Biomedicine: Human Sciences

Lecture 2:
Terminology,
Landmarks,
Skeletal System
Learning Outcomes

In today’s topic you will learn:

- Describe anatomical directions, regions and planes of the body using anatomical terminology
- The major bones of the body
- Key surface landmarks
- Bone structure and development
- Joint structure
- Common pathologies of bones and joints
- Medical terminology of the skeletal system and disease states (please refer to the glossary and prefixes and suffixes for this topic which can be found on the student website)
Anatomical Position

- Person stands erect
- Feet parallel, flat on the floor
- Arms are at the sides of the body
- Palms forward

- ‘Directional terms’ always refer to the anatomical position, regardless of the body's actual position.
Prone and Supine

• If the body is lying face down the position is described as **prone**

• If the body is lying face up it is described as **supine**
# Directional Terms

<table>
<thead>
<tr>
<th>Anatomical Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medial</strong></td>
<td>Nearer to the midline</td>
</tr>
<tr>
<td><strong>Lateral</strong></td>
<td>Further (away) from the midline. Towards the sides</td>
</tr>
<tr>
<td><strong>Bilateral</strong></td>
<td>Both sides</td>
</tr>
<tr>
<td><strong>Unilateral</strong></td>
<td>One side</td>
</tr>
<tr>
<td><strong>IpSilateral</strong></td>
<td>On the Same side</td>
</tr>
<tr>
<td><strong>Contralateral</strong></td>
<td>On the opposite side</td>
</tr>
<tr>
<td><strong>Proximal</strong></td>
<td>Nearer to the trunk</td>
</tr>
<tr>
<td><strong>Distal</strong></td>
<td>Further from the trunk</td>
</tr>
</tbody>
</table>
# Directional Terms

<table>
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<th>Anatomical Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cephalad or Cranial</td>
<td>Head / towards the head</td>
</tr>
<tr>
<td>Caudal or Caudad</td>
<td>Tail / towards the tail</td>
</tr>
<tr>
<td>Anterior/Ventral</td>
<td>Nearer the front</td>
</tr>
<tr>
<td>Posterior/dorsal</td>
<td>Nearer the back</td>
</tr>
<tr>
<td>Superior</td>
<td>Towards the top</td>
</tr>
<tr>
<td>Inferior</td>
<td>Towards the bottom</td>
</tr>
<tr>
<td>Superficial</td>
<td>Closer to the skin/surface</td>
</tr>
<tr>
<td>Deep</td>
<td>Further under the skin</td>
</tr>
</tbody>
</table>

**Video: Directional Terms:** [https://www.youtube.com/watch?v=wBAwxZ_yxnE](https://www.youtube.com/watch?v=wBAwxZ_yxnE)
Directional Terms

http://anatomysullivan.wordpress.com/2012/05/21/directional-terms/

Planes of the Body

Coronal / frontal plane
• Separating the body front and back

Sagittal plane
• Separating the body left and right

Horizontal / transverse plane
• Separating the body top and bottom

Source: www.kungfuonline.com/define.php?s=anatomical-planes-of-the-body
Planes of the Body

Which one is: coronal, sagittal, transverse?

A

B

C

Source: www.sites.google.com/a/wisc.edu/neuroradiology/image-acquisition/the-basics
The Human Skeleton

- There are **206 bones** in the human body!
- Accounts for 18% of body weight

**FUNCTIONS:**
- **Support framework** for the body
- **Forms boundaries** (skull)
- **Attachment** for muscles and tendons
- **Permits movement** (joints)
- **Haemopoiesis** - formation and development of blood cells
- **Mineral homeostasis** (mostly calcium and phosphate)
- **Triglyceride storage** (yellow bone marrow)
Bone Cells

1. **Osteogenic cells:**
   - Uns specialised stem cells
   - Only bone cell to undergo division (produces osteoblasts)

2. **Osteoblasts:**
   - Bone building cells
   - Synthesise and secrete collagen and other components of bony matrix
   - Initiate calcification
   - As they surround themselves with extracellular matrix they become trapped in their secretions and become osteocytes

Source: www.histology.leeds.ac.uk/bone/bone_cell_types.php

\[ \text{Osteo} = \text{Bone} \]
Bone Cells

3. **Osteocytes: Greek for osteo = bone / cyte = cell**
   - **Mature bone cells**, main cells in bone tissue
   - Maintain daily metabolism of bone, such as nutrient/waste exchange

4. **Osteoclasts: Greek for osteo = bone / clasts = broken**
   - **Huge cells** derived from fusion of as many as 50 monocytes
   - Concentrated in the endosteum
   - On the side facing the bone surface, the plasma membrane is folded into a “**ruffled border**” where the cell releases powerful lysosomal enzymes and acids that digest bone matrix
   - Breakdown of bone extracellular matrix is termed **resorption**

Hence osteoclasts are derived from bone marrow cells
Bone Cells

Video: Bone Remodelling Animation:
www.youtube.com/watch?v=0dV1Bwe2v6c
Compact Bone

- 80% of skeleton is compact bone
- Contains **few spaces** and is **strong**
- Found beneath periosteum of all bones and makes up the bulk of the diaphysis of long bones
- A structural unit of compact bone is an osteon
- Osteons are aligned in **same lines as stress**. These lines change as a baby learns to walk and in response to activity.
Compact Bone

An Osteon contains 4 parts:

1. **Central/Haversian canal**: Contains blood vessels and nerves

2. **Lamellae**: Concentric rings of calcified extracellular matrix containing minerals and collagen

3. **Lacunae**: Between lamellae are small spaces called lacunae that contain osteocytes

4. **Canaliculi**: A mini system of interconnected canals that provides a route for nutrients/waste

Compact Bone

Figure 6-5 The Structure of Compact Bone.

