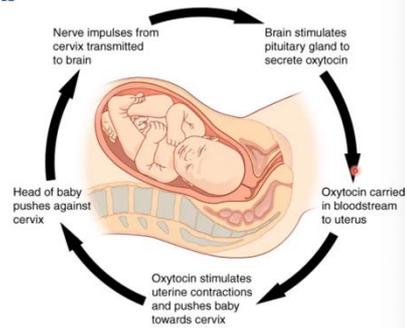
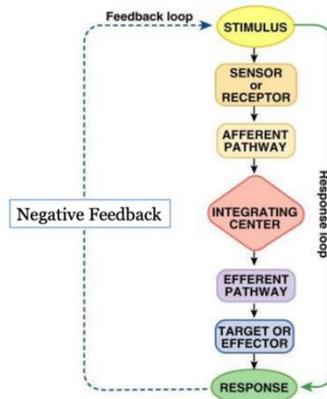
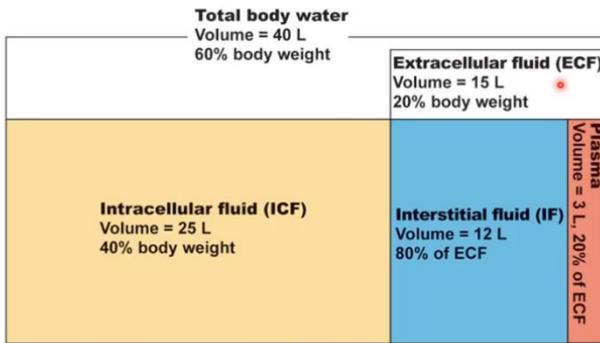


## Physiology

### Osmosis and Diffusion

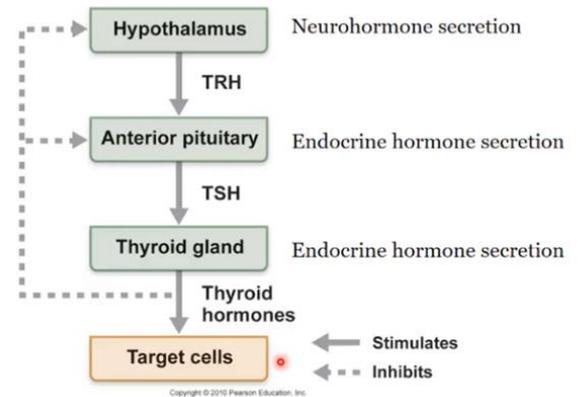


### Saline 0.9%

- isotonic
- no change in osmolarity or osmotic pressure of the extracellular compartment
- no NaCl or water moves into the cell as NaCl is a nonpenetrating solute
- Increase extracellular fluid volume by 1L

### Dextrose 5%

- hypotonic
- Dextrose is penetrating solute
- dextrose moves into the cell, increasing the total number of solutes inside the cell, increasing the osmolarity
- Water moves into the cell, increasing the intracellular fluid volume
- Note: some fluid remains in the intravascular and interstitial space, but bulk of water ultimately ends up inside the cell due to dextrose moving into the cell.



## Homeostasis

**Posterior Pituitary Gland** = neurohormones oxytocin + ADH

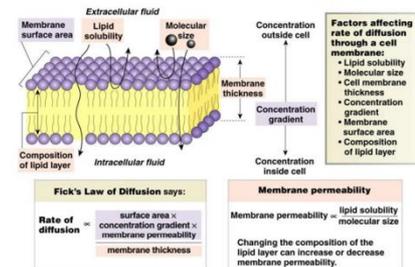
**Anterior Pituitary Gland** = tropic hormones

## Membrane Potentials

**Na/K+ pump** establishes concentration gradient (3Na+ out, 2K+ in)

**K+ leak channels** – membrane 40x more permeable to K+ (membrane potential closer to K+ equilibrium potential)

$$\delta \text{diffusion} \propto SA \times \frac{\text{Lipid solubility}}{\text{Molecular weight}} \times \frac{(C_1 - C_2)}{(X_1 - X_2)}$$



Ion	Concentration outside (in mM)	Concentration inside (in mM)	Ratio Out : In	E <sub>ion</sub> (at 37°C)
K <sup>+</sup>	5	100	1 : 20	-80 mV
Na <sup>+</sup>	150	15	10 : 1	62 mV
Ca <sup>2+</sup>	2	0.0002	10,000 : 1	123 mV
Cl <sup>-</sup>	150	13	11.5 : 1	-65 mV

**Membrane potential** = charge difference across membrane in mV – calculated with **Goldman Hodgkin Katz equation** (excludes Ca<sup>2+</sup> due to small concentration)

**Resting membrane potential** = due entirely to leak channels, no voltage gated channels open, approx. **-65mV** (membrane more negative on inside due to K<sup>+</sup> leaving cell through leak channels)

**Equilibrium potential/reversal potential/Nernst potential** = when chemical gradient potential energy = electrical gradient potential energy, net movement of ion = zero -> electrical drive = chemical drive – calculated using **Nernst Equation**

Ion will move across the membrane to make the equilibrium potential = the membrane potential

**V<sub>m</sub> > E<sub>k</sub>**, K<sup>+</sup> exits cell -> hyperpolarisation

**V<sub>m</sub> < E<sub>k</sub>**, K<sup>+</sup> enters cell -> depolarisation

**Driving force** = Membrane potential – equilibrium potential, DF on Na<sup>+</sup> much greater than K<sup>+</sup> (will move faster)

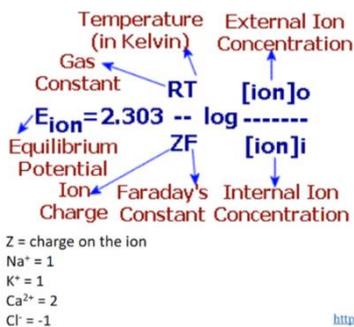
Which best explains why the reversal potential for Cl<sup>-</sup> (E<sub>Cl</sub>) is close to resting membrane potential but significantly positive to the reversal potential for K<sup>+</sup> (E<sub>K</sub>)? – The presence of a Na<sup>+</sup>/K<sup>+</sup> pump but the absence of a Cl<sup>-</sup> pump.

Opening of a monovalent ion channel will result in depolarisation of the membrane due to the stronger driving force on Na<sup>+</sup> than K<sup>+</sup> (Na<sup>+</sup> moves into the cell)

Opening a Na<sup>+</sup> selective ion channel will depolarize the membrane.

Opening a K<sup>+</sup> selective ion channel will hyperpolarize the membrane.

### Nernst Equation:



[http://www.physiologyweb.com/calculators/nernst\\_potential\\_calculator.htm](http://www.physiologyweb.com/calculators/nernst_potential_calculator.htm)

- R = Constant = 8.314
- T = assume in body = 37°C or = 310.15K
- Thus RT = constant = 96.5 K<sup>i</sup> mol<sup>-1</sup>
- Thus 2.3(RT/F) = 61.54

### Goldman Hodgkin Katz Equation (no Ca<sup>2+</sup>), p<sub>K</sub> = permeability to K<sup>+</sup>

$$V_m = \frac{RT}{F} \ln \left( \frac{p_K [K^+]_o + p_{Na} [Na^+]_o + p_{Cl} [Cl^-]_i}{p_K [K^+]_i + p_{Na} [Na^+]_i + p_{Cl} [Cl^-]_o} \right)$$

$$V_m = 26.8mV \ln \left( \frac{40(5) + 1(150) + 1(13)}{40(100) + 1(15) + 1(150)} \right)$$

$$V_m = 26.8mV \ln \left( \frac{200 + 163}{4000 + 165} \right) = 26.8 \ln \left( \frac{363}{4165} \right) = 26.8 \ln(0.09)$$

$$V_m = 26.8mV \times -2.4$$

$$V_m = -64.34mV$$

## Pharmacology

**Drug** = A chemical substance of known structure, other than a nutrient or an essential dietary ingredient\*, which, when administered to a living organism produces a biological effect note: cannabis not a drug, cannabidiol is the drug found in cannabis!

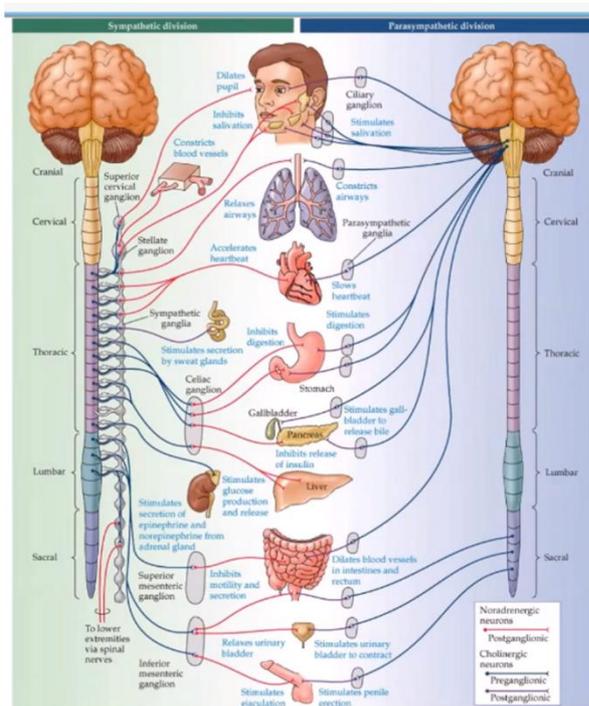
**Excipients + active ingredient** = pharmaceutical formulation

**Drug class** = Group of drugs with a similar chemical structure and therefore a similar mechanism of action

**Drug targets** = large regulatory proteins – enzymes, receptors, ion channels, carrier molecules

**Pharmacokinetics** = The science of the actions of the body on drugs - Rate in (absorption + distribution), rate out (metabolism + excretion)

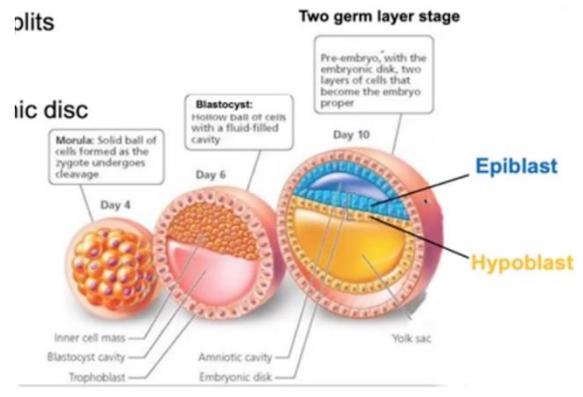
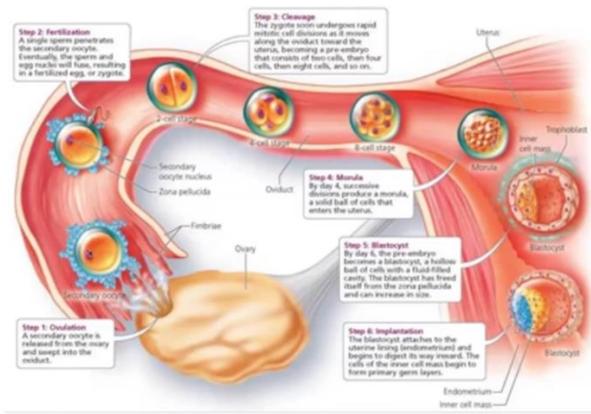
**Speed fast to slow:** ligand-gated ion channels > G-protein coupled receptors > catalytic receptors (intrinsic catalytic activity) > nuclear receptors



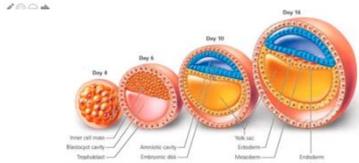
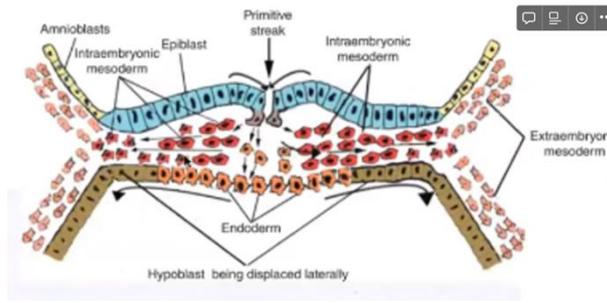
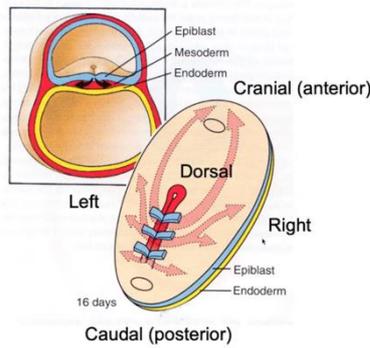
# Embryology

1. **Conceptus** - Fertilisation to end of 2nd week
2. **Embryo** - Beginning of 3rd week to end of 8th week
3. **Fetus** - 3rd month to birth

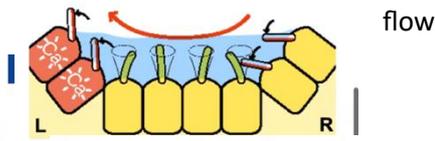
**Zygote** -> **Morula** -> **Blastocyst** (ICM + Trophoblast 1 cavity), implants 5-10 days -> **2 germ layer stage** (epiblast, hypoblast, 3 cavities) -> **3 germ layer stage** (endoderm, mesoderm, ectoderm)



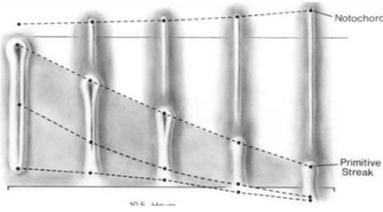
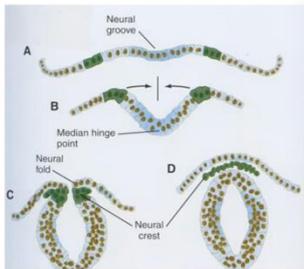
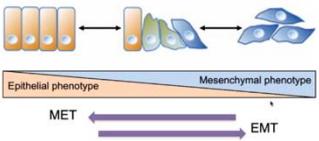
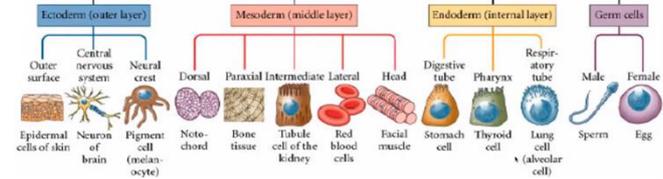
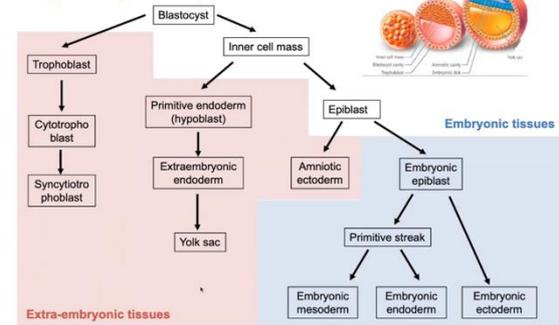
## Embryonic body axes



leftward fluid

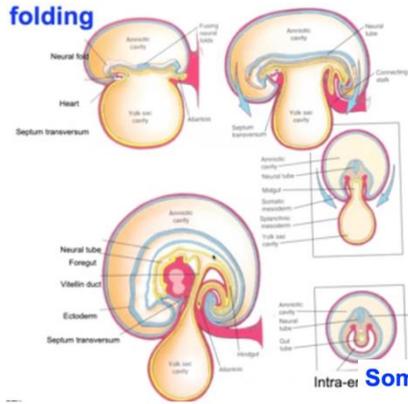


## Summary - early development



EMT – neural crest  
MET - somites

Embryonic disc and amnion: high growth rate  
 Yolk sac: almost no growth



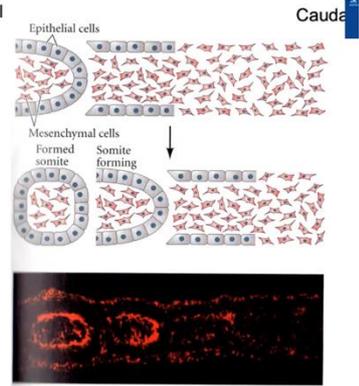
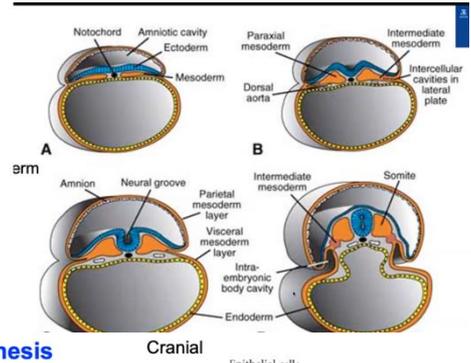
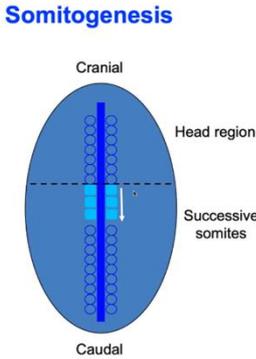
**Paraxial Mesoderm:**

- Somites – dermatome (dermis), sclerotome (axial skeleton), myotome (axial and limb muscle)
- Somitogenesis = cranial to caudal

**Intermediate Mesoderm:**

- Urogenital system (kidneys, gonads, ducts)

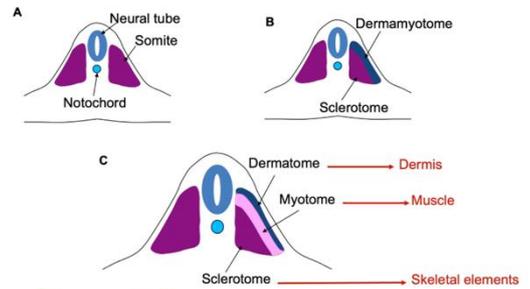
Pronephros = degenerates quickly  
 Mesonephros = embryonic kidneys, overlying epithelium proliferates + differentiates into gonads  
 Metanephros = adult kidney



**Lateral mesoderm (somatic/parietal – lines body cavity, visceral/splanchnic – wall of gut):**

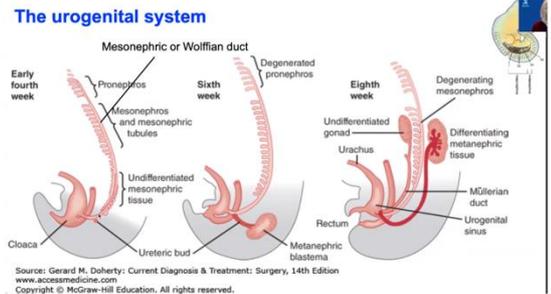
- Blood vessels
- Heart
- Bones of the limbs
- Wall of gut
- Ventrolateral body wall (connective tissue not muscle)

**Somite differentiation**



**Vasculogenesis – de novo assembly of blood vessels**

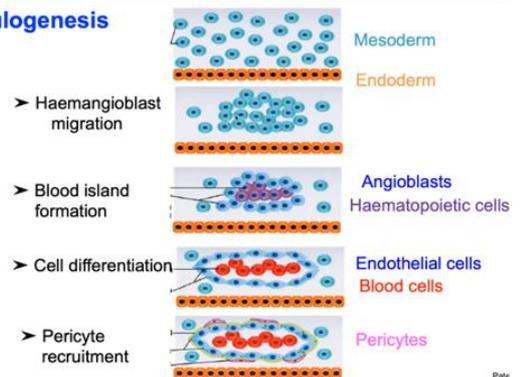
1. Endoderm signals to mesoderm
2. Mesoderm cells cluster and form haemangioblasts
3. Haemangioblasts differentiate into angioblasts (form endothelial cells on outside) and haematopoietic cells (form blood cells on inside)
4. Recruit pericytes



**Angiogenesis – assembly of blood vessels from pre-existing blood vessels**

1. Hypoxic cells produce VEGF-A
2. Blood vessel cells have receptor for VEGF-A, migrate towards gradient to form new blood vessels

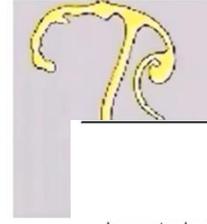
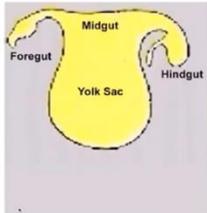
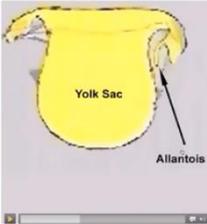
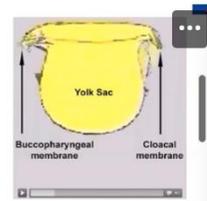
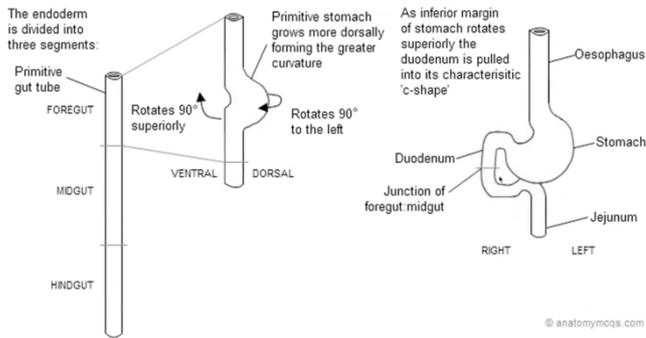
**Vasculogenesis**



**Heart** - Heart starts of as 2 endocardial tubes that fuse and swell up to form chambers, then start looping and rotating. Then septa form to divide this into 4 chambers

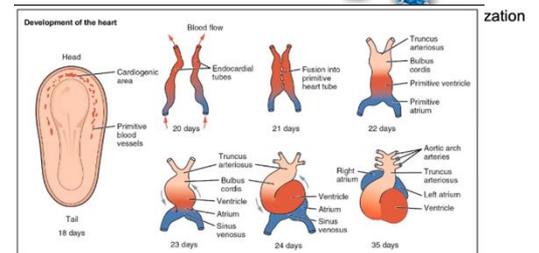
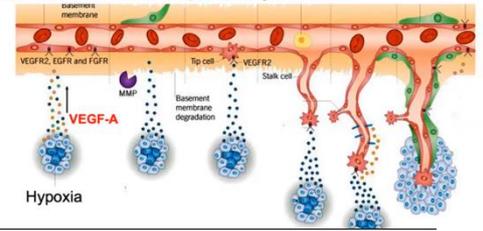
**Stomach:**

1. Dorsal grows faster than ventral
2. 90 degrees rotation clockwise -> dorsal to left, ventral to right
3. Rotation superiorly (bends duodenum into C shape)

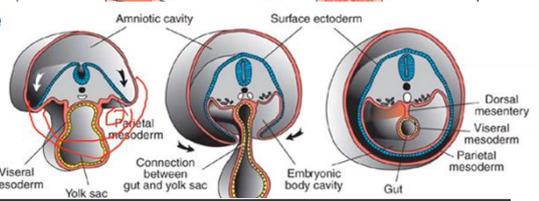


**Angiogenesis**

Blood vessels formation from pre-existing vasculature

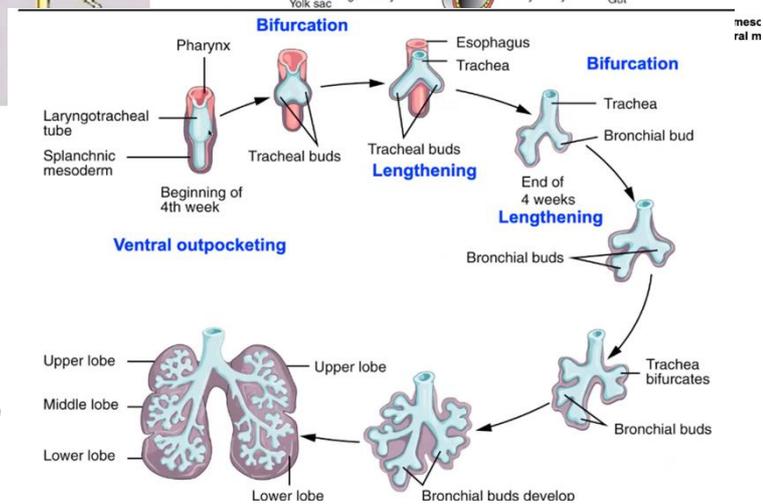


**lbe**



**Lungs:**

- Ventral out-pocketing of endoderm called respiratory diverticulum → will form trachea
- Growths ventro-caudally (front then down)
- Bifurcation ► forms right and left primary tracheal buds ► will form bronchi
- Next bifurcation: secondary bronchial buds (3 on right, 2 on left) ► lung lobes
- Third bifurcation: tertiary bronchial buds ► bronchopulmonary segments
- 14 more branchings ► terminal bronchioles

