Functional Musculoskeletal Anatomy

ANAT2029/ANAT2000

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Lecture 1 – Development of the Nervous System

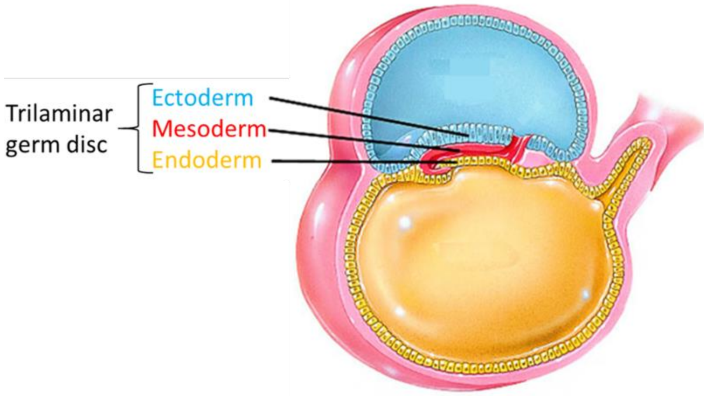
0-8 weeks = embryo: initial development of each system

9-38 weeks = fetus: period of functional maturation of each system

Nervous system starts developing in week 3

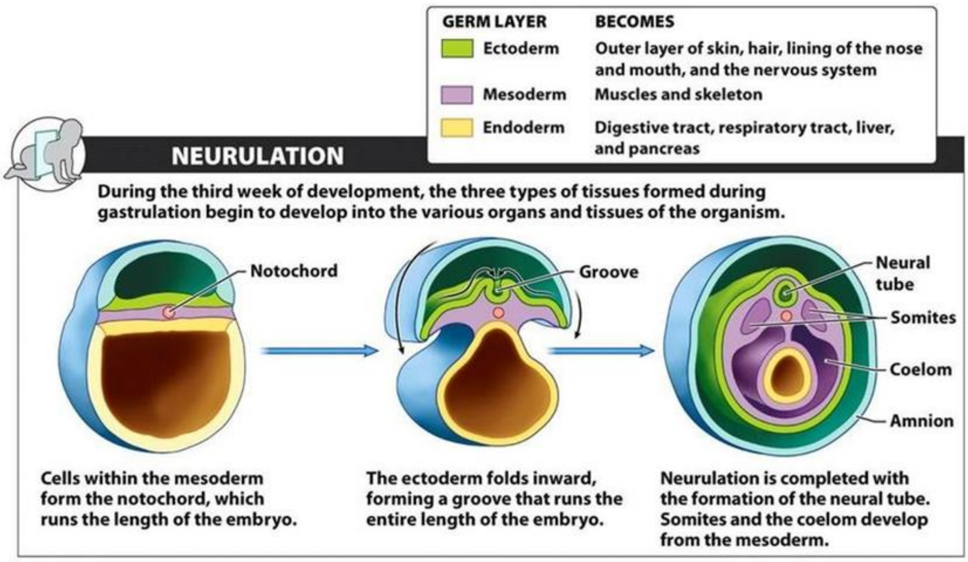
Week 3:

- Trilaminar germ disk – 3 layers of an oval shape disk (each layer is a derm)
  1. Ectoderm – forms nervous system
  2. Mesoderm – forms Musculoskeletal
  3. Endoderm – forms GI tract



Neurulation – development of neural tube and neural crest cells

* **Notochord –** a rod-shaped piece of mesoderm that makes ectoderm become the nervous system



<u>Neurulation summary</u>

1. Notochord forms from mesoderm
2. Neural plate
3. Neural groove
4. Neural tube
5. CNS

Lecture 3 – Histological Anatomy: Cells and Tissues

Levels of organisation in the body

- Atoms
- Molecules
- Cells
- Tissues
- Organs
- Organ Systems
- Organism

Cells

- Nucleus – control centre
- Plasma membrane – outer limit of the cell
- Cytoplasm – contents between the nucleus and plasma membrane

Cells are the smallest living structures

Cell structure varies greatly, which reflects their specialisation

Tissue – a group of similar cells, and their extracellular products that are organised to perform a common function

- Extracellular matrix – everything produced by the cell that is outside of the cell
  - In a tissue, cells produce and maintain the extracellular matrix. In response to physical stress, some cells will build more extracellular matrix and other cells will break it down

Four Tissue Types

1. Epithelial tissue – covers body surfaces, lines cavities, and forms glands
2. Connective tissue – underlies or supports the other tissues
3. Muscle tissue – responsible for movement
4. Nervous tissue – receives, transmits, and integrates information to control the body

Connective Tissue

- Large extracellular matrix (cells are separated)
- Connective tissue protects and binds tissues, and supports organs

Connective tissue is comprised of:

- Cells – different cells for different types of connective tissue
  - E.g., fibroblasts, osteocytes, adipocytes
- Protein fibres
  - E.g., elastic fibres, collagen, reticular fibres
- Ground substance – a mixture of proteins and carbohydrates mixed in water and salt
  - E.g., watery, gel, semi-solid, solid substance

Extracellular matrix is made of **protein fibres** and **ground substance**

- **Protein fibres in connective tissue**
  - Collagen
    - Most abundant protein in the body
    - High tensile strength (stretching)
    - Long, unbranching, and flexible
      - Type I: tendons, ligaments, bones
      - Type II: cartilage
  - Elastic fibres
    - 3D branching pattern – appears wavy
    - Allows tissues to stretch and return to shape
    - Interwoven with collagen
    - Smaller

- **Ground substance in connective tissue**
  - Watery gel
  - Proteins
  - Carbohydrates
  - Salts
  - Water
    - Highly variable amounts of water
      - Viscous
      - Semisolid
      - Solid

All adult connective tissue develops from mesenchyme

Mesenchyme is embryonic connective tissue made up of:

- Mesenchymal cells
- Immature protein fibres

Lecture 6 – Muscles of the Shoulder Complex

Translation – straight-line displacement when a force is applied through the centre of rotation

Torque – rotation caused by a force that is applied at a distance from the centre of rotation

When a muscle contraction pulls on a bone, and the bone is fixed at some point (joint), the bone will rotate around the fixed point

The force results in a rotation called a torque (moment of force)

- $T = F \times r$

Strength = Torque

Muscle Contraction

- Concentric – muscle torque is greater than external torque, thus the muscle shortens
- Isometric – muscle torque is equal to external torque, thus the muscle length stays the same
- Eccentric – muscle torque is less than external torque, thus the muscle lengthens

Biomechanics

- Bones = levers
- Joints = axes/centre of rotation
- Muscles = provide force
- Line of Action = when a muscle contracts it will pull its attachment sites toward the centre of the muscle
- Moment arm = perpendicular distance from the centre of rotation to the line of action of the force
- Torque = the rotation effect of a force (torque = force x moment arm)
- Force couple = a pair of equal but opposite forces at an equal distance on the opposite side of the centre of rotation

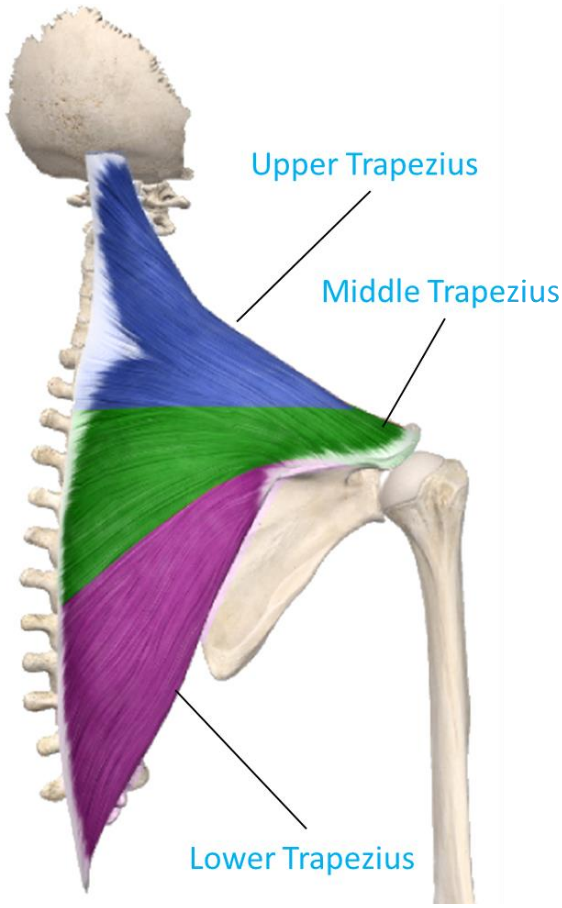
The ability of that force to rotate the body segment is affected by 2 things

1. The amount of force that the muscle can produce
   - Increasing the PCSA will increase the amount of force a muscle can produce
     - Deep muscles tend to have a short moment arm
     - Superficial muscles tend to have a long moment arm

2. The efficiency of that force (i.e., moment arm)
    - Increasing the moment arm increases the strength of rotation caused by that contraction force