Source: www.eugraph.com/histology/crtbone/compbon.html

Source: www.easynotecards.com/notecard_set/18419
Spongy Bone/Cancellous Bone

- Does not contain osteons. However it consists of an irregular lattice of thin columns called trabeculae (not random)
- Trabeculae contain lamellae, osteocytes, lacunae & canaliculi
- Osteocytes receive nourishment from blood circulating in vessels between trabeculae
- Macroscopic spaces between trabeculae help make bone lighter and can be filled with bone marrow
Spongy Bone/Cancellous Bone

• Makes up most of interior bone tissue of short, flat, irregularly shaped bones and epiphysis of long bone

• Always covered with layer of compact bone

• Trabeculae appear randomly arranged but orientated along lines of stress

Why do you think it is covered like this?

http://anthropology.si.edu/writteninbone/inside_look.html
Spongy & Compact Bone
Bone Matrix

• Like other connective tissues, **bone contains extracellular matrix** that surrounds separated cells.

• The most abundant mineral is **calcium phosphate**. This combines with other mineral salts such as magnesium, sulphate, potassium.

• These **minerals are deposited and crystallise (harden) in the framework formed by collagen fibres** of the matrix.
Long Bones

- A bone that has a **greater length than width**

- **Contains:**
  - A shaft = *diaphysis* and 2 heads = *epiphyses*

- Slightly curved for strength (even distribution of force)

- Consists mostly of compact bone in diaphysis and spongy bone in epiphysis

- **Examples:** Femur, Tibia, Fibula
Long Bones

**EPIPHYSIS:**
- The proximal and distal end of bone
- Separated from diaphysis by **epiphyseal plate** (a layer of hyaline cartilage that allows diaphysis to grow in length)
- Thin outer compact bone covered by articular/hyaline cartilage
- Inner spongy bone with **red marrow**

**DIAPHYSIS:**
- Tubular shaft of long bones
- Outer compact bone covered by **periosteum**
- Central, medullary cavity that contains **red/yellow** bone marrow
- ALL marrow starts off as red marrow
Periosteum

- **Surrounds external bone surface** when its not covered by cartilage

- Hyaline cartilage replaces periosteum on joint surfaces

- Protects bone and assists in fracture repair

- **Vascular Membrane** - provides blood supply. Periosteal arteries enter the diaphysis through many perforating canals and supply periosteum and compact bone

- **Serves as attachment** for ligaments & tendons
Periosteum

• **Double layered:**
  1. **Outer fibrous layer:** Tough, fibrous, protects the bone
  2. **Inner osteogenic layer:** Composed mostly of osteoblasts and osteoclasts (growth and repair)

• Contains **nociceptors** - nerve endings that sense pain

• Attached to underlying bone through thick bundles of collagen that extend into the matrix
Periosteum and Endosteum

- a (Muscle)
- b (Fibrous layer of Periosteum)
- c (Cellular layer of Periosteum)
- e (Endosteum)
Long Bones

Articular cartilage

Cancellous bone

Marrow cavity

Periosteum

Epiphyseal plate

Compact bone

Epiphysis

Head

Diaphysis

Shaft

Epiphysis
Types of Bone

- **Short Bones** (Cube shaped mostly spongy bone): Carpals, tarsals
- **Irregular Bones** (complex shapes): Vertebrae
- **Flat Bone** (2 plates of compact bone): Skull, scapula
- **Sesamoid**: Patella

- All have the same general structure: **Periosteum, Compact bone, Spongy bone** (containing red bone marrow)

- **2 types of bone marrow**: Both contain numerous blood vessels
  - **Red Marrow (myeloid tissue)**: Red blood cells, platelets, white blood cells created
  - **Yellow Marrow**: Fat cells, some white blood cells created.
Short, irregular, flat & sesamoid

Carpal Bones

Scapula

Vertebræ

Sacrum
Coccyx

Femur
Pelvis
Fibula
Tibia
Metatarsals
Phalanges
Bone Formation
Also known as Osteogenesis/Ossification

• Occurs:
  – During **foetal development**
  – During **growth**
  – During bone **remodelling** (throughout life)
  – Repair

1. **Intramembranous ossification**
   - In the **embryo & foetus**
   - All flat bones (i.e. Skull) and clavicles develop in this way

2. **Endochondral ossification**
   Greek for endo = within / chondral = cartilage
   - From 2 months in utero throughout life
   - Hyaline cartilage model is broken down as ossification proceeds
Endochondral Ossification

1. Formation of bone collar around hyaline cartilage model.
2. Cavitation of the hyaline cartilage within the cartilage model.
3. Invasion of internal cavities by the periosteal bud and spongy bone formation.
4. Formation of the medullary cavity as ossification continues; appearance of secondary ossification centers in the epiphyses in preparation for stage 5.
5. Ossification of the epiphyses; when completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages. (The epiphyseal plates promote longitudinal growth until young adulthood.)

Source: www.knowosteoporosis.wordpress.com/physiology/
Bone Growth

*Long bones grow in length, whilst all other bones grow in thickness*

**Bone elongation:** (interstitial growth)
- **From epiphyseal plate** - a layer of hyaline cartilage in the epiphyses where bone cells are produced by mitosis.
- **Osteoblasts** move in and ossify the matrix to form bone.
- In the early twenties, the epiphyseal (growth) plate *completely ossifies* so that only a thin *epiphyseal line* remains and the bones can no longer grow in length.
- If a bone fracture damages the epiphyseal plate during childhood the fractured bone may be shorter than normal once adult stature is reached.