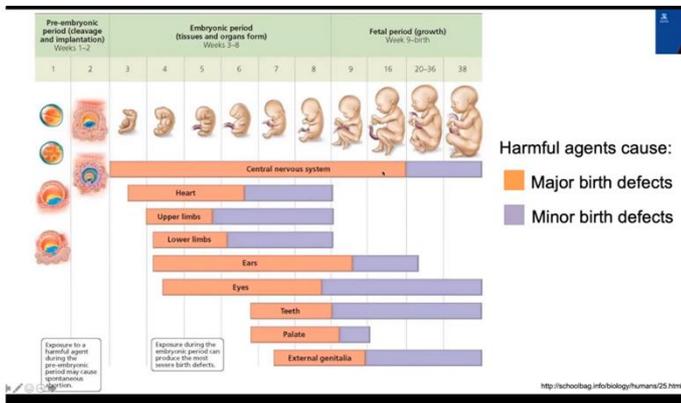
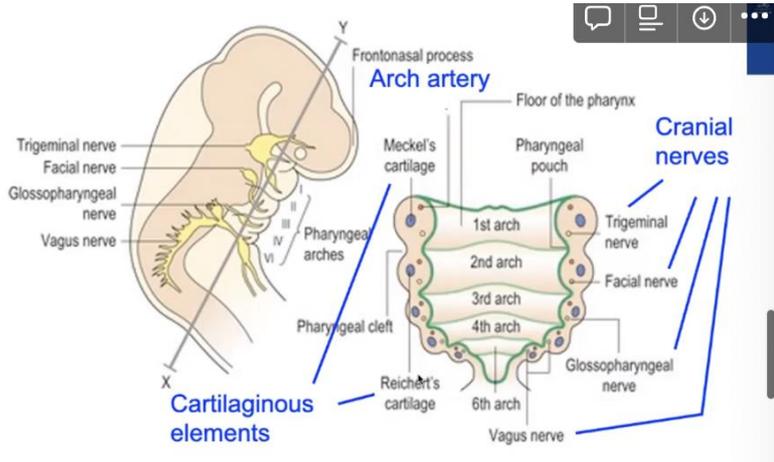


Each pharyngeal arch contains:

- Central cartilaginous skeletal element (derived from neural crest)
- Striated muscle rudiment (derived from head mesoderm)
- Arch-specific cranial nerve
- Aortic arch artery (endothelial cells derived from mesoderm)

**The gut and its derivatives**

	Gut tube proper	Derivatives
Foregut	Pharynx Oesophagus Stomach Proximal duodenum	Thyroid Parathyroid Thymus Lungs Liver Gall bladder Pancreas
Midgut	Distal duodenum, half of colon	
Hindgut	Other half of colon to anus	Urinary bladder



# Nervous System

## Brain

**CNS** = brain + spinal cord

**PNS** = ganglia

**Neurons + glial cells** (oligodendrocytes CNS multiple myelinations, Schwann cells PNS single myelination)

**Diencephalon** = hypothalamus, thalamus, pineal gland

Cerebellum has **folia**, brain has **sulci** and **gyri**

**Meninges** – dura mater, arachnoid mater (arachnoid villi extend into subarachnoid space), pia mater

**Subarachnoid space** filled with **CSF**

**Corpus Callosum** = axons connecting hemispheres

**Brain Stem** = midbrain, pons, medulla oblongata

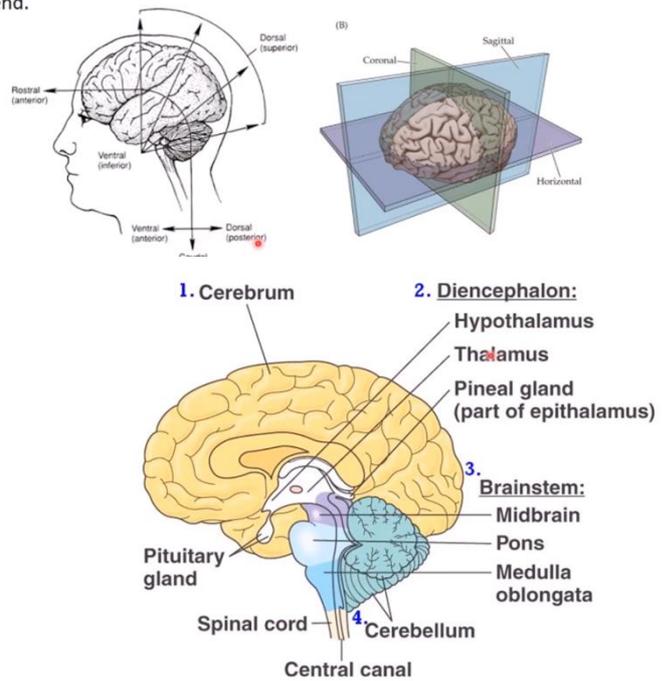
Brain = Grey matter out, white matter in

Spinal cord = grey matter in, white matter out

### Production and drainage of CSF:

- Made in ventricles of brain (**choroid plexus**) from blood filtrate
- Bathes brain in subarachnoid space
- Arachnoid villi project into **superior sagittal sinus** in dura mater and drain CSF back into blood when pressure builds -> failure = pressure on brain/**hydrocephalus in children**

end.



### Dural Folds

- Falx cerebri
- Tentorium cerebelli
- Falx cerebelli

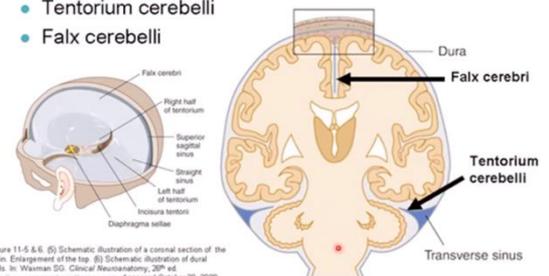
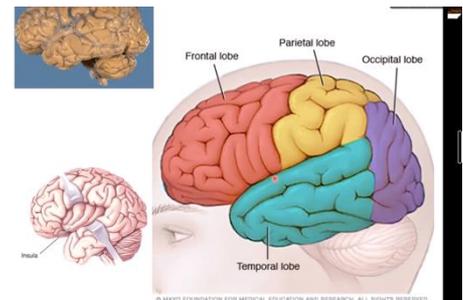
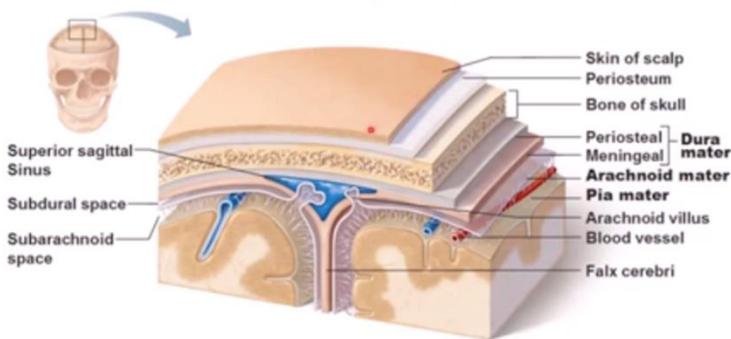
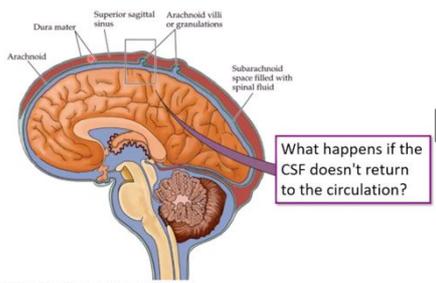
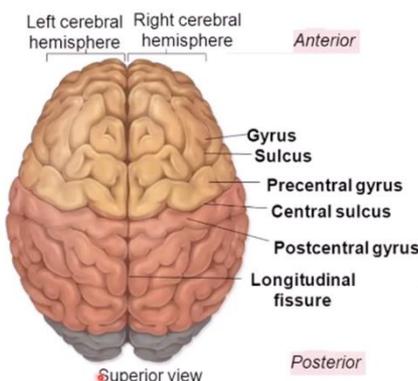
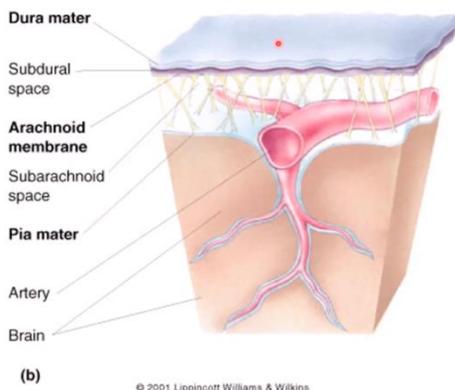


Figure 11-5 & 6. (A) Schematic illustration of a coronal section of the brain. Enlargement of the top. (B) Schematic illustration of dural folds. In: Waxman SG. Clinical Neuroanatomy, 30th ed. <http://www.accessguyton.com>. Accessed October 20, 2009.

## The Dura Mater



## Spinal Cord



Cervical, thoracic, lumbar, sacral

**Dura mater, arachnoid membrane, pia mater**, CSF in subarachnoid space

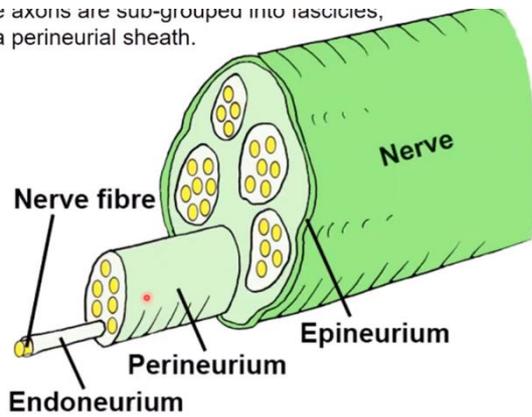
Cervical and lumbar enlargements (innervation to upper and lower limbs)

**Conus medullaris (L2)** end of spinal cord, **Cauda equina** (single nerves), **filum terminale** (pia mater)

Lumbar puncture – collect CSF from L3/L4

**Nerve** = collection of axons (sensory or motor) – **epineurium**, fascicles surrounded by **perineurium**, individual neuron surrounded by **endoneurium**

Nerve axons are sub-grouped into fascicles, by a perineurial sheath.



**Ramus** = branch of mixed spinal nerve (dorsal and ventral)

**Plexus** = Swapping of axons between adjacent spinal nerves to create peripheral nerves (evolutionary e.g. phrenic nerve for diaphragm part of cervical plexus – contributions C3,4,5)

**Spinal nerves** – from spinal cord (31 pairs vs 30 vertebral bones = extra in cervical (7 bones vs 8 nerves))

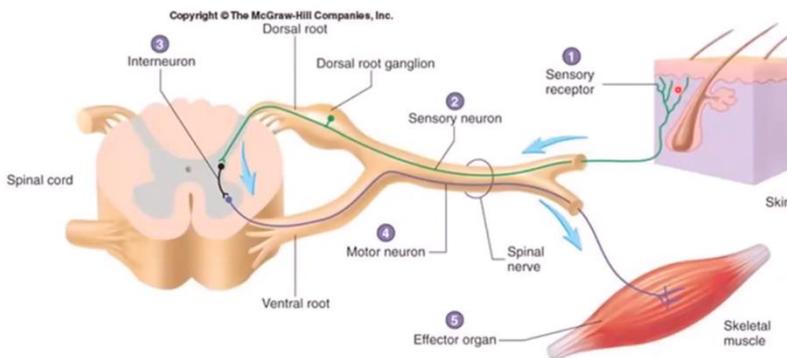
**Cranial nerves** – from brain stem or cerebrum (optic + olfactory) – 12 nerves

**Sensory neuron** cell body in dorsal root ganglia

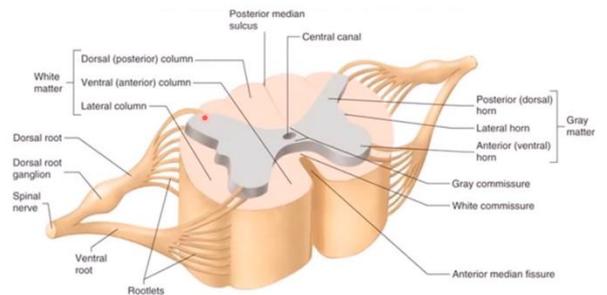
**Motor neuron** cell body in ventral horn of spinal cord

## Spinal cord – Typical spinal segment

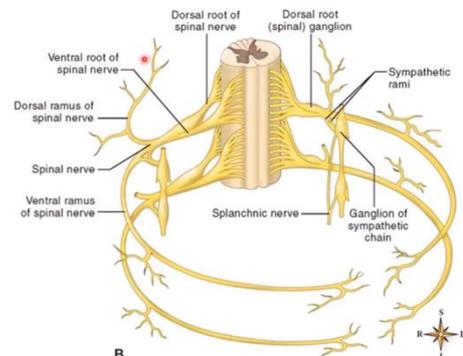
### Spinal reflexes



## Spinal cord – Typical spinal segment



## Ventral (anterior) and dorsal (posterior) rami



A **dermatome** is an area of skin that is mainly supplied by a single spinal nerve - sensory component

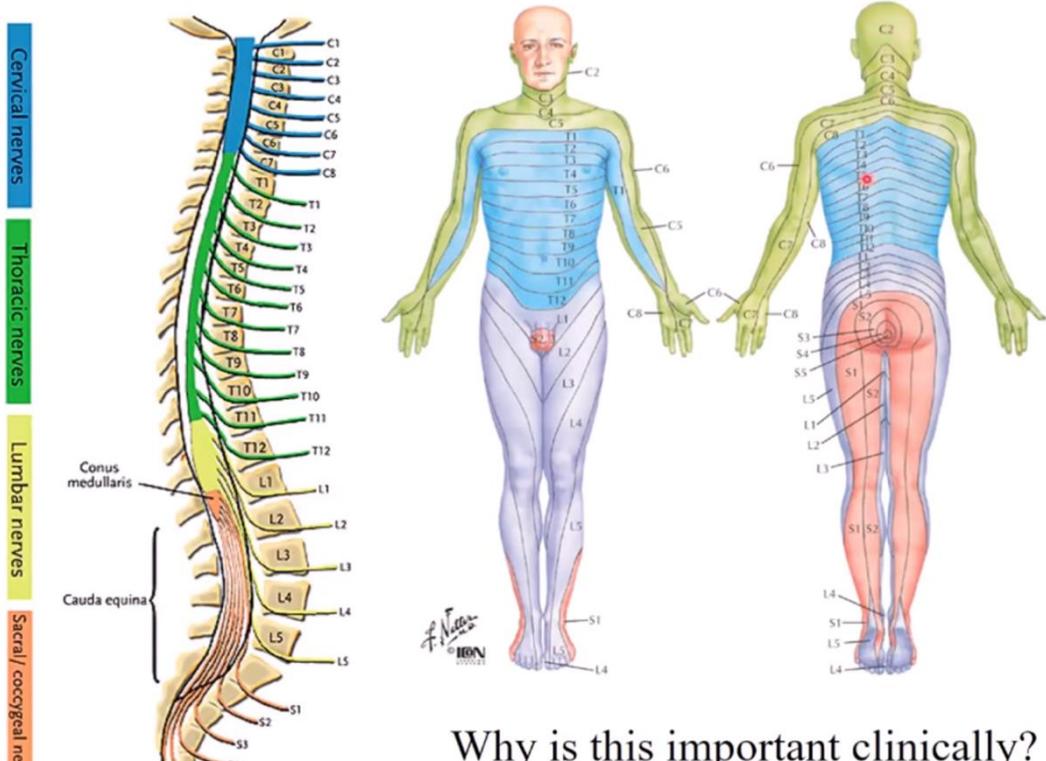
A **myotome** is the group of muscles that a single spinal nerve innervates - motor component

Dermatome of spinal nerves starts at C2 (lower jaw and back of head) – no C1 dermatome

**31 pairs of spinal nerves:**

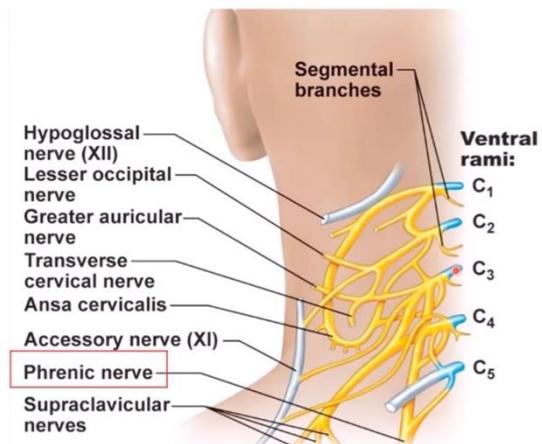
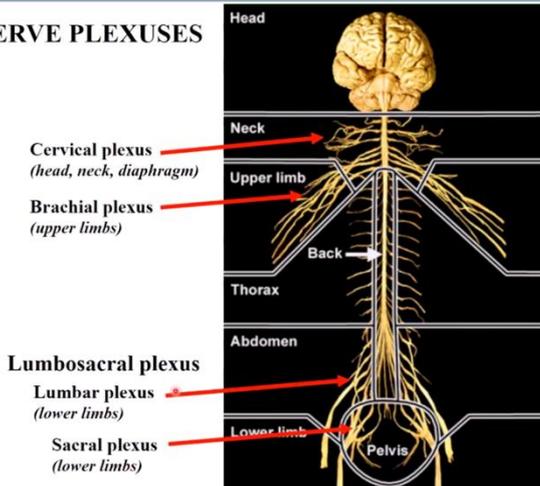
- 8 pairs of cervical nerves (C1-C8)
- 12 pairs of thoracic nerves (T1 – T12)
- 5 pairs of lumbar nerves (L1-L5)
- 5 pairs of sacral nerves (S1-S5)
- 1 pair of coccygeal nerves (Co1)

- C1 nerve above C1 bone
- C8 nerve below C7 bone
- After named for bone above e.g. T1 nerve below T1 bone



Why is this important clinically?  
**Cervical Plexus**

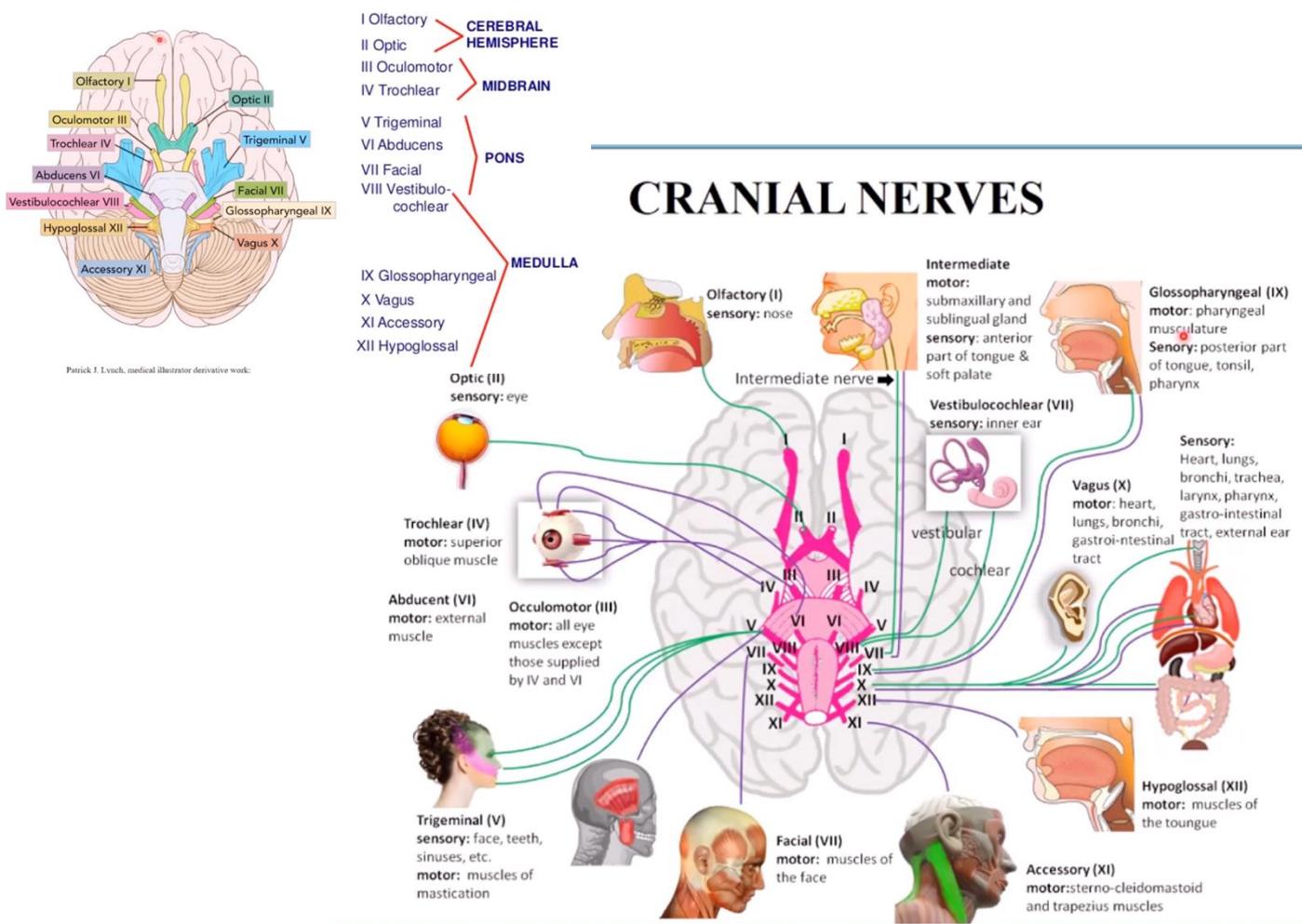
**NERVE PLEXUSES**



## Cranial Nerves

- I - **Olfactory** - primary sensory nerve needed for smell (projects into nose)
- II - **Optic** - primary sensory nerve needed for vision (innervates retina)
- III - **Oculomotor** - nerve that moves the eye
- IV - **Trochlear** - nerve that moves the eye
- V - **Trigeminal** - major sensory nerve that provides sensory innervation to the face - cranial nerve dermatome for face
- VI - **Abducens** - nerve that moves the eye
- VII - **Facial** - controls muscles of facial expression
- VIII - **Vestibulocochlear** - nerve that goes to inner ear, important for balance and hearing
- IX - **Glossopharyngeal** - Nerve that provides sensory innervation to the tongue (taste) and to the pharynx
- X - **Vagus** - Major parasympathetic nerve in the body - innervates all of our internal organs like the heart and lungs, parts of intestinal system - autonomic control of these structures
- XI - **Accessory** - Innervates things in the neck (neck movements, shoulder rotations)
- XII - **Hypoglossal** - nerve that allows you to move your tongue