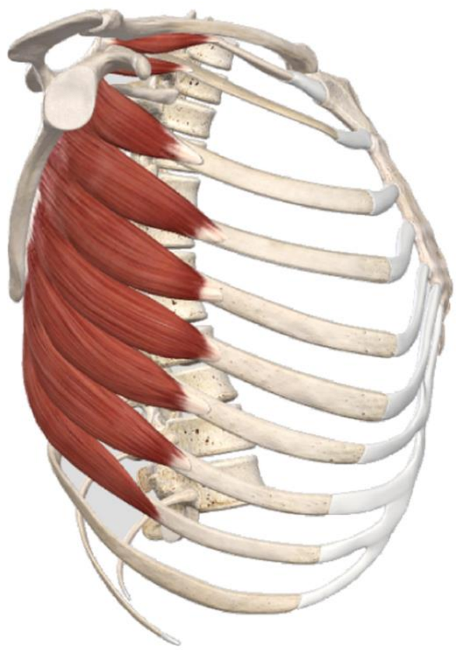
Muscles of the shoulder complex

1. Axioclavicular and Axioscapula



- **Upper Trapezius**
    - Origin
        - External occipital protuberance
        - Ligamentum nuchae
        - Spinous process of C7
    - Insertion
        - Lateral clavicle
    - Motion
        - Scapula elevation
        - Scapula adduction (retraction)
        - Scapula upward rotation

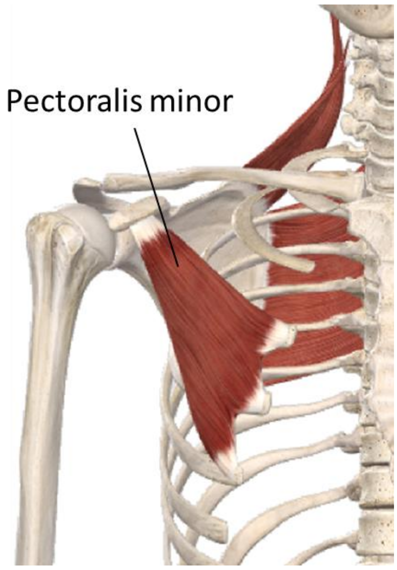
- **Middle Trapezius**
    - Origin
        - T1-T4
    - Insertion
        - Acromion
    - Motion
        - Scapular adduction (retraction)
        - Scapula upward rotation



- **Lower Trapezius**
    - Origin
        - T5-T12
    - Insertion
        - Spine of Scapula
    - Motion
        - Scapula depression
        - Scapula adduction (retraction)
        - Scapula upward rotation

- **Serratus Anterior**
    - Origin

- **Pectoralis Minor**
  - Origin
    - Ribs 3-5
  - Insertion
    - Coracoid process
  - Motion
    - Scapula depression
    - Scapula abduction (protraction)

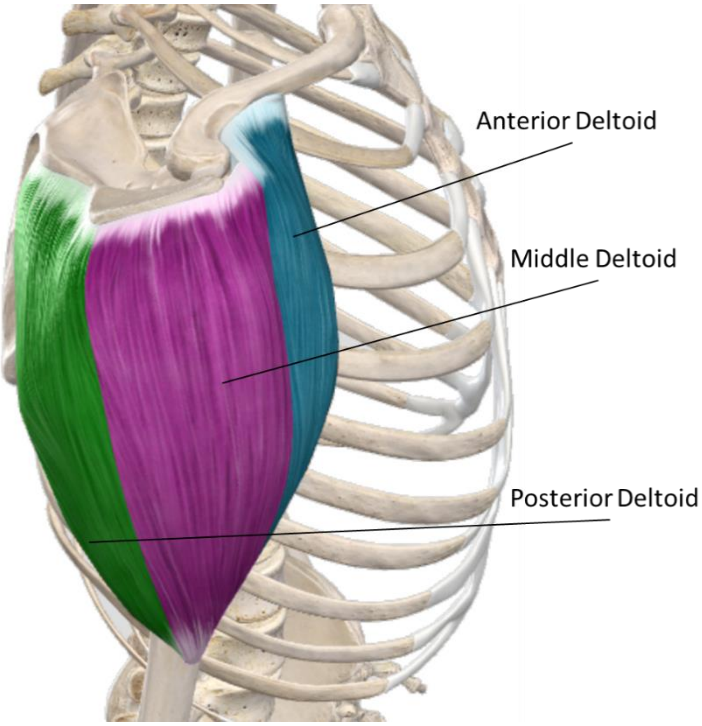


Force Couples

- Levator scapulae and rhomboid major and minor downwardly rotate the scapula
  - Pectoralis minor – levator scapulae/rhomboids force couple
    - Protraction and retraction cancel out
    - Elevation and depression cancel out

2. **Scapulohumeral**

- **Anterior Deltoid**
  - Origin
    - Lateral clavicle
  - Insertion
    - Deltoid tuberosity of humerus
  - Motion
    - Glenohumeral flexion
    - Glenohumeral horizontal flexion
    - Glenohumeral internal rotation



- **Middle Deltoid**
  - Origin
    - Acromion
  - Insertion
    - Deltoid tuberosity of humerus
  - Motion
    - Glenohumeral abduction