**Growth in thickness:** (appositional growth)
- Continues through life due to stress, muscle activity and weight.
- Bone is *deposited by osteoblasts in periosteum* (develop new osteons)

Epiphyseal Growth Plate

**epi-** is Greek for upon, on, outside

**di-** is Greek for two

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**EPHYSEAL (GROWTH) PLATE:**
- Zone of resting cartilage
- Zone of proliferating cartilage
- Zone of hypertrophic cartilage
- Zone of calcified cartilage

(c) Lengthwise growth of bone at epiphyseal plate

Source: en.wikipedia.org/wiki/Epiphyseal_plate
Source: www.higheredbcs.wiley.com/legacy/college/tortora/0470565101/hearthis_ill/pap13e_ch06_illustr_audio_mp3_am/simulations/hear/epiphyseal.html
Zone 1: resting cartilage
- Secures epiphyses to epiphyseal plate

Zone 2: proliferating cartilage
- Rapid mitotic division (of chondrocytes)

Zone 3: hypertrophic cartilage
- Stop dividing
- Grow in size

Zone 4: calcified cartilage
- Mineral deposition

Zone 5: Zone of ossification
- Capillaries invade
- Brings Osteoblasts/osteocalsts

Some extra details of the growth plate structure...
Bone Hormones

- Many hormones affect bone growth and remodelling (density) by altering the ratio of osteoblast to osteoclast activity.

**CHILD:**
1. **Growth hormone:** Stimulate osteoblasts
2. **Thyroid hormones:** Promote osteoblasts
3. **Cortisol (& steroid medications):** accelerates bone loss

**ADULT:**
1. **Testosterone & oestrogen**
2. **Calcitonin:** Lowers blood calcium
3. **Parathyroid hormone:** Increases blood calcium
Bone Homeostasis

• Bone is an important **mineral reservoir.** (Especially **calcium** – 99%)

• **Blood calcium levels** have to be tightly controlled to ensure proper **Blood clotting, nerve & muscle function**

If Blood Calcium Levels are low: **Hypocalcaemia**
• **Osteoclasts** break down bone and release calcium into the blood

If Blood calcium levels are high: **Hypercalcaemia**
• Increased osteoblast activity (takes calcium back into bone)

• Calcium exchange is regulated by the **parathyroid glands** & the **thyroid gland.**

Even small changes in **Ca**²⁺ concentration outside this range may prove fatal – the heart may stop!
Parathyroid Hormone

• **Increases blood calcium**

1. **Increases the activity of osteoclasts** (resorption)

2. **Stimulate kidneys to reabsorb & retain calcium in the blood.**

3. **Increases formation of calcitriol** which promotes calcium uptake from food.

*Calcitriol = The active form of vitamin D*
Calcitonin

- A hormone that lowers blood calcium

- Secreted by parafollicular cells of the thyroid gland

- It inhibits osteoclasts and promotes osteoblast deposition of calcium in the bones

- Overall result is increased bone formation & decreased blood calcium
## Hormone Summary

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Location produced</th>
<th>Effect on blood calcium levels</th>
<th>Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parathyroid Hormone</strong>&lt;br&gt;(PTH)</td>
<td>Parathyroid gland</td>
<td>Increases</td>
<td>1. Increases osteoclast activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Increased renal calcium absorption</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Increases calcitriol</td>
</tr>
<tr>
<td><strong>Calcitonin</strong></td>
<td>Thyroid gland (parafollicular cells)</td>
<td>Decreases</td>
<td>Inhibits osteoclast and promotes osteoblasts</td>
</tr>
</tbody>
</table>
Exercise

• Within limits bone can become stronger in response to mechanical stress e.g. pull of skeletal muscle & gravity.

• Mechanical stress leads to increased mineral deposition and increased production of collagen fibres.

• Mechanical stress is important for ensuring bone formation occurs more quickly than bone resorption.

• Lack of stress on bones can cause bone mass loss of up to 1% per week e.g. bedridden, astronauts.

• Orthodontists use braces to place stress on the bone sockets that anchor teeth. Osteoclasts and osteoblasts remodel the sockets so teeth align properly. 

Greek for ortho = correct or straighten / dentist = teeth
Summary Quiz!

1. What is meant by the following: Superior; medial; distal; supine; bilateral
2. What type of bone cell builds bone?
3. What type of bone cell has a ruffled border that secretes enzymes?
4. What’s the name for a structural unit of compact bone?
5. In what direction are the trabeculae of spongy bone positioned/directed?
6. What is the role of the central/haversian canal?
7. Explain the role of the periosteum
8. Give an example of a short and sesamoid bone?
9. Does parathyroid hormone increase or decrease blood calcium?
Axial Skeleton

- The skeleton is divided into the axial and appendicular sections
- The axial skeleton is the “Central skeleton” and consists of 80 bones
- The appendicular skeleton consists of the bones supporting the extremities (arms/legs)
- Serves to **protect** the body's most vital organs.

- **5 parts:**
  - Skull
  - Inner ear ossicles
  - Throat hyoid bone
  - Chest (thoracic cage)
  - Vertebral column (spine)
Skull

- Forms the cranium ("upper head") and face
- Encapsulates the Brain

- The skull bones are joined with **Sutures**.

- **Sinuses:**
  - Communicates with nasal cavity
  - Give resonance to the voice
  - Lighten bones of face and cranium

- **Fontanelles**
  - Fibrous sutures (soft spots) on a baby’s head joining the 5 Skull Bones together.
  - Allow the baby’s head through the birth canal. Ossify 12-18 months
Vertebral Column

- **24 movable VERTEBRAE:**
  - Cervical (7) C1-C7
  - Thoracic (12) T1-T12
  - Lumbar (5) L1-L5
  - Sacrum (5 in human embryo)
  - Coccyx (4 in human embryo)

- Vertebrae are named by region and number. For example C1 articulates with the cranium above and C2 below. C7 articulates with T1, T12 articulates with L1 etc.