## CRANIAL NERVES



## Motor Neuron Circuits (SNS, ANS)

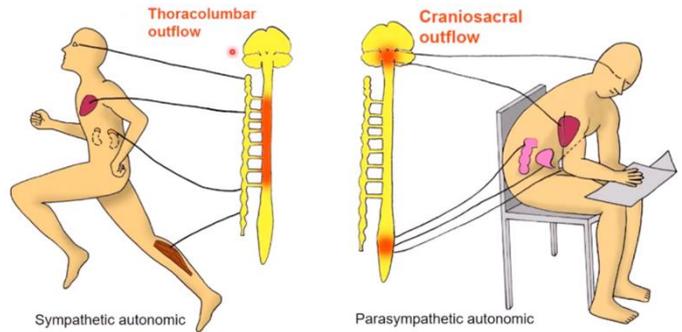
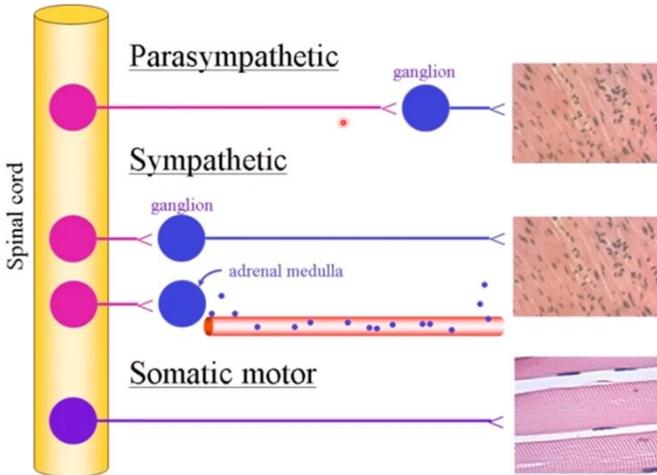
Parasympathetic and Sympathetic have pre and post ganglionic neuron

Preganglionic neuron soma in **lateral horn** of spinal cord

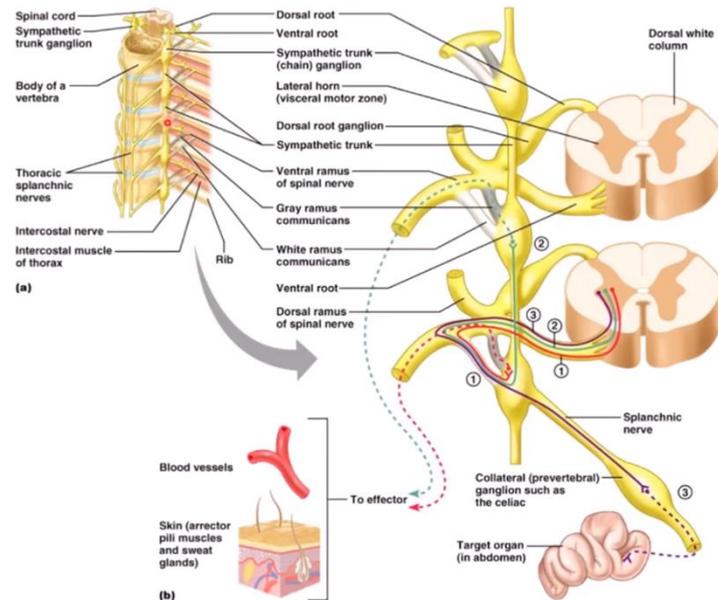
**Sympathetic** = short, long -> enter sympathetic ganglia via **white ramus**, leave via **grey ramus**

**Parasympathetic** = long, short – ganglia close to target tissue

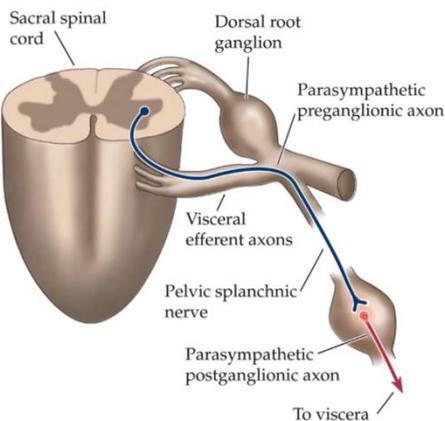
Sympathetic = **thoracolumbar** outflow, parasympathetic = **craniosacral** outflow



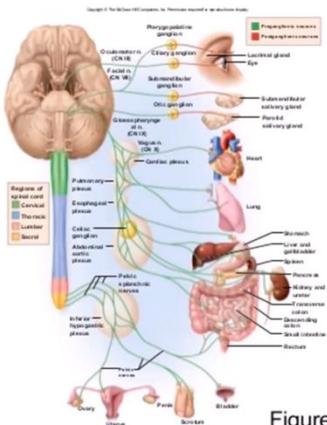
## Sympathetic Trunks and Pathways



## PARASYMPATHETIC SACRAL NERVE



## Parasympathetic Cranial Nerves



- **Oculomotor nerve (III)**
  - narrows pupil and focuses lens
- **Facial nerve (VII)**
  - tear, nasal and salivary glands
- **Glossopharyngeal nerve (IX)**
  - parotid salivary gland
- **Vagus nerve (X)**
  - viscera as far as proximal half of colon
  - cardiac, pulmonary, and esophageal plexus

Figure 15.7

## Anatomy

### Anatomical Principles

**Anatomical position** – palms forward, look straight ahead

**Flexion** = decreasing angle between bones

**Extension** = increasing angle between bones

**Abduction** = moving away from midline

**Adduction** = moving towards midline

**Internal/medial rotation** = rotation towards midline

**External/lateral rotation** = rotation away from midline

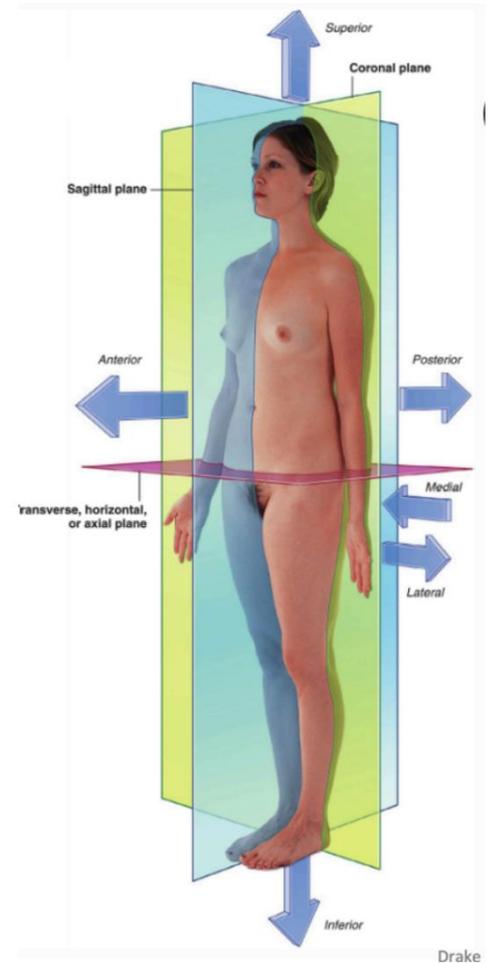
**Elevation** = movement superior

**Depression** = movement inferior

**Protrusion** = movement anteriorly

**Retrusion** = movement posteriorly

**Protraction** = anterolateral movement of scapula



Drake

**Movement of the heel in and the toes out is knee external rotation, movement of the heel out and the toes in is knee internal rotation**

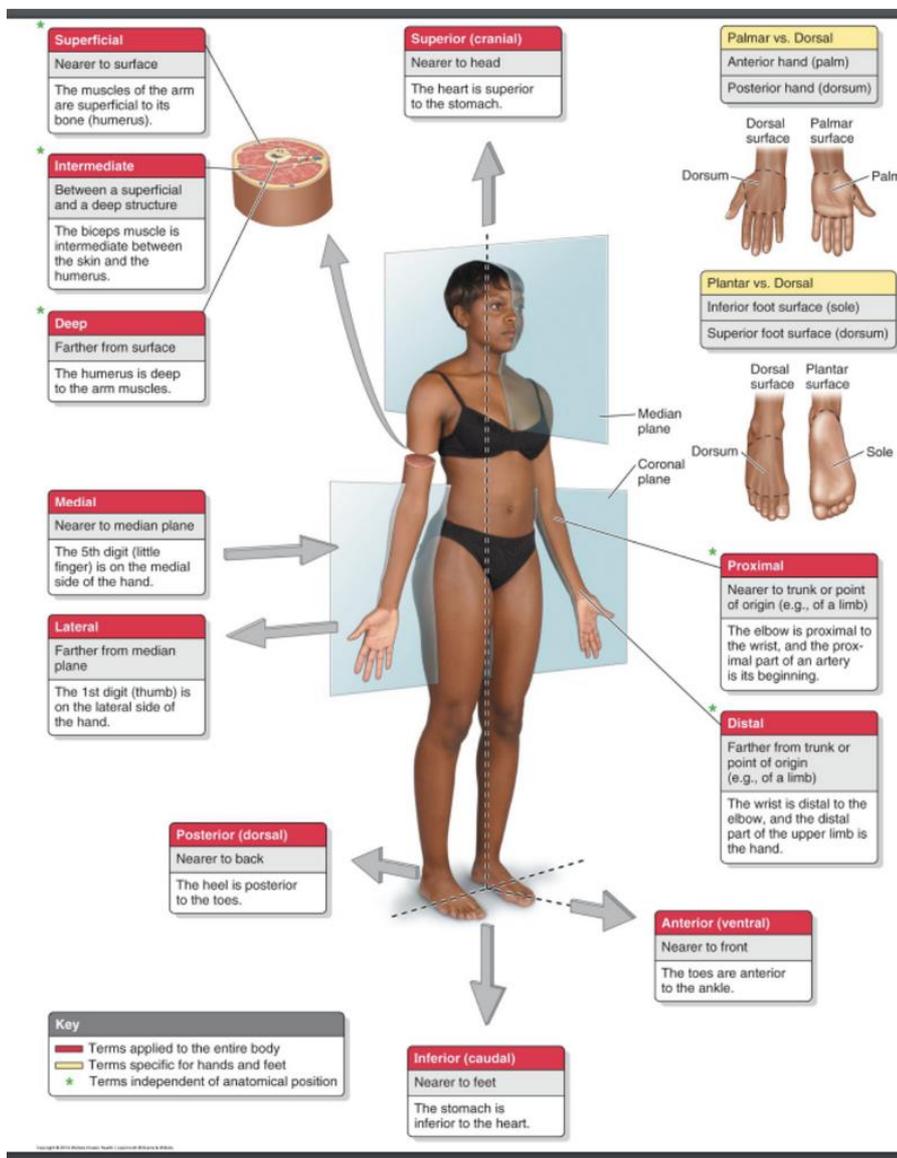
**Retraction** = posterolateral movement of scapula

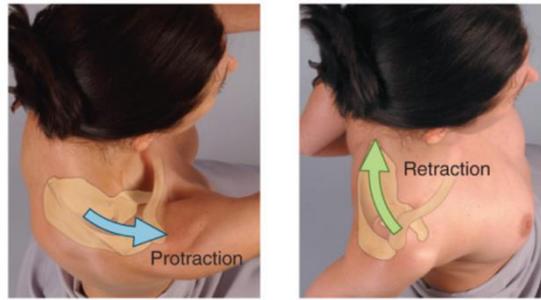
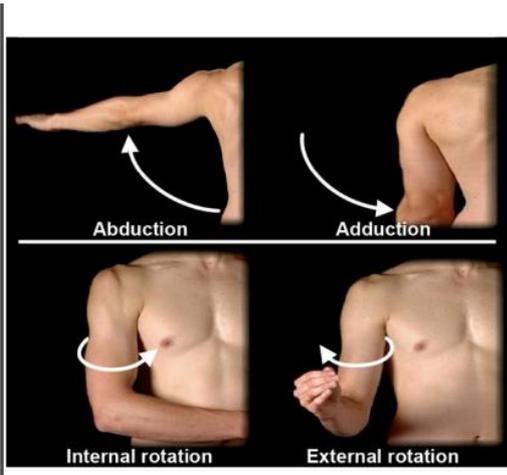
**Supination** = radius uncrosses ulna, move palms facing up

**Pronation** = radius crosses ulna, move palms facing down

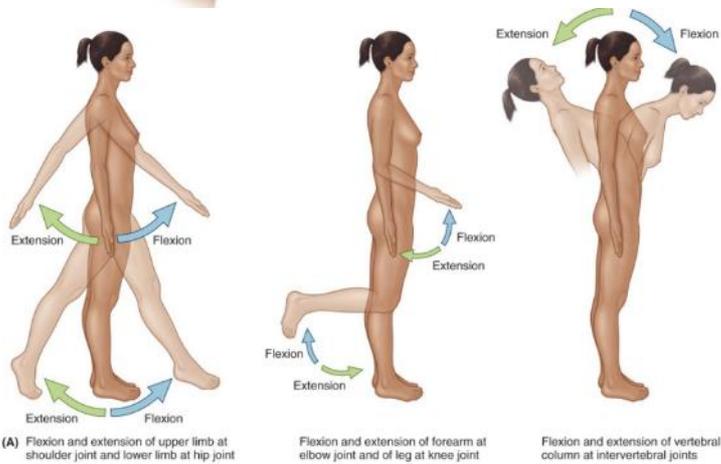
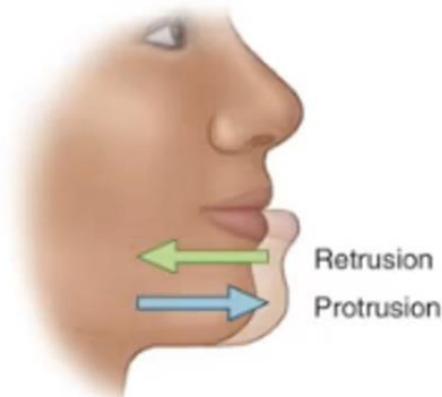
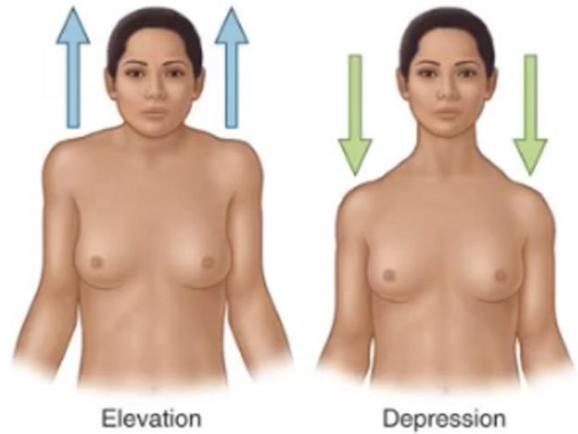
**Dorsiflexion and Plantarflexion** of foot

**Inversion** (away from arch) and **Eversion** (towards arch) of foot





(M) Protraction and retraction of scapula on thoracic wall



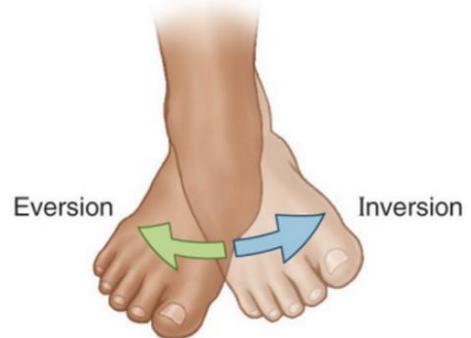
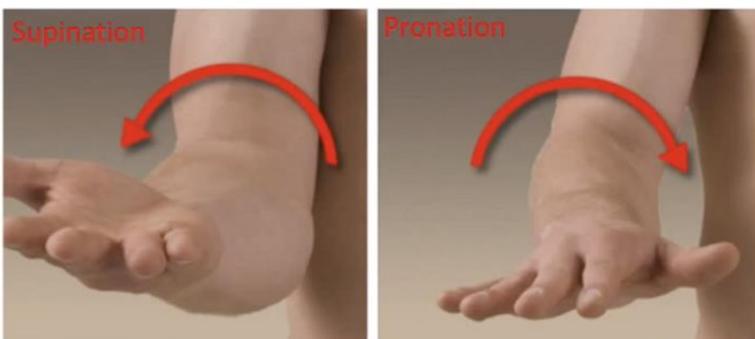
(A) Flexion and extension of upper limb at shoulder joint and lower limb at hip joint

Flexion and extension of forearm at elbow joint and of leg at knee joint

Flexion and extension of vertebral column at intervertebral joints



Dorsiflexion and plantarflexion of foot at ankle joint

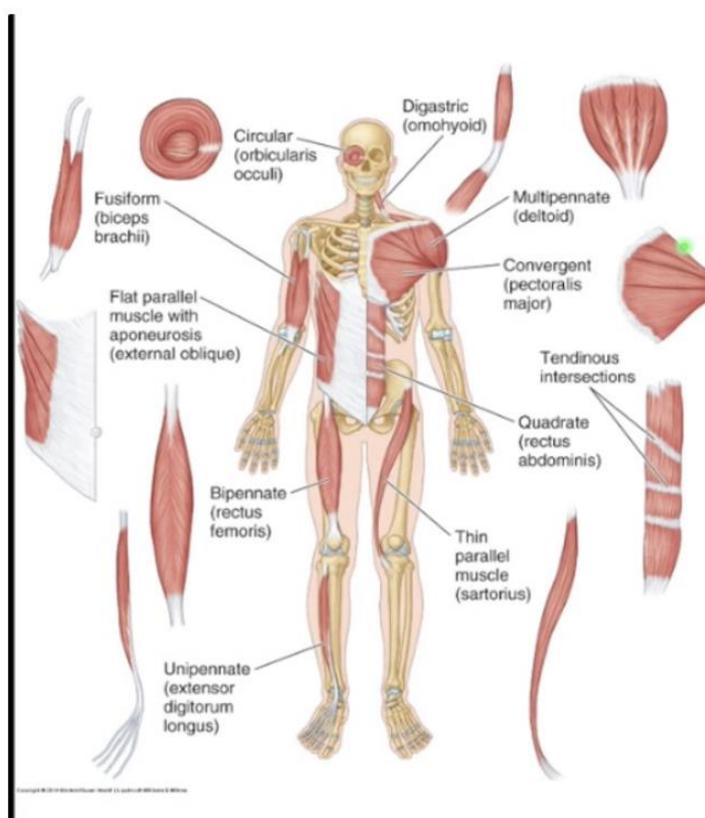
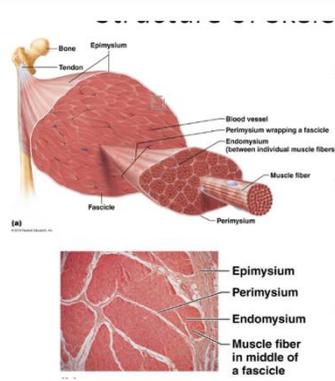
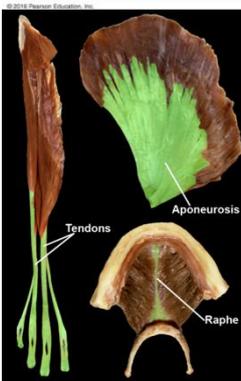


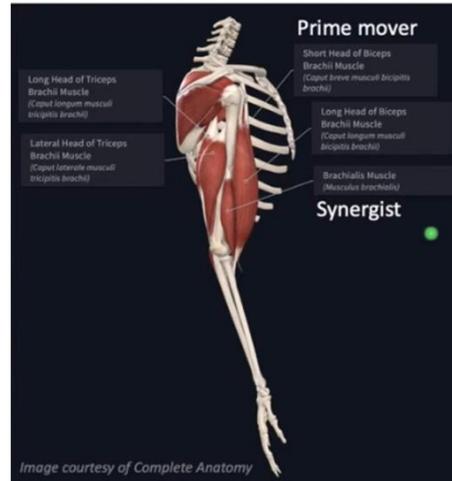
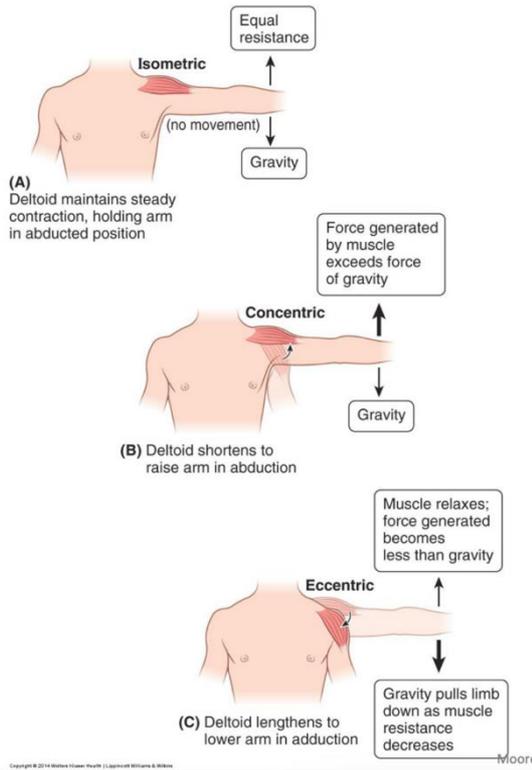
(I) Inversion and eversion of foot at subtalar and transverse tarsal joints

## Muscles:

- Functions – posture, movement, thermogenesis, stabilise joints
- Contractility, Elasticity, Extensibility, Electrical excitability
- **Smooth** (unstriated), **Cardiac** (striated, branched), **Skeletal** (multinucleated, striated)
- Muscle surrounded by **epimysium**, fascicles surrounded by **perimysium**, muscle fibres surrounded by **endomysium**
- Muscle only contracts in direction of its fascicles – parallel, circular, pennate, convergent
- Greater power = greater cross-sectional area
- **Origin** (proximal attachment to immovable bone) + **Insertion** (distal attachment to moveable bone)
- **Ligaments** = join bone to bone (**collagen fibres**)
- **Tendon** = join muscle to bone
- **Aponeurosis** = broad flat membrane which joins muscle to bone
- **Raphe** = Line of fibrous tissue joining 2 muscles
- **Retinaculum** = deep fascia that holds down tendons to prevent bowstringing
- **Isometric** (contracting without changing length), **Miometric/Concentric** = shortening, **Pliometric/Eccentric** = lengthening
- **Prime mover** (agonist) e.g. biceps brachii, **Synergist** (adds force to contraction e.g. brachialis (limits unnecessary movement), **Fixator** stabilises proximal end of limb through isometric contraction e.g. rotator cuff muscles, **Antagonist** (opposes movement through relaxation) e.g. triceps brachii
- **Fascia** = superficial to epimysium, deep to skin
- **Superficial fascia contains lymphatic vessels, veins and lymph nodes (looks like fatty tissue)**
- **Deep fascia** made of collagen fibres (inelastic, no expansion) e.g. **intermuscular septa** separates muscle compartments, **retinaculum** holds down tendons

CHARACTERISTIC	SKELETAL	CARDIAC	SMOOTH
Body location	Attached to bones or (some facial muscles) to skin	Walls of the heart	Unitary muscle in walls of hollow visceral organs (other than the heart); multi unit muscle in intrinsic eye muscles, airways, large arteries
Cell shape and appearance	Single, very long, cylindrical, multinucleate cells with obvious striations	Branching chains of cells; uni- or binucleate; striations	Single, fusiform, uninucleate; no striations