- **Posterior Deltoid**
  - Origin
    - Spine of Scapula
  - Insertion
    - Deltoid tuberosity of humerus

Lecture 13 – Biomechanics of Tendons and Ligaments

Tendons and ligaments are dense regular connective tissue well-adapted to resist tensile forces

- **Ligament function**
  - Transmit tensile forces from bone to bone
  - Strong enough to provide stability
  - Flexible enough to permit joint motion

In the spine, there are anterior and posterior longitudinal ligaments

- Superficial layer – fibres span several levels
- Deep layer – fibres cross only adjacent vertebrae, attach to the annulus fibrosis
- In different regions of the vertebral column, the ligaments restrict different movements (e.g., flexion in some areas and extension in others)

Bigger ligaments are harder to damage than smaller ligaments

The plantar ligaments of the feet behave similarly to tendons

They function to adapt to surfaces and dampen impact forces. They also form the arches of the foot

- Anterior cruciate ligament (ACL)
  - Resists anterior tibial translation and rotational loads
  - 2 bundles with a non-linear load-elongation curve
  - They function to stabilise the knee in various positions and loading conditions
  - Common sporting injury (females 4 times more likely)

Tendons – transmit force from muscle to bone

- **Absorb, store, and release energy**
  - Maximise exercise efficiency (conserve energy)
    - Muscles are expensive to change length
  - Achilles and patellar tendons are good at storing energy
    - Most tendons fail between 3-8%
    - The Achilles tendon can stretch more than 12% of its original length
      - Storing energy in tendons helps save metabolic energy during movement

- **Power amplification**
  - Slowly store energy, but release it quickly—more power

- During stance, the Achilles tendon slowly stores and quickly releases energy during push-off to propel to the next step

- **Protect muscle from damage (shock absorber)**
  - Muscles hate being lengthened quickly, but tendons can take up this length change
    - During jump landing or walking down a hill, tendon lengthens before muscles to prevent eccentric damage

Achilles tendon

- Triceps surae (both heads of gastrocnemius and soleus) insert onto it
  - Medial gastrocnemius has parallel fibres
  - Lateral gastrocnemius and soleus have twisted fibres
    - The behaviours of the tendons components of these muscles vary with movement speed, which is important to accommodate different ground surfaces

Mechanical properties of tendon affect muscle output

- A more compliant tendon requires a higher level of muscle contraction before force is generated around a joint
- When the muscle starts to move, the tendon must move in order for the force to be transferred
  - There is a delay between the activation of a muscle and its production of force – electro-mechanical delay
    - More compliant tendon = greater electro-mechanical delay, less force transmitted for a given change in length

- An aponeurosis is a broad sheet of dense regular connective tissue
  - Aponeurosis is similar to tendons
    - Tendons are rope-like
    - Aponeurosis are sheet-like

Enthesis – where tendons/ligaments insert onto bone (100x stiffer than tendon/ligament)

Muscle-tendon junction – abrupt transition between muscle and tendon

- Collagen fibres and muscle cell membrane interdigitate to increase surface area, which reduces stress between tendon and muscle

Different structures surrounding tendons

- Fibrous sheath

Lecture 15 – Pelvic Girdle and Hip

Pelvic girdle – 2 hip bones (oscoxae)

Pelvis – includes sacrum

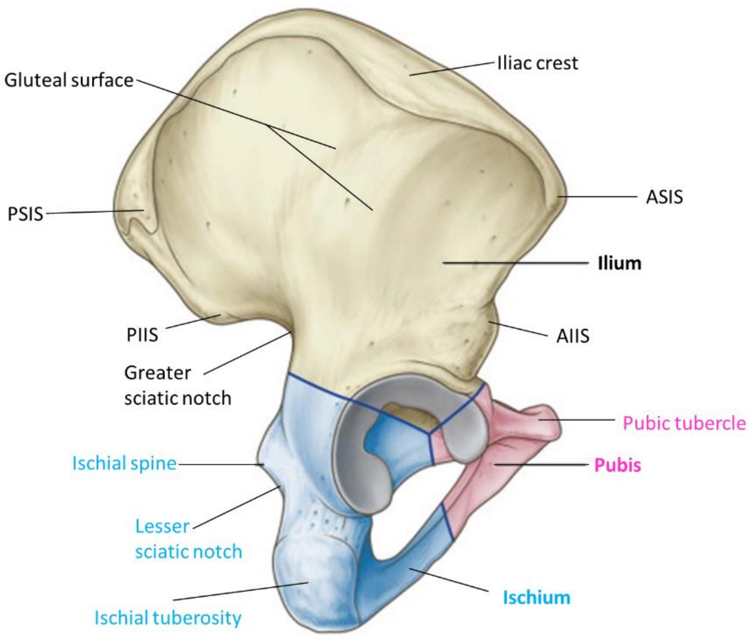
Functions of the pelvic girdle and hip joint