- **FUNCTION**: Protection for spinal cord, movement (e.g. side bending), supports skull, forms axis of the trunk
Vertebral Column

INTERVETEBRAL DISCS:

• **24** (none in sacrum)
• Get progressively thicker towards the base of the spine
• **Shock-absorbing**
• Separating
• **Bind vertebral bodies**
• No blood vessels
• Make up **1/3 of the length** of spinal column
• 2 parts: annulus fibrosus, nucleus pulposus
  • Nucleus pulposus is a gel-like pad
Thoracic Cage and Ribs

Consists of:

- Sternum
- Ribs (12 pairs)

- Ribs 11 + 12 are called “floating ribs” as they have no anterior bony attachments (attach posteriorly to vertebrae T11 + T12)
Appendicular Skeleton

• Distal skeleton - any appendages to a major body part. Consists of **126 bones**

• **FUNCTION:** Body movement, protects organs of digestion, excretion and reproduction.

• **Six major areas:**
  – Shoulder girdle
  – Arm
  – Hand
  – Pelvic girdle
  – Leg
  – Foot
Arms and Shoulder

Shoulder girdle:

• **Clavicle** (anteriorly)
• **Scapula** (posteriorly)
• **Humerus** (from Latin *upper arm*)
• **Ulna** (from Latin, *elbow*)
• **Radius** (from Latin, ray, *spoke of a wheel*)
• **Carpals** (from Greek karpos, fruit)
• **Metacarpals** (Meta from Greek, with the meanings after/along with)
• **Phalanges** (proximal, intermediate, distal)
Pelvic Girdle

- **Pelvis** = Hip bones + sacrum

![Diagram of Pelvic Girdle]

- **Right Sacro-iliac joint**

- **Hip bones**
- **Sacrum**
- **Coccyx**
Leg

- **Femur**
  - Longest and strongest bone in the body
- **Tibia** (from Latin, *shin bone*),
- **Fibula** (from Latin, *clasp*),
- **Patella** (Latin for a small pan, dish, plate)
- **Tarsals** (ankle bones) (from Greek meaning flat surface)
- **Metatarsal bones** (from Greek, meta meaning flat + tarsos, *flat surface*)
- **Phalanges**
Origin and Insertion Points

• The muscle's points of attachment to bones or other muscles are designated as ORIGIN or INSERTION.

• The point of origin is the point of attachment to the bone to which the muscle is anchored.

• The point of insertion is the attachment of a muscle to the part which it moves.

• Generally, the muscles are attached by tough fibrous structures called tendons.

• Attachments bridge one or more joints so that muscle contraction produces movement of these joints.
Joints

- The point where two structures join but can move
- There are 187 joints in the human body

1. **Fibrous joints:**
   - No synovial cavity and articulating bones held very close together by dense irregular connective tissue.
   - Permit limited movement
   - An example of a fibrous joint is a suture, like those between skull bones

2. **Cartilaginous joints:**
   - Allow almost no movement or limited
   - Articulating bones tightly connected by hyaline cartilage or fibrocartilage
   - **Examples:** Epiphyseal growth plate, pubic symphysis, intervertebral discs (spine)
Synovial Joints

- Synovial joint cavity allows free movement

- Bones at the joints are covered by a layer of **hyaline cartilage** called articular cartilage that reduces friction/shock absorbs

- Covered by **articular capsule** which unites articulating bones.

- Contains **synovial fluid**, which consists mostly of hyaluronic acid and interstitial fluid filtered from blood
Synovial Joints

- **Types include:**
  
a) **BALL & SOCKET:** Hip & shoulder joints
  
b) **HINGE:** Elbow, ankle, knee
  
c) **PIVOT:** Radioulnar joint & C1/2
  
d) **PLANAR / GLIDING:** (back and forth/side to side) Intercarpal & Intertarsal joints
  
e) **ELLIPSOID:** (Flexion/extension) Wrist joint, MCPJs (2\textsuperscript{nd}-5\textsuperscript{th})
  
f) **SADDLE:** Thumb, carpal & metacarpal
Synovial Joints

Articulating bone
Articular cartilage

Articulating bone

Synovial (joint) capsule:
Fibrous membrane
Synovial membrane

Synovial (joint) cavity (contains synovial fluid)

Periosteum

(a) Gliding joint
(b) Hinge joint
(c) Pivot joint
(d) Ellipsoidal joint
(e) Saddle joint
(f) Ball-and-socket joint
Ball & socket
Hinge
Pivot
Plane
Ellipsoid (condylar)
Saddle
No nerve endings
Or blood supply.

As a result it obtains its nutrients by diffusion (joint movement is essential for this to happen!)
Bursae

- **Sac-like structures** that are strategically located to reduce friction

- Inside it consists of connective tissue fluid similar to synovial fluid

- Located between: Skin & bone, tendon & bone, muscle & bone or ligament & bone.

- Can get tendon (synovial) sheaths that are tube-like and surround certain tendons
Angular Movements

Increase or decrease in the angle between bones.

- **Flexion** - Decrease in angle (usually sagittal plane)
- **Extension** - Increase in angle (usually sagittal plane)
- **Hyperextension** - Extension beyond anatomical position
- **Rotation** - Movement around its longitudinal axis. In the limbs it can be medial (towards the midline) or **lateral** (away from the midline)
- **Lateral flexion** - Movement of trunk away from the midline
- **Abduction** – Movement **away** from Midline
- **Adduction** – Movement **towards** Midline
- **Circumduction** – Circular - flexion, abduction, extension, hyperextension, adduction in succession.