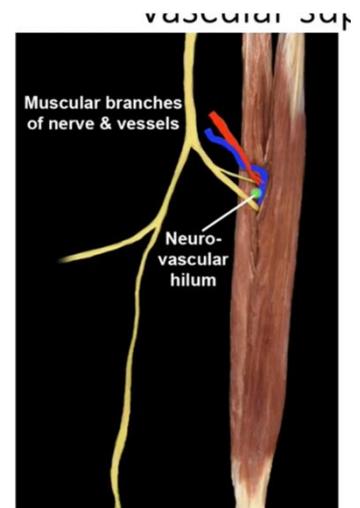




1. If a muscle is crossing on the **anterior** side of a joint, it is usually producing **flexion**
2. If a muscle is crossing on the **posterior** side of a joint, it is usually producing **extension**
3. If a muscle crosses on the **lateral** side of a joint it produces **abduction** (movement away from the midline)
4. If a muscle crosses on the **medial** side of a joint it produces **adduction** (moving towards the midline)

## More handy naming conventions:

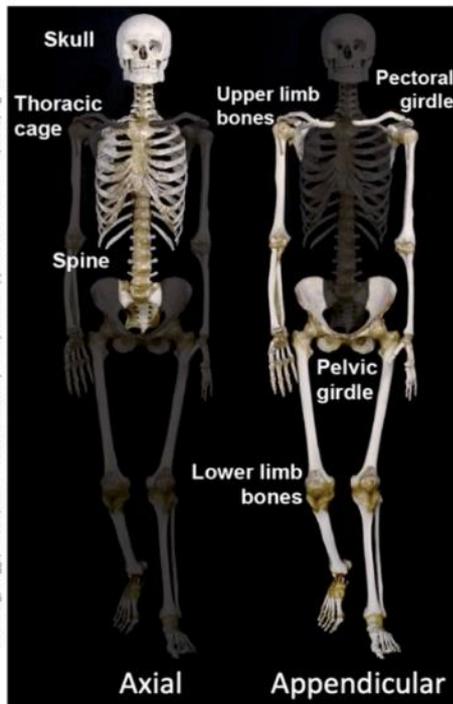
- **Brevis** – short
- **Longus** – long
- **Superficialis** - superficial
- **Flexor** – results in flexion
- **Extensor** – results in extension
- **Carpi** – related to the bones of the wrist (carpal bones)
- **Digit** – related to the bones of the digits (phalanges)
- **Pollicis/hallucis** – related to the thumb/great toe
- **Indicis** – related to the index finger
- **Ulnar/Radial/Fibular** – associated with the ulna/radius/fibula
- Breaking down names provides crucial information (ie. **Extensor carpi radialis longus**)
  - **Extensor carpi** – extends the carpals/hand
  - **radialis longus** – is a long muscle that runs alongside the radius (lateral forearm)



- One nerve, one artery and one or more veins per muscle – enter/exit near centre/belly in **neurovascular hilum**
- Every skeletal muscle fibre has a nerve ending

## Skeletal System and Bones

**Functions** – Protection, Support, movement, mineral homeostasis, blood cell production (red bone marrow in spongy bone), triglyceride storage (yellow bone marrow in medullary cavity of long bones)  
**Divisions** = **axial + appendicular**



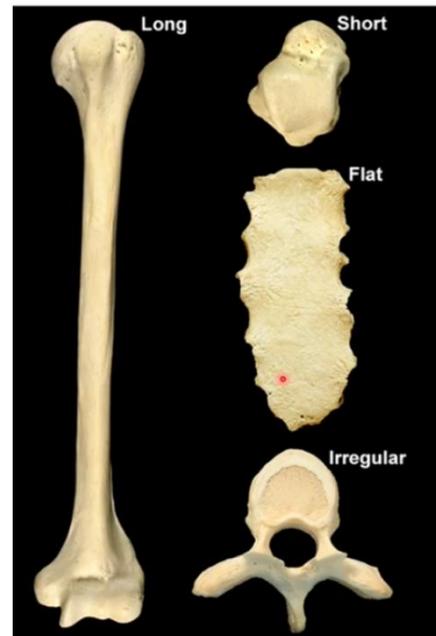
Bones are made of 45% organic components (collagen + water), 55% inorganic hydroxyapatites (mineral salts – calcium phosphate, calcium carbonate)  
 Ions such as  $Mg^{2+}$ ,  $F^-$ ,  $K^+$  and  $SO_4^{2-}$  deposited in the collagen fibre framework in the extracellular matrix → they then harden and crystallise in a process called calcification

**Spongy/Cortical bone** – interior of bone, lamellae arranged into regular columns called trabeculae aligned with compressive and tensile stress lines (force transfer)

**Compact/Trabecular bone** – surrounding spongy bone, dense, osteons (concentric lamellae arranged around central haversian canal parallel to diaphysis)

### Bone Shapes:

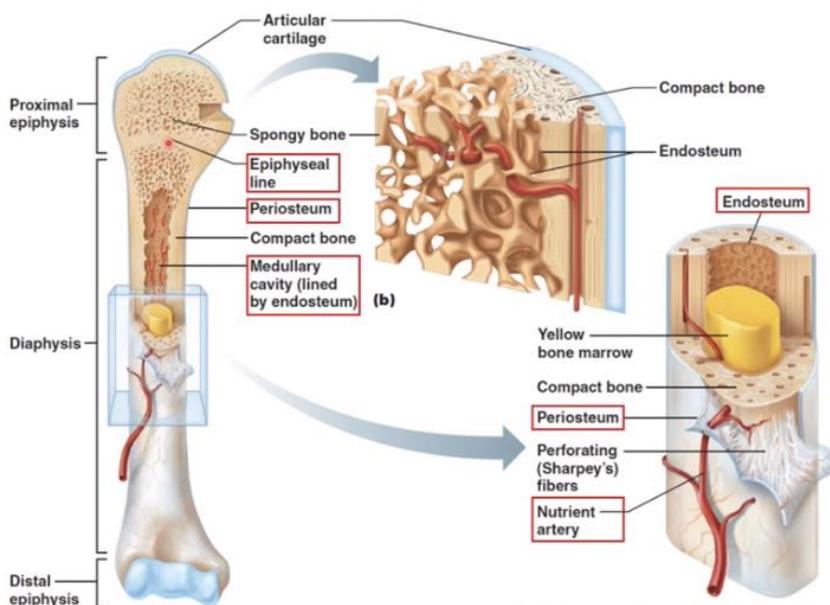
Sesamoid bones relieve tension within muscles and tendons – short bones



### Anatomy of a Long Bone

Metaphysis contains epiphyseal growth plate

## Gross anatomy of a long bone



Marieb & Hoehn. Human Anatomy and physiology 10<sup>th</sup> ed. Pearson 201

## Blood Supply of Bone

- **Nutrient arteries** - long bones have one or more, which typically pass through the long bone at the diaphysis in a space called the nutrient foramen
- The ends of long bones are supplied by **epiphyseal** and **metaphyseal arteries**
- The periosteum is supplied by a **periosteal artery**
- Nerves accompany blood vessels
- Vasomotor nerves within bones (not sensory)
- Sensory innervation in periosteum – breaking bone pain

## Cell Types

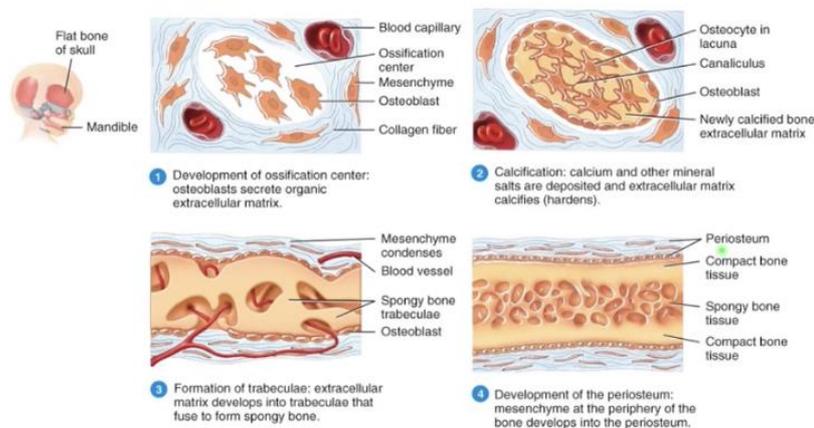
- **Osteoblasts** – build new bone - Synthesise and secrete collagen fibres, organic components to build extracellular matrix of bone, Initiate calcification - where mineral salts and ions are deposited in the collagen fibre network of the ECM
- **Osteoclasts** – break bone ECM down - Releases lysosomal enzymes + acids to digest protein and mineral components of ECM

## Intramembranous Ossification

Mesenchyme -> Bone

1. Ossification centre forms, mesenchyme cells differentiate into osteoblasts
2. Osteoblasts secrete bone ECM
3. Calcium and mineral salts deposited, ECM calcifies
4. Trabeculae form to create spongy bone + fuse around blood vessels
5. Mesenchyme at the periphery of the bone condenses and develops into the periosteum. Eventually a thin layer of compact bone replaces the surface layers of spongy bone

## Steps of intramembranous ossification



- Flat bones of skull, facial bones, mandible, parts of clavicle, hardening of fontanelles

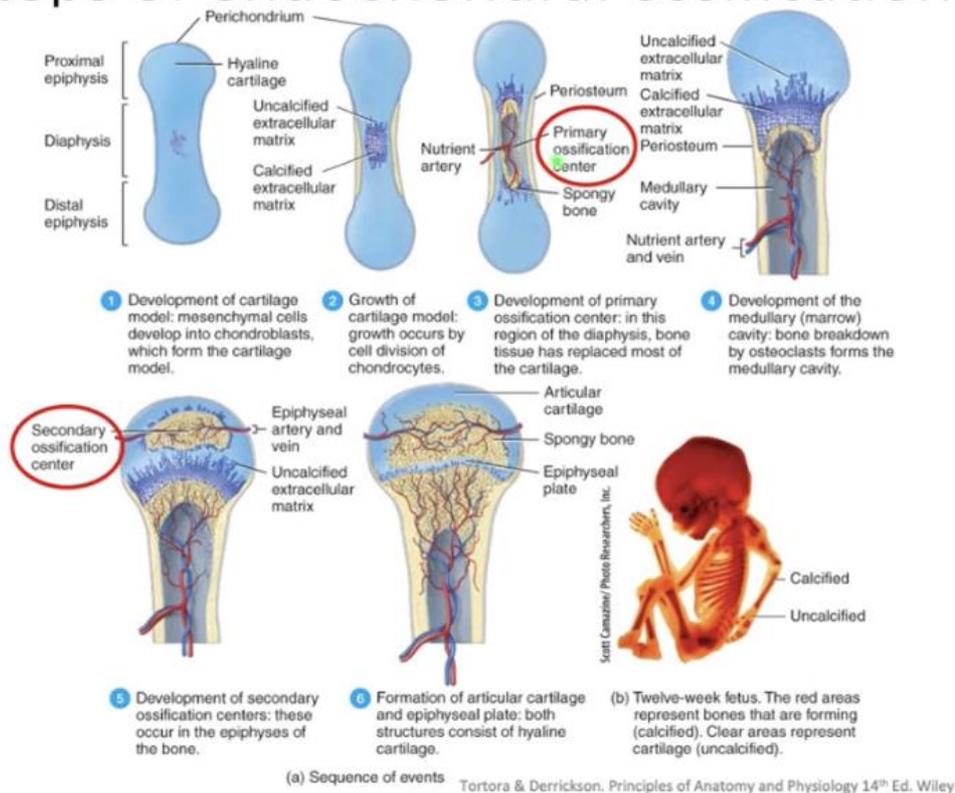
Tortora & Derrickson. Principles of Anatomy and Physiology 14<sup>th</sup> Ed. Wiley 2014. Fig 6.5

## Endochondral Ossification

1. Cells of mesenchyme condense and differentiate into chondroblasts
2. Chondroblasts secrete ECM that forms cartilage model (hyaline cartilage)
3. Cartilage hypertrophies and calcifies in midregion of bone
4. Periosteal capillaries glow into calcified cartilage to supply its interior
5. Blood supply triggers primary ossification centre (bone tissue replaces cartilage)
6. Primary ossification centre grows towards the end of the bone, osteoclasts break down bone to form medullary cavity

7. Branches of periosteal artery enter still-forming bone of proximal and distal epiphyses and triggers development of secondary ossification centre at the ends of the long bones
8. Same as primary ossification centre, except spongy bone in centre is not broken down by osteoclasts (no medullary cavity)

## Steps of endochondral ossification



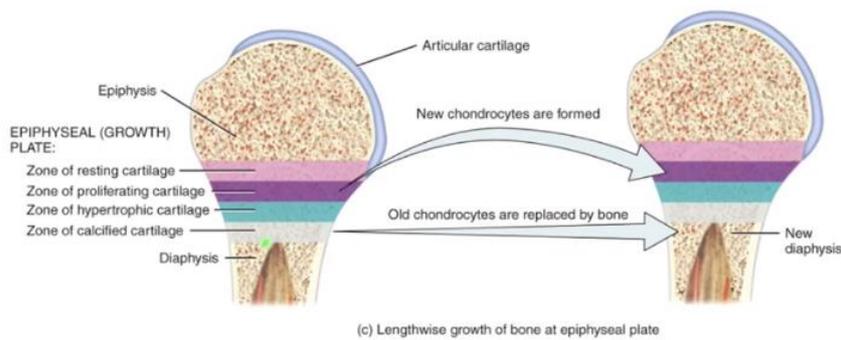
### Bone Growth

- Occurs in 2 directions until around 25 yrs – **longitudinal and appositional**
- Only in diameter after 25 yrs

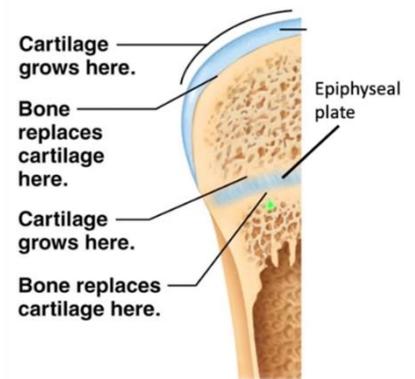
### **Longitudinal:**

- Occurs at epiphyseal plate
  - Epiphyseal plate closes at around 18yo in F and 21yo in M, leaves bony epiphyseal line
1. Interstitial growth of cartilage on the epiphyseal side of the epiphyseal plate – chondrocytes proliferate on epiphyseal side
  2. Replacement of cartilage on the diaphyseal side with bone via endochondral ossification – dead chondrocytes in zone of calcified cartilage (osteoclasts dissolve calcified cartilage, osteoblasts replace calcified cartilage with bone ECM through endochondral ossification)

## Structure of the epiphyseal plate



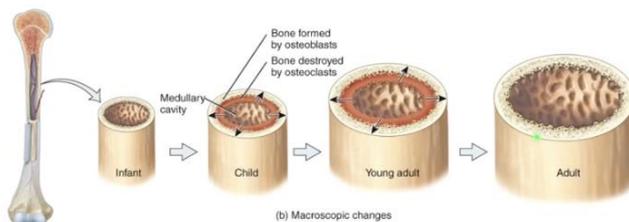
## Bone growth



### Appositional:

1. Periosteum cells differentiate into osteoblasts – lay down new bone ECM to extend diameter of bone
2. Osteoclasts in centre of bone break down bone to increase diameter of medullary cavity

## Appositional bone growth



### Bone Remodelling

- Every week we recycle 5-7% of our bone mass
- Spongy bone is replaced every 3-4 yrs
- Compact bone is replaced every ~10 yrs
- Bone remodeling is the combination of **bone deposit (by osteoblasts)** and **bone resorption (by osteoclasts)**
- Loss of bone mass faster and earlier in females due to menopause (stop making oestrogen which stimulates osteoblasts and slows osteoclasts)
- For individuals who have estrogen as their main sex hormone, the demineralisation usually begins after the age of 30 and is greatly accelerated at around 45 years as levels of endogenous estrogen decrease - Once bone mass decreases, around 8% of bone mass is lost around each 10 years

- For people who produce testosterone as the main sex hormone, demineralisation doesn't typically begin until after the age of 60 → bone loss is comparably more gradually (3% loss every 10 years)

### Factors affecting remodelling:

#### 1. Vitamins and minerals

- Calcium hardens bone extracellular matrix
- Vit D (calcitriol) increases calcium absorption from foods
- Vitamin A stimulates activity of osteoblasts
- Vitamin C for synthesis of collagen (ECM that surrounds bone)
- Vitamin K and B12 for synthesis of bone proteins

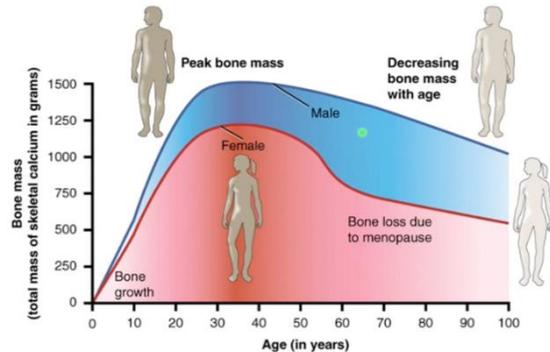
#### 2. Exercise

- Weight-bearing activities stimulate osteoblasts → squats, lunges, running

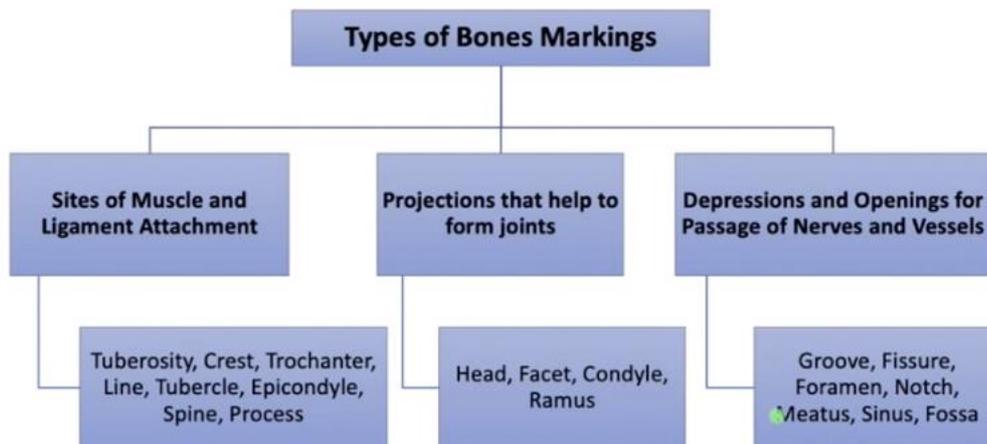
#### 3. Hormones

- At puberty (bone growth) + during adulthood (bone remodelling) → Estrogen and testosterone stimulate bone deposition by osteoblasts, slows bone resorption by osteoclasts
- During childhood hormones most important for bone growth are insulin-like growth hormones (IGFs)

### Effects of Ageing



- Demineralization begins earlier in females due to reduced estrogen



## Articular System and Joints

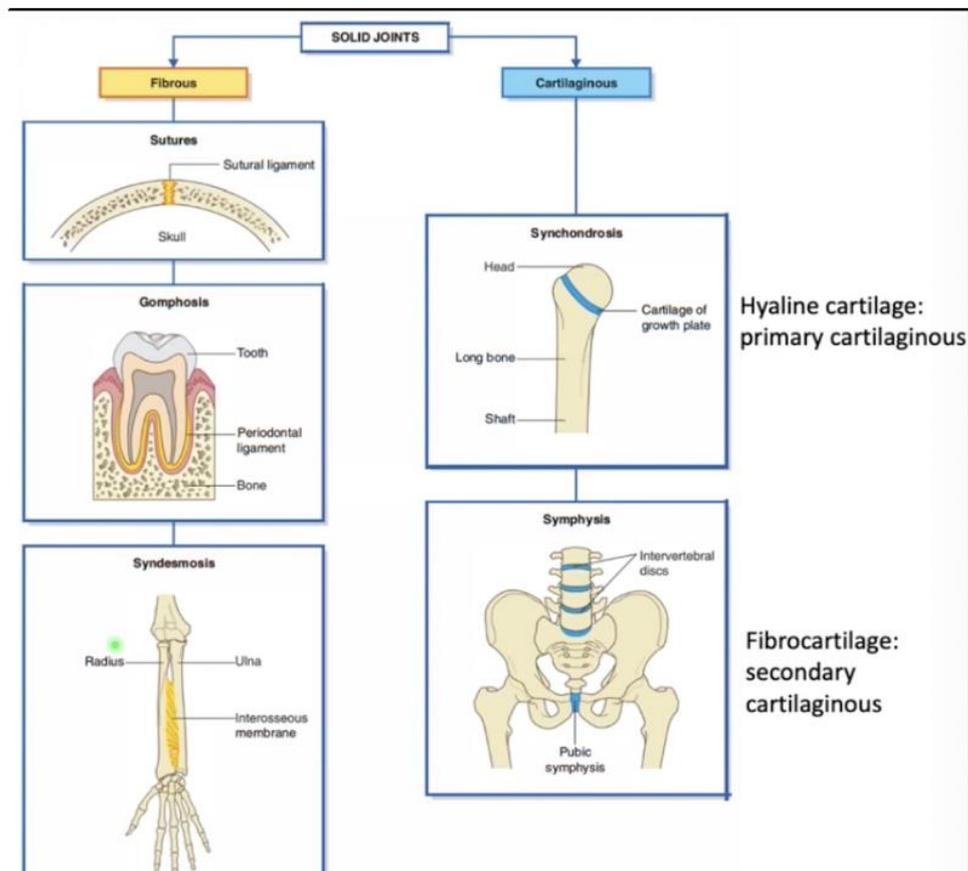
Cartilage has no blood supply – hard to repair damage (substances for repair must diffuse)

**Types of Cartilage** – hyaline (moderate collagen), fibrocartilage (mix of fibrous tissue + hyaline cartilage, most collagen fibres, strongest cartilage), elastic (elastic fibres)

**Fibrocartilage** – intervertebral disc, meniscus, labrum, pubic symphysis

**Types of joints** – Synovial (movement), cartilaginous (minimal movement), fibrous (minimal movement)

- **Cartilaginous joints** (bones united by cartilage) – **primary synchondrosis** (hyaline) e.g. epiphyseal plate, first sternocostal joint. **Secondary symphysis** (fibrocartilage) e.g. intervertebral disc, pubic symphysis
- Fibrous joints (bones united by fibrous tissue) – **gomphosis** (periodontal ligament), **suture** (skull bones), **syndesmosis** (interosseous membrane between radius and ulna, distal tibiofibular syndesmosis)

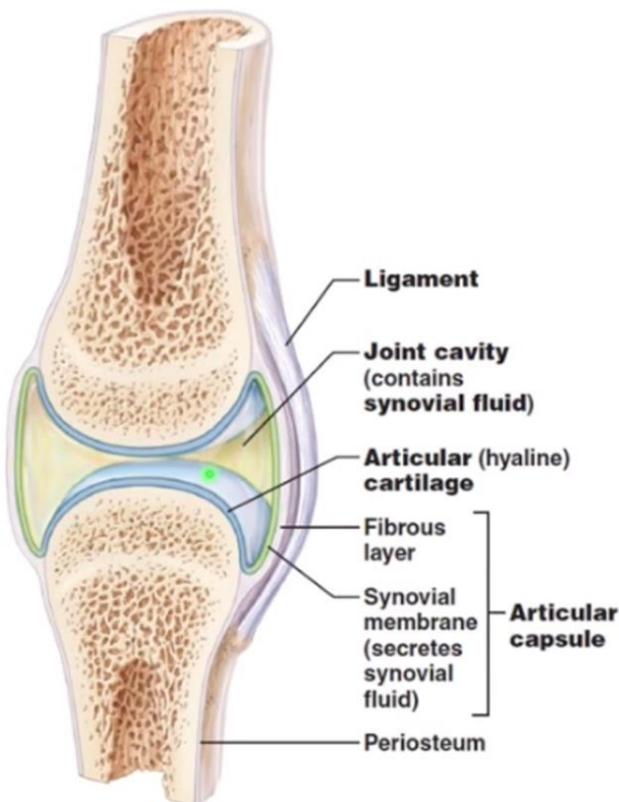


**Synovial**

**Joints:**

**Synovial membrane** has a lot of elastic fibres – secretes synovial fluid

**Fibrous capsule** has a lot of collagen fibres (high tensile strength)



Factors Contributing to Stability of Synovial Joints

- Congruency of articulating surfaces e.g. hip vs shoulder
- Ligamentous and muscle support
- Accessory structures e.g. labrum, articular disc, meniscus