- Weight-bearing in standing and sitting
- Force transfer from lower limb to upper limb
- Gait—makes walking efficient by minimizing COG movement, which limits energy expenditure
    - Pelvis internally rotates, which lengthens the limb, and hip externally rotates
    - Hip adducts during walking to keep feet close to midline, which minimizes lateral shift in COG
    - Stance leg abducts, which limits pelvic tilt (drop) and minimizes rise in COG
    - Knee flexes on landing to shock absorb

Bones

Os coxae (hip bones)

- **Ilium**
    - Iliac crest
    - Anterior superior iliac spine (ASIS)
    - Anterior inferior iliac spine (AIIS)
    - Posterior superior iliac spine (PSIS)
    - Posterior inferior iliac spine (PIIS)
    - Greater sciatic notch
    - Gluteal surface
- **Pubis**
    - Pubic tubercle
- **Ischium**
    - Ischial spine
    - Lesser sciatic notch
    - Ischial tuberosity

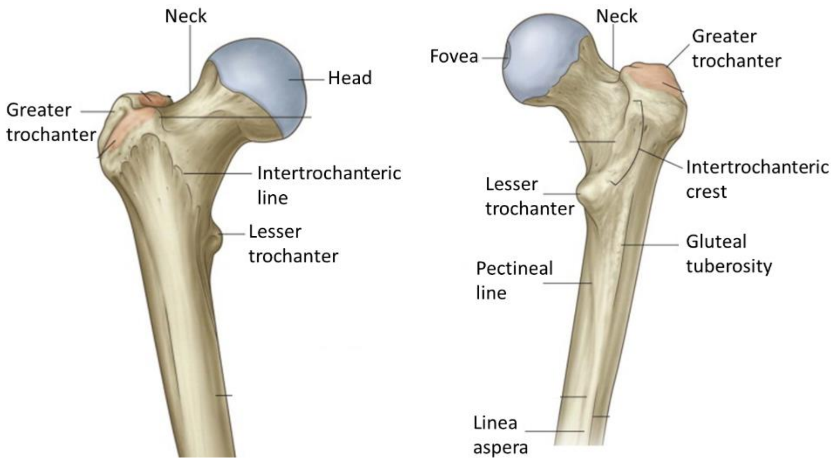


Bones fuse around 12-16 years at the acetabulum, but before they fuse they articulate at the triradiate cartilage

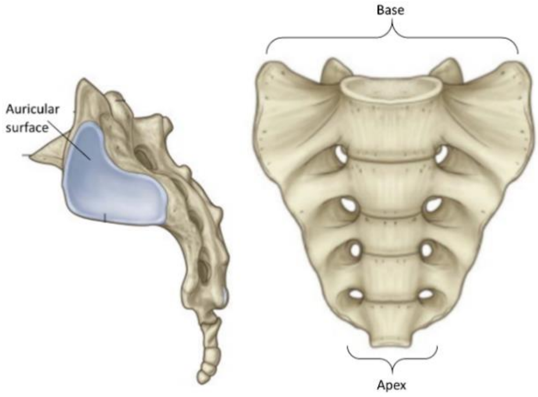
- In a child, the triradiate cartilage is a site of weakness

ASIS and pubic symphysis are in vertical alignment

ASIS and PSIS – posterior and superior at an angle of 4-15°



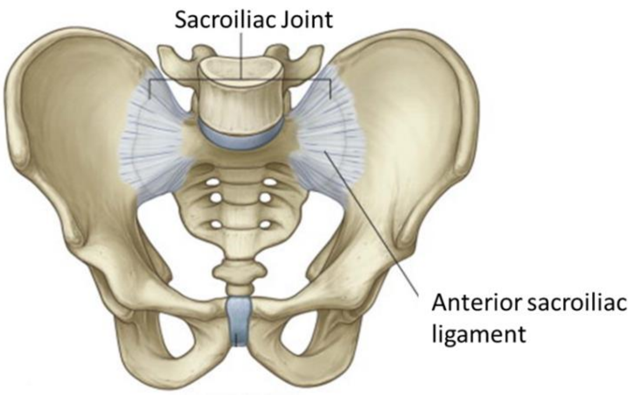
- **Femur**
  - Head
  - Neck
  - Greater trochanter
  - Lesser trochanter
  - Intertrochanteric line
  - Intertrochanteric crest
  - Fovea
  - Gluteal tuberosity
  - Pectineal line
  - Linear aspera