HYPERMOBILITY?
The more flexible a joint is, the more unstable it is. Hence many dislocations..
Angular Movements

Extension

Hyperextension

Flexion

Hyperextension

Flexion

Extension

Adduction

Abduction

Circumduction

Rotation

Lateral rotation

Medial rotation

Circumduction


Special Movements

• **Occur at specific joints:**
  • **Elevation** - Superior movement *(up)*
  • **Depression** - Inferior movement *(down)*
  • **Protraction** - Anterior movement in transverse plane *(forward)*
  • **Retraction** - Posterior movement in transverse plane *(backward)*
  • **Inversion** – Medial movement of *sole* *(turn in)*
  • **Eversion** – Lateral movement of *sole* *(turn out)*
  • **Dorsiflexion** – Bending *foot up*
  • **Plantar flexion** – Bending *foot down*
  • **Supination** – Movement of forearm to turn the *palm up*
  • **Pronation** – Movement of forearm to turn the *palm posteriorly*
  • **Opposition** – Movement of *thumb* across palm to *touch fingertips*
Special Movements

Video: www.youtube.com/watch?v=qQOkyGmiB4A
Summary Quiz

1. Name the thigh bone
2. Name the bones of the forearm
3. Is the vertebral column part of the axial or appendicular skeleton?
4. What is the fibrocartilage structures called between vertebrae?
5. What is the function of a bursa?
6. Give an example of a fibrous joint in the body
7. Name three types of synovial joints
8. In the movement flexion, do you increase or reduce the angle of a joint?
9. What is the movement plantarflexion?
Skeletal Pathologies: Fractures

- Any break in a bone

- Causes include trauma, low bone density, vitamin D deficiency

- Can damage blood vessels that supply bone

- **Classification:**
  - Complete – completely separated
  - Incomplete
  - Linear – Along bone length
  - Transverse – Dissects across bone
  - Compound – Protrudes through skin
  - Simple – Does not protrude skin
    - Examples: Avulsion, greenstick, comminuted (fragments between), stress
Fractures Repair

1) **HAEMATOMA (& INFLAMMATION)**
   Blood vessels crossing fracture line are broken and blood leaks into fracture site. Causes death of local cells and swelling.

2) **FIBROCARTILAGINOUS CALLUS FORMATION**
   Phagocytes clean up the debris. Fibroblasts invade fracture site and lay down collagen forming a soft callus. It takes 2-3 weeks to form the soft callus.

3) **BONY CALLUS FORMATION**
   Osteoblasts replace fibrocartilage with new bone (<3 months)

4) **BONE REMODELLING**
   The callus is mineralised, compact bone laid down. Then Osteoclasts reshape and the new bone. Remodelling occurs over months to years, facilitated by mechanical stress (months – years)

Callus = mass of tissue
Fractures Repair

Fracture animation: https://www.youtube.com/watch?v=P5HwYWSbBhw

HAEMATOMA  FIBROCARTILAGINOUS CALLUS FORMATION  BONY CALLUS FORMATION  BONE REMODELLING

For more information on this process read: Biology of fracture healing. By K.Ito
Fractures

TREATMENT:

• Improve circulation and nutrients to the bone to aid repair.

• Creams and ointments can be very effective – get absorbed in to the area.

• **Herbs** – comfrey

• **Nutrients** – calcium, vitamin D, vitamin C

• **Homeopathic** – Arnica for bruising, Ruta for injured nerve on the bone. Calc Phos 4c given for 3 weeks helps to fuse bones together.
Sprains

• Trauma forcing a joint beyond normal range
• Causing a stretching / tearing of ligaments
• Leads to joint instability.

TREATMENT:
• First Aid – RICE (Rest, Ice, Compression, Elevation).
• Herbs locally and internally – tissue repair e.g. comfrey,
• Nutrients – glucosamine, vit. C, zinc, vit. E
• Homeopathy
• Acupuncture

Ligaments are bands of connective tissue that attach bone to bone. They are tougher than muscle but less flexible and prevent movement outside of normal ranges. They are often injured when a joint is forcefully stretched beyond its normal range.
**Subluxation/Dislocation**

**SUBLUXATION**
- Incomplete or partial dislocation (misalignment) of a joint or organ.

**DISLOCATION**
- Complete separation of two bones at a joint
  - Deformity and reduced strength and movement
  - Muscular disease, arthritis or torn ligaments may predispose the individual
  - Accompanied by soft tissue damage, possibly involving nerves and blood vessels.

http://radiopaedia.org/articles/anterior-shoulder-dislocation
X-Rays

- Commonly used to **visualise** lungs, heart, teeth and skeletal system.

- **Electromagnetic radiation** upon a specified region in the body.

- Pass through less dense matter (air, fat, muscle, and other tissues) but absorbed or scattered by denser materials (bones, tumors, lungs affected by severe pneumonia) appearing white

- **Side effects:** Cancer (DNA damage) – will be discussed further in oncology
X-Rays are not only used for detecting fractures…

This patient has been diagnosed with a Pulmonary Embolism (a clot that has dislodged in the blood and has now become trapped in the lungs (yellow arrows))

Why do you think it appears white on an X-Ray?
Kyphosis

• A normal, healthy spinal curve will include a **thoracic spine kyphosis**

• However some people can develop an **exaggerated kyphosis** which is often called a ‘Hunchback’.

• This may be as a result of poor posture (due to occupation, stress, body language etc)

• Can occur secondary to a disease (eg. Often found with osteoporotic stress fractures)

• May cause muscular fatigue around the scapula (shoulder blade) or even rib irritation. May interfere with breathing.

• Can respond well to manual therapies (e.g osteopathy), exercise, postural training and bowen Technique
Lordosis

- Increased concavity of lumbar spine.