Accessory Structures

1. **Menisci** – fibrocartilage, shock absorber + increases congruency between tibial plateau and condyles of femur (2 per knee)
2. **Articular Discs** – fibrocartilage – divide synovial cavity into 2 separate chambers (different movement in each chamber) - Articular discs are found in the jaw/temperomandibular joint → opening and closing of jaw, jutting jaw forward and back (2 separate movements in same joint space)
3. **Articular Labra** – fibrocartilage, Increase contact area between bones, deepens the socket e.g. glenoid labrum, acetabular labrum

4. **Fat Pads** – accumulation of adipose tissue, Fat pads usually sit between the synovial and fibrous joint capsules and provide a cushioning for the moving joints e.g. behind patella in knee joints

Types of Synovial Joints:

1. **Plane** – allows sliding e.g. acromioclavicular, intercarpal, intertarsal, sacroiliac, zygapophyseal, proximal tibiofibular
2. **Pivot** – allows rotation e.g. proximal and distal radioulnar, atlantoaxial
3. **Hinge** – allows flexion + extension e.g. humeroulnar, interphalangeal, talocrural note: knee is a modified hinge (allows rotation)
4. **Condyloid/Condylar** – 2 axes allows flexion, extension, abduction, adduction (less) e.g. metacarpophalangeal (knuckle), radiocarpal (wrist)
5. **Saddle** – 2 axes allows flexion, extension, abduction, adduction e.g. 1<sup>st</sup> carpometacarpal (thumb), sternoclavicular
6. **Ball and Socket** – 3 axes allows flexion, extension, abduction, adduction, rotation and circumduction e.g. glenohumeral (shoulder), hip

The anatomical types of synovial joints, with joint models and examples

Types of Synovial Joints	Models of Joint Motion	Examples
<b>Gliding joint</b> 		<ul style="list-style-type: none"> <li>• Acromioclavicular and sternoclavicular joints</li> <li>• Intercarpal and intertarsal joints</li> <li>• Vertebrocostal joints</li> <li>• Sacro-iliac joints</li> </ul>
<b>Hinge joint</b> 		<ul style="list-style-type: none"> <li>• Elbow joints</li> <li>• Knee joints</li> <li>• Ankle joints</li> <li>• Interphalangeal joints</li> </ul>
<b>Pivot joint</b> 		<ul style="list-style-type: none"> <li>• Atlas/axis</li> <li>• Proximal radio-ulnar joints</li> </ul>
<b>Ellipsoid joint</b> 		<ul style="list-style-type: none"> <li>• Radiocarpal joints</li> <li>• Metacarpophalangeal joints 2-5</li> <li>• Metatarsophalangeal joints</li> </ul>
<b>Saddle joint</b> 		<ul style="list-style-type: none"> <li>• First carpometacarpal joints</li> </ul>
<b>Ball-and-socket joint</b> 		<ul style="list-style-type: none"> <li>• Shoulder joints</li> <li>• Hip joints</li> </ul>

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5. **Bursae and Tendon Sheaths** – extracapsular, flattened fibrous sacs lined with synovial fluid, alleviates friction in joints

**Range of Motion** = the range, measured in degrees of a circle (360°) through which the bones of a joint can be moved

Factors Affecting Joint Mobility:

1. **Structure/shape of articulating bones** – how closely they fit together
2. **Strength and tension of joint ligaments**
3. **Arrangement and tension of muscles** – e.g. flexed hamstring limits flexion of hip
4. **Contact of soft parts**
5. **Hormones** – e.g. relaxin produced by placenta and ovaries near end of pregnancy increases flexibility of pubic symphysis + loosens ligaments between sacrum, hip bones and coccyx (permits expansion of pelvis to assist in childbirth)
6. **Disuse** – decreases synovial fluid, ligament and tendon flexibility, muscle atrophy

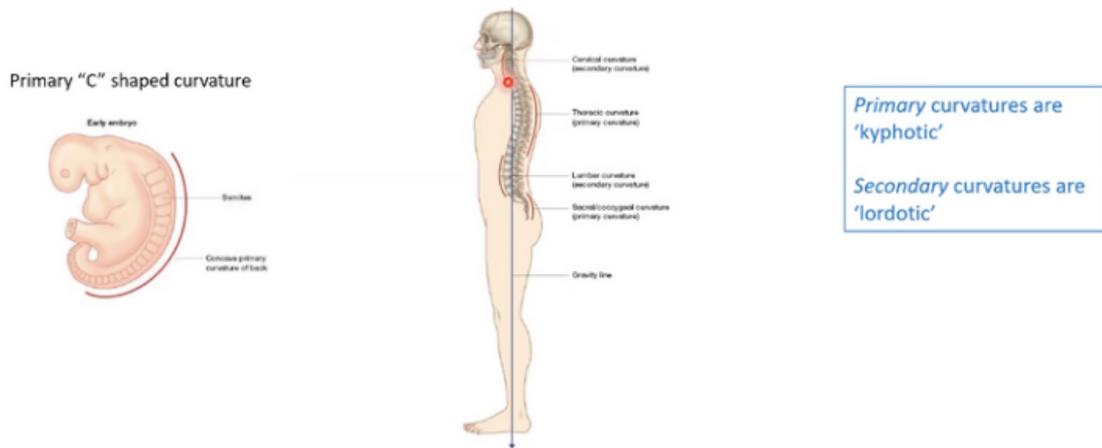
**Vertebral Column and Back**

- Function – protect spinal cord, movement, structure (muscle attachment)
- Axial skeleton
- Cervical (7), Thoracic (12), Lumbar (5), Sacral (fused 5), Coccyx (3-5) -> increasing size on way down

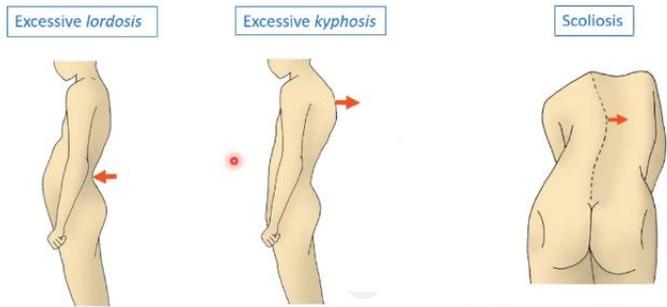
Curvatures:

- **Primary curvatures** = Thoracic, Sacral (**kyphosis**)
- **Secondary curvatures** = Cervical + Lumbar (**lordosis**) – cervical develops first

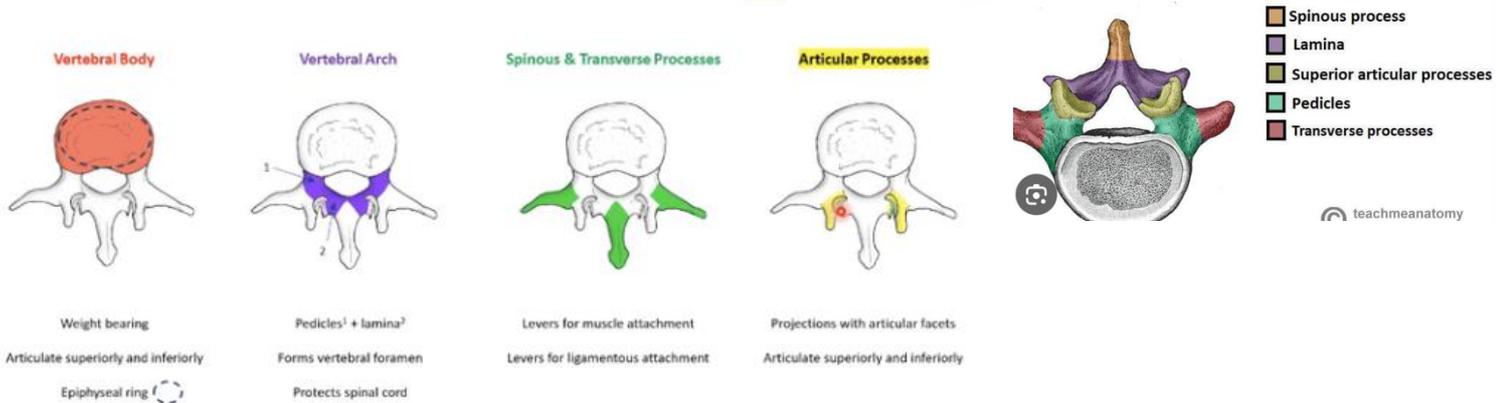
Secondary “lordotic” curves develop in cervical and lumbar regions



- **Excessive kyphosis** = hunchback in thoracic
- **Excessive lordosis** = in lumbar
- **Scoliosis** = off-centre spine



Vertebra Anatomical Landmarks

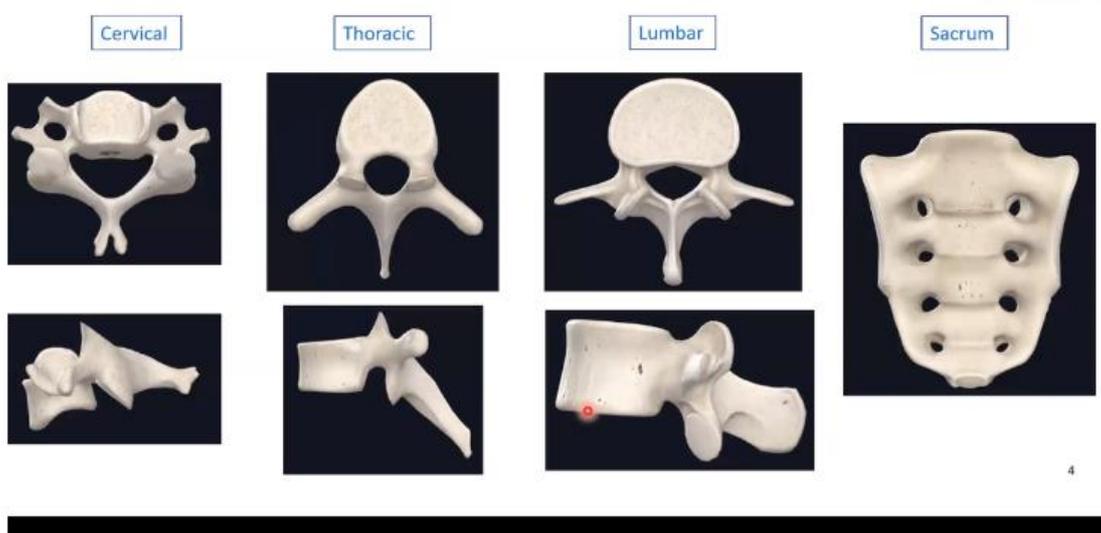


**Cervical** – Transverse foramina, bifid spinous process, smallest vertebral bodies

**Thoracic** – Upside down heart shaped vertebral body, Spinous process of thoracic bone going down (posteriorly and inferiorly) - thoracic region curves in the kyphotic region (furthest point on the back, don't want spinous processes to be sticking out on the back), limited extension, small vertebral foramen (less innervation)

**Lumbar** – Kidney-shaped vertebral body, big and thick spinous process, many transverse processes (for muscle attachment), increase in size

**Sacrum** – fused vertebra

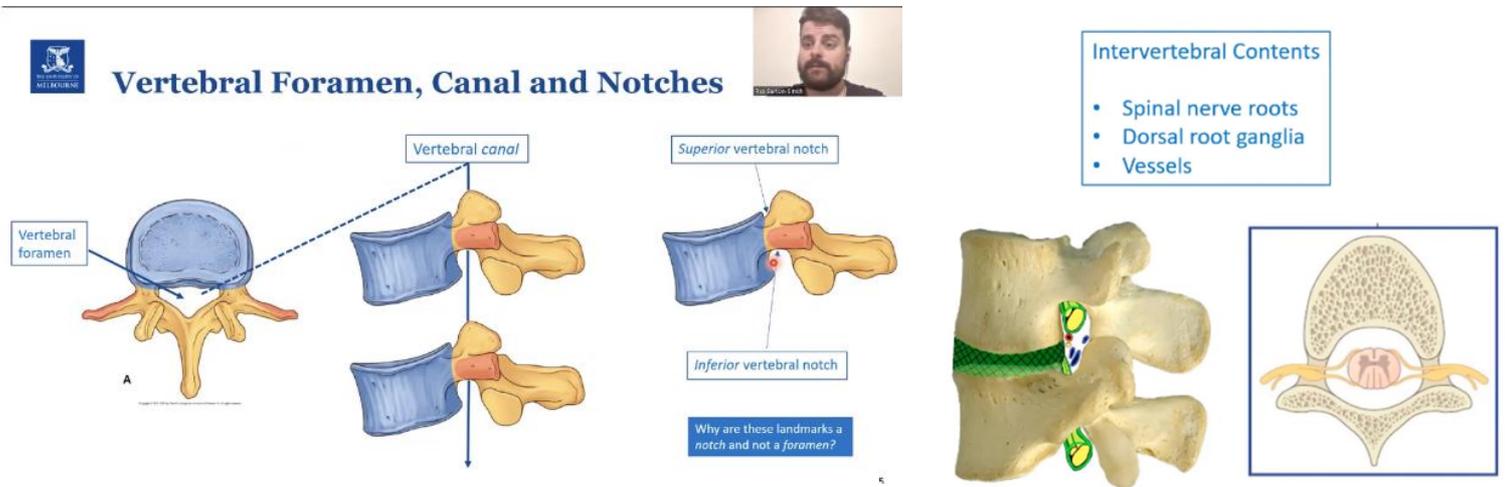


**Vertebral foramen** = hole in middle of vertebra for spinal cord – vertebral body + pedicles+ lamina

**Vertebral Canal** = stack vertebra, spinal cord traverses vertebral canal

**Superior and inferior vertebral notches** – notches used to create intervertebral foramen

**Intervertebral foramen** = hole on side between 2 vertebra – where nerves exit spinal cord - location of spinal nerve roots, dorsal root ganglia, vessels – Inferior notch of superior vertebra + superior notch of inferior vertebra + zygapophyseal joint (articular processes) + intervertebral disc



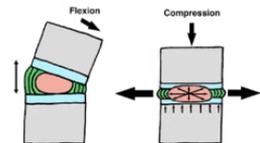
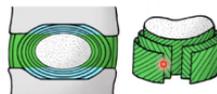
Intervertebral disc:

**Annulus Fibrosis**

- Outer component, attaches to epiphyseal ring of vertebra above and below
- Keeps the vertebra together
- Concentric lamellae of collagen (criss-crossing of fibres in different directions) → allows for flexibility in movement, but also helps resist excessive rotation

**Nucleus Polposus:**

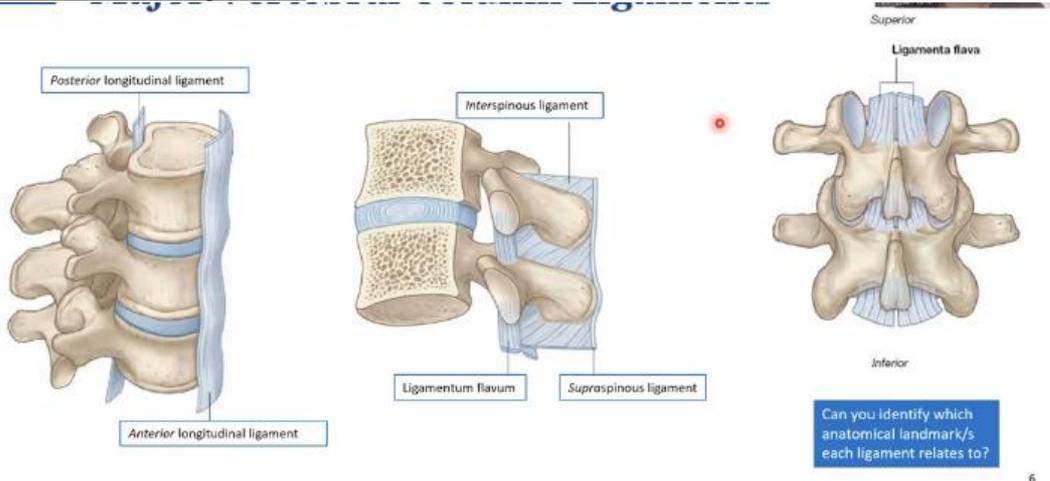
- Gelatinous consistency
- Keeps the vertebra 'apart' → helps resist heavy compression forces to maintain relative distance between vertebra
- Shock absorber -disperses compressive forces
- Deforms but not compressible



**Zygapophyseal Joints** = plane synovial (gliding)

- What plane are the thoracic articular surfaces in?
  - Not true coronal plane, a bit bent
  - Allow rotation and some side bending/lateral flexion, but is restricted by thoracic cage + ribs that are attached
  - If we were to take off our ribs we would have significantly larger amount of motion from these joints
- What plane are the lumbar articular surfaces in?
  - Anterior and posterior
  - Flexion and extension in sagittal plane (bending over)

## Vertebral Column Ligaments



## Extrinsic Back Muscles/Posterior axio-appendicular Muscles

Can move limbs

### 1. Trapezius

- Vertebral column -> spine of scapula, acromion, clavicle
- scapula retraction, scapula elevation + depression, vertebral column extension + lateral flexion, scapula rotation

### 3. Latissimus dorsi

- Vertebral column -> anterior side of humerus (crossed)
- Humerus extension, humerus internal rotation, humerus adduction, trunk lateral flexion, lumbar vertebral column extension

### 4. Levator Scapulae

- Vertebral column -> scapula
- Scapula elevation, Vertebral column lateral flexion and extension

### 5. Rhomboid Major

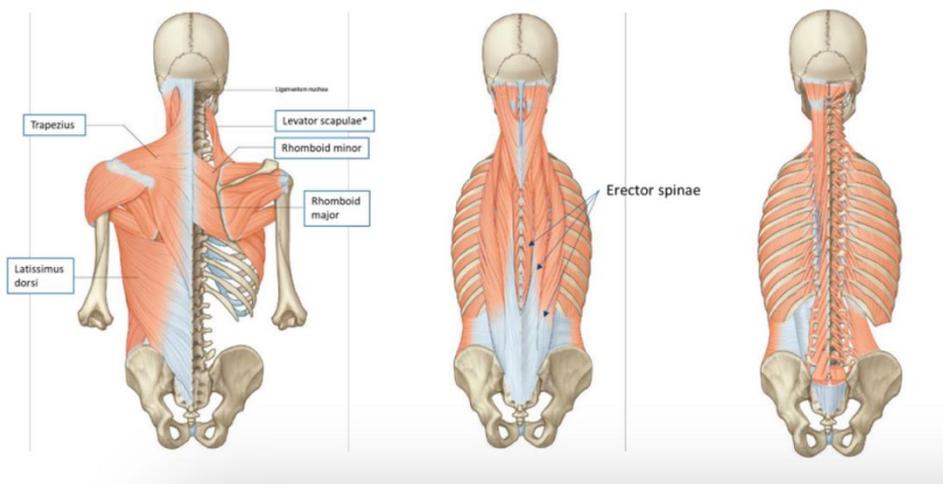
- Vertebral column -> scapula
- Scapula retraction
- Deep to trapezius

### 6. Rhomboid Minor

- Vertebral column -> scapula
- Scapula retraction
- Deep to trapezius



→ Progressively deeper →



## Intrinsic Back Muscles

Move back

### 1. Superficial - Erector Spinae

- Prime movers of back in sagittal plane, trunk extension
- Antagonis (trunk flexion) = rectus abdominus, transversus abdominus

### 3. Deep – Transversospinalis

- Segmental movements – fine movements in vertebral segments

- Multifidus in lumbar spine

## Anatomy - Upper Limb

Appendicular skeleton

**Arm** = shoulder to elbow

**Forearm** = elbow to wrist

**Hand**

**Shoulder girdle** = clavicle + scapula

## Upper Limb Bones and Joints

Clavicle:

- Long bone
- S shape – accommodates brachial plexus
- Sternal and acromial ends
- Smooth superior surface, rough inferior
- **Joints:** sternoclavicular (saddle joint, articular disc, only connection between appendicular and axial skeletons), acromioclavicular (plane)

Scapula:

- Flat bone
- Spine (posterior)
- Acromion + coracoid process -> coracoid more anterior
- Glenoid fossa (where humerus head articulates)

Joints:

### 1. Sternoclavicular

- Only join between axial and appendicular skeletons
- Saddle synovial
- Elevation, depression, protraction, retraction
- Intra-articular disc (increase congruency)
- Costoclavicular ligament
- Strong capsule

### 2. Acromioclavicular

- Plane synovial
- Coracoclavicular ligaments – Trapezoid and conoid (trapezoid more lateral)
- Weak capsule

Humerus:

- Lesser tubercle – can see anterior
- Greater tubercle on side
- Capitulum = lateral condyle
- Trochlea = medial condyle

1

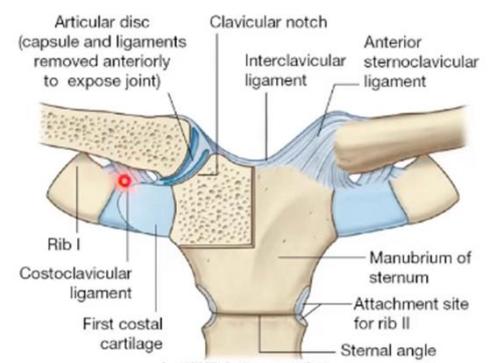


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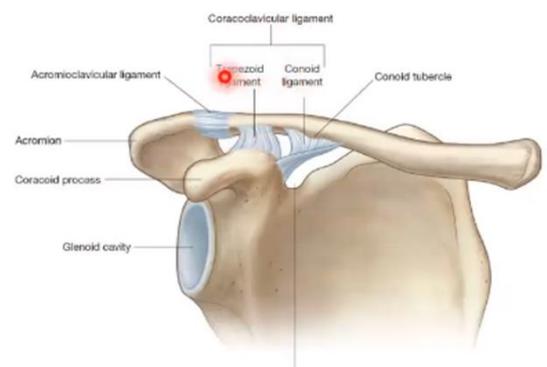
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## Sternoclavicular Joint



Pix: Barton-Smith

## Acromioclavicular Joint



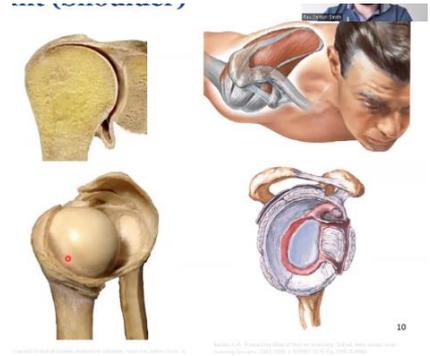
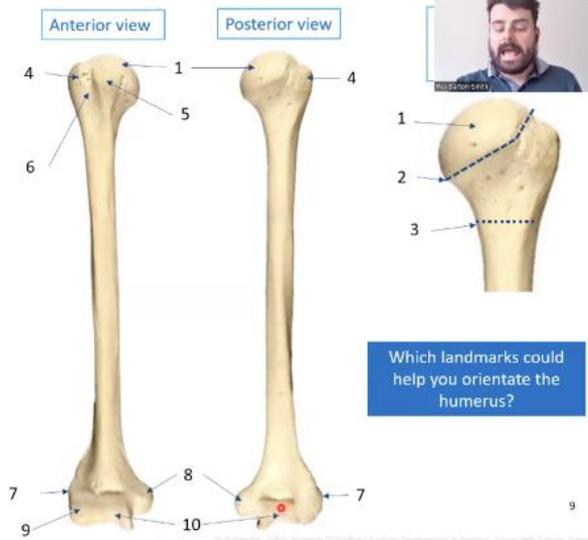