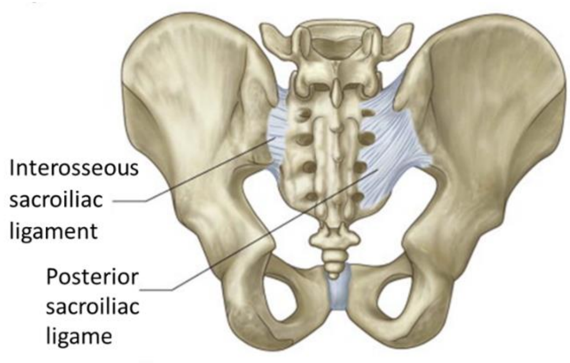
- **Sacrum**
  - Base
  - Apex
  - Auricular surface

Joints

1. **Sacroiliac Joint**
   - Joint includes
     - Iliac tuberosity
     - Sacral tuberosity
     - Sacroiliac interosseous ligament

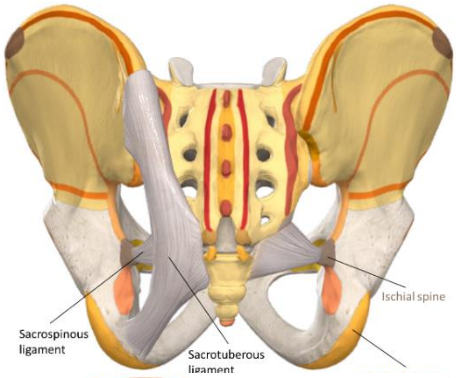


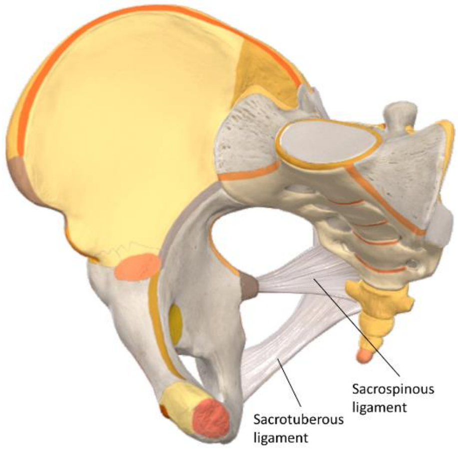
- **Stability**
  - Good bony stability
    - Bones fit well together
  - Good ligamentous stability



- **Ligaments**
  - Interosseous sacroiliac ligament
  - Anterior sacroiliac ligament
  - Posterior sacroiliac ligament
    - Overlying the interosseous ligament
  - Sacrospinous
    - From the sacrum and coccyx to the ischial <u>spine</u>
  - Sacrotuberous
    - From the PSIS, sacrum, and coccyx to the ischial <u>tuberosity</u>
  - Auricular surface

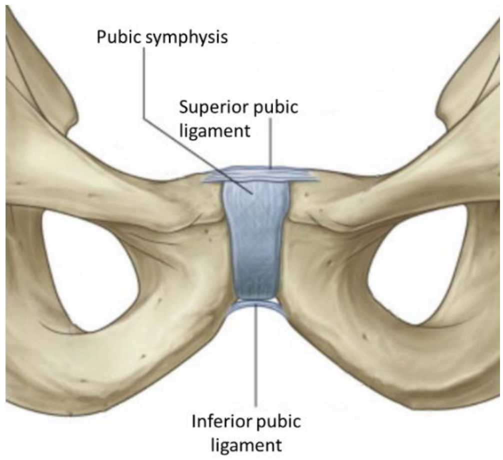
- **Movements**
  - Synovial plane joint
  - Fibrous syndesmosis
    1. Nutation
       - o Sacral nutation – anterior tilt of the sacrum relative to the ilium
         - ▪ Base moves down: apex moves up
         - ▪ Body weight acts anteriorly and inferiorly to the axis of the sacrum, which rotates the apex posteriorly and superiorly
           - 2 situations:
             - o Sacrum moving on ilium (end range trunk flexion)
             - o Ilium moving on sacrum (end range hip flexion)
  - Counternutation = opposite to sacral nutation
    - o Posterior tilt of the sacrum relative to the ilium





2. Pubic Symphysis

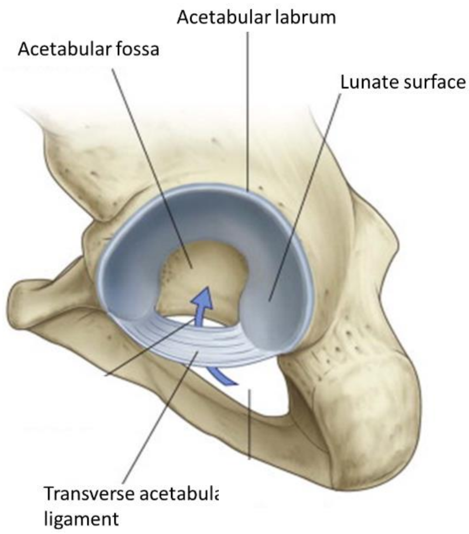
- **Ligaments**
  - Pubic symphysis
    - o Fibrocartilage disc – pubic symphysis is exposed to shear forces
  - Superior and inferior pubic ligaments