- A normal, healthy spinal curve will include a **cervical spine and lumbar spine lordosis**. However people can develop excessive lordoses.

- May be a genetic/ethnic cause, secondary to other musculoskeletal changes. More common in obesity.

- Also a normal adaptation for **pregnancy**.

- An exaggerated lordosis can cause muscular fatigue and also encourages the bony joints of the vertebrae to move closer.

- Treatment may include manual therapy, exercise, postural training and bowen Technique.
Scoliosis

- A lateral ‘S’ shaped curve in the spine

- Generally the more pronounced the abnormal curve, the more clinically relevant. People often live with a scoliosis and are asymptomatic

- People can be born with a scoliosis or develop them throughout their life (often adolescent onset)

- They can develop as a result of everyday imbalances (e.g. carrying rucksack on one shoulder)
- Commonly associated with a leg length discrepancy

- A marked scoliosis can even cause spinal nerve impingement

- Treatment may include Osteopathy, chiropractic, bowen
Osteoporosis

- Chronic, progressive thinning of the bone (“porous bone”)
- Characterised by decreased bone mineral density (BMD) leading to bone fragility & increased risk of fracture.

Osteoporosis animation video: https://www.youtube.com/watch?v=c5tc01WFYks
Diagnosis: Dual X-Ray Absorptiometry

- DXA measures: Bone mineral content (g) Area (cm²)

Report gives you two readings:
- **T-Score** (compared to young normal adult of same sex – age 30)
- **Z-Score** for adults <50 yrs (compared to normal adult of same age, sex, height)

<table>
<thead>
<tr>
<th>T above or equal to -1.0</th>
<th>Normal bone density</th>
</tr>
</thead>
<tbody>
<tr>
<td>T is between – 1.0 and -2.5</td>
<td>Osteopenia (low bone mass)</td>
</tr>
<tr>
<td>T is -2.5 or lower</td>
<td>Osteoporosis</td>
</tr>
</tbody>
</table>

NICE Guidelines Osteoporosis
Osteoporosis

Can be classified as:

1. **Primary osteoporosis**: Age related or idiopathic (unknown cause)
2. **Secondary osteoporosis**: Secondary to another condition/medication/lifestyle.

http://www.physioplusedinburgh.co.uk/2016/06/osteoporosis/
Osteoporosis Risk Factors

- **Increasing age** – over 30 years of age ability to retain calcium lowers

- **Female & Post-menopausal** – estrogen would normally suppresses osteoclast activity

- **Poor diet** - high acid-forming diet (high in sugars & proteins), low in minerals, malnourished, excess sodium, caffeine, fizzy drinks

- **Drugs** - Corticosteroid therapy
- **High alcohol consumption and smoking**
- **Hyperparathyroidism** – increases parathyroid hormone = increases osteoclast activity
- **Toxins** (heavy metals)
- **Ethnicity** - higher risk in caucasian women of northern European descent.
- **Genetics** - family history
- **Sedentary lifestyle**
- **Endocrine problems** e.g. inability to produce oestrogen
Osteoporosis

SIGNS & SYMPTOMS:
• **Asymptomatic** until the bone has reached critical thinness whereby fragility **fractures** occur spontaneously with minor trauma
• Pain is usually severe & localised to site of fracture.
• **Aggravated** by increased sitting, standing or bending
• **Relieved** by lying on side with hips & knees flexed.
• Rib or Spinal Deformities such as kyphotic posture
• Loss of height due to vertebral crumpling and fracture

DRUG TREATMENT: **Bisphosphonates** (Aledronic Acid) – Inhibit osteoclast activity
Side effects: Over 1 in 10 get bone, muscle or joint pain, dizziness, hair loss, heartburn, fever, eye pain and **BONE FRACTURES**!

TREATMENT: Healthy **none acidic diet**, calcium, vitamin D, weight bearing exercise, herbs (hormone balancing), avoid toxins.

WHAT MIGHT YOU SEE?
If you observe the skin overlying the site of a vertebral crush fracture, you will often see creasing of skin where local vertebral height is lost...

Osteomalacia & Rickets

- Inadequate mineralisation of bone matrix in spongy and compact bone

- Characterised by decalcification of bone and “softening”

- Especially in the spine, pelvis and legs

- **Rickets**: prior to epiphyseal plate closure (>18yrs)

- **Osteomalacia**: as an adult or adolescent

Osteo = bone
malacia = “softening”
Osteomalacia & Rickets

CAUSES:
• Vitamin D Deficiency possibly due to:
  • Insufficient sunlight
  • Insufficient vitamin D in the diet
  • Secondary deficiency: malabsorption disorders
  • Reduced receptor sites for vitamin D in tissues

SIGNS & SYMPTOMS:
• Deformed bones (bowing of legs)
• Severe back pain
• Severe muscle weakness
• Fracture
• In rickets: Delayed closure of fontanelles and skull softening

TREATMENT: Increase vitamin D status – foods, supplementation, regular sunlight.
Vitamin D

Are you getting enough Sunlight?

90%

10%

Liver

Intestines

Kidneys

Food sources of vitamin D

Ultraviolet B rays convert vitamin D precursor in the skin to vitamin D3

Needed for calcium absorption from gut
= crucial for healthy bones

active vitamin D3

Hypercalcaemia

- **Elevated blood calcium** = serum calcium above 2.5 mmol.