# Humerus

Long bone

### Key Features

- Head<sup>1</sup>
- Neck (anatomical<sup>2</sup> and surgical<sup>3</sup>)
- Tubercles (greater<sup>4</sup> and lesser<sup>5</sup>)
- Bicipital/intertubercular groove<sup>6</sup>
- Epicondyles (lateral<sup>7</sup> and medial<sup>8</sup>)
- Condyles (capitulum<sup>9</sup> and trochlea<sup>10</sup>)



## Glenohumeral Joint/Shoulder Joint

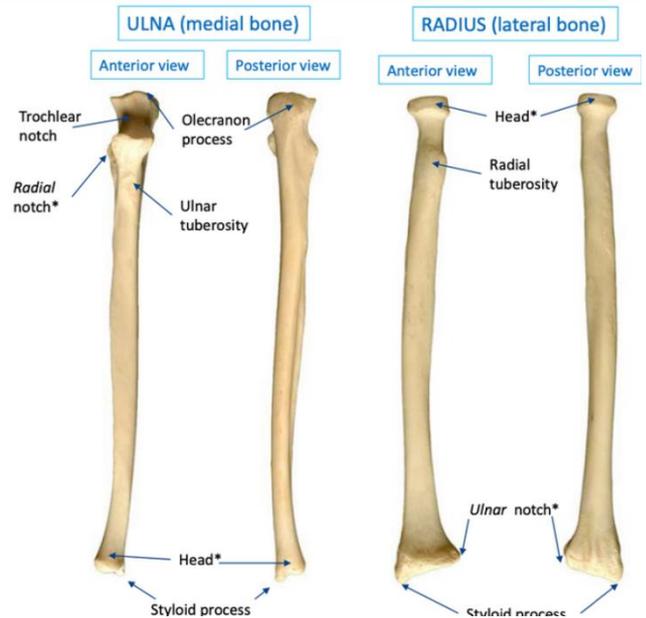
- Relatively incongruent – less than hip
- Glenoid fossa with head of humerus
- Ball and socket – flexion, extension, abduction, adduction, rotation, circumduction
- Unstable -> needs glenoid labrum fibrocartilage, rotator cuff muscles blend into joint capsule, ligaments
- Ligaments – **glenohumeral, coracohumeral**
- Anterior dislocation most common

## Ulna and Radius

RAD (thumbs up) - ulna more medial, radius more lateral and close to thumb

Radius larger distally, ulna larger proximally

- Trochlear notch on ulna
- Olecranon process on ulna
- Syndesmosis (interosseus membrane)
- Styloid processes

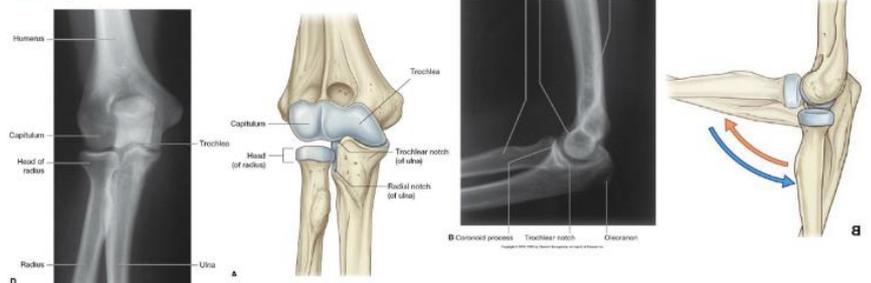


## Elbow Joint

- Hinge synovial joint – flexion + extension
- Shares synovial cavity with proximal radioulnar joint
- Humeroulnar joint (trochlea of humerus – medial, with trochlear notch of ulna)
- Radius contacts humerus when moving into flexion
- Ligaments – **ulnar collateral and radial collateral**



## Elbow Joint



## Proximal and Distal Radioulnar Joints

- Both pivot synovial joints

- Proximal (radial head in radial notch on ulna)
- Distal (ulnar head in ulnar notch on radius)
- Allows supination and **pronation (radius crosses ulna)**
- **Annular ligament** wraps around head of radius

**Proximal & Distal Radioulnar Joints**

Which movement results in the forearm bones 'crossing' each other?

**Pivot joint (synovial)**  
 Radial head  $\leftrightarrow$  Radial notch on the ulna  
 Annular ligament encircles the radial head

**Pivot joint (synovial)**  
 Ulnar head  $\leftrightarrow$  Ulnar notch on the radius

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### Wrist and Hand

- 8 carpal bones, 5 metacarpal bones, 14 phalangeal bones (2 in thumb, 3 in other fingers)
- Thumb is 1<sup>st</sup> digit, pinky is 5<sup>th</sup> digit

**'Bone Groups' of the Wrist and Hand**

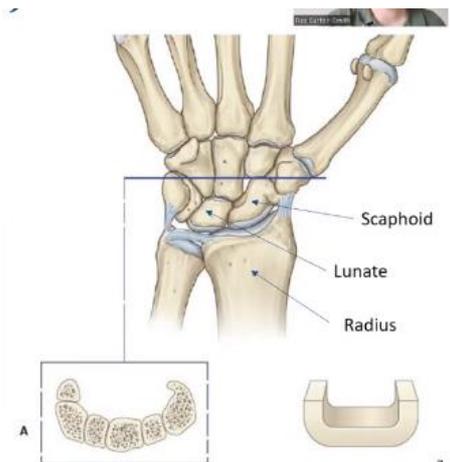
Which bony groups are there? Which are short bones?

**What are sesamoid bones? Where are there other examples in the body?**

7

### Radiocarpal Joint

- Condylod synovial joint – flexion, extension, abduction, adduction
- Radius with carpal bones (scaphoid and lunate) -> scaphoid more lateral, lunate more medial
- Complex ligamentous support
- Articular disc between ulna and carpals
- FOOSH injury risk of bony necrosis (immediate X-ray needed)



### Joints of the Hand

1. **Intercarpal joints** - plane synovial
2. **2<sup>nd</sup> to 5<sup>th</sup> carcometacarpal joints** - plane synovial
3. **1<sup>st</sup> carpometacarpal joint** (thumb) – saddle synovial, most degenerative in body

4. **Proximal and Distal Interphalangeal joints** (except for thumb where there is only 1) – hinge synovial

## Upper Limb Muscles

### Anterolateral Axio-Appendicular Muscles

#### 1. Pectoralis Major

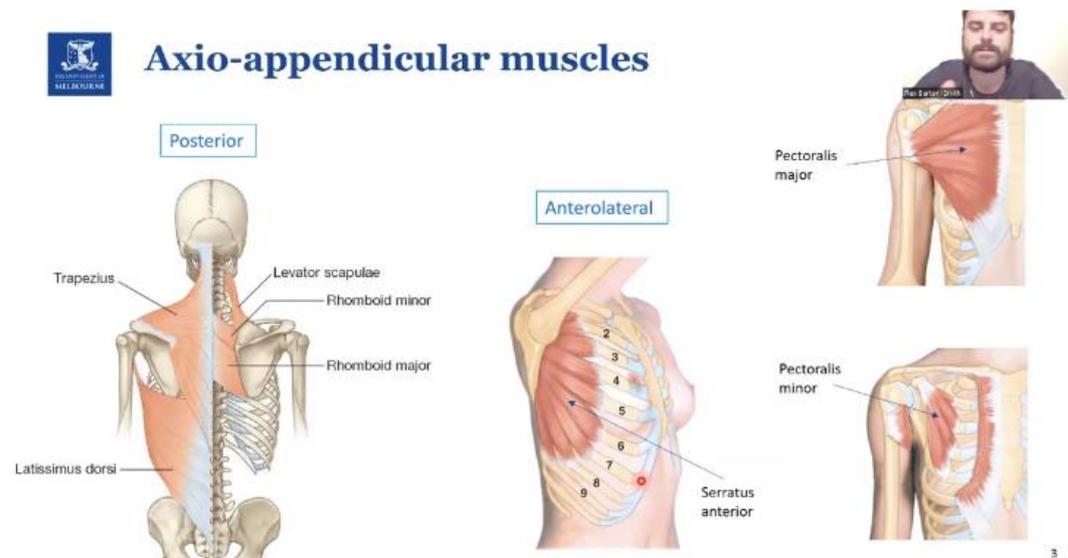
- Sternum + part of clavicle -> greater tubercle of humerus (lateral, can cause internal rotation)
- Internal rotation of humerus, humerus adduction

#### 2. Pectoralis Minor

- Ribs -> coracoid process of scapula
- Protraction (anterolateral) of scapula
- Deep to pectoralis major

#### 3. Serratus Anterior

- Ribs -> medial scapula (anterior -> travels underneath scapula)
- Scapula protraction



### Scapulohumeral Muscles - Rotator Cuff

Blend into glenohumeral joint capsule, compress humeral head into glenoid fossa

### 1. Supraspinatus

- Posterior scapula above spine -> greater tubercle on humerus
- Humerus abduction

### 2. Infraspinatus

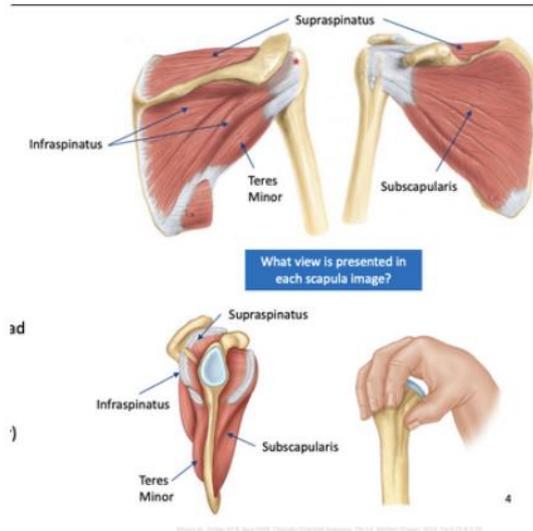
- Posterior scapula below spine -> greater tubercle on humerus
- Humerus external rotation

### 4. Teres minor

- Flat surface on posterior scapula below spine -> greater tubercle on humerus
- Humerus external rotation

### 5. Subscapularis

- Anterior side of scapula -> lesser tubercle of humerus (anterior)
- Humerus internal rotation



### Scapulohumeral Muscles – Non-Rotator Cuff

#### 1. Deltoid

- Spine of scapula, acromion, acromial end of clavicle -> humerus
- Humerus abduction, humerus flexion, humerus extension, humerus internal and external rotation

#### 2. Teres Major

- Posterior scapula -> lesser tubercle of humerus (under armpit to anterior side)
- Inferior to teres minor
- Humerus internal rotation, humerus extension, humerus adduction

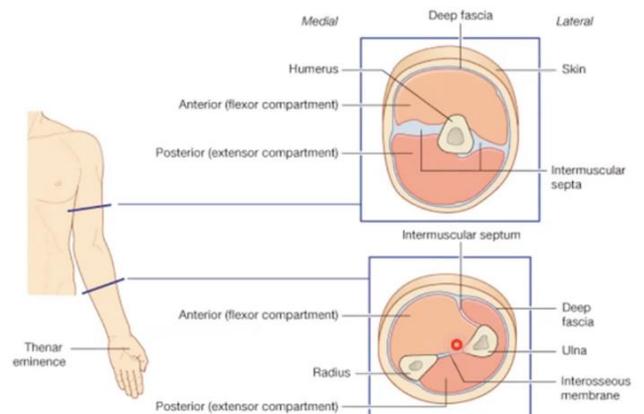


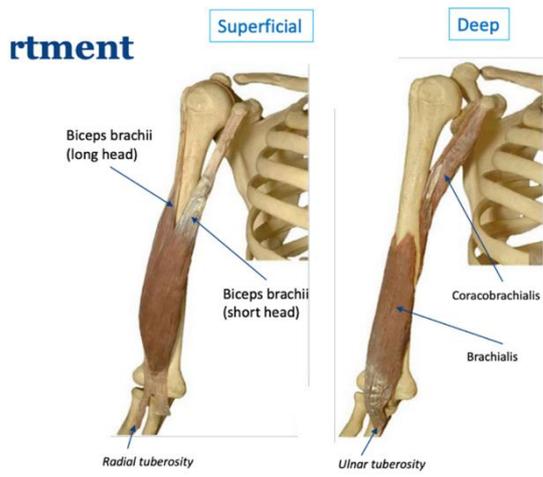
Muscles are separated into compartments largely by intermuscular septa

### Anterior Compartment of Arm

#### 1. Biceps Brachii

- Long head to scapula, short head to coracoid process of scapula -> Radial tuberosity
- Long and short heads (long head more lateral, enters synovial cavity of glenohumeral joint)
- Elbow flexion, supination (attaches to radius, uncrosses radius)
- Prime mover of elbow flexion





## 2. Brachialis

- Humerus -> ulnar tuberosity
- Elbow flexion
- Synergist of elbow flexion

## 3. Coracobrachialis

- Coracoid process -> humerus
- Humerus flexion, humerus adduction

## Posterior Compartment of the Arm

### Triceps Brachii:

#### 1. Long head

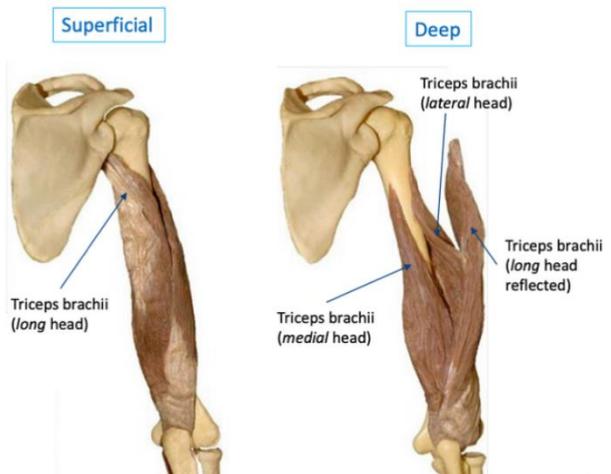
- Scapula -> olecranon of ulna
- Shoulder extension, elbow extension

#### 1. Lateral head

- Humerus -> olecranon of ulna
- Elbow extension

#### 1. Medial head

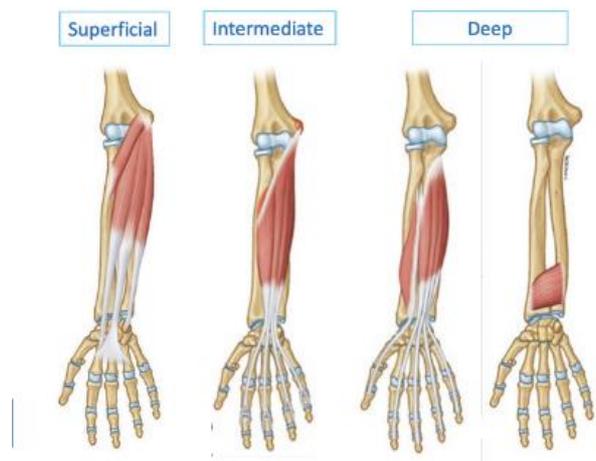
- Humerus -> olecranon of ulna
- Deep to lateral and long heads
- Elbow extension



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## Anterior Compartment of Forearm

- **Superficial** (oblique crossing over radius is a pronator), **intermediate** and **deep** (distal attachment into radius = pronator)
- Superficial and intermediate muscle groups attach to **medial epicondyle of humerus**
- Wrist and finger flexors
- Attaches to carpals/metacarpals = **wrist flexor**
- Attaches to digits = **finger flexor**
- Distal attachment into radius = **pronator**
- Crosses radius (superficial) = **pronator**

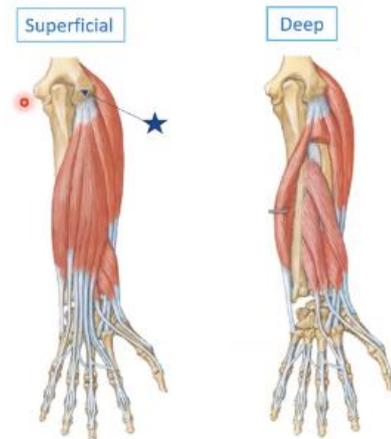


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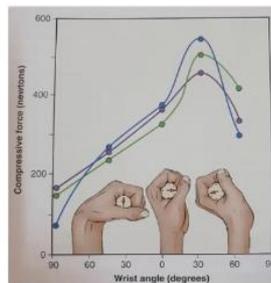
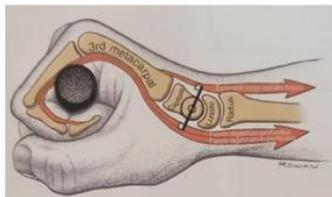
## Posterior Compartment of Forearm

- Superficial and deep muscle groups
- Superficial muscle group attaches to **lateral epicondyle** of humerus
- Wrist and finger extensors
- Attaches to carpals/metacarpals = **wrist extensor**
- Attaches to digits = **finger extensor**

**Optimum grip strength** = slight extension (contraction of wrist extensors) -> allows finger flexors to maintain optimum length to flex digits



Contraction of wrist extensors can allow finger flexors to maintain an optimal length to flex the digits



## Hand Muscles

1. **Thenar** – Thumb e.g, opponens pollicis (oppositional movement of thumb)
2. **Interosseus** – between metacarpal bones, abduction and adduction of fingers
3. **Hypothenar** – Pinky muscles



### Hand Musculature

**Expectations**

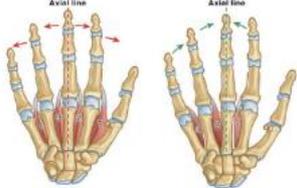
- Identify basic muscle groups and know which region they are located
- Thenar
- Hypothenar
- Interosseous

**Compartments**

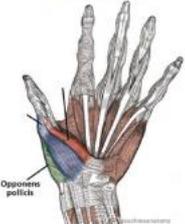
- Hypothenar
- Thenar
- Central
- Adductor
- Interosseous



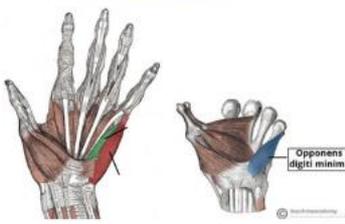
Interosseous



Thenar



Hypothenar



## Upper Limb Nerves

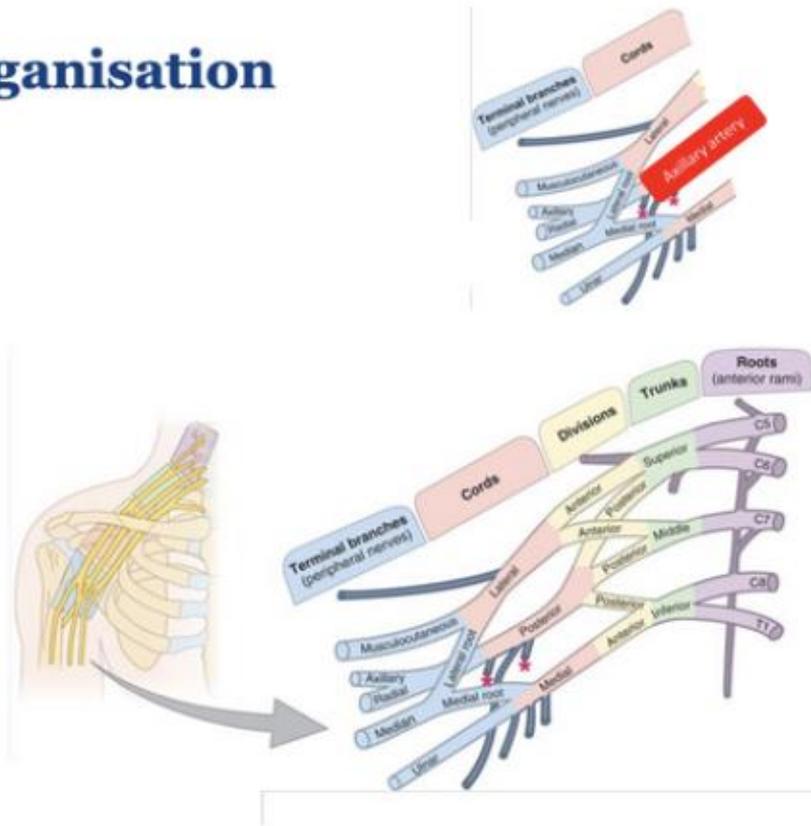
- 5 distinct sections: **Roots, trunks, divisions, cords, and terminal branches**
  - Cords named in reference to anatomical relationship with axillary artery
- All cords from anterior rami
- Roots C5-T1

# Organisation

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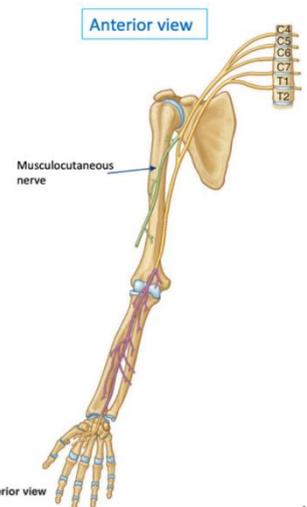


## 1. Musculocutaneous Nerve

- Continuation of the **lateral cord**
- Pierces the coracobrachialis to enter the anterior compartment of the arm
- Supplies **the anterior compartment of the arm**

## 2. Median Nerve

- Receives contributions from **medial and lateral cord**
  - Travels across the midline of the anterior elbow to enter the forearm - passes through cubital fossa
  - **Major supply for the anterior compartment of the forearm**
  - Travels across the midline of the anterior wrist to enter the hand - **travels through carpal tunnel**
  - **Minor supply of hand musculature**



(B) Anterior view

#### 4. Ulnar Nerve

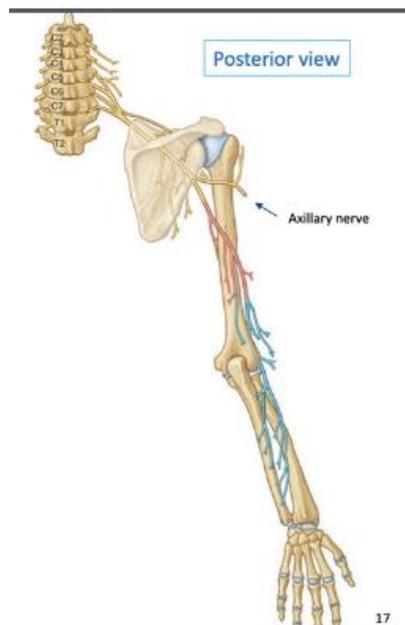
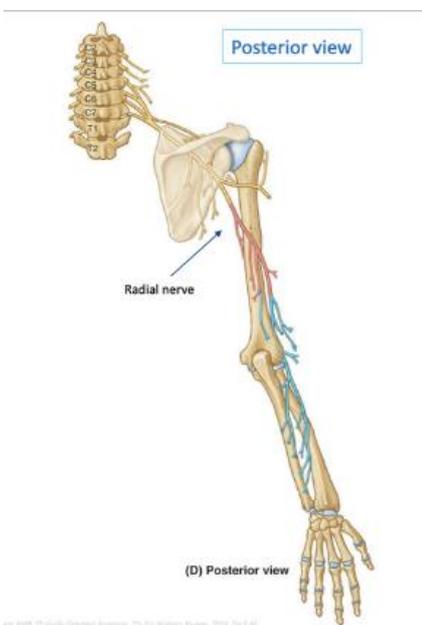
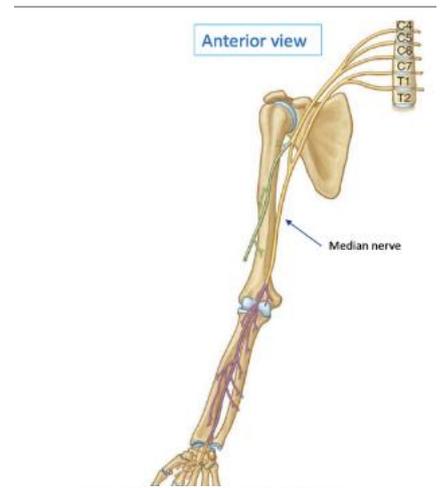
- Continuation of the **medial cord** – more medial than median nerve
- No branching in the arm
- Travels **posterior to the medial epicondyle**
- **Minor supply for the anterior compartment of the forearm**
- **Major supply of hand musculature**
- When you hit your funny bone it is actually a compression of the ulnar nerve against medial epicondyle of humerus

