **where it all goes wrong!**

  7 marks per SAQ

  Usually a stem, sometimes based around a patient-based scenario, with ~3-4 subquestions

Tips:
-Read the question carefully
-Answer the question being asked rather than just regurgitating everything you know on the topic
-Don't try to hedge your bets by writing two contradictory answers
-Number of marks per sub-question indicates number of points required in your answers
-If it says name 3 things, name 3 (not 4!)

Please don't ruin my summer holiday –
I don't want to mark your resits!

TILOs

- Musculoskeletal system: describe the macroscopic and microscopic structure of bone, soft tissues (ligaments &tendons), muscles and joints, and relate their properties to their function.
- Joints: outline the pathophysiology and clinical presentation of different types of arthritis
- Joints: describe the clinical approach to a patient with joint pain e.g. hot swollen joint including investigation and management of different types of arthritis