**CAUSES:**
- Uncontrolled release of calcium from bones e.g. tumour
- **Hyperparathyroidism**
- Immobility – leads to demineralisation of bone
- Excess intake of calcium / vitamin D
- Milk-alkali syndrome - Increased intake of milk, antacids & Calcium supplements

**SIGNS & SYMPTOMS:**
- Muscle weakness, lethargy, anorexia, nausea, polyuria, irregular heartbeat, anxiety
- If high calcium is coming from the bones, bone density will be compromised and fractures may occur

Calcium plays a critical role in nerve impulse transmission and muscle contraction.
Osteomyelitis

- A bacterial infection of the bone marrow (often staphylococcus aureus)
- Results in necrosis of bone cells and hence becomes weak
- Often affecting lumbar vertebrae or distal femur / proximal tibia in children

CAUSES:
- Bacterial infection (staphylococcus aureus) through the blood supply or after a fracture.
- Immune–suppression, diabetes, alcoholics, injecting drug users

INVESTIGATIONS:
- Blood test: Elevated ESR, CRP, WBCs
- X-ray, MRI
Osteomyelitis

SIGNS & SYMPTOMS:
- **Severe pain** and local tenderness over affected areas (sensitive to percussion)
- **Swelling**
- **Erythema, warmth**
- Severe night pain
- Muscular guarding of paravertebral muscles

ALLOPATHIC TREATMENT:
- **Intravenous (IV) antibiotics** (Side effects: lowered immunity, disturbed gut function (diarrhoea, bloody stools, poor digestion & absorption), candida/thrush)

TREATMENT: Herbs (infection & immunity), local compresses, homeopathy.

The infection is associated with inflammation in bone – heat swelling and redness are key signs of inflammation.
Bone Tumours

BENIGN TUMOURS:
• Grow inside bones, cause pressure, deep pain, fracturing.
• Can potentially become malignant

MALIGNANT TUMOURS:
• **Osteosarcomas**: malignancy of bone
• Primary osteosarcomas typically affect children (knee)
• Usually “secondaries” from other organs.
• **From**: Breast, lungs, thyroid, kidneys & prostate.
• Pain, swelling, localised tenderness, erythema, night pain
• Poor prognosis

ALLOPATHIC TREATMENT: Radiotherapy
SUPPORT: Herbs and nutrition
Disc Herniation/Protrusion

- The nucleus pulposus of the disc leaks out through the annulus fibrosis

- This tends to affect discs with the highest fluid content (30-40 years of age). Most commonly lumbar spine (L4/5 or L5/S1), then cervical.

- The classic mechanism of injury is combined lumbar spine flexion and rotation (bending and twisting)

- A herniated disc can compress spinal nerves causing pain into the legs (although it doesn’t always)

- Treatment involves manual therapy, muscle strengthening, homeopathy (arnica), herbs

If this is the case, one clue to diagnosis is that the pain in the legs is worse than pain in the back..
Osteoarthritis

• A degenerative wear & tear arthritis of the articular cartilage, typically affecting the weight bearing (larger) joints.

SIGNS & SYMPTOMS: (see table in a few slides..)
• Onset is gradual, pain increasing over months to years
• More commonly seen in older people.
• Movements become restricted and joints deformed.
• Not usually associated with systemic inflammatory symptoms

CAUSES:
• Congenital ill-development
• Irregularity of articulating surfaces e.g. from fracture
• Previous injuries e.g. torn meniscus
• Previous disease e.g. RA
• Mal-alignment of a joint
• Obesity and overweight.
Osteoarthritis

PATHOPHYSIOLOGY:
Articular cartilage wears away, until the underlying bone is exposed.
- Subchondral bone becomes hard and glossy (eburnation)
- Cysts and sclerosis occurs in bone surface.
- Bone at margins hypertrophies, forming projecting spurs = Osteophytes

DIAGNOSIS:
- **X-ray** - Joint space narrowing, subchondral cysts, osteophyte (projecting spurs) formation, squaring of rounded joint surfaces. *NOTE: Side effects of X-Ray!*

TREATMENT:
- Nutrition, glucosamine, Vitamin C, MSM, Herbs – comfrey, turmeric, weight loss
Osteoarthritis

Knee

Hands


http://www.healthline.com/health-slideshow/osteoarthritis-hand

Rheumatoid Arthritis

- Autoimmune inflammation of the synovium, potentially affecting ALL organs except the brain (systemic inflammation).
- Affects 1% of people worldwide
- Peak occurrence is between Age 30–50yrs.

**SIGNS & SYMPTOMS:**

- **Symmetrical** / bilateral arthritis affecting small joints (hands and feet mostly).
- Gradually spreads through more proximal structures.
- **Morning stiffness**
- **Deformity of joints** e.g. swan neck, ulnar deviation
- General malaise
- Subcutaneous nodules
- Eye problems – pain in eyes or dry eyes
- C1/2 subluxation & compression of the spinal cord leading to quadriplegiasis / neurological complications
- Kidney problems
Rheumatoid Arthritis

ALLOPATHIC TREATMENT:
• Anti-inflammatories and immunosuppressant's! *(significant implications of immune system suppression)*
• Surgery

ALTERNATIVE TREATMENT:
• Nutrition (anti-inflammatory)
• Herbs (for pain & inflammation & immune modulation)
• Homeopathy
### Rheumatoid vs Osteoarthritis

<table>
<thead>
<tr>
<th></th>
<th>OA</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of disease (cause)</strong></td>
<td>Degenerative wear &amp; tear process</td>
<td>Autoimmune</td>
</tr>
<tr>
<td><strong>Tissue(s) affected</strong></td>
<td>Articular cartilage</td>
<td>Synovial membrane</td>
</tr>
<tr>
<td><strong>Type of JOINT affected</strong></td>
<td>Mostly hips &amp; knees (weight bearing joints)</td>
<td>Any synovial joints. (tends to be systemic)</td>
</tr>
<tr>
<td><strong>Age of onset</strong></td>
<td>50 yrs+</td>
<td>20-50 yrs</td>
</tr>
<tr>
<td><strong>Symmetrical</strong></td>
<td>Asymmetrical</td>
<td>Symmetrical / Bilateral</td>
</tr>
<tr>
<td><strong>Additional symptoms</strong></td>
<td>Not usually</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Radiology findings</strong></td>
<td>Osteophytes, narrowed joint space, subchondral cysts</td>
<td>Bone erosions on X-Ray. Synovitis on ultrasound/MRI</td>
</tr>
<tr>
<td><strong>Blood tests</strong></td>
<td>No abnormal findings</td>
<td>Raised: ESR, CRP, Rheumatoid factor</td>
</tr>
</tbody>
</table>
# Rheumatoid vs Osteoarthritis