#### 5. Axillary Nerve

- Smaller branch of the **posterior cord**
- Immediately exits out of the axilla (armpit)
- Wraps around humerus posteriorly (around surgical neck) **to supply the deltoid and teres minor**
- Dislocation of shoulder creates significant stretch on nerve

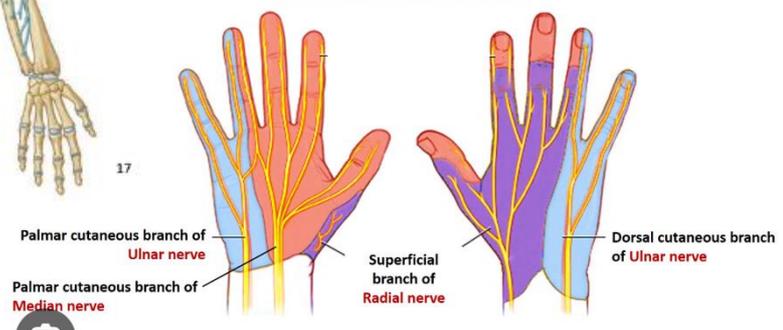
#### 6. Radial Nerve

- Largest branch of the **posterior cord**
- Long posterior journey
- Passes anteriorly for a short distance in the distal arm, over the lateral epicondyle
- Significant supply to the posterior upper limb:
  - **Posterior compartment of the arm**
  - **Posterior compartment of the forearm**



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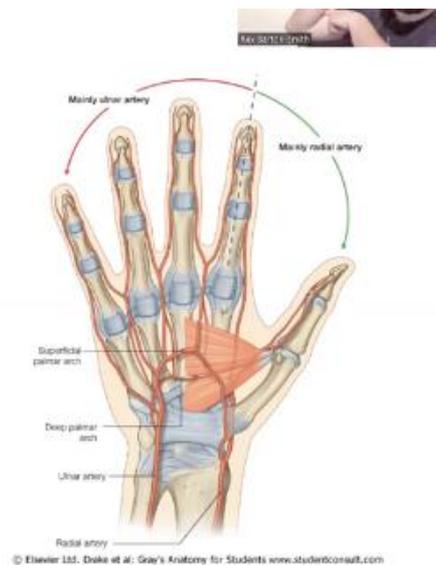
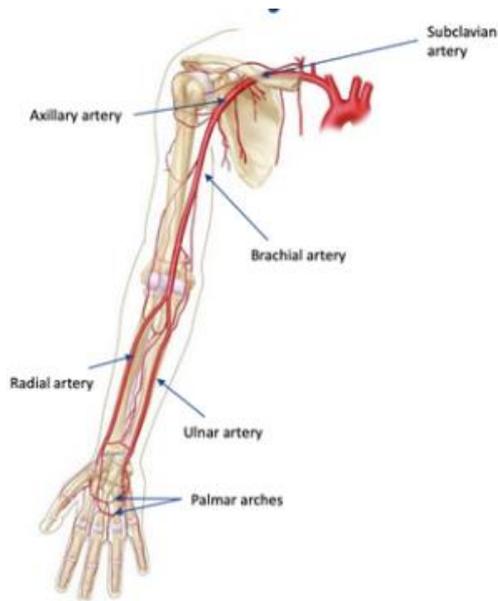
#### Cutaneous Innervation of Hand



## Upper Limb Arteries

- Brachial artery = occluded during blood pressure readings
- Radial artery = taking pulse on wrist
- Flexor side of joints
- Anastomoses at joints

**Aorta -> Subclavian (under clavicle) -> Axillary (armpit) -> Brachial (arm) -> Radial and Ulnar (forearm) -> Superficial and Deep Palmar Arches**



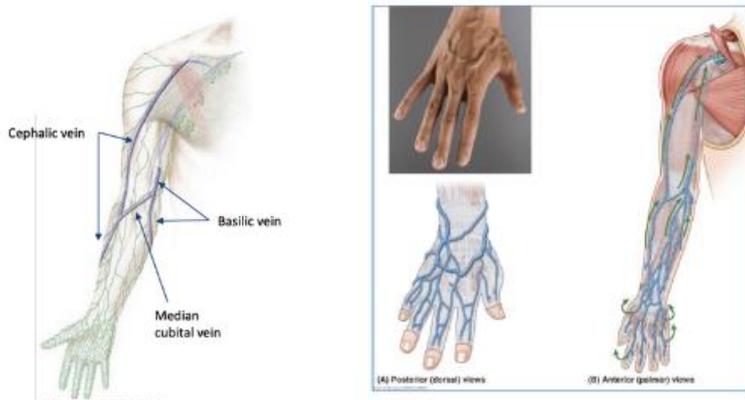
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## Upper Limb Veins – Superficial

Highly variable, commonly visible

- **Dorsal venous arches** – IV, blood samples
- **Cephalic Vein** – vein closest to head if you lift arm up
- **Basilic Vein** – vein closest to base if you lift arm up
- **Median Cubital vein** – IV

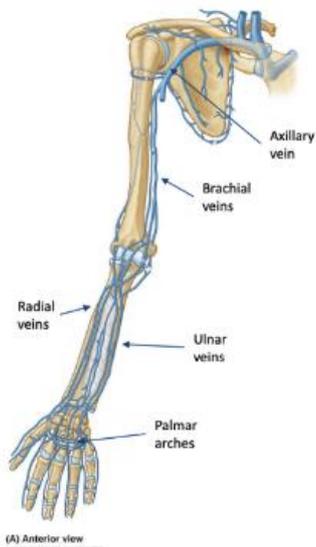
**Lymphatic vessels follow superficial veins** – flow into axillary lymph nodes



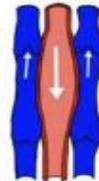
## Upper Limb Veins – Deep

- **Venae comitans** – veins accompanying arteries (usually 2)
- Largely anterior, over flexors

Palmar Arches -> Ulnar + Radial Veins -> Brachial Veins -> Axillary Vein (singular)



### 'Venae Comitans'



## Lower Limb Anatomy

**Gluteal Region** = pelvis

**Thigh** = hip to knee

**Leg** = knee to foot

**Foot**

### Line of Gravity

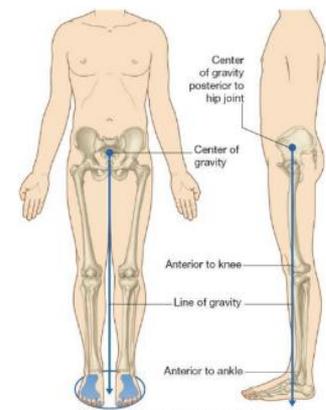
- Posterior to hip
- Anterior to knee and ankle
- Muscles tend to relax, joints and ligaments bear weight

### Line of Gravity

passes behind hip joint  
(resisted by anterior capsule)

slightly in front of knee  
(resisted by ligaments and posterior capsule)

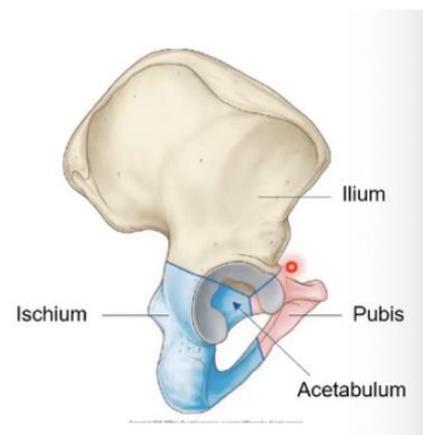
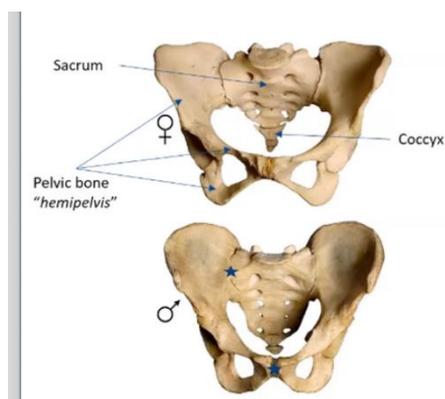
long way in front of ankle  
(resisted by calf muscles, especially soleus)



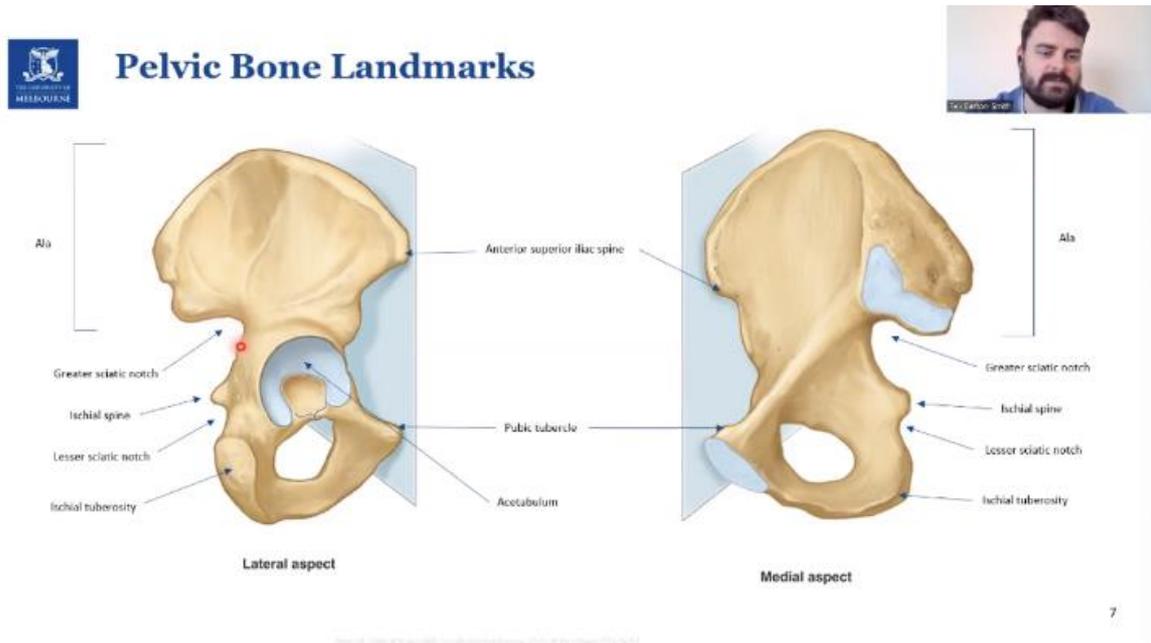
## Bones and Joints

### Pelvic Girdle

- Irregular bone
- 3 fused bones – ilium, ischium, pubis (forms hemipelvis)
- Lateral shift of ala of ilium from primates to humans for bipedal locomotion
- Male vs female: male more vertical, dense + compact, smaller pelvic outlet, less wide pubic arch - > childbirth

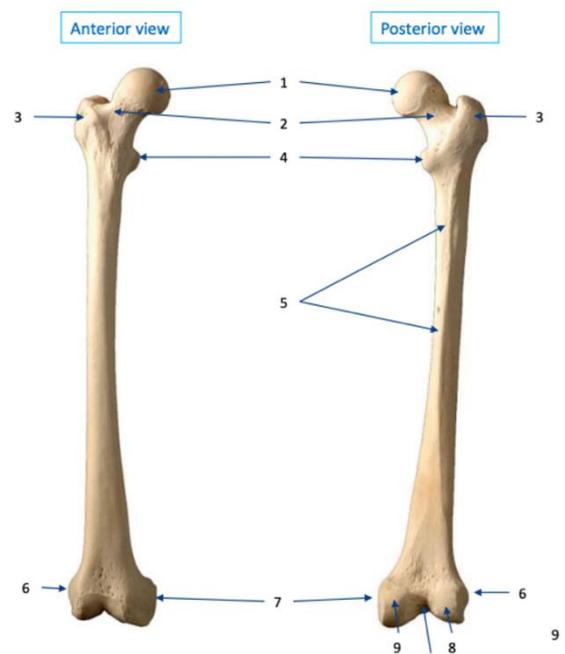
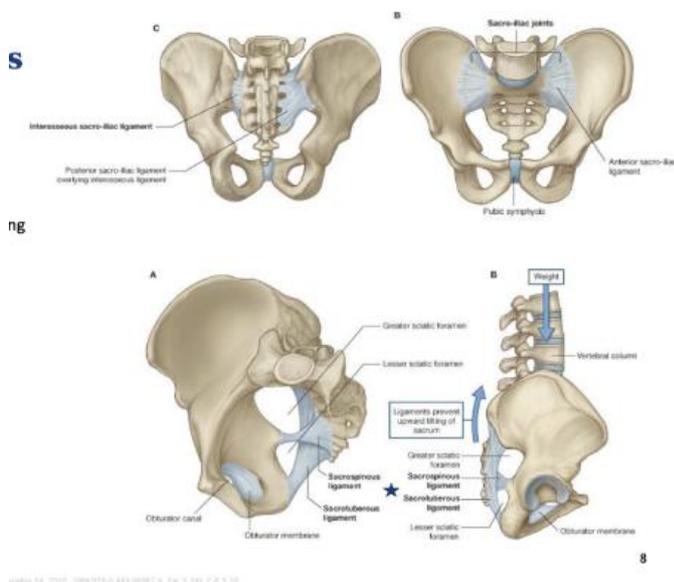


Sitting down on ischial tuberosities -> sacral ligaments resist movement (sacrospinous and sacrotuberous)



### Pelvic Girdle Joints

1. **Pubic Symphysis** – secondary cartilaginous joint (fibrocartilage)
  2. **Sacroiliac joints** – plane synovial joints
- **Ligaments** – sacrospinous (forms greater sciatic foramen), sacrotuberous, anterior and posterior sacroiliac



### Femur

Linea aspera only seen posteriorly

- **Head (1)** - large and round, more of a ball (fits deeper) into pelvic bone
- **Neck (2)** - narrowing, accommodates a degree of hip movement (flexion) otherwise we would not be able to bend the bone within its socket as well

- **Trochanters (greater (3) and lesser (4))** - muscle and tissue attachment
- **Linea aspera (5)** - thick line, can only see posteriorly - a lot of different muscles attached
- **Epicondyles (lateral (6) and medial (7))** -
- **Condyles (lateral (8) and medial (9))**
- **Intercondylar notch/fossa (10)**

### Hip Joint

- Acetabulum of femur with head of femur – more congruent than shoulder
- **Ball and socket synovial** – flexion, extension, abduction, adduction, rotation, circumduction
- **Acetabular labrum** – creates suction fit
- Ligaments – iliofemoral, ischiofemoral, pubofemoral – particularly taught during hip extension
- Common dislocation posteriorly

### Tibia and Fibula

- Tibia more medial, fibula more lateral



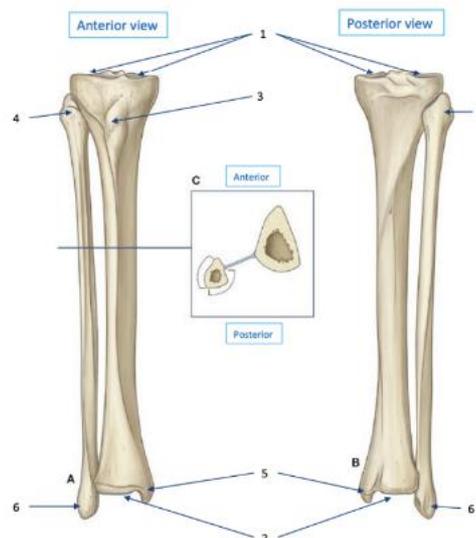
## Tibia and Fibula

Long bones

Tibia is the larger and weight bearing bone with significant articular surfaces at the tibial plateau<sup>1</sup> and trochlear notch<sup>2</sup>

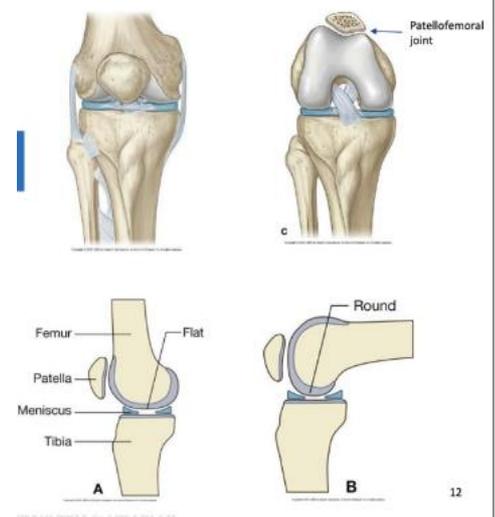
Very palpable landmarks on both bones:

- Tibial tuberosity<sup>3</sup> (tibia)
- Fibular head<sup>4</sup> (fibula)
- Medial malleolus<sup>5</sup> (tibia)
- Lateral malleolus<sup>6</sup> (fibula)

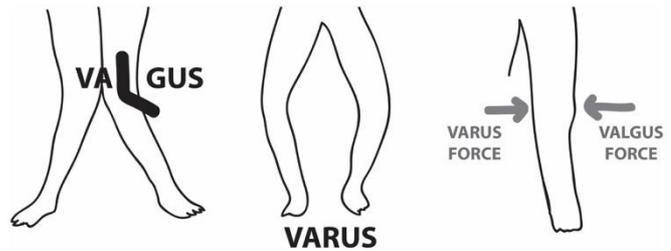


### Knee Joint

- Modified hinge joint (allows rotation in flexed position, flexion, extension)
- Femur with tibial plateau + femur with patella -> 2 joints same synovial cavity
- Patella dislocation usually occurs laterally when knee is subjected to valgus force
- Medial and lateral meniscus – fibrocartilage, increase congruency, spread synovial fluid, shock absorbers
- Extracapsular Ligaments – **medial (tibial) collateral** (fibres blend onto medial meniscus), **lateral (fibular) collateral** -> medial more prone to damage – medial resists valgus force, lateral resists varus force
- Intracapsular Ligaments – Anterior cruciate, posterior cruciate
- ACL more prone to damage
- ACL is taut and PCL is loose when knee is straight, reverse when knee is bent
- **Push tibia anteriorly = stretch ACL**
- **Push tibia posteriorly = stretch PCL**



- **Anterior cruciate ligament** - attaches more anteriorly on the tibia and then travels up to the femur
- **Posterior cruciate ligament** - attaches more posteriorly on the tibia and then travels up to the femur



## Knee Joint

### Cruciate Ligaments

- Named relative to their tibial attachment
- ACL more prone to damage due to typical injury mechanism

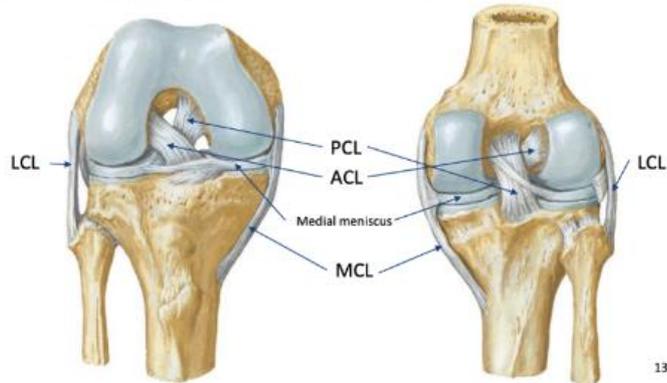


### Collateral Ligaments

- Medial resists valgus, lateral resists varus force
- Medial more prone to damage due to attachments and typical injury mechanism

Knee - Cruciate and Collateral Ligaments  
Right Knee in Flexion: Anterior View

Knee - Cruciate and Collateral Ligaments  
Right Knee in Extension: Posterior View



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## Tibiofibular Joints:

### 1. Superior

- Plane synovial (gliding)

### 2. Inferior

- Fibrous joint (syndesmosis)
- prevents tibia & fibula from separating
- good stability + low loading -> dislocation rare, but can be sprained



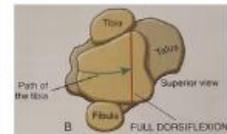
Medial view  
'Deltoid' ligament

Lateral view  
Lateral ligaments



## Talocrural (ankle) Joint:

- Hinge synovial joint with complex axis – dorsiflexion and plantarflexion
- **Talus of tarsals with distal tibia and fibula**
- Medial view – **Deltoid ligament**
- Lateral view - fibula with 3 thinner bands of ligamentous tissue coming off - ligamentous support less significant
- **Trochlea of the talus is wider more anteriorly.** This contributes to increased stability when the ankle is dorsiflexed



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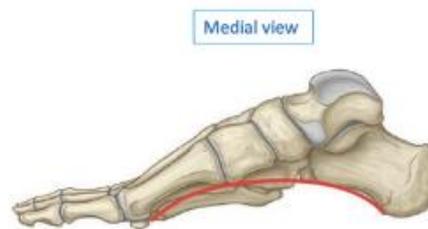
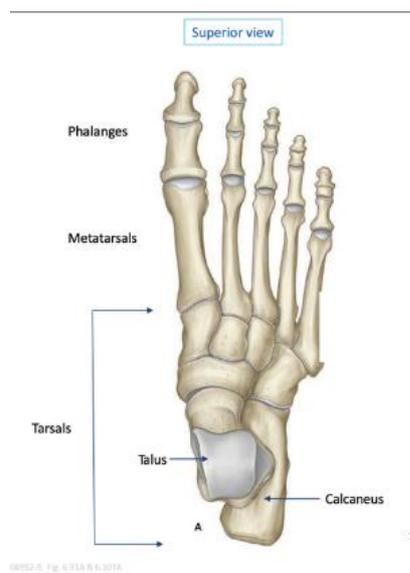
**Lateral rolled ankle/ankle sprain = plantarflexion + inversion**

## Bones of the Foot

- Tarsals – talus (talocrural joint), calcaneus (heel bone) – short bones
- Metatarsals – long bones
- Phalanges – long bones

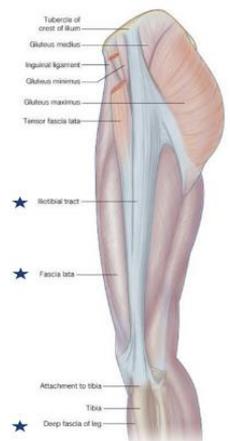
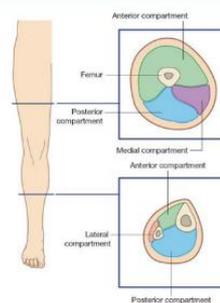
## Joints of the Foot

- Subtalar and midtarsal region – inversion and eversion
- **Intertarsal joints** – plane synovial
- **Tarsometatarsal joints** – plane synovial
- **metatarsophalangeal** – condyloid synovial, 1<sup>st</sup> metatarsophalangeal joint important for ‘toe off’ extension to create efficient loading through the lower limb for bipedal gait
- **Interphalangeal** – hinge synovial