3. Hip Joint

- Synovial ball and socket
- Multiaxial diarthrosis

- **Acetabulum** (orientation – anterior, lateral, inferior)
  - Acetabular fossa
    - o Non-weight bearing
  - Lunate surface
    - o Weight-bearing on the acetabulum on the anterior, superior, and posterior portions, which is where the lunate surface is
  - Transverse acetabular ligament
  - Acetabular labrum

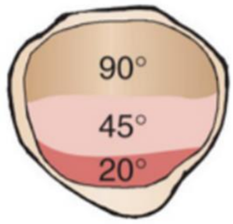


- **Femur**

- Odd facet

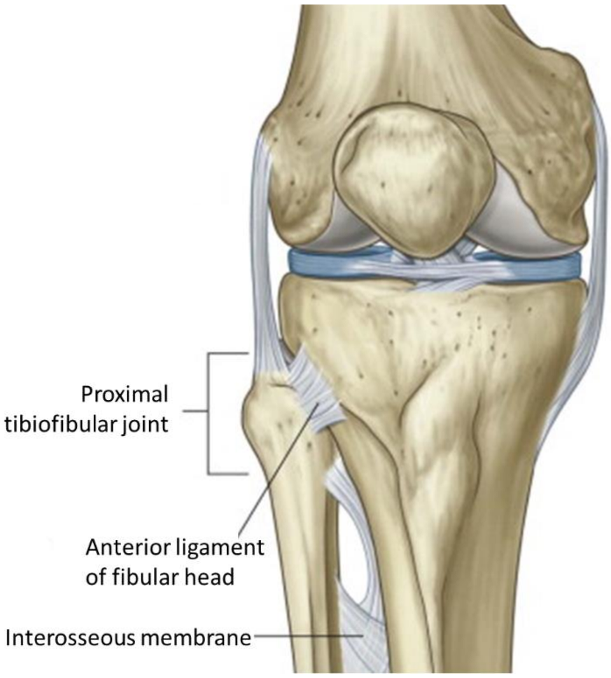
Contact area location and amount change through range with increasing knee flexion – contact moves proximally and increases

- With increasing knee flexion, the patellar moves distally around the femur
  - Full knee extension (standing) – no contact
  - 20° knee flexion – bottom part of patella touches femur
  - 45° knee flexion – middle part of patella touches femur
  - 90° knee flexion – top part of patella touches femur



Increasing contact area helps distribute force

Patella most commonly dislocates laterally

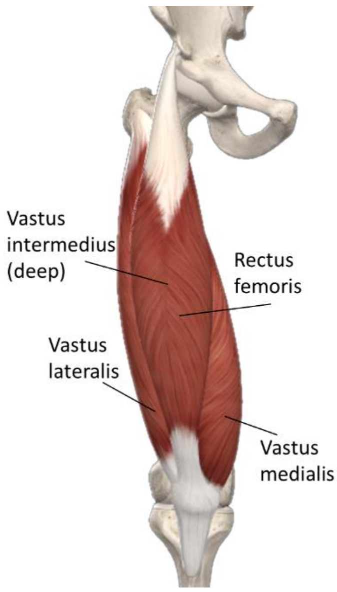


3. Proximal tibiofibular joint
  - Joint includes
    - Head of fibula
    - Lateral tibial condyle

- Fibrous syndesmosis
- Fibular collateral ligament

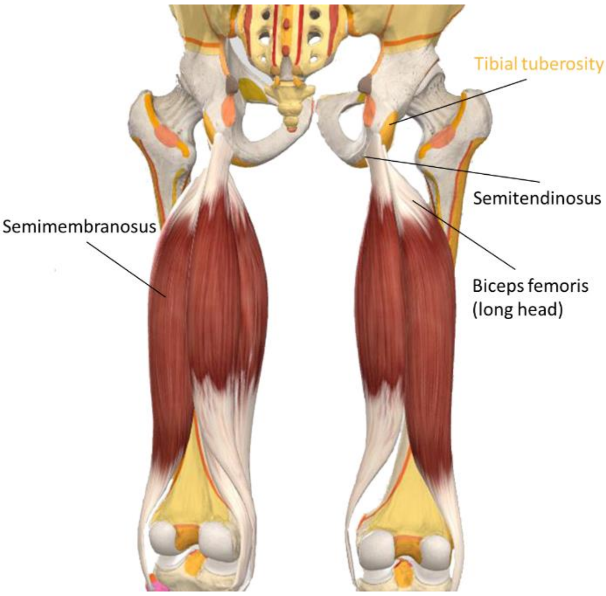
Knee extensors

- Quads
  - Vastus medialis
    - Longus (VML)
    - Obliquus (VMO)
      - Horizontal fibres coming from adductor magnus tendon and inserting on the medial side of the patellar
        - Medial stability of the patellofemoral joint