<table>
<thead>
<tr>
<th>Signs &amp; symptoms</th>
<th>OA</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradual onset with increasing pain</td>
<td>Bilateral joint pain affecting small joints (hands &amp; feet mostly)</td>
<td></td>
</tr>
<tr>
<td>months to years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight bearing joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning stiffness &lt;30 mins</td>
<td>Morning stiffness &gt;1 hour</td>
<td></td>
</tr>
<tr>
<td>Often worse in the evening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eventually the joints become deformed</td>
<td>Deformities occur.</td>
<td></td>
</tr>
<tr>
<td>Enlarged joint in distal finger</td>
<td>Ulnar deviation of digits.</td>
<td></td>
</tr>
<tr>
<td>Not usually associated with systemic inflammation</td>
<td>Swan neck of fingers</td>
<td></td>
</tr>
<tr>
<td>Systemic symptoms eg. Fatigue, weight loss, anaemia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteophyte / bone spurs</td>
<td>Subcutaneous nodules</td>
<td></td>
</tr>
<tr>
<td>Can affect C1/2 joint and cause vertebral subluxation and spinal cord compression</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ankylosing Spondylitis

- Chronic inflammation of spine & sacroiliac joints, often leading to spinal fusion (ankylosis) & reduced movement.

- May have genetic link - 95% of patients carry HLA–B27 gene and 1/3 have a family history.

- Age of onset 20–45 yrs.

- **Males** : Females is 8:1.

- Elevated blood inflammatory markers (ESR/CRP) and X-Ray/MRI findings assist diagnosis.
Ankylosing Spondylitis

SIGNS & SYMPTOMS:
• **Early**: lumber lordosis flattens & mobility is reduced. *Lower back pain* may radiate into posterior thighs. Hip and heel pain are common. *Stiffness* & pain is marked in the mornings & *improves with activity*. Ascending spinal involvement (from sacroiliac joints)
  
  • 20% suffer *acute iritis* – *(HLA-B27 diseases)*
  
  • **Later**: Thoracic spine restricted, rib joints stiffen, chest expansion diminished.
  
  • Remember it is a *systemic autoimmune disease* potentially affecting anywhere in the body. Fever & malaise

ALLOPATHIC TREATMENT: Surgery, anti-inflammatories (side effects!)

ALTERNATIVE TREATMENT: Nutrition & herbs (anti-inflammatory)
Gout

• Excess uric acid crystals in tissues & fluids within the body.
• One of the most common forms of arthritis in Men (40+ years)
• Excess uric acid forms solid crystals (monosodium urate) on cartilage surfaces
• This causes white blood cells to infiltrate activating an acute inflammatory response.
• Hyperuricemia = elevated blood uric acid levels - due to overproduction or under excretion
• Uric acid - derived from the breakdown of nucleic acids

CAUSES:
• Purine excess (red wine, shellfish etc)
• Dehydration, trauma, obesity, excessive alcohol consumption (competes with uric acid for elimination by the kidney), hypercholesterolaemia, hypertension, type II diabetes, kidney disease
Gout

Uric acid crystals under a microscope

The classic appearance of a gout affected joint
Gout

SIGNS & SYMPTOMS:
• Affects men more than women (8:1), often presenting around 40 years of age
• Most often affects the big toe. Can affect the mid-feet, ankles, knees, elbows, hands
• Usually monoarticular (one joint), but can also be polyarticular.
• Intensely painful, red, hot & swollen joints (can last 12-24 hours)
• Skin over the joint appears shiny & may peel.
• Painless ‘tophi’ – collection of urate crystals outside the joints, under your skin.

DIAGNOSIS:
• Blood serum for uric acid (not definitive / fluctuates) but can be useful to monitor treatment. Analysis of synovial fluid (needle aspiration) to identify crystals

TREATMENT:
• Corticosteroid injection (Side effects: Indigestion, rapid heartbeat, nausea, insomnia, mood changes, diabetes, glaucoma, mood changes)
• Nutrition (anti-inflammatory), Herbs (for inflammation), Homeopathy

Bursitis

- **Inflammation of a bursae**

- Found around many joints in the body. Commonly affects the shoulder (sub-acromial) and hip (trochanteric)

**CAUSES:**
- Sudden trauma, infection, wear and tear.
- **Repetitive use** (for example: shoulder bursitis might occur following lots of overhead work e.g. decorating)

**TREATMENT:**
- Herbs (for pain & inflammation & infection if present)
- Resting, ice pack, manual therapy
- Nutrition (anti-inflammatory), Homeopathy
1. Compare the causes of osteoarthritis and rheumatoid arthritis
2. What tissue is likely to be damaged in an ankle sprain?
3. List symptoms of ankylosing spondylitis
4. List FOUR risk factors of osteoporosis
5. What is the difference between rickets and osteomalacia?
6. Who is most at risk of developing gout? What joint is typically affected in gout?
7. Where do primary malignancies of bone typically affect?
8. Why is vitamin D important for bone health?
9. Why might somebody develop bursitis?
10. Define the term Osteomyelitis