## Lower Limb Fascia

Muscles are separated into compartments largely by intermuscular septa



## Lower Limb Muscles

**Fascia lata** - deep fascia broadly around muscles in the thigh, continue down into deep fascia of the leg

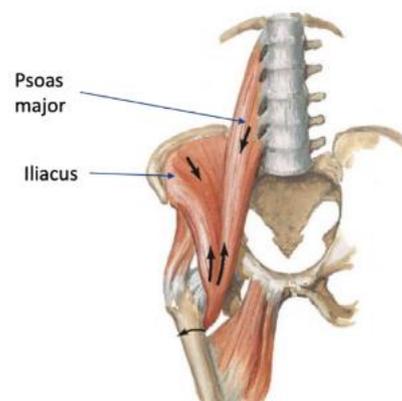
**Iliotibial band/tract** - thickening of fascia lata, multiple muscles use it as an attachment e.g. gluteus maximus

## Anterior Musculature of Pelvic Girdle

Iliopsoas

Attach onto lesser trochanter of femur

1. **Iliacus (ilium to femur)**
2. **Psoas Major (vertebra to femur)**  
→ strong hip flexors



## Posterior Musculature of Pelvic Girdle

### 1. Gluteus maximus

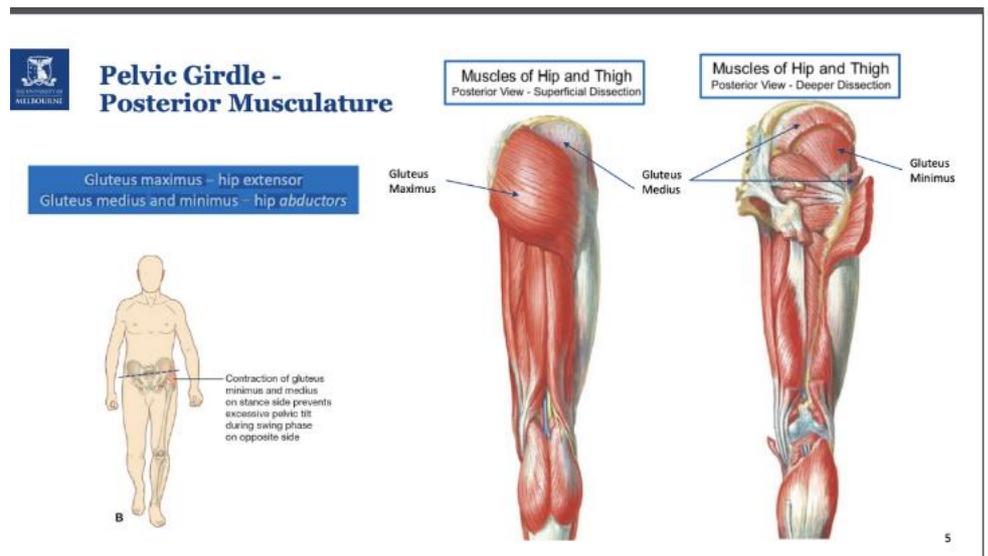
- Ilium of pelvis -> femur
- Hip extension, propulsion during walking

### 2. Gluteus medius

- Ilium of pelvis -> greater trochanter of femur (lateral)
- Hip abduction, stabilisation of pelvis in neutral position on stance leg

### 3. Gluteus minimus

- Deep to gluteus medius
- Ilium of pelvis -> greater trochanter of femur (anterolateral)
- Hip abduction, stabilisation of pelvis in neutral position on stance leg



## Anterior Compartment of Thigh

### 1. Sartorius

- Anterior superior iliac spine -> Anterior tibia
- Hip flexion, knee flexion, knee internal rotation, hip external rotation,

### Quadriceps (4 heads):

#### 2. Rectus femoris

- Ilium -> quadriceps tendon (connects to patella -> patella tendon over knee joint to tibial tuberosity)
- Hip flexion, knee extension

#### 4. Vastus lateralis

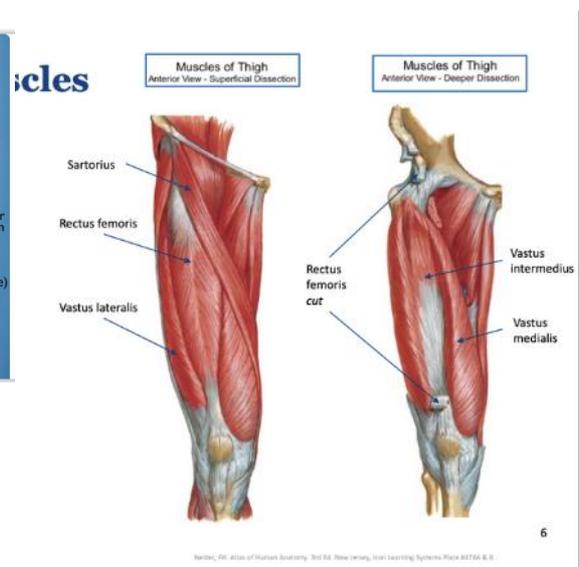
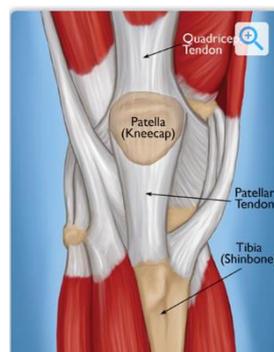
- Femur -> over knee
- Knee extension

#### 5. Vastus medialis

- Femur -> over knee
- Knee extension

#### 6. Vastus intermedius

- Deep to rectus femoris
- Femur -> over knee
- Knee extension



## Posterior Compartment of Thigh

### Hamstrings:

#### 1. Semitendinosus

- Ischial tuberosity -> medial tibia (inferior to medial condyle)

- Hip extension, knee flexion, knee internal rotation

### 1. Semimembranosus

- Deep to semitendinosus
- Ischial tuberosity -> medial and posterior aspect of tibia (inferiorly to the medial condyle)
- Hip extension, knee flexion, knee internal rotation

### 1. Biceps femoris (long and short heads)

- Short head deep to long head

#### Long head:

- Ischial tuberosity -> head of fibula
- Hip extension, knee flexion, knee external rotation

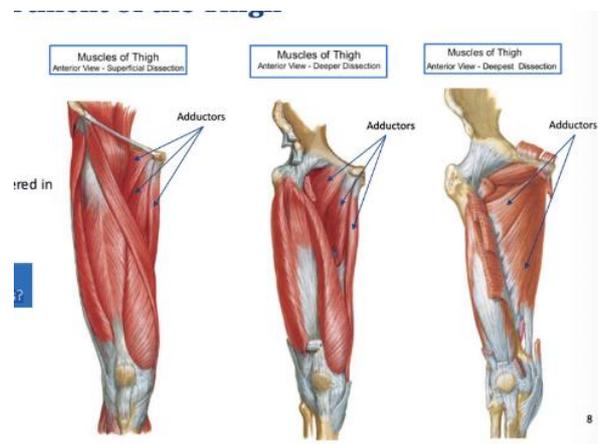
#### Short head:

- Linea aspera of femur -> head of fibula
- Knee flexion, knee external rotation
- Knee external rotation

Motion of the toes outward and the heel inward is knee external rotation. As the toes go in and the heel goes out, this is knee internal rotation.

### Medial Compartment of Thigh

- Anchor to pubic and ischial bones -> femur
- Hip adductors
- Femoral artery passes through adductor hiatus



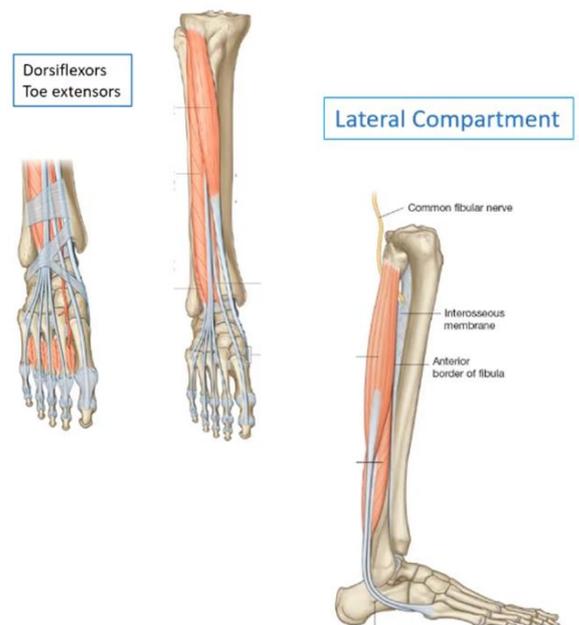
### Anterior Compartment of Ankle

- Dorsiflexion
- Toe extension
- The most medial muscle terminates in the midfoot and does inversion
- The most lateral fibre terminates laterally in the midfoot and does eversion

Anterior Compartment

### Lateral Compartment of Ankle

- Everters
- Travel just posteriorly to lateral malleolus → also weak plantarflexors
- One sneaks under the foot



### Posterior Compartment of Ankle – Superficial

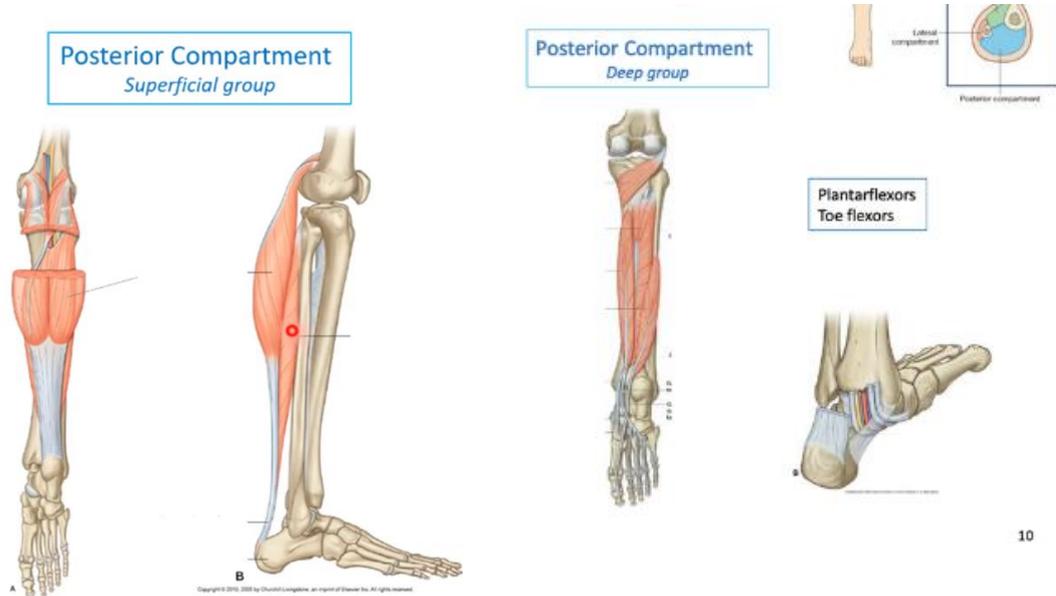
- Strong plantarflexors
- Collectively blend into the calcaneal/achilles tendon
- Tendon is a fair way from the actual ankle joint - strong plantarflexion (lifting heel of ground, walking jumping → very powerful)

### Posterior Compartment of Ankle – Deep

- Plantarflexors and toe flexors

- Apoplateal muscle (near top) unlocks knee → lateral rotation at the knee (stand and lock knee into extension, this muscle creates a twist that allows for flexion)
- Muscles go through the tarsal tunnel and largely go towards the toes or finish midfoot
- Tendons go medial to calcaneus - just posterior to medial malleolus

NE



### Intrinsic Foot Muscles

Primarily on plantar side of foot

1. **Hallucis** – big toe (1<sup>st</sup> digit)
2. **Digiti minimi** – little toe (5<sup>th</sup> digit)
3. **Central muscles** – flexor digitorum (plantar), extensor digitorum (dorsal)

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### INTRINSIC FOOT MUSCLES

100 Lecture 5-20

Primarily on the plantar side of the foot

3 major groups

- Hallucis muscles – 1<sup>st</sup> digit (big toe)
- Digiti minimi muscles – 5<sup>th</sup> digit (small toe)
- Central muscles – varied attachments and functions

Plantar Views

Dorsal View



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## Lower Limb Nerves

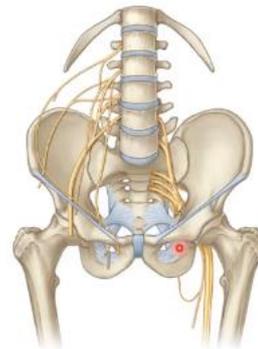
### Lumbar Plexus and Lumbosacral Plexus

- Lumbar plexus - Originating from anterior rami of the lumbar region
- Lumbosacral plexus - Fibres originating from the lower lumbar and sacral region
- Pelvis, lower abdomen, lower limb

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Lumbar Plexus

Lumbosacral Plexus

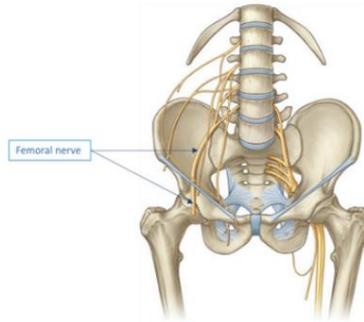


The lumbar and lumbosacral plexi supply the lower limb in addition to components of the pelvis and lower abdomen.

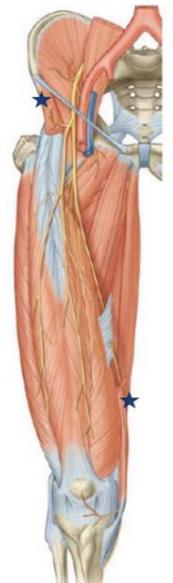
**1. Femoral Nerve**

- Receives input from L2-4 anterior rami
- Travels lateral to psoas major
- Leaves the **abdomen** by travelling deep to inguinal ligament with major femoral vessels
- Significant branching upon entering **thigh to supply anterior compartment**
- Lift up sartorius - great way to find a lot more expansion of femoral nerve

rve



Anterior View



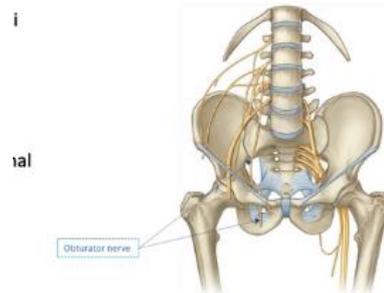
**2. Obturator Nerve**

- Receives input from L2-4 anterior rami
- Travels medial to psoas major
- Leaves the pelvis via the obturator canal
- Splits into two branches which supply the **medial compartment** of the thigh

t

Which major anterior compartment of the thigh muscle has been partially removed in this image? (labelled with stars) →

rve



Anterior View



**4. Sciatic Nerve**

- Receives input from L4-S3 anterior rami
- Forms within the pelvis and leaves posteriorly via the greater sciatic foramen
- Typically inferior to the piriformis
- Significant lower limb muscular supply
- **Posterior compartment of the thigh**
- **All leg compartments**
- **All foot muscles**
- Two nerves in a common sheath:
  - Tibial nerve • Common fibular nerve

ial

Common Fibular Nerve:

- Travels posterolateral to the knee joint
- Wraps around the fibular neck and splits into two major branches

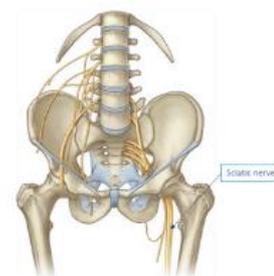
**1. Superficial fibular nerve supplies the lateral compartment of the leg**

- 2. Deep fibular nerve supplies the anterior compartment of the leg**  
 - Also supplies intrinsic foot muscles (dorsal side)



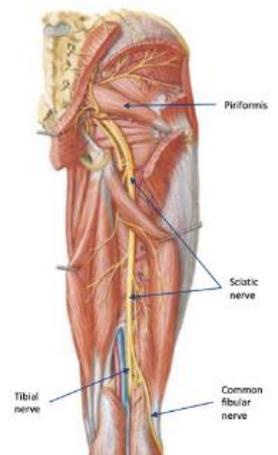
Anterior View

n



Components of the sciatic nerve may leave the pelvis superior to or even through the piriformis muscle.

Posterior View



### Tibial Nerve:

- Travels posterior to the knee joint to enter the leg
- Supplies the **posterior leg compartment (superficial and deep groups)**
- Travels through the **tarsal tunnel** to enter the foot
- Supplies **the majority of the foot musculature (plantar side)**



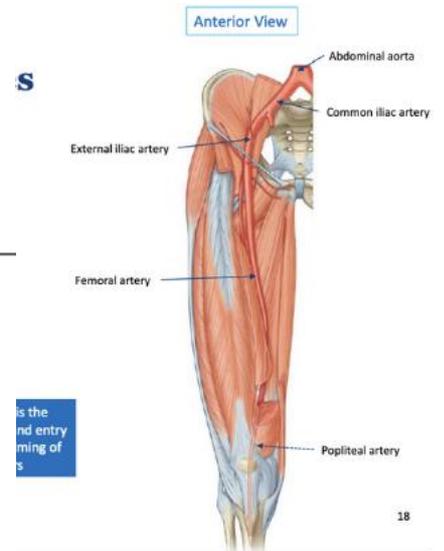
Posterior View

### Lower Limb Arteries

- Flexor side of joints (opposite sides on hip and knee)
- Anastomoses at joints

Abdominal Aorta -> Common Iliac -> External Iliac -> Femoral (leaves through adductor hiatus) -> Popliteal (back of knee) -> Posterior and anterior tibial arteries -> Posterior tibial artery gives off fibular artery, posterior tibial artery continues through tarsal tunnel with tibial nerve -> Plantar arteries

Posterior tibial artery gives off fibular artery  
Anterior tibial artery comes through a small gap in the interosseus membrane



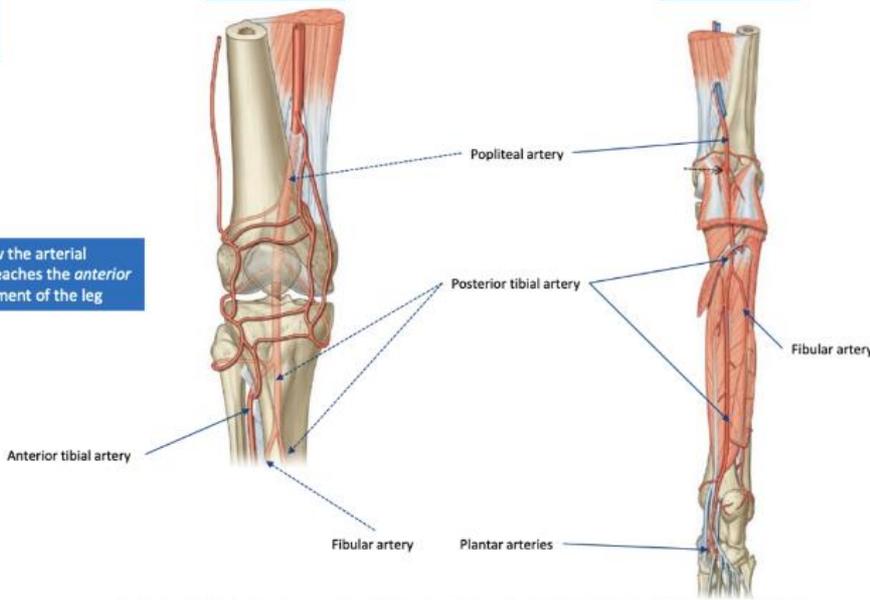
Anterior View

17



Anterior View

Posterior View



Note how the arterial system reaches the anterior compartment of the leg

is the end entry point of the arterial system

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### Lower Limb Veins

#### Superficial:

1. **Dorsal Venous Arch**
2. **Great Saphenous vein** – anterior to medial malleolus and dives into femoral vein through hiatus in fascial tissue
3. **Small Saphenous vein** – near lateral malleoli, travels posteriorly on the leg and dives deep into the popliteal vein (already in the deep system)

**Deep**

Plantar veins, traversing up through anterior and posterior tibial veins up to popliteal vein (1 single vein), continues up to femoral vein and then external iliac, common iliac and inferior vena cava

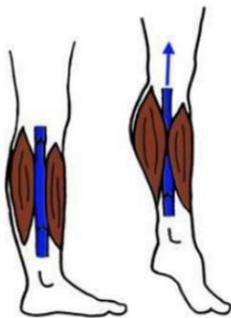


**Major Lower Limb Veins**

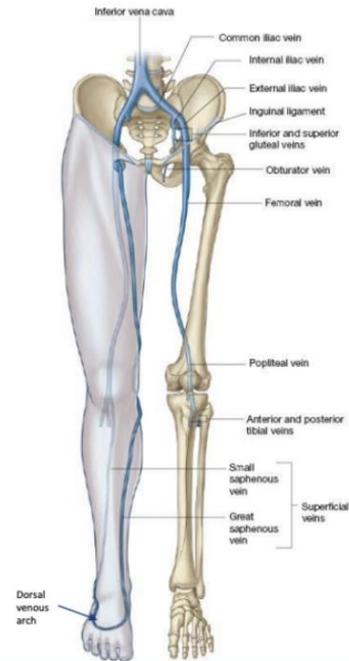
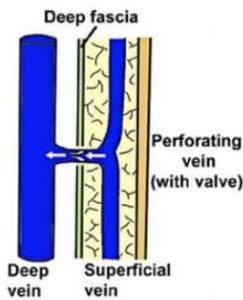
Superficial Veins

Deep Veins

Muscular venous pump plays a major role in venous return



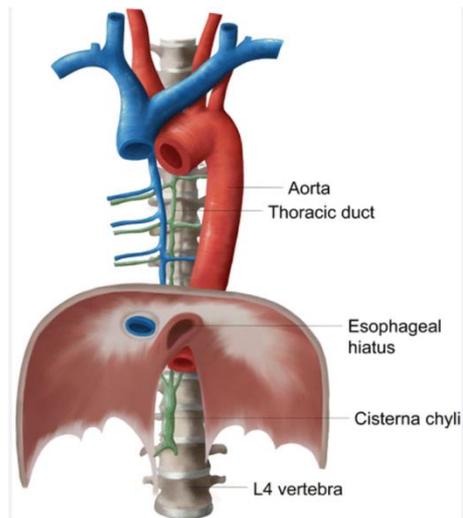
Venous valves are to permit a uni-directional flow



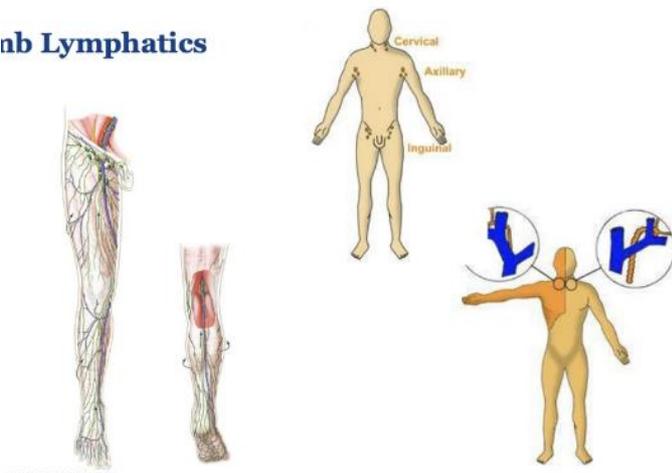
Bl Drake, AW Vogl, AWM Mitchell, Gray's Anatomy for Students, 2nd Edition, Churchill Livingstone Elsevier, Philadelphia PA, 2010. ISBN 978-0-443-06952-9. Fig. 6.37  
N Eizenberg, C Briggs, C Adams, G Ahern, An@Tomeida: General Anatomy, Principles & Applications, McGraw Hill, ISBN 9780070134676. 1st ed. 2008, Fig. 11.19 & 11.29

**Lower Limb Lymphatics**

- Follow superficial venous tissues
- Drainage progresses for both limbs to enter the **cysterna chyli** and **thoracic duct**
- Traverse up from a distal to proximal perspective
- Progress through major lymph nodes in different regions - a lot of lymph nodes in femoral and inguinal region progressing up through the pelvis



**nb Lymphatics**



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