Weakness in quadriceps reduces gait speed, and ability to stand up from a chair

Knee flexors



- Biceps femoris
- Semitendinosus
- Semimembranosus

All 3 posterior muscles on the thigh—biceps femoris, semitendinosus, and semimembranosus—are biarticular

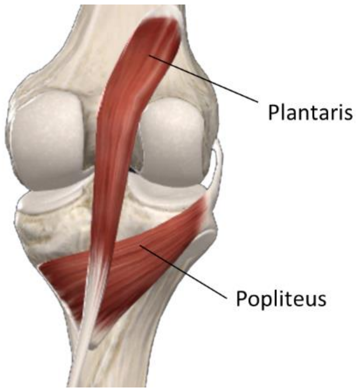
Semimembranosus is the deepest of the 3 posterior thigh muscles

Semitendinosus and biceps femoris (long head) converge and originate on the tibial tuberosity

Common fibular nerve innervates biceps femoris (short head)

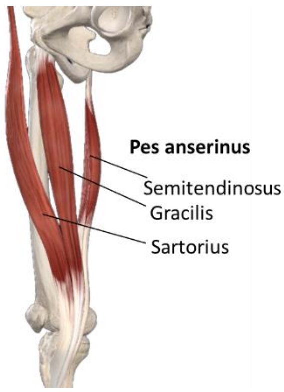
The others are innervated by the tibial nerve

- Gastrocnemius
  - Flexes the knee



- Plantaris
  - Flexes the knee

- Popliteus
  - If non-weight bearing, the tibia will move
  - If weight bearing, the femur will move
  - Requires lateral rotation of the femur on the tibia to 'unlock' the extended knee = popliteus action



- Pes anserinus (gooses foot)
  - Sartorius (anterior compartment)
  - Gracilis (medial compartment)
  - Semitendinosus (posterior compartment)

Lecture 20 – Vertebral Column Development, Maturation, and Ageing

Neuropores are openings at the cranial and caudal end of the spinal cord

- Cranial neuropore fuses on day 24
- Caudal neuropore fuses on day 26

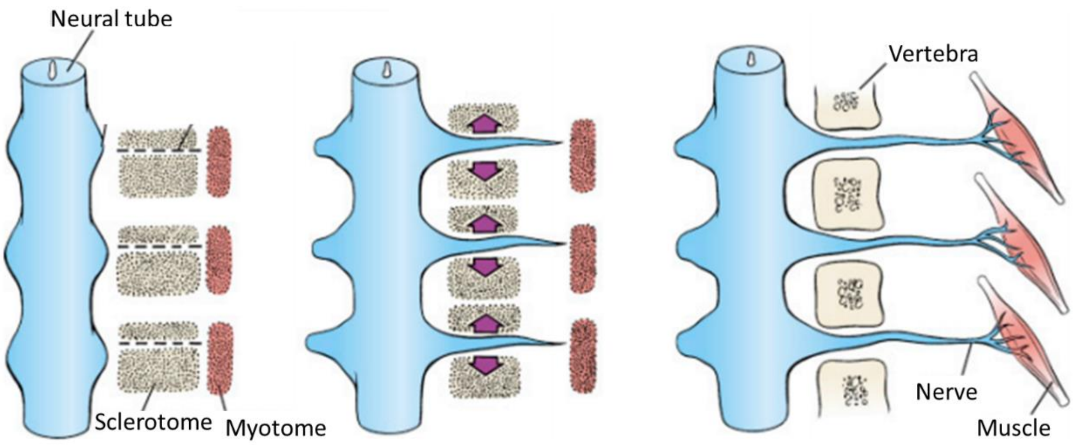
Malformations in the vertebral column can lead to spina bifida or anencephaly

Somites produce the segmental organisation of the body

The myotome slits and forms an epimere (produces dorsal spinal muscles) and ventral hypomeres

Sclerotome forms the vertebral bodies and intervertebral discs

- Sclerotomes are in the shape of the vertebral bodies and they split through the middle, which is where the spinal nerves pass through
- The sclerotome vertebrae split, so the adult vertebrae have parts from the vertebrae above and below



The notochord might contribute to the nucleus pulposus of the intervertebral disc

- **Typical vertebra**
  - 3 primary ossification centres
    - One centre for the body (1)
    - One for each half of the neural arch (2)
  - 5 secondary ossification centres
    - One at the tip of the spinous process (1)
    - One at the tip of each transverse process